NFPA 203

1995 Edition

Guide on Roof Coverings and Roof Deck Constructions

1995 Edition

This edition of NFPA 203, *Guide on Roof Coverings and Roof Deck Constructions*, 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 203 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 203

In 1909, the former NFPA Committee on Devices and Materials presented a report on the Classification of Roofing Materials, which was revised and officially adopted in 1910. This report included standards on testing and certain other details that have since become obsolete. When the committee was suspended in 1911, the responsibility for the classification of roofing materials was assumed by Underwriters Laboratories Inc., and the UL classification system was adopted and published by NFPA in 1960 in NFPA 203, together with the 1910 Classification of Roofing Materials and a suggested roofing ordinance.

The 1970 edition was issued as a manual that provided general information on roof coverings and their fire characteristics. The 1970 edition was revised in 1980 and editorially updated to reflect the NFPA *Manual of Style*. The 1987 edition represented a reconfirmation of the 1980 edition. The 1992 edition updated terminology and revised text needing clarification. In addition, the document was revised from a manual to a guideline.

The 1995 edition was editorial, revised for usability.

Technical Committee on Building Construction

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 203
Guide on
Roof Coverings and
Roof Deck Constructions

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Information on referenced publications can be found in Chapter 6.

Chapter 1 Introduction

1-1 General.

1-1.1

The term *roof covering* refers to the material or the combination of materials applied on top of the roof deck for weatherproofing and can include insulation.

1-1.2

Since most roof coverings are combustible to some degree, they could be vulnerable to external fire exposure. Some roof coverings propagate a rapidly spreading fire over the surface or allow the fire to penetrate the roof covering and to communicate to the interior of the building and need to be avoided.

1-1.3

Roof coverings over metal and some other decks also should be considered for their possible contribution to fire spread originating on the interior of the building. The heat of the interior fire rises to the ceiling and can cause the liberation of combustible gases and flaming droplets through the joints, overlaps, and distortions of the deck. This can contribute significantly to the fire by means of flame spread beneath the roof and ignition of combustible contents by means of burning droplets of flowing materials.

1-1.4

A wide variety of roof coverings and roof deck constructions have been fire tested and listed by testing laboratories with respect to their characteristic behavior when subjected to both external and internal fire exposure.

1-1.5

Precautions should be taken during the installation of roof decks or coverings and above-deck components to prevent fire. (For further information, see NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*.)

Chapter 2 General Types of Roof Coverings

2-1 Composition Built-up.

As the term implies, these coverings consist of alternate layers of felt and bitumen built up into a weatherproof membrane. The felts are supplied in rolls and could be composed of organic, glass, polyester, or other fibers saturated with bituminous material. Bitumen is used to bond the felts to each other and, in some cases, to the deck. It could consist of hot or cold applied asphalt or hot applied coal tar pitch. The finished surface could be a smooth flood coat of bitumen, or it could have gravel or slag imbedded in it. The gravel or slag surfacing acts to reflect heat, to prevent flow and cracking of the bitumen, and to improve the fire performance of the coverings. Another finish could be a granular-surfaced capsheet. These coverings normally are applied to low slope roofs.

2-2 Prepared Coverings.

These coverings are factory produced and ready for attachment to the deck, providing the complete weatherproofing. They include tile, slate, metal, shingle, and sheet goods. The shingle and sheet materials are of organic, glass felt, or other felt base coated with asphalt and surfaced with granules. Prepared coverings need sufficient slope for drainage.

2-3 Wood Shingles and Shakes.

These usually are made from red cedar, redwood, or cypress wood. The shingles are sawed with a taper and applied with nails exposing one-third of the thick end. Shakes are split pieces resulting in a rough and uneven surface. They are applied like shingles. A sufficient slope for drainage is needed.

2-4 Elastomer Coverings.

Elastomer is a term given to coverings of essentially one layer that are applied in a thin membrane having elastic properties. Some of the advantages include light weight, reflectivity, color, resistance to corrosive atmospheres, and capability of application on steep or complex-shaped roofs. The materials generally are synthetic rubber or plastic products supplied in sheet form that is cemented to the deck or in liquid form for brush, spray, or roller application. The sheets usually are 35 mil to 60 mil thick, and the dry film of the liquid form is approximately 20 mil to 30 mil thick. A solid deck with grouted or taped joints and cracks is necessary for use of elastomer coverings. The manufacturer's specifications should be followed carefully for proper application.

Chapter 3 Fire Performance Classification

3-1 Exterior Exposure.

3-1.1

One test method that should be used for the evaluation of roof coverings from exterior fire exposure has gained national recognition. In fact, no other method of evaluation is recognized as acceptable by any approval authorities. A detailed description of the test procedure, apparatus, and criteria for classification can be obtained by reference to Underwriters Laboratories Inc. The same basic test methods also are provided in NFPA 256, *Standard Methods of Fire Tests of Roof Coverings*.

3-1.2

The tests consist of exposing the top surface of specimen roof decks to both gas flames and burning wood brands to determine if the coverings allow any of the following:

(a) Exposure of the deck below, or

(b) Excessive flame propagation of the covering itself, or

(c) Release of flaming or glowing material from the covering or the deck.

3-1.3

The tests are arranged to provide three levels of severity by adjusting the temperature and duration of the gas flame and the sizes of the burning wood brands. Successful coverings are rated Class A, Class B, or Class C, with Class A withstanding the most severe exposure, Class B withstanding intermediate exposure, and Class C withstanding the least severe exposure. A photograph of the test apparatus is shown in Figure 3-1.3(a), and an illustration of the wood brands is shown in Figure 3-1.3(b).

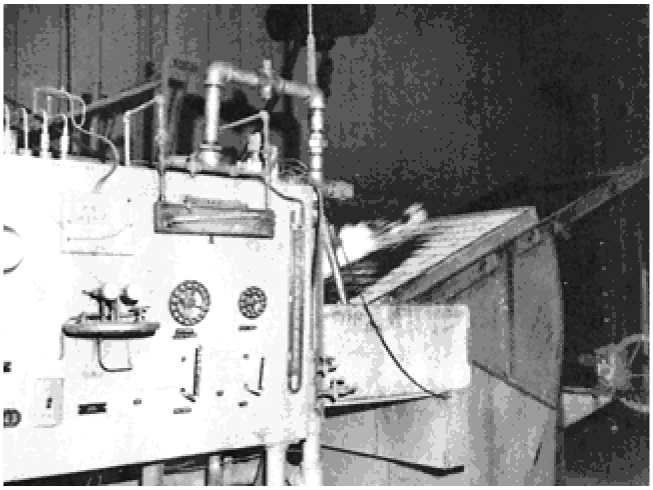

Figure 3-1.3(a) Test apparatus.

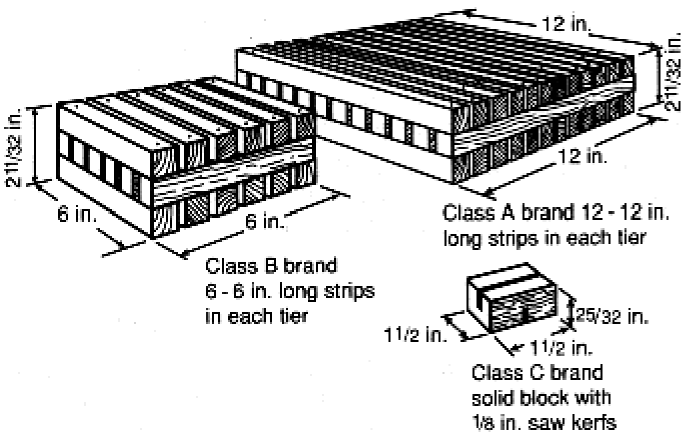

Figure 3-1.3(b) Class A, Class B, and Class C brands.

3-1.4

Supplementary rain and weathering tests are conducted on wood shingles and shakes to ensure a high level of permanence for the treating materials.

3-1.5

In addition to roof coverings that have been classified in accordance with NFPA 256, *Standard Methods of Fire Tests of Roof Coverings*, concrete, slate, concrete masonry, brick, metal, and tile generally are considered acceptable where Class A roof coverings are required by building codes.

Chapter 4 Fire Classification—Interior Exposure

4-1 Insulated Metal Deck.

4-1.1 General.

In the case of interior fires, the entire assembly comprised of the metal deck, vapor retarder, adhesives, insulation, and roof covering should be considered. A rapidly spreading under-the-deck fire is possible in such an assembly. Since the insulation frequently is considered part of the covering, an examination of insulated metal deck is appropriate.

4-1.2

Fire experience has demonstrated that the nature and quantity of combustible adhesives, the vapor retarder, the insulation, the roof covering, or a combination thereof above a metal roof deck can contribute significantly to the development of an interior fire. The heat from the fire is readily transmitted to the combustibles directly above the metal deck, where destructive distillation liberates combustible gases. These hot gases build up pressure and, since they are unable to vent to atmosphere because of the watertight roof covering, they are forced downward through the joints in the metal deck, where they are ignited.

4-1.3

If these gases are liberated in sufficient quantity, they could progressively vaporize, surrounding the insulation, vapor retarder, and adhesive in a cyclic manner. Therefore, the fire beneath the roof can propagate rapidly and independently of the fire in the contents. Adhesive could drip through the roof deck joints, rain down on combustible contents, and ignite them.

4-1.4

The Factory Mutual Research Corporation and Underwriters Laboratories Inc. conducted comprehensive large-scale fire tests to determine the fire characteristics of insulated metal deck roof constructions. In a 20 ft x 100 ft (6.1 m x 30.5 m) fire test building with a severe fire source at one end, fire propagation beneath the roof deck was demonstrated and droplets of adhesive ahead of the fire source were evident. Continued studies established that a roof assembly consisting of a metal deck, a 1-in. (25.4-mm) thick vegetable fiberboard mechanically fastened to the deck, and a built-up roof covering would not propagate a rapidly spreading fire. The performance of this assembly established the criteria for judging other assemblies. Views of the test building are shown in Figures 4-1.4(a), (b), and (c).

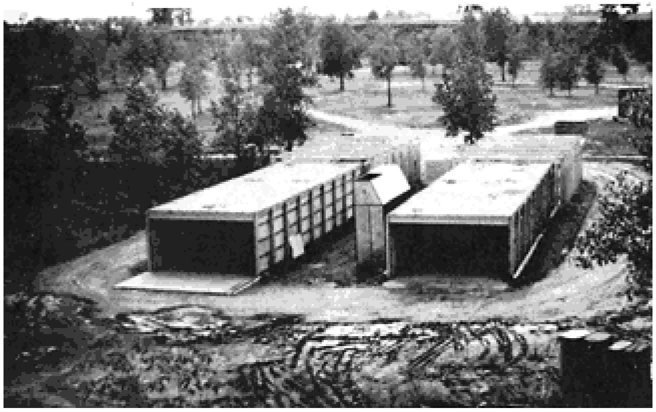

Figure 4-1.4(a) Overall view of 20 ft x 100 ft (6.1 m x 30.5 m) fire test building from exhaust end.

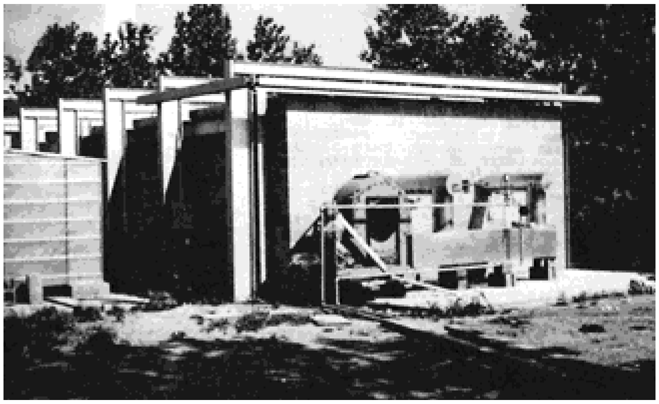

Figure 4-1.4(b) View of firing mechanism of fire test building.

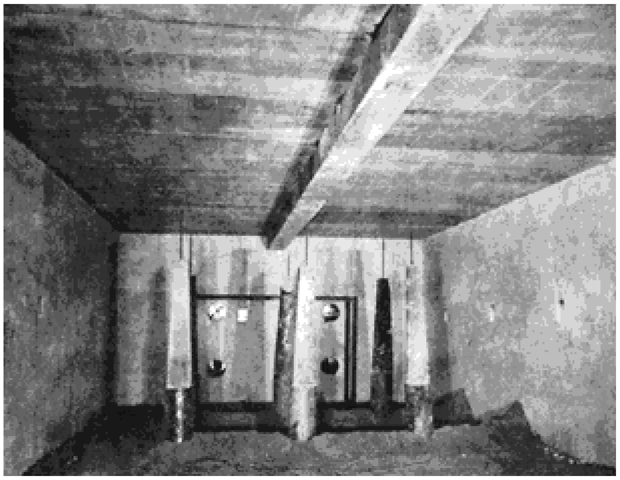

Figure 4-1.4(c) Interior view of firing end of fire test building.

4-1.5

Small-scale tests for the classification of roof decks have been developed by both the Factory Mutual Research Corporation and Underwriters Laboratories Inc. based upon performance in the large building tests of acceptable constructions.

4-2 Factory Mutual Classification.

Assemblies are placed in the construction materials calorimeter, which yields results in terms of rate of heat release. Those assemblies that release heat at a sufficiently low rate are designated as in Class I. Metal roof deck assemblies that fail to meet the fire requirements are designated in Class II.

4-3 Underwriters Laboratories Inc. Classification.

Where a basic roof deck design has demonstrated its performance in the 100-ft (30.5-m) building test, variations of that design can be tested in the Steiner Tunnel furnace and compared to the performance of the appropriate acceptable roof assembly. If equivalent, the assembly is listed and given a construction number. Equivalency is judged on the basis of flame spread, absence of drippage, and extent of damage.

Chapter 5 Selection of Roof Coverings from a Fire Standpoint

5-1 General.

The selection of roof coverings and roof deck constructions to resist fire propagation should be based on the proximity and severity of the external fire exposure and on the threat of internal fire from the contents and operation within the building. Those roof coverings with the greatest resistance to severe fire (Class A) are preferable. Both built-up and prepared roof coverings can be specified with a Class A rating, while treated wood shingles generally qualify for Class B or Class C ratings. The manufacturer's specifications should be followed carefully, and no variation from the materials or methods of construction for classified systems should be permitted.

5-2 Built-up Coverings.

Gravel or slag could be needed on the roofing surface for its fire resistance qualities. (Gravel or slag is also desirable for resistance to hailstones.) Many built-up roofs are limited in maximum slope.

5-3 Prepared Roofs.

As with built-up roofs, roof slope is a design consideration.

5-4 Wood Shingles and Shakes.

Untreated wood shingle roofs have been looked at with disfavor by the NFPA for many years. NFPA statistics indicate that wood shingles have been a contributing factor in more conflagrations than any other of twenty-seven factors from 1901 to 1967. This was particularly true in the first half of this period, before the full impact of modern building codes, which restricted the construction of wood shingled roofs. If wood shingles or shakes are to be used, they should be fire-retardant treated and classified. Untreated shingles or shakes should not be used. Where wood shingles or shakes are to be used, they should be fire-retardant treated by a pressure impregnation process and classified in accordance with NFPA 256, *Standard Methods* *of Fire Tests of Roof Coverings*.

5-5 Elastomer Coverings.

Some of the liquids used in applying these coverings are flammable, and no open flames should be permitted near the areas of application.

Chapter 6 Referenced Publications

6-1

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.

6-1.1 NFPA Publications.

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

NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*, 1993 edition.

NFPA 256, *Standard Methods of Fire Tests of Roof Coverings*, 1993 edition.

6-1.2 Other Publications.

6-1.2.1 FMRC Publication. Factory Mutual Research Corporation, P.O. Box 9102, 1151 Boston-Providence Turnpike, Norwood, MA 02062-9102.

FMRC Approval Standard 4470, *Roof Covers*, April 1986.

NFPA 204M

1991 Edition

Guide for Smoke and Heat Venting

1991 Edition

This edition of NFPA 204M, *Guide for Smoke and Heat Venting*, was prepared by the Technical Committee on Smoke Management Systems, released by the Correlating Committee on Building Construction, 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 204M

This project was initiated in 1956 when the NFPA Board of Directors referred the subject to the Committee on Building Construction. A Tentative Guide was submitted to NFPA in 1958. Revised and tentatively adopted in 1959 and again in 1960, the guide was officially adopted in 1961. In 1968 a revised edition was adopted that included a new section on Inspection and Maintenance.

In 1975, a reconfirmation action failed as concerns over use of the guide in conjunction with automatic sprinklered buildings had surfaced. Because of this controversy, work on a revision to the guide continued at a slow pace.

The Technical Committee and Subcommittee members agreed that the state of the art has progressed sufficiently to develop improved technologically based criteria for design of venting and, therefore, the 1982 edition of the document represented a major advance in engineered smoke and heating venting, although reservations over vent/sprinkler applications still existed.

At the time this guide was formulated, the current venting theory was considered unwieldy for this format and, consequently, the more adaptable theory as described herein was adopted. Appreciation must be extended to Dr. Gunnar Heskestad at the Factory Mutual Research Corporation for his major contribution to the theory applied in this guide, which is detailed in Appendix A.

The 1985 edition again revised Chapter 6 on the subject of venting in sprinklered buildings. Test data from work done at the Illinois Institute of Technology Research Institute, which had been submitted to the Committee as part of a public proposal, did not permit consensus to be developed whether sprinkler control was impaired or enhanced by the presence of automatic roof vents of typical spacing and area. The revised wording of Chapter 6 encourages the designer to use the available tools and data referenced in the document while the use of automatic venting in sprinklered buildings is under review.

This 1991 edition makes minor changes to Chapter 6 to acknowledge that a design basis does exist for using both sprinklers and automatic heat venting together but that such has not received wide recognition.

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Alternates

NFPA 204M
Guide for
Smoke and Heat Venting

1991 Edition

Chapter 1 General Information

1-1 Importance.

1-1.1

Since the end of World War II there has been a general trend toward the construction of large industrial and storage buildings with extensive undivided floor areas. In many cases, large undivided floor areas are necessary for the functional operation of the building. One result, from a fire protection viewpoint, has been the increased potential for large loss fires involving extensive individual fire areas. To a great extent, this tendency has been offset through the increased use of automatic sprinkler protection.

1-1.2

Furthermore, large undivided floor areas present extremely difficult fire fighting problems, since the fire department must enter these areas in order to combat fires in central portions of the building. If the fire department is unable to enter because of the accumulation of heat and smoke, fire fighting efforts may be reduced to a futile application of hose streams to perimeter areas while fire consumes the interior. Windowless buildings also present similar fire fighting problems. One fire protection tool that may be a valuable asset for fire fighting operations in such buildings is smoke and heat venting. Guidance is provided herein relative to the use of smoke and heat venting.

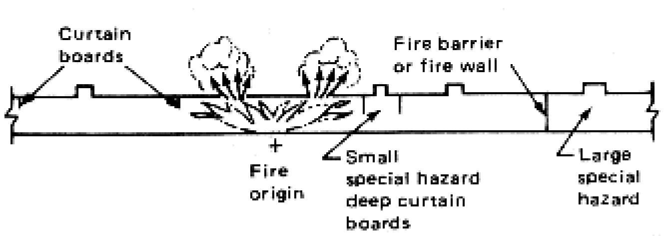


Figure 1-1 Behavior of Combustion Products Under Vented and Curtained Roof.

1-1.3

Two different types of guidance are provided. The first has to do with the venting of limited-growth fires. These are fires that are not expected to grow beyond a predictable heat-release rate. By following the recommendations in the case of limited-growth fires, containment of the effects of the fire to the upper volume of the curtained area of fire origin can be anticipated as long as the building construction remains intact. The second type of guidance is relevant to the venting of fires that, if unchecked, will continue to grow to some unknown size. For this type of continuous-growth fire, the specific guidance provided allows one to establish a minimum predictable design time during which (a) the effects of the fire will be confined to the curtained area, and (b) visibility up to a design-elevation above the floor of the curtained area will be maintained. This minimum clear-visibility design time will facilitate such activities as locating the fire, appraising the fire severity and extent, evacuating the building, and making an informed decision on deployment of personnel and equipment to be used for fire fighting. The minimum clear-visibility design time is measured from the time the first vents activate.

1-1.4

Vents are not a substitute for sprinklers or other extinguishing facilities.

1-2 Application and Scope.

1-2.1

Provisions of Sections 1-3 through 4-4.3 are intended to offer guidance in the design of facilities for the emergency venting of products of combustion from uncontrolled fires in nonsprinklered, single-story buildings. Information regarding venting in sprinklered buildings is included in Chapter 6. The provisions do not attempt to specify under what conditions venting must be provided as this is dependent upon an analysis of the individual situation.

1-2.2

The provisions of this guide may be applied to the top story of multiple-story buildings. There are many features that would be difficult or impractical to incorporate into the lower stories of such buildings.

1-2.3

This guide does not apply to other ventilation (or lighting, as may be the case with monitors and skylights) designed for regulation of temperature within a building, for personnel comfort or production equipment cooling, or to venting provided for explosion pressure relief (*see NFPA 68, Guide for Explosion Venting*).

1-2.4

Building construction of all types is included.

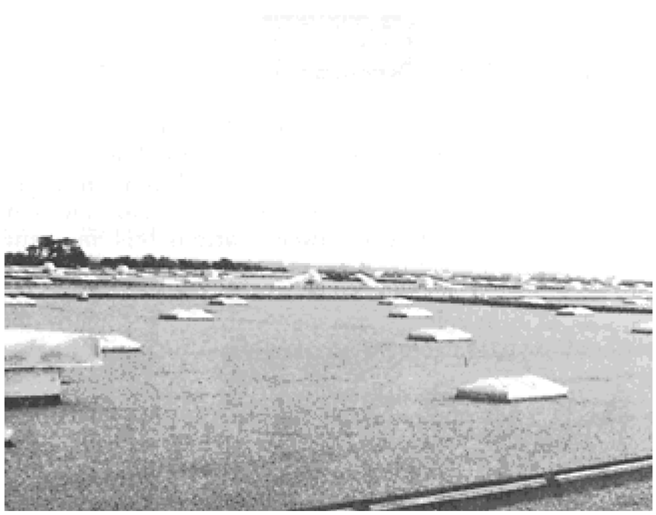


Figure 1-2 Plant With Roof Vents.

1-2.5

The concepts set forth in this guide were developed for venting fires in large undivided floor areas with ceiling heights sufficient to allow the design fire plume and smoke layer to develop [normally, 15 ft (4.57 m) or greater]. Such conditions are frequently encountered in industrial and storage buildings. The information in Chapter 4 relative to fire growth was specifically developed for these occupancies. The application of these concepts to buildings of other occupancies or lower ceiling heights requires careful engineering judgment.

1-3 Principles of Venting.

1-3.1

The following is a description of the significant phenomena that occur during a fire when a fire venting strategy is implemented:

(a) Due to buoyancy, hot gases rise vertically from the combustion zone and then flow horizontally below the roof until blocked by a vertical barrier (a wall or draft curtain), thus initiating a layer of hot gases below the roof.

(b) The volume and temperature of gases to be vented are a function of the rate of heat release of the fire and the amount of air entrained into the buoyant plume produced.

(c) The depth of the layer of hot gases increases, the fire continues to grow, and the layer temperature continues to rise until vents operate.

(d) Operation of vents within a curtained area will enable some of the upper layer of hot gases to escape and slow the rate of deepening of the layer of hot gases. With sufficient venting area, the rate of deepening of the layer can be arrested and even reversed. The rate of discharge through a vent of given area is primarily determined by the depth of the layer of hot gases and its temperature. Adequate quantities of replacement inlet air from low level air inlets are required if the products of combustion-laden upper gases are to escape according to design.

1-3.2

The heat-release rate of the fire is the basis by which all the phenomena of 1-3.1 can be computed. In this regard, this guide is based on an appropriate characterization of the fire's growth potential per Tables 4-1 and 4-2. Once such a characterization is made and subsequent design guides are implemented, the desired benefits described in 1-1.3 can be anticipated.

1-4 Classification of Occupancies.

1-4.1

Tests and studies provide a basis for division of occupancies into classes depending upon the fuel available for contribution to fire. There is a wide variation in the quantities of combustible materials in the many kinds of industrial plants and also between various buildings and areas of most individual plants. Classification should take into account the average or anticipated fuel loading and the rate of heat release anticipated from the combustible materials or flammable liquids contained therein.

1-4.2

To assist in quantifying the type of fire in occupancies of interest, Table 4-1 presents characteristic heat-release rates for limited-growth fires, and Table 4-2 presents characteristic growth times for continuous-growth fires, in a variety of different types of fuel arrays.

1-4.3

It is to be recognized that many plants will have buildings or areas with different fire hazards. Accordingly, venting facilities may be designed for the appropriate fire growth characteristics as discussed in this guide.

Chapter 2 Vents

2-1 Types of Vents.

2-1.1

Experience has shown that any opening in a roof, over a fire, will relieve some heat and smoke. However, building designers and fire protection engineers cannot rely on casual inclusion of skylights, windows, or monitors as adequate venting means. Standards now exist (Underwriters Laboratories, Factory Mutual) that include design criteria and test procedures for unit vents that call for simulated fire tests as well as engineering analysis.

2-1.2

The guides and tables in this document are based on automatic operating vents as the result of activation of a heat-responsive device rated at 100°F (37.8°C) to 220°F (104.4°C) above ambient having a time constant of not more than 233 sec at 5 ft (1.53 m) per second gas velocity with such a device fitted to each vent.

2-1.3

An alternate mode of operation, whether by heat, smoke, or other method, may be tailored to the hazard so long as the accepted system will operate at least as fast as the above noted heat-responsive device and is either listed or proven to be equivalent by satisfactory data or by engineering analysis.

2-2 Vent Design Constraints.

2-2.1

Materials of construction and methods of installation must be used appropriately to resist expected extremes of temperature, wind, building movement, rain, hail, snow, ice, sunlight, corrosive environment, internal and external dust, dirt, and debris. Compatibility between the vent mounting elements and the building structure to which they are attached must be assured (holding power, electrochemical interaction, wind lift, building movement, etc.).

2-2.2

Vents designed to have multiple functions (daylighting, roof access, comfort ventilation, etc.) require maintenance of the fire protection function that might be impaired by the other uses. These may include loss of spring tension, racking or wear of moving parts, adverse exterior cooling effects on the fire protection release mechanism, adverse changes in performance sequence such as premature heat actuation leading to vent opening, or reduced sensitivity to heat.

2-2.3

To avoid inadvertent operation, it is important that the actuating element be selected with regard to the expected full range of ambient conditions.

2-2.4

Vents may be single unit (entire unit opens fully with a single sensor) or multiple units in rows, clusters, groups, or other arrays that will satisfy the venting requirements for the specific hazard.

2-2.5

If the hazard is localized (dip tank, solvent storage, etc.), it is preferable for the vents to be located directly above such hazard.

2-2.6

It is essential that the specific vent mechanism and structure (or a representative modular section) be arranged to be easily inspected.

2-2.7

Remote or programmed operation of vents may be used to complement, but not to replace or impair, individual automatic sensor actuation.

2-3 Methods of Operation.

2-3.1

An "automatic" mechanism for opening the roof vents is desirable for effective release of heat, smoke, and gaseous by-products. If excessive smoke is likely to be generated prior to the release of sufficient heat to open vents, smoke detectors with appropriate linkages to open vents may be preferred.

2-3.2

Automatic actuation and operation need to have a minimum of "failure points" (any one of which could impair the vent). If "failure" of a component occurs, it will preferably lead to an "open vent" condition as a less hazardous mode than a "nonopening" condition if a fire occurs. Gravity as a source of "force to open" is preferred, with assurance that such a mechanism is not easily blocked by snow or roof debris or internal projections. Alternate opening mechanisms need to be approved as to reliability of performance and estimated useful life.

2-3.3

All automatic vents should also be designed to open by manual means.

2-3.4

To be effective, latching mechanisms need to be jam-proof, corrosion-resistant, and resistant to pressure differentials arising from windstorms, process operations, overhead doors, or traffic vibrations.

2-3.5

Hot or cold exterior winds penetrating and adversely affecting the heat-actuated sensors may have an adverse effect on the "automatic" response of the vent to an interior fire. This fact necessitates a critical analysis of specific installations of fixed or operating louvers, shutters, or dampers into the overall venting system.

2-4 Dimensioning and Spacing of Vents.

The dimensioning and spacing of vents are considered to be effective when the following criteria are met:

(a) The area of a unit vent or cluster does not exceed $2d^2$, where d is the depth of the curtain board or the design depth of the smoke layer. These depths are measured from the center line of the vent. (*See Figure 3-1*.)

(b) The width of the monitor does not exceed the depth of the curtain board d or the design depth of the smoke layer when curtains are not provided.

(c) The vent spacing does not exceed an arrangement such that on plan the distance between any point on the floor and the nearest vent, all within the curtained area, does not exceed 2.8H (the diagonal of a square whose side is 2H), where H is the ceiling height. (*Also see Figure 3-1*.)

(d) The total vent area per curtain compartment under the ceiling depends on the severity of the expected fire, which is discussed in Chapter 4.

(e) Where mechanical vents are considered, the total suggested vent area may be replaced by “total exhaust flow.”

Chapter 3 Curtain Boards

3-1 General.

3-1.1

Curtain boards are important for prompt and positive activation of the vents because they bank up heat in the curtained area.

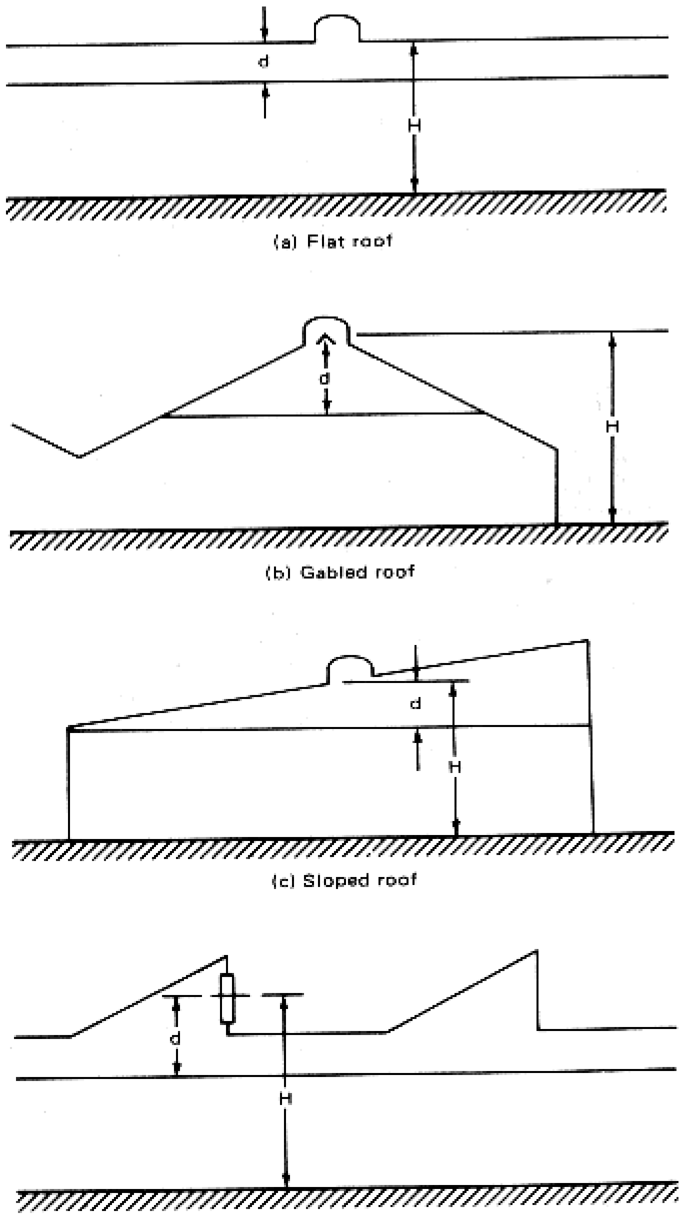


Figure 3-1 Measurement of Ceiling Height (H) and Curtain Depth (d).

3-1.2

Curtain boards serve to limit the spread of heat and smoke beneath the ceiling during design duration of the venting system.

3-2 Construction.

It is desirable that curtain boards be made of any substantial, noncombustible material that will resist the passage of smoke.

3-3 Location and Depth.

3-3.1

Curtain boards, where provided, should extend down from the ceiling for a sufficient distance to ensure that the value of d as shown in Figure 3-1 is a minimum of 20 percent of ceiling height (H) where H is:

(a) For flat roofs, measured from ceiling to floor.

(b) For sloped roofs, measured from center of vent to the floor.

NOTE: See Figure 3-1. When d exceeds 20 percent of H, it is desirable that H± d be not less than 10 ft (3.05 m).

3-3.2

Around special hazards, the curtain should preferably extend down to within approximately 10 ft (3.05 m) from the floor.

If, however, the hazard is located more than 10 ft (3.05 m) above the floor, the depth of the curtain board may need to be decreased to allow for effective application of fire fighting appliances, provided that the basic criteria for venting included in this guide are observed.

3-4 Spacing.

3-4.1

The distance between curtain boards should not exceed 8 times the ceiling height to ensure that vents remote from the fire within the curtained compartment will be effective.

3-4.2

Smaller curtained areas may be desirable where occupancies are particularly vulnerable to damage. However, it is important that the distance between curtain boards be not less than 2 times the ceiling height, unless the curtain boards extend down to a depth of at least 40 percent of the ceiling height.

Chapter 4 Installed Vent Area or Exhaust Capacity

4-1 General.

4-1.1 Curtained Compartments.

4-1.1.1 It is essential that curtained compartments or the ceiling area of buildings requiring no curtain boards be furnished with a total installed vent area (or exhaust capacity in case of mechanical ventilation) sufficient to vent fires of the expected severity.

4-1.1.2 In addition to the expected fire severity, the installed vent area (or exhaust capacity) will depend on the depth of the curtain boards or the design depth of the smoke layer.

4-1.1.3 Unless the occupancy or hazard is such that the expected fire will peak or level off at a predictable maximum size, the installed vent area (or exhaust capacity) will also depend on the minimum clear-visibility design time (*see 1-1.3*) as measured from the time the first vents activate.

4-1.2

Recommended vent areas per curtained compartment have been established for two general classes of fires:

4-1.2.1 *Limited-Growth Fires* include those which are not expected to grow past a predictable maximum size, such as special hazard fires.

4-1.2.2 *Continuous-Growth Fires* include those which can be expected to grow indefinitely until intervention by fire fighters.

4-1.3

The recommended vent areas (installed vent areas) are based on the assumption that the aerodynamic discharge coefficient of the vents is 0.6, which is normal for commercial gravity vents. If the discharge coefficient is different from 0.6, the recommended vent areas need to be multiplied by the ratio of 0.6 to the actual discharge coefficient.

4-1.4

For mechanical venting systems capable of functioning under the expected fire exposure, recommended exhaust capacities per curtained compartment are obtained by simple conversion from the recommended vent areas per curtained compartment. The conversion depends on the depth of the curtain board, or the design depth of the smoke layer, in the following manner:

Curtain Depth (ft)	Mechanical Exhaust Capacity per Unit Area of Gravity Vent (SCFM/ft^2)
6	354
8	409
10	457
12	501
16	578
20	647
24	708

NOTE: SCFM = Standard Cubic Feet per Minute (Standard Temperature and Pressure).
For SI Units: 1 ft = .3048 m; 1 ft^2 = .0929 m^2.

4-2 Limited-Growth Fire.

4-2.1 Recommended Vent Area.

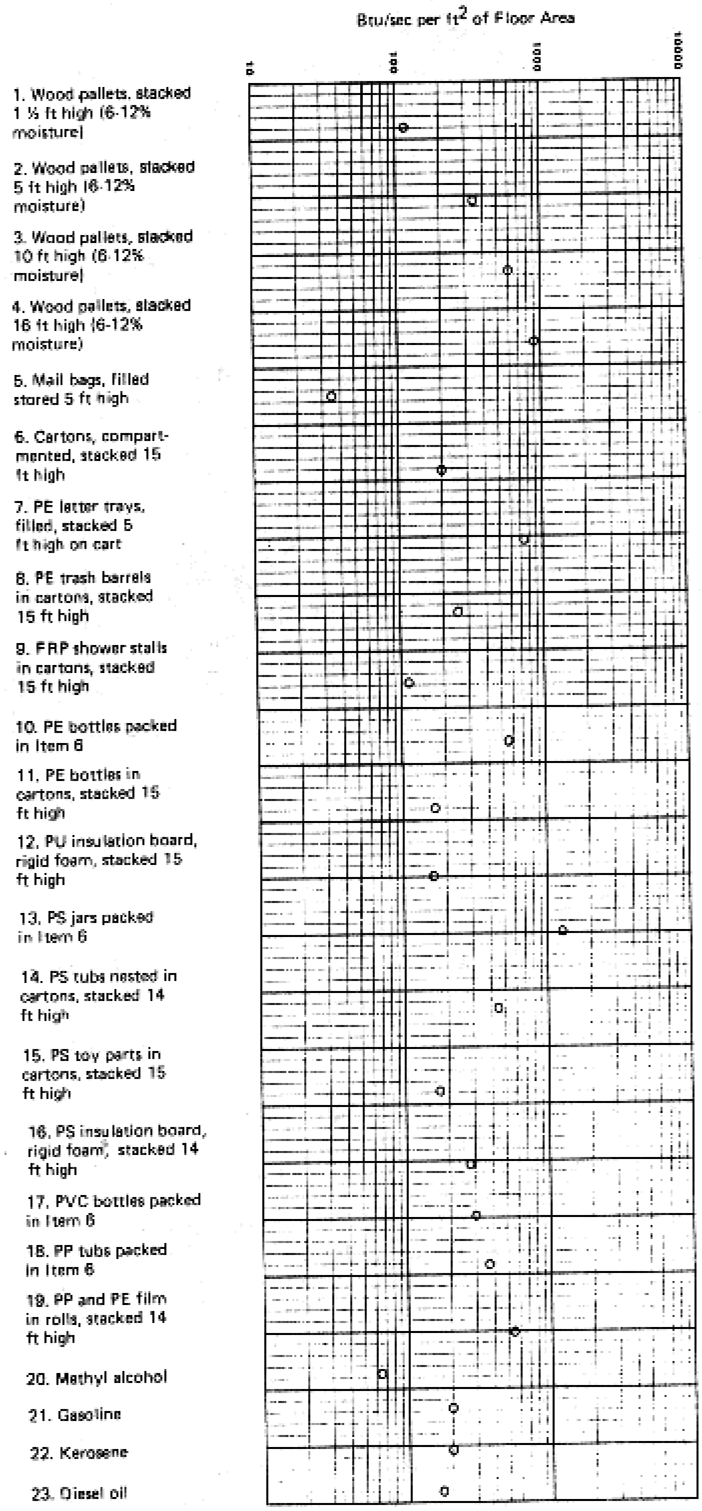
4-2.1.1 Recommended vent areas per curtained compartment (in sq ft) are plotted in Figure 4-1 against the expected maximum heat-release rate (in Btu/second) of the combustibles underneath the curtained compartment (*see Table 4-1*). The figure pertains to a curtain depth that is 20 percent of the ceiling height. For each ceiling height, the respective curve begins at a heat-release rate where vents whose operating device is defined by 2-1.2 are first expected to be useful.

4-2.1.2 Furthermore, for each ceiling height, the respective curve terminates near a heat-release rate beyond which the feasibility of the venting approach recommended in this guide might be questioned ($Q_{feasible}$).

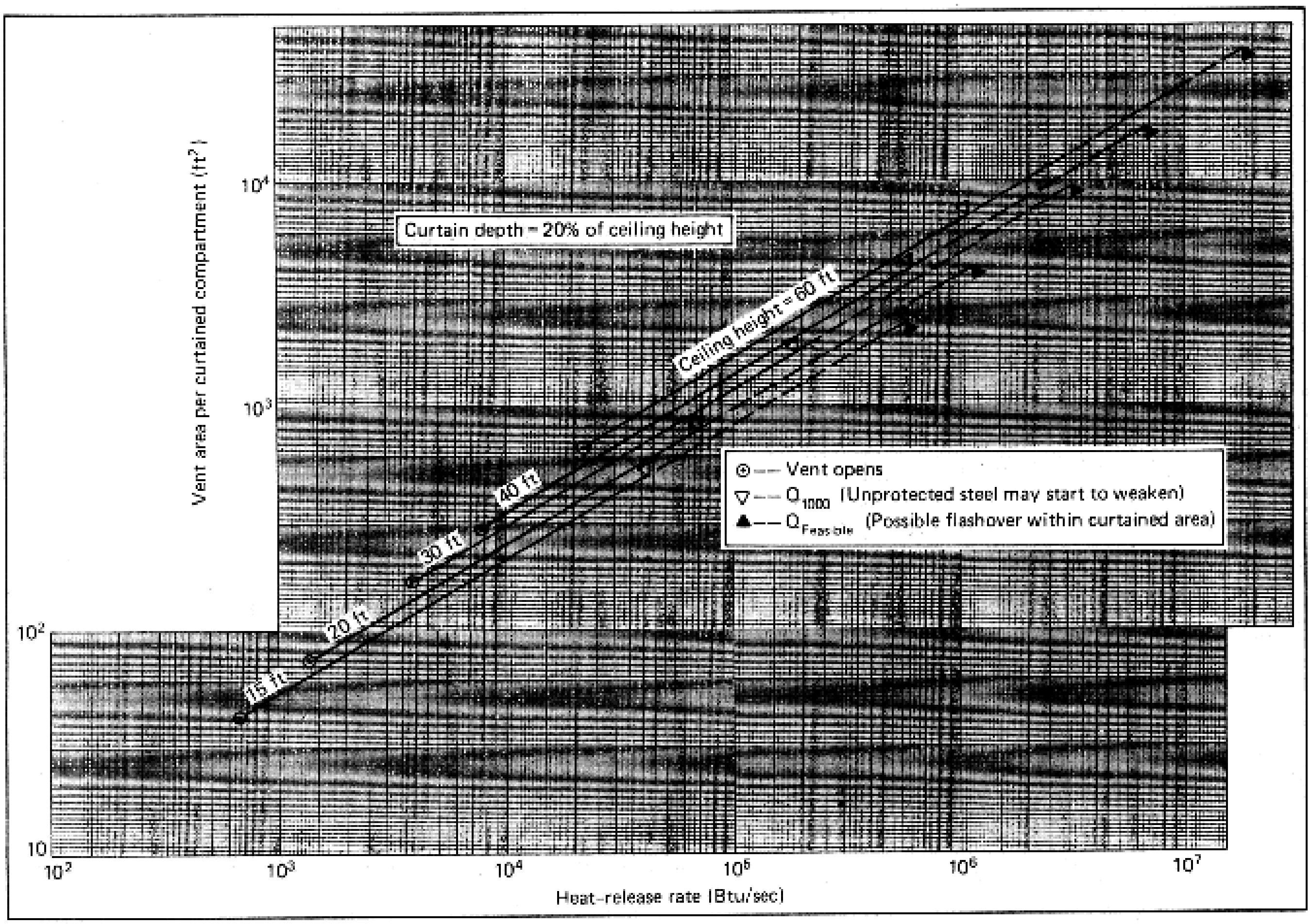
Table 4-1 Limited-Growth Fires

Heat-release rate per unit floor area of fully involved combustibles, assuming 100 percent combustion efficiency.

(PE = polyethylene; PS = polystyrene; PVC = polyvinyl chloride; PP = polypropylene; PU = polyurethane; FRP = Fiberglass-Reinforced Polyester.)



For SI Units: 1 ft = .3048 m; 1 ft² = 0.929 m².



For SI Units: 1 in. = 25.4 mm; 1 ft² = .093 m²; 1 Btu/sec = 1.054 kw.

Figure 4-1 Limited Fire Growth: Recommended Vent Areas per Curtained Compartment for Various Maximum Heat-Release Rates (Btu/second).

4-2.1.3 Along the dashed segment of the curves, gas temperatures in excess of 1000°F (537.7°C) will be reached; unprotected structural steel may begin to lose strength, and flashover may occur within the curtained area. The lowest rate of heat release at which this occurs is referred to as Q_{1000}.

4-2.1.4 For curtain depths greater than 20 percent of the ceiling height, the vent areas read from Figure 4-1 may be multiplied by the following factors:

Curtain Depth in Percent of Ceiling Height	Multiplication Factor
30	0.71
40	0.53

50	0.40
60	0.29
70	0.20
80	0.13

For SI Units: 1 ft = .3048 m.

4-2.1.4.1 For curtain depths greater than 20 percent of the ceiling height, Q_{1000}, which is the heat-release rate where gas temperatures in excess of 1000°F (537.7°C) may occur, can be estimated from the following equation (where H is the ceiling height in ft and d is the curtain board depth in ft):

$$Q_{1000} \text{ (Btu/sec)} = 69 (H - d)^{5/2}$$

4-2.1.4.2 For curtain depths greater than 20 percent of the ceiling height, the heat-release rate beyond which venting may not be feasible according to the venting approach in this guide, $Q_{feasible}$, can be estimated from:

$$Q_{feasible} \text{ (Btu/sec)} = 1130 (H - d)^{5/2}$$

4-2.2

Vent areas per curtained compartment, determined according to 4-2.1.1 and 4-2.1.4, are to be sized and distributed within the constraints of 2-4.1.

4-2.3

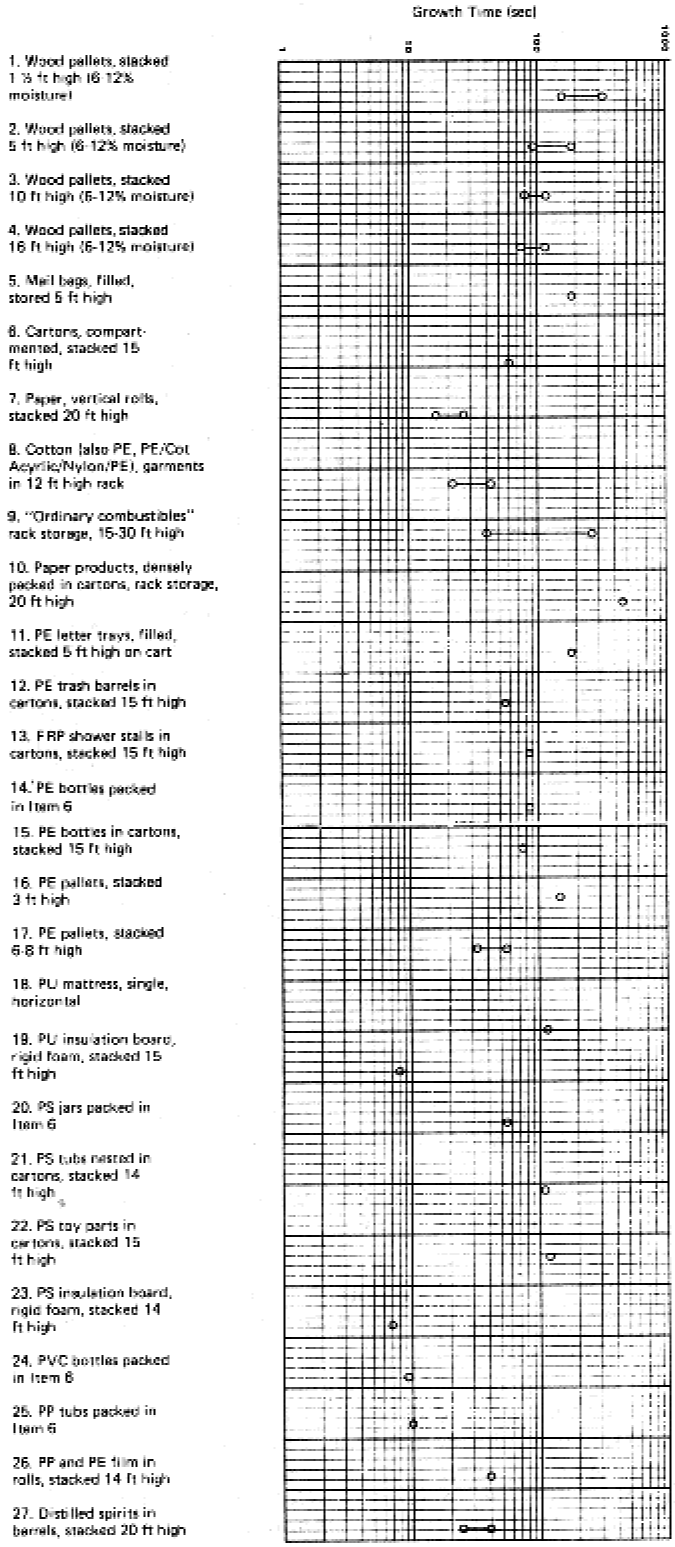
Consult Table 4-1 for examples of heat-release rate data. Most of these data pertain to fairly high storage. For lower storage heights, it may be assumed that heat-release rate is proportional to storage height. Larger storage heights should be extrapolated with caution.

4-3 Continuous-Growth Fire.

4-3.1 Recommended Vent Area.

4-3.1.1 Starting after an incubation period, the heat-release rate of these fires grows continuously proportional to the square of time. The growth time of a given fire is defined as the interval of time between the effective ignition time and the time when the fire reaches an intermediate energy release rate of 1000 Btu/sec. (*See Figure 4-2 and Table 4-2*.)

Table 4-2 Continuous-Growth Fires Growth times of developing fires in various combustibles, assuming 100 percent combustion efficiency. (*See 4-3.1.1 for definition of growth time*.)(PE = polyethylene; PS = polystyrene; PVC = polyvinyl chloride; PP = polypropylene; PU = polyurethane; FRP = Fiberglass-Reinforced Polyester)



For SI Units: 1 ft = .3048 m; 1 ft² = .0929 m².

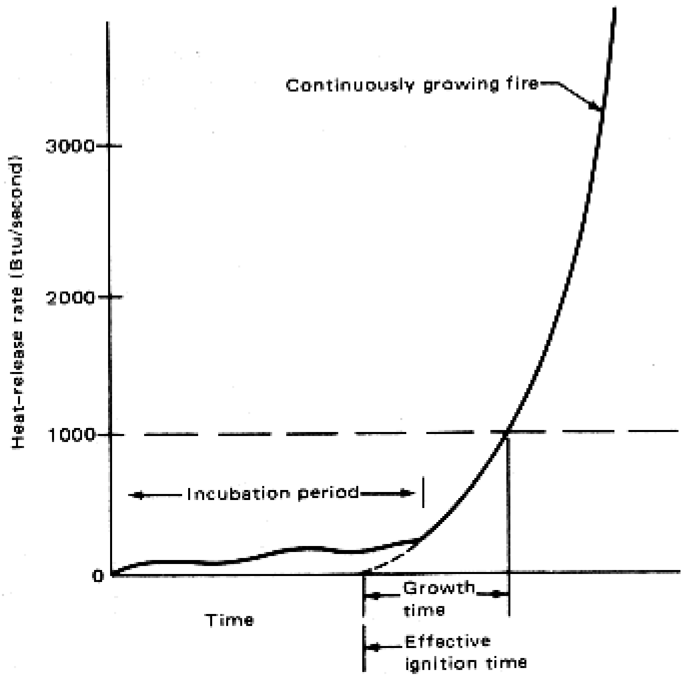


Figure 4-2 Conceptual Illustration of Continuous Fire Growth.

4-3.1.2 Recommended vent areas per curtained compartment depend on the ceiling height (H) and the growth time (*see 4-3.1.1*). They also depend on the spacing of curtain boards (S_c), the vent spacing and means of vent activation, as well as the desired minimum clear-visibility design time from the time the first vents activate.

4-3.1.3 Recommended vent areas per curtained compartment are listed in Table 4-3 for the minimum recommended curtain depth of 20 percent of ceiling height (*see 3-3.1*) and for vents spaced at no more than one half of the curtain board spacing. For other than square curtains, the spacing S_c is interpreted as the largest spacing defined by the curtained area.

4-3.1.4 The tabulated areas are approximate, pertaining to vents that are operated by heat-responsive devices of average thermal inertia and rated between 100°F (37.8°C) and 220°F (104.4°C) above the ambient temperature. Each entry in Table 4-3 gives the range of vent areas [in 1000 ft^2 (90 m^2)] associated with the selected range of temperature ratings.

4-3.1.5 Entries boxed in are not possible (since the vent areas exceed the largest possible curtained area of $S_c \times S_c$); however, these entries may be needed for curtain depths greater than 20 percent of ceiling height as treated in 4-3.1.9.

4-3.1.6 Where values are not given in Table 4-3, heat-release rates are greater than $Q_{feasible}$. (*See 4-2.1.1 and 4-2.1.4.*)

4-3.1.7 Entries in parentheses correspond to levels of heat release greater than Q_{1000}. (*See 4-2.1.1 and 4-2.1.4.*)

4-3.1.8 To illustrate use of the table, consider an installation with heat-responsive devices rated approximately 100°F (37.8°C) above ambient, a ceiling height of 20 ft (6.1 m), a growth time of 150 sec, a curtain spacing of 80 ft (24.4 m) ($S_c = 4 \times H$), and a minimum clear-visibility design time of 10 min; the lower limit 100°F (37.8°C) of the appropriate entry in Table 4-1 indicates a vent area per curtained compartment of $0.64 \times 1000 = 640$ ft^2 (59.5 m^2) for this case.

4-3.1.9 The recommended vent area per curtained compartment is reduced if larger curtain depths than minimum (20 percent of ceiling height) are installed. The reduced areas are calculated by multiplying the values listed in Table 4-3 by the appropriate multiplication factor listed in 4-2.1.4, depending on curtain depth.

4-3.2

The maximum vent area in any compartment need not exceed the vent area recommended for a limited-growth fire of all the combustibles beneath the curtained area calculated in accordance with Section 4-2 of this guide.

4-3.2.1 To determine if Notes 4 or 6 from Table 4-3 apply to the newly derived values for vent areas, it is necessary to determine the relationship of the vent areas associated with Q_{1000} and $Q_{feasible}$.

4-3.2.2 For curtain depths greater than 20 percent of the ceiling height, the calculated vent area, A_{1000}, associated with heat-release rate, Q_{1000}, can be calculated from the following equation (where H is the ceiling height in ft and d is the curtain depth in ft):

$$A_{1000}\ (\mathrm{ft}^2) = \frac{1.6\ (H - d)^{5/2}}{d^{1/2}}$$

4-3.2.3 For curtain depths greater than 20 percent of the ceiling height, the calculated vent area, $A_{feasible}$, associated with $Q_{feasible}$, can be estimated from:

$$A_{feasible}\ (\mathrm{ft}^2) = \frac{8.5\ (H - d)^{5/2}}{d^{1/2}}$$

4-3.3

Vent areas per curtained compartment, determined according to 4-3.1.2 and 4-3.1.9 or 4-3.1.2, should be sized and distributed within the constraints of 2-4.1. In some cases, the calculated number of vents may be so large that the vent spacing will be considerably smaller than the design spacing for vents assumed in Table 4-3, $^1/_2\ S_c$. The closer vent spacing implies earlier operation of the first vents than is the case for the designs of Table 4-3. Earlier operation, like an auxiliary fire detection system, would, under conditions of clear visibility, increase the time available for carrying out activities of the types outlined in 1-1.3.

Table 4-3 Vent Area (in 1000 ft^2) per Curtained Compartment for Heat-Responsive Device Operated Vents With Various Curtain Board Spacings (S_c) and Minimum Clear-Visibility Design Times (5, 10, or 15 min).

Ceiling Height H Ft	Growth Time Sec	$S_c = 2 \times H$			$S_c = 4 \times H$			$S_c = 8 \times H$		
		5 min	10 min	15 min	5 min	10 min	15 min	5 min	10 min	15 min
15	20				(1.9-2.1)			(2.2-2.5)		
	40	$\boxed{.87-.97}$			(.98-1.1)	(1.8-2.0)		(1.1-1.4)	(2.0-2.3)	
	80	(.44-.52)	(.82-.90)		(.52-.64)	(.90-1.0)	(1.3-1.4)	(.64-.83)	(1.0-1.2)	(1.5-1.7)
	150	.25-.32	(.43-.50)	(.63-.70)	.31-.41	(.50-.60)	(.70-.80)	(.41-.58)	(.60-.77)	(.81-.98)
	300	.15-.20	.23-.29	.32-.38	.20-.28	.28-.36	.37-.46	.27-.41	.36-.51	(.46-.61)
	600	.10-.14	.13-.18	.17-.23	.13-.21	.17-.25	.21-.29	.20-.34	.24-.38	.29-.43
20	20	$\boxed{2.2-7.3}$			(2.5-2.7)			(2.7-3.2)		
	40	(1.1-1.2)	$\boxed{2.1-2.2}$		(1.2-1.5)	(2.2-2.5)	(3.3-3.6)	(1.5-1.8)	(2.5-2.9)	(3.6-4.0)
	80	.56-.68	(1.0-1.1)	$\boxed{1.5-1.6}$	.68-.86	(1.1-1.3)	(1.6-1.8)	(.87-1.2)	(1.3-1.6)	(1.8-2.1)
	150	.34-.43	.55-.65	(.77-.88)	.43-.58	.64-.80	(.88-1.0)	.58-.83	(.80-1.1)	(1.0-1.3)
	300	.21-.29	.30-.39	.40-.50	.28-.41	.38-.52	.48-.63	.40-.65	.51-.76	.62-.88
	600	.14-.22	.19-.27	.23-.32	.20-.33	.25-.38	.30-.44	.32-.56	.37-.61	.42-.67
30	20	(2.9-3.2)	$\boxed{5.6-6.0}$		(3.2-3.8)	(6.0-6.6)		(3.8-4.6)	(6.7-7.6)	
	40	1.5-1.8	(2.7-3.0)	$\boxed{4.0-4.3}$	(1.8-2.2)	(3.0-3.4)	(4.3-4.8)	(2.2-2.9)	(3.5-4.2)	(4.8-5.6)
	80	.82-1.0	1.4-1.6	(2.0-2.2)	1.0-1.4	1.6-2.0	(2.2-2.6)	1.4-2.0	(2.0-2.6)	(2.6-3.2)
	150	.51-.71	.78-.99	1.1-1.3	.68-.99	.96-1.3	1.3-1.6	.97-1.5	1.3-1.8	(1.6-2.2)
	300	.34-.53	.47-.66	.59-.80	.48-.77	.61-.91	.74-1.1	.74-1.3	.88-1.4	1.0-1.6
	600	.26-.44	.32-.50	.38-.57	.38-.67	.44-.74	.50-.81	.62-1.2	.69-1.2	.76-1.3
40	20	(3.6-4.1)	$\boxed{6.7-7.3}$	$\boxed{10-11}$	(4.1-4.9)	(7.4-8.2)	(11-12)	(5.0-6.3)	(8.3-9.7)	(12-13)
	40	1.9-2.3	(3.3-3.8)	(4.8-5.3)	2.3-3.0	(3.8-4.5)	(5.3-6.1)	(3.0-4.1)	(4.5-5.6)	(6.1-7.3)
	80	1.1-1.5	1.7-2.1	2.4-2.8	1.4-2.0	2.1-2.7	2.8-3.4	2.0-3.0	2.7-3.7	(3.4-4.5)
	150	.72-1.1	1.0-1.4	1.4-1.8	.98-1.5	1.3-1.9	1.7-2.2	1.5-2.4	1.8-2.8	2.2-3.2
	300	.51-.84	.66-1.0	.81-1.2	.74-1.3	.89-1.4	1.1-1.6	1.2-2.2	1.4-2.3	1.5-2.5
	600	.41-.74	.48-.81	.55-.89	.61-1.1	.69-1.2	.77-1.3	1.1-2.0	1.1-2.1	1.2-2.2
60	20	4.9-5.9	(8.9-10)	(13-14)	5.9-7.4	(10-12)	(14-16)	(7.5-10)	(12-14)	(16-19)
	40	2.8-3.6	4.6-5.5	6.5-7.4	3.5-4.8	5.4-6.7	(7.3-8.8)	4.8-7.0	(6.7-9.1)	(8.7-11)
	80	1.7-2.5	2.5-3.4	3.4-4.3	2.3-3.5	3.2-4.4	4.1-5.4	3.4-5.6	4.3-6.6	5.2-7.6
	150	1.2-2.0	1.6-2.4	2.1-2.9	1.7-2.9	2.2-3.4	2.6-3.9	2.8-4.9	3.2-5.4	3.7-5.9
	300	.95-1.7	1.2-1.9	1.3-2.1	1.4-2.6	1.6-2.8	1.8-3.1	2.4-4.6	2.6-4.8	2.9-5.1
	600	.82-1.6	.92-1.7	1.0-1.8	1.3-2.4	1.4-2.6	1.5-2.7	2.2-4.4	2.3-4.5	2.5-4.6

For SI Units: 1 ft = .3048 m; 1 ft^2 = .0929 m^2.

Notes to Table 4-3

1. Vents are assumed to be spaced at one-half of the curtain board spacing. *(See 4-3.1.9 and 4-3.4 for other spacings.)*
2. Curtain depth assumed at 20 percent of ceiling height. *(See 4-3.1.9 for other depths.)*
3. Each entry is the vent-area range (in 1000 ft^2) associated with heat-responsive devices rated between 100°F and 220°F (37.8°C and 104.4°C) above ambient temperature.
4. No Entries: Heat-release rates greater than $Q_{feasible}$.
5. Entries Boxed-In: Not possible, but needed for curtain depths greater than 20 percent.
6. Entries in Parentheses: Correspond to levels of heat release greater than Q_{1000}.

4-3.4

The extra time identified in 4-3.3 is represented by the symbol Δt_e and can be estimated from the equation:

$$\Delta t_e \text{ (min)} = C \times [t_g \text{ (sec)}]^{0.9} \times [H \text{ (ft)}]^{1.2}$$

4-3.4.1 Here, t_g is the growth time and H is the ceiling height. The coefficient C depends on the curtain board spacing (S_c), vent spacing (S_v), as well as the temperature rating of the heat-responsive devices. For devices rated at 100°F (37.8°C) above the ambient temperature, some values of C are:

$S_c = 8 \times H$, $S_v = {}^1/_2\, S_c$: C = 0 (design case, Table 4-3)

$S_c = 8 \times H$, $S_v = {}^1/_4\, S_c$: C = 0.0010

$S_c = 8 \times H$, $S_v = {}^1/_8\, S_c$: C = 0.0016

$S_c = 4 \times H$, $S_v = {}^1/_2\, S_c$: C = 0 (design case, Table 4-3)

$S_c = 4 \times H$, $S_v = {}^1/_4\, S_c$: C = 0.0005

4-3.4.2 For heat-responsive devices rated at 220°F (104.4°C), the values of C above are to be increased by about 60 percent.

4-3.4.3 The extra time is not very significant for fast-growing fires. However, for slow-growing fires, the extra time may be significant. [For t_g = 600 sec, $S_c = 8 \times H$, and $S_v = {}^1/_4\, S_c$, the extra time varies from 8-13 min at 15-ft (4.57-m) ceiling height to 40-70 min at 60-ft (18.3-m) ceiling height.]

4-3.4.4 The extra time available with vents spaced at less than ${}^1/_2\, S_c$ may be considered to represent a safety factor for venting systems designed according to 4-3.1.2 and 4-3.1.9.

4-3.5

Consult Table 4-2 for examples on growth time. Most of the examples pertain to fairly high storage. Estimates for lower heights may be made by noting the relative effect of storage height on growth time for wood pallets. Careful engineering judgment is needed in interpreting Table 4-2 and for assessing other material arrays.

4-4 Fresh Air Make-Up.

4-4.1

To function as intended, a venting system needs sufficiently large fresh air openings at low levels in the building. In order to be effective, the total area of these openings must normally be at least as great as the installed vent area per curtained compartment.

4-4.2

If doors and windows below designed smoke level cannot meet the total required inlet area, special air-inlet provisions are necessary.

4-4.3

It is essential that a dependable means for providing inlet air within one minute after the first vent opens be provided.

Chapter 5 Inspection and Maintenance

5-1 Importance.

Vents, like other fire protection equipment, are vulnerable to mishandling, improper installation, and on-site impairments. This is especially true for emergency equipment that may not be subject to fire use for many years. Thus, regular inspection and maintenance are essential.

5-2 General.

5-2.1

Various types of approved automatic thermal smoke and heat vents have been made available commercially that fall into two general categories:

5-2.1.1 Mechanically Opened Vents. (For example: spring-lift, pneumatic-lift, or electric motor-driven.)

5-2.1.2 Gravity-Opened Vents. (For example: PVC or acrylic drop-out panels.)

5-2.2

Generally, mechanically opened vents are provided with manual release devices that permit direct inspection and/or maintenance as well as replacement of actuation components (heat-responsive devices, thermal sensors, compressed gas cylinders, explosive squibs, etc.).

5-2.3

Gravity-opened vents do not permit nondestructive operation, but inspection of the installed unit is necessary to ensure the units were installed in accordance with accepted trade practices and all components are in place, undamaged, and free of soiling, debris, and extraneous items that may interfere with the function of the unit.

5-2.4

The inspection and maintenance of multiple-function vents need to ensure that other functions will not impair the intended fire protection operation.

5-3 Frequency of Inspection and Maintenance.

5-3.1 Mechanically Opened Vents.

5-3.1.1 The manufacturer’s recommendations regarding maintenance and inspection schedule of mechanically operated vents are necessary.

5-3.1.2 It is important that an acceptance performance test and inspection of all mechanically opened vents be conducted immediately following installation to establish that all operating mechanisms function properly and that the installation is in accordance with accepted trade practices.

5-3.1.3 Written schedules and procedures for inspection and maintenance need to include provisions for all units to be tested at 12-month intervals or a scheduling of a percentage of the total units to be tested every month or every two months. Such procedures improve reliability.

5-3.1.4 Recording of all pertinent characteristics of performance and logging to permit comparison of results with those of previous inspection or acceptance tests will permit a comparison that provides a basis for determining need for maintenance or for modifying the frequency of the inspection schedule to fit the experience.

5-3.1.5 Where there is a change in plant occupancy, or in neighboring plants, which might introduce a significant change in nature or severity of corrosive atmosphere exposure, debris accumulation, or physical encumbrance, a change in the inspection schedule may be needed.

5-3.1.6 Special mechanisms such as gas cylinders, thermal sensors, or detectors need to be checked regularly on a schedule provided by the manufacturer.

5-3.2 Gravity-Opened Vents.

5-3.2.1 The same general considerations for inspection that apply to mechanically opened vents (*see 5-3.1*) also pertain to gravity-opened vents. The thermoplastic panels of these vents are designed to soften and "drop out" into the vent opening in response to the heat of a fire. This mode of behavior makes impractical an operational test after installation. Recognized fire protection testing laboratories have developed standards and procedures for evaluating gravity-opened vents including factory and field inspection schedules.

5-3.2.2 An acceptance inspection of all gravity-opened vents should be conducted immediately after installation. Manufacturers' drawings and recommendations should be verified by direct examination. A suitable installation should follow accepted trade practices.

5-3.2.3 A written schedule and procedures for inspection and maintenance need to be enforced and also provide for written notations as to time, date, changes in appearance, damage to any component, fastening security, weathertightness, adjacent roof, and flashing condition.

5-3.2.4 Prompt and careful removal of any soiling, debris, or encumbrances that could impair the operation of the vent is essential.

5-4 Conduct and Observation of Operational Tests.

5-4.1 Mechanically Opened Vents.

5-4.1.1 Where feasible, release of the vent should simulate actual fire conditions by disconnecting the restraining cable at the heat-responsive device (or other releasing device) and suddenly releasing the restraint, thus permitting the trigger or latching mechanism to operate normally.

5-4.1.2 Since the heat-responsive device restraining cable is usually under considerable tension, observation of its whip and travel to determine any possibility that the vent, building construction feature, or service piping, which could obstruct complete release, is desirable. Any possible interference needs to be corrected by removal of obstruction, enclosure of cable in a suitable conduit, or other appropriate rearrangement. Following any modification, the unit needs to be retested for evaluation of adequacy of corrective measures.

NOTE: The whipping action of the cable upon release presents the possibility of injury to anyone in the area. For this reason, the person conducting the test must ensure that he/she and all other personnel are well clear of the area where whipping of the cable may occur.

5-4.1.3 The latch needs to release smoothly, and the vent to start to open immediately and move through its design travel to full-open position without any prompting and without undue delay indicative of sticking weather seal, corroded or unaligned bearings, distortion binding, etc.

5-4.1.4 Manual releases need to be tested to determine that the vents will operate.

5-4.1.5 All operating levers, latches, hinges, and weather-sealed surfaces should be examined to determine any indication of deterioration, accumulation of foreign material, etc., that might warrant corrective action or suggest another inspection in advance of the normal schedule.

5-4.1.6 Following painting of the interior or exterior of vents, the units need to be opened and inspected as a check against the gluing characteristic of paint between matching surfaces. Painted heat-responsive devices need to be replaced with devices having an equivalent temperature and load rating.

5-4.2 Gravity-Opened Vents.

5-4.2.1 Testing of manual releases is considered a part of total testing to ensure that the vents will operate.

5-4.2.2 Following painting of the interior or exterior of vents, it is important to open and inspect them as a check against the gluing characteristic of paint between matching surfaces.

5-5 Ice and Snow Removal.

Removal of ice and snow from vents is an essential part of a maintenance program for such devices.

Chapter 6 Venting in Sprinklered Buildings

6-1

The previous chapters represent the state of technology of vent design in the absence of sprinklers. A broadly accepted equivalent design basis for using both sprinklers and vents together for hazard control (e.g., property protection, life safety, water usage, obscuration, etc.) has not been universally recognized.

6-2

For occupancies that present a high challenge to sprinkler systems, concern has been raised that inclusion of automatic roof venting may be detrimental to the performance of automatic sprinklers. Although there is no universally accepted conclusion from fire experience [Section 6-5(a)], studies on a model scale [Section 6-5(b)] suggested:

(a) Venting delays loss of visibility.

(b) Venting results in increased fuel consumption.

(c) Depending on the location of the fire relative to the vents, the necessary water demand to achieve control is either increased or decreased over an unvented condition. With the fire directly under the vent, water demand is decreased. With the fire equidistant from the vents, water demand is increased.

6-3

A series of tests was conducted to increase the understanding of the role of automatic roof vents simultaneously employed with automatic sprinklers [Section 6-5(c)]. The data submitted did not permit consensus to be developed whether sprinkler control was impaired or enhanced by the presence of automatic (roof) vents of typical spacing and area.

6-4

While the use of automatic venting in sprinklered buildings is still under review, the designer is encouraged to use the available tools and data referenced in this document for solving problems peculiar to a particular type of hazard control.

6-5

References of interest include:

(a) Miller, E. E., Position Paper to 204 Subcommittee, “Fire Venting of Sprinklered Property.”

(b) Heskestad, G., *Model Study of Automatic Smoke and Heat Vent Performance in Sprinklered Fires*, Technical Report FMRC Serial No. 21933RC74-T-29, Factory Mutual Research Corp., Norwood, MA, September 1974.

(c) Waterman, T. E., et al., *Fire Venting of Sprinklered Buildings*, IITRI Project J08385 for Fire Venting Research Committee, IIT Research Institute, Chicago, IL 60616, July 1982.

Appendix A Derivation of Venting Relationships

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

A-1

At the time this guide was formulated, an approximate venting theory already existed (*see Section A-9, references 1 and 2*), which has served as a foundation of several European venting standards. However, that theory was deemed unwieldy for the format of this venting guide. Consequently, the alternative, more adaptable theory described here was adopted. It is emphasized that the alternative theory gives results for specific venting situations that do not differ greatly from the predictions of the previous theory.

Elements of Problem.

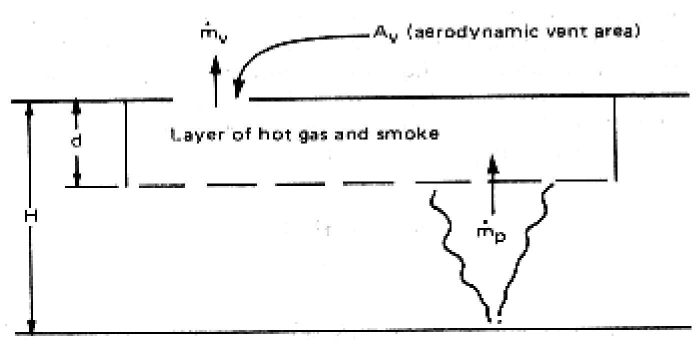


Figure A-1 Schematic of Venting System.

A-2

Refer to Figure A-1. Assume steady state. H is the floor-to-ceiling height; d is the depth of the curtain boards (or design depth of the smoke layer); $\dot{m}_p$ is the mass flow rate of hot gases from the fire plume into the smoke layer; $\dot{m}_v$ is the mass flow rate of hot gas out of the vent (or vents); and A_v is the aerodynamic vent area (total aerodynamic vent area in curtained compartment, if several vents). At equilibrium, the mass flow rate into the smoke layer ($\dot{m}_p$) matches exactly the mass flow rate out of the vent ($\dot{m}_v$). In the following, separate sections are devoted to obtaining mathematical expressions for $\dot{m}_p$ and $\dot{m}_v$, which subsequently are matched to yield expressions for the required area, A_v.

A-3 Mass Flow Rate in Plume,

$\dot{m}_p$.

At a given elevation within the plume, below the level where the plume enters the smoke layer, the local mass flow rate in the plume is:

$$\dot{m}_p = \int_0^R u\,\rho\,2\pi r dr$$

where u is the gas velocity; ρ is the mass density of the gas; r is the observation radius; and R is the radius of the fire plume. The gas density, ρ can be written:

$$\rho = \rho_o - \Delta\rho \qquad (2)$$

where ρ_o is the ambient density, and Δρ is the local density defect relative to the ambient density. The following relation can be formed from equations (1) and (2):

$$\dot{m}_p = 2\pi R^2 u_c \left[\rho_o \int_0^1 \frac{u}{u_c}\,\frac{r}{R}\,d\left(\frac{r}{R}\right) - \Delta\rho_c \int_0^1 \frac{u}{u_c}\,\frac{\Delta\rho}{\Delta\rho_c}\,\frac{r}{R}\,d\left(\frac{r}{R}\right)\right] \qquad (3)$$

where u_c and $\Delta\rho_c$ are centerline values of u and Δρ, respectively.

It is now assumed that the flow in the plume is self-preserving: i.e., profiles of velocity and density defect preserve their shapes along the plume axis except for changes in centerline values and changes in the plume radius. Under this assumption, the integrals in equation (3) are universal, nondimensional constants. Then equation (3) can be written:

$$\dot{m}_p = 2\pi R^2 u_c \left[A\rho_o - B\Delta\rho_c \right] \qquad (4)$$

where:

$$A = \int_0^1 \frac{u}{u_c} \frac{r}{R} \, d\left[\frac{r}{R}\right] \qquad (5)$$

$$B = \int_0^1 \frac{u}{u_c} \frac{\Delta\rho}{\Delta\rho_c} \frac{r}{R} \, d\left[\frac{r}{R}\right] \qquad (6)$$

To develop equation (4) further, an expression for the flux of convective heat in the plume is sought. First, note that the flux of convective heat, Q, can be considered conserved along the plume axis and can be written:

$$Q = C_p \int_0^R \rho u \Delta T 2\pi r dr \qquad (7)$$

where C_p is the specific heat of the plume gases (essentially air) and ΔT is the local excess temperature of the plume gases relative to the ambient temperature. With the aid of the equation of state for a perfect gas, it can be shown:

$$\rho u \Delta T = u T_o \Delta\rho \qquad (8)$$

where T_o is the ambient temperature. With equation (8), equation (7) can be written:

$$Q = 2\pi R^2 C_p T_o u_c \Delta\rho_c \int_0^1 \frac{u}{u_c} \frac{\Delta\rho}{\Delta\rho_c} \frac{r}{R} d\left[\frac{r}{R}\right] \qquad (9)$$

or using the definition in equation (6):

$$Q = 2\pi R^2 C_p T_o u_c \Delta\rho_c B \qquad (10)$$

Substitution for $2\pi R^2 u_c$ from equation (10) into equation (4) gives:

$$\dot{m}_p = \frac{Q\left[1 - \frac{B}{A} \frac{\Delta\rho_c}{\rho_o}\right]}{C_p\, T_o\, (B/A)\, (\Delta\rho_c / \rho_o)} \qquad (11)$$

With the aid of the equation of state for a perfect gas, equation (11) can be written:

$$\dot{m}_p = \frac{Q\left[1 + \left(1 - \frac{B}{A}\right)\frac{\Delta T_c}{T_o}\right]}{C_p\, (B/A)\, \Delta\, T_c} \qquad (12)$$

Measurements of plume profiles (3) have given values A = 0.164 and B = 0.111, such that B/A = 0.68. For plume centerline temperatures, the following relation is consistent with theory and experiments (4):

$$\Delta T_c / T_o = 0.60\, Q^{2/3} z^{-5/3} \qquad (13)$$

where z is, approximately, the elevation above the fire source (Q in Btu/sec, z in ft). With the aid of these results, equation (12) takes the following engineering form:

$$\dot{m}_p \text{ (lb/s)} = CQ^{1/3}z^{5/3}[1 + 0.19\, Q^{2/3}z^{-5/3}] \qquad (14)$$

where C = 0.019. A direct measurement of mass flow rate in a fire plume (3) has indicated that a better value for C is:

$$C = 0.022 \qquad (15)$$

In the vent problem, the elevation in the plume at entry into the smoke layer is z = H-d, assuming the fire source does not reach much above the floor level. Hence, the mass flow rate feeding the smoke layer is, from equations (14) and (15):

$$\dot{m}_p\text{(lb/s)} = 0.022\, Q^{1/3}(H-d)^{5/3}[1 + 0.19\, Q^{2/3}(H-d)^{-5/3}] \qquad (16)$$

Equation (16) ceases to be valid when the continuous flaming region (as opposed to the intermittent flaming region) reaches into the smoke layer, which essentially coincides with the occurrence of a gas temperature rise of about 1600°F (871.1°C) (“flame temperature”) in the plume as it enters the smoke layer. According to equation (13), the associated (convective) heat-release rate, Q = Q_c, is calculated as:

$$Q_c \text{ (Btu/sec)} = 11.3(H-d)^{5/2} \qquad (17)$$

At heat-release rates greater than Q, the mass flow rate into the smoke layer from the fire is estimated from the entrainment relation by Ricou and Spaulding[5]. This relation is:

$$\frac{d\dot{m}_p}{dz} = K(M\rho_o)^{1/2} \qquad (18)$$

where K is an “entrainment constant” (nondimensional) and M is the local momentum flux in the plume. Assuming that the continuous flaming region beneath the smoke layer has a constant centerline velocity, u_f; gas density, ρ_f; and radius b_f, the entrained flow beneath the smoke layer is estimated to be proportional to:

$$\dot{m}_p \propto (H-d)(M\rho_o)^{1/2} \propto (H-d)\,(\rho_f\, u_f^2\, b_f^2\, \rho_o)^{1/2} \qquad (19)$$

An expression for the radius of the fire plume, b_f, follows from the expression for convective heat flux:

$$Q \propto \rho_f\, u_f\, b_f^2\, C_p \Delta T_f \qquad (20)$$

Substitution for b_f in equation (19) from equation (20) results in the following proportionality if ρ_0, C_p, *and* ΔT_f are considered constant*:*

$$\dot{m}_p \propto (H-d) u_f^{\;1/2}\, Q^{1/2} \qquad (21)$$

For the flame-gas velocities, u_f, it is known from past work(6) that:

$$u_f \propto Q^{1/5} \qquad (22)$$

which in equation (21) gives:

$$\dot{m}_p \propto (H-d)\, Q^{3/5} \qquad (23)$$

Hence, knowing the mass flow rate into the smoke layer for a heat-release rate of Q_c [from equation (16), with $Q = Q_c$ according to equation (17)], mass flow rates at greater heat-release rates follow from:

$$\dot{m}_p \approx (\dot{m}_p)_c\, (Q/Q_c)^{3/5} \qquad (24)$$

where $(\dot{m}_p)_c$ is $\dot{m}_p$ at $Q = Q_c$.

Note that for $Q = Q_c$, the convective heat flux, Q, must be regarded as a pseudo heat flux, being the convective heat flux of the associated “free-burning” fire, which is not influenced by the vitiated air of the smoke layer. Unreached fuel carried by the plume into the smoke layer will not burn to completion, and the actual heat released will be less than in free-burn. To avoid ambiguity, the convective heat flux Q should always be interpreted, in this theory, as the convective heat produced by the associated free-burning rate of the actual building fire.

A-4 Mass Flow Rate Through Vents, $\dot{m}_v$.

Assume first that the entry area for fresh air into the building is “not small” [at least as large as vent area according to Thomas and Hinkley[2]].

Equating the buoyancy head across the vent to the dynamic head in the vent (from Bernoulli’s equation) gives:

$$1/2\ \rho u^2 = \Delta\rho g\ d \qquad (25)$$

where ρ is the smoke layer density, $\Delta\rho = \rho_o$ - u is the gas velocity in the vent, and g is the acceleration of gravity. It follows from equation (25) that:

$$\dot{m}_v^{\,2} = A_v^{\,2}\, p^2\, u^2 = 2A_v^{\,2}\, \rho\Delta\rho\ g\ d \qquad (26)$$

where A_v is the aerodynamic vent area (well-approximated by 0.6 times geometric through-flow area for simple apertures). From the equation of state for a perfect gas:

$$\rho\Delta\rho = \rho_o^{\,2}\frac{T_o\Delta T}{T^2} \qquad (27)$$

where T is the smoke layer temperature and $\Delta T = T - T_o$. Then equation (26) becomes:

$$\dot{m}_v = (2\ \rho_o^{\,2}\ g)^{1/2}\left[\frac{T_o\Delta T}{T^2}\right]^{1/2} A_v\, d^{\,1/2} \qquad (28)$$

Note that the factor $(T_o\ \Delta T/T^2)^{1/2}$ is quite insensitive to temperature as long as the smoke layer temperature is not small. For example, assuming T_o = 530 R, the factor varies through 0.47, 0.50, 0.48 as the smoke layer temperature varies through 350°F (176.7°C), 600°F (315.5°C), 1000°F (537.7°C). Consequently, it is simply assumed in the vent application that the factor may be taken as constant at:

$$\left[\frac{T_o \Delta T}{T^2}\right]^{1/2} = 0.5 \qquad (29)$$

A-5 Required Vent Area Versus Heat-Release Rate.

The mass flow rate through the vent, equation (28) with the approximation in equation (29), is equated with the mass flow rate into the smoke layer:

$$0.5\ (2\rho_o{}^2 g)^{1/2} A_v d^{1/2} = \dot{m}_p \qquad (30)$$

which is solved for A_v:

$$A_v = \frac{2}{(2\rho_o{}^2 g)^{1/2}} \frac{\dot{m}_p}{d^{1/2}} \qquad (31)$$

The value of $\dot{m}_p$ is determined as described in the preceding section. First Q_c is determined from equation (17) to establish which regime the fire is in. For ($Q \leq Q_c$), equation (16) for $\dot{m}_p$ is substituted into equation (31):

$$A_v\ (\text{ft}^2) = 0.073\ Q^{1/3}[1 + 0.19\ Q^{2/3}(H-d)^{-5/3}]\ \frac{(H-d)^{5/3}}{d^{1/2}} \qquad (32)$$

(Q in Btu/sec; H and d in ft)

For ($Q > Q_c$), $\dot{m}_p$ is obtained from equation (24), where $(\dot{m}_p)_c$ is calculated from equation (16) with $Q = Q_c$ according to equation (17):

$$(\dot{m}_p)_c = 0.097\ (H-d)^{5/2} \qquad (33)$$

such that:

$$\dot{m}_p = 0.097\,(H - d)^{5/2}\,(Q/Q_c)^{3/5} \qquad (34)$$

This expression for $\dot{m}_p$ is substituted into equation (31), with the desired results:

$$A_v\,(\mathrm{ft}^2) = 0.32\,(Q/Q_c)^{3/5}\,\frac{(H-d)^{5/2}}{d^{1/2}} \qquad (35)$$

(H and d in ft)

These relations can be greatly simplified whenever Q/Q_c is larger than approximately 0.2 (nearly always the case in vent design). Then it may be shown that equations (32) and (35) can be consolidated into a single relation with the aid of equation (17), valid for heat-release rates both smaller and larger than Q_c:

$$A_v\,(\mathrm{ft}^2) = 0.075\,Q^{3/5}\,\frac{H-d}{d^{1/2}} \qquad 36$$

(Q in Btu/sec; H and d in ft)

A-6 Vent Areas for Steady Fires (Limited-Growth Fires).

For stationary fires, or fires that do not develop beyond a maximum size, the required vent areas are calculated from equation (32) or equation (35), depending on the heat-release rate relative to Q, or from the simplified expression in equation (36). Paragraphs 4-2.1.1 and 4-2.1.4 are based on the simplified relation in equation (36), with the vent areas adjusted to a discharge coefficient of 0.6.

A-7 Vent Areas for Growing Fires (Continuous-Growth Fires).

A simple fire-growth model is first stipulated:

$$Q = 1000\,(t/t_g)^2 \qquad (37)$$

(Q in Btu/sec; t and t_g in sec)

where t is time from a virtual ignition event representative of the developed fire following an incubation period, and t_g is the time, t, at which the developed fire exceeds an intermediate size of 1000 Btu/sec. The growth time, t_g is a measure of the fire-growth rate; the smaller the growth time, the faster the fire grows.

A venting system must be able to handle the fire from the time of ignition to the last instant of the clear-visibility design time interval, t_r, as measured from the time, t_d, when the first vents activate. In other words, a venting system must be able to handle the fire at the intervention time, $t_r + t_d$, following ignition. Once the intervention time is known, the fire size at intervention can be calculated from equation (37) for the expected fire-growth time, t_g. Required vent areas are calculated from equations (32) and (35) or from the simplified expression in equation (36).

A convenient relation for the required vent area is obtained if the simplified expression in equation (36) is adopted. Together with equation (37) and the definitions of t_d and t_r, equation (36) leads to:

$$A_v\,(\mathrm{ft}^2) = 4.8 \left(\frac{t_d + t_r}{t_g}\right)^{6/5} \frac{H-d}{d^{1/2}} \qquad (38)$$

(t_d, t_r, t_g in sec; H and d in ft)

Paragraphs 4-3.1.2 and 4-3.1.9 are based on equation (38), with the vent areas adjusted to a discharge coefficient of 0.6. The detection time, t_d, was taken as the time of operation of the first vent in a square matrix (vent farthest possible from the fire location). The vents were assumed to be activated by heat-responsive devices of various temperature ratings above the ambient temperature. Link activation times (t_d) were calculated from a thermal-response equation for heat-responsive devices derived previously[7], together with generalized data on gas temperatures and velocities under extensive flat ceilings[4]. The time constant[7] of the heat-responsive device was taken as 233 sec at 5 ft/sec (1.53 m/sec) gas velocity, which is considered to be a conservatively high value for heat-responsive devices listed by testing laboratories.

Paragraphs 4-3.1.2 and 4-3.1.9 are based on equation (38), with the vent areas adjusted to a discharge coefficient of 0.6. The detection time, t_d, was taken as the time of operation of the first vent in a square matrix (vent farthest possible from the fire location). The vents were assumed to be activated by heat-responsive devices of various temperature ratings above the ambient temperature. Link activation times (t_d) were calculated from a thermal-response equation for heat-responsive devices derived previously [7], together with generalized data on gas temperatures and velocities under extensive flat ceilings [4]. The time constant [7] of the heat-responsive device was taken as 233 sec at 5 ft/sec (1.53 m/sec) gas velocity, which is considered to be a conservatively high value for heat-responsive devices listed by testing laboratories.

A-8 On Conservatism Built into Guide.

All calculations have assumed that the top of the combustible is essentially level with the building floor, which results in larger required vent areas than would higher elevations of the combustible. The underlying rationale is that by the last moments of the intervention time, and during the clear-visibility design time, the fire will be at such an advanced stage that the combustible may, in fact, have collapsed to near floor level.

For the vent activation times (t_d) needed in calculations of vent areas recommended in 4-3.1.1 and 4-3.1.9, it is recalled that an additional assumption was made, i.e., the heat-responsive device was exposed to gas temperatures and velocities similar to those generated by fires under extensive flat ceilings. This assumption may appear to be optimistic for installations involving beamed ceilings. However, any delay in vent operation due to beams is probably compensated by opposite effects of (1) heat banking up under the ceiling because of curtain boards or walls, (2) the top of the combustible being closer to the ceiling than assumed in the calculations (floor level assumed), and (3) the nearest vent to the fire usually being closer than assumed in the calculations (greatest possible distance assumed).

A-9 References

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1. Thomas, P.H., Hinkley, P.L., Theobald, C.R. and Simms, D.L., "Investigations Into the Flow of Hot Gases in Roof Venting," Fire Research Technical Paper No. 7, Department of Scientific and Industrial Research and Fire Offices' Committee, Joint Fire Research Organization, London: H.M. Stationery Office, 1963.
2. Thomas, P.H. and Hinkley, P.L., "Design of Roof-Venting Systems for Single-Story Buildings," Fire Research Technical Paper No. 10, Department of Scientific and Industrial Research and Fire Offices' Committee, Joint Fire Research Organization, London: H.M. Stationery Office, 1964.
3. Heskestad, G., "Optimization of Sprinkler Fire Protection, Progress Report No. 9: Fire Plume Simulator," Factory Mutual Research Corporation Report 18792, 1974.
4. Heskestad, G., "Similarity Relations for the Initial Convective Flow Generated by Fire," American Society of Mechanical Engineers, Paper No. 72-WA/HT-17 November 1972.
5. Ricou, F.P. and Spaulding, D.B., "Measurements of Entrainment by Axisymmetrical Turbulent Jets," J. *Fluid Mechanics*, Vol. 11, p. 21, 1961.
6. Heskestad, G., "Peak Gas Velocities and Flame Heights of Buoyancy-Controlled Turbulent Diffusion Flames," Eighteenth Symposium (International) on Combustion, University of Waterloo, Canada, August 17-22, 1980.
7. Heskestad, G. and Smith, H.F., "Investigation of a New Sprinkler Sensitivity Approval Test: The Plunge Test," Factory Mutual Research Corporation Report 22485, 1976.

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 References.

Bengston, S. "Protection Measures, re: Fire Damage and Safety." *Fire Research and Development News 1*, pp. 13-20 (1978). SPFA, Stockholm, Sweden.

Boston Fire Department Fire Academy. "Tests of Plexiglass Glazed Windows," September, 1964.

Colt Ventilation and Heating Ltd. “Full Scale Fire Ventilation Tests at Victoria Barracks, Portsmouth, August 1966.” Research and Development Department, Havant Hampshire, England.

Crouch, C.W. “Roof Vent Requirements,” General Motors Corp., Detroit, Michigan (1958).

Crouch, C.W. “Roof Ventilation for Industrial Plants,” Argonaut Realty Division, General Motors Corp., Detroit, Michigan (1958).

Factory Mutual Research. *Approval Standard for Heat and Smoke Vents,* No. 4430, Norwood, Massachusetts (1973).

Heskestad, G. “Model Study of Automatic Smoke and Heat Vent Performance in Sprinklered Fires,” Tech. Report RC74-T-29September 1974, Factory Mutual Research Corp.

Industrial Risk Insurers. “Heat and Smoke Venting,” P.2.6 (1980).

Keough, J.J. “Venting Fires Through Roofs,” Report No. Up 334, Commonwealth Exp. Bldg. Sta., Chatswood, Australia (1972).

Miller, E.E. “Fire Venting of Sprinklered Property,” Position Paper to 204 Subcommittee, National Fire Protection Association, March 1980.

National Fire Protection Association. “General Motors Fire, Livonia, Michigan, August 12, 1953.” Reprint from NFPA Quarterly, October 1953.

Property Insurance Association. “Guidelines, Smoke and Heat Vents,” Cologne, Germany (1973).

SPFA, *Fire Ventilation Recommendations,* Stockholm, Sweden (1973).

Underwriters Laboratories Inc. “Automatically Operated Smoke and Heat Roof Vents,” No. 793, Northbrook, Illinois (1990).

Waterman, T.E., “Fire Venting of Sprinklered Buildings,” *Fire Journal*, Volume 78, March 1984, pp. 34, 36-39, 86.

Youngstown, PVC Fire Tests. Unpublished Test Data and FIA “Sentinel” article, February 1964.

B-2 Additional References.

See Appendix A, Section A-9.

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 68, *Guide for Venting of Deflagrations,* 1988 edition

NFPA 211

1996 Edition

Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances

1996 Edition

This edition of NFPA 211, *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances*, was prepared by the Technical Committee on Chimneys, Fireplaces, and Venting Systems for Heat-Producing Appliances 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 211

In 1906, the NFPA Committee on Chimneys and Flues presented its first report. In 1914, under the jurisdiction of the then Committee on Field Practice, recommendations on chimneys and flues were prepared as Chapter VII of the *Field Practice Manual*, presented in 1914 and adopted in 1915. In 1926, the Association adopted the Chimney Construction Ordinance of the National Board of Fire Underwriters. In 1944, the Association adopted Article XI of the 1943 edition of the *Building Code of the National Board of Fire Underwriters* to supersede the former chimney ordinance. This action was taken by the Board of Directors in the name of the Association on the recommendation of the Committee on Field Practice.

In 1948, the subject of chimneys and flues was transferred to the Committee on Building Construction. In 1950, the Association adopted Article X of the 1949 *National Building Code of the National Board of Fire Underwriters*, to supersede the 1944 standard, upon recommendation of the Committee on Building Construction and action by the Board of Directors.

In 1955, the subject of chimneys and flues was transferred to the newly appointed Committee on Chimneys and Heating Equipment. NFPA 211 was revised in 1957 to make the text consistent with the provisions on the same subject appearing in the *National Building Code of the National Board of Fire Underwriters*. NFPA 211 was revised in 1961 and completely rewritten in 1964. The 1964 edition included requirements for chimney connectors, which were previously covered in NFPA 212. This latter standard was withdrawn in 1964. Since 1964, revised editions of the standard have been adopted by the Association in 1966, 1968, 1970, 1971, 1972, and 1977. In 1969, new text was added to cover the subject of spark arresters, which had been covered in NFPA 213, a standard that was withdrawn in 1969.

In 1980, the scope of NFPA 211 was expanded to include solid-fuel appliances, and in the 1984 edition, major revisions were made to many sections, including important tables and graphs.

The 1988 edition included revisions to wall pass-through systems, including a new Table 5-7 showing four chimney connector systems. A complete revision to Table 5-5(b) and changes to upgrade test requirements for factory-built chimneys were included.

The 1992 edition included new figures to show fireplace clearance requirements and other construction details, new requirements for combustion air ducts for fireplaces, and a new maintenance chapter that addressed inspection, cleaning, and repair of chimneys, vents, and fireplaces.

Definitions for "vent" and "chimney" have been revised in the 1996 edition, and the chimney and vent selection charts have been moved from Chapter 1 to a new Chapter 2. Included in the new Chapter 2 are new figures to aid in the selection of chimney types.

Technical Committee on Chimneys, Fireplaces, and Venting Systems for Heat-Producing Appliances

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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.

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, installation, and use of chimneys, fireplaces, vents, venting systems, and solid fuel-burning appliances. It also shall be responsible for documents on clearances of heat-producing appliances from combustible materials and terms relating to chimneys, vents, and heat-producing appliances.

NFPA 211
Standard for
Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances

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 B.

Chapter 1 General

1-1 Scope.

This edition of NFPA 211 contains provisions for chimneys, fireplaces, venting systems, and solid fuel-burning appliances including their installation. The standard applies to residential as well as commercial and industrial installations.

1-2 Purpose.

1-2.1

The primary concern of this standard is the removal of waste gases, the reduction of fire hazards associated with the construction and installation of chimneys, fireplaces, and venting systems for residential, commercial, and industrial appliances, and the installation of solid fuel-burning appliances.

1-2.2

This standard provides minimum construction and installation requirements for chimneys and vents suitable for use with fuel-burning appliances.

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.

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 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 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.

1-5.1

Other definitions relating to chimneys, fireplaces, and venting systems are contained in NFPA 97, *Standard Glossary of Terms Relating to Chimneys, Vents, and Heat-Producing Appliances*.

1-5.2 General Definitions.

Air, Combustion. The air necessary to provide for the complete combustion of fuel and usually consisting of primary air, secondary air, and excess air.

Air, Dilution. The air that enters the relief opening of a draft hood or draft diverter, or the air that enters another opening in an appliance flue or venting system.

Appliance. Utilization equipment, normally built in standardized sizes or types, that is installed or connected as a unit to perform one or more functions such as clothes washing, air conditioning, food mixing, cooking, heating, or refrigeration.

Appliance, Automatically Lighted Fuel-Burning. A fuel-burning appliance in which fuel to the main burner is normally turned on and ignited automatically.

Appliance, Building Heating. A fuel-burning or electric boiler operating at not over 50 psig [345 kPa (gauge)] pressure, a central furnace, or a heater intended primarily for heating spaces having a volume exceeding 25,000 ft^3 (708 m^3).

Appliance, Cooking (Floor-Mounted Restaurant-Type). A range, oven, broiler, or other miscellaneous cooking appliance, designated for use in hotel and restaurant kitchens and for mounting on the floor.

Appliance, Residential-Type Heating. Fuel-burning and electric heating appliances, not including high-pressure steam boilers, for heating building spaces having a volume of not more than 25,000 ft^3 (708 m^3) and other heat-producing appliances of the type mainly used in residences but that might be used in other buildings, such as cooking stoves and ranges, clothes dryers, fireplace stoves, domestic incinerators, laundry stoves, water heaters, and heat pumps.

Appliance Casing (Jacket). An enclosure forming the outside of the appliance.

Appliance Categories. See Gas Appliance Categories.

Appliance Flue. The flue passages within an appliance.

Appliances, Counter (Gas). Appliances such as gas-operated coffee brewers and coffee urns and any appurtenant water-heating equipment, food and dish warmers, hot plates, and griddles.

Appliances, Nonresidential.
Low-Heat Appliance. A commercial, industrial, or institutional appliance needing a chimney capable of withstanding a continuous flue gas temperature not exceeding 1000°F (538°C).
1400°F Appliance. A commercial, industrial, or institutional appliance needing a chimney capable of withstanding a continuous flue gas temperature not exceeding 1400°F (760°C).
Medium-Heat Appliance. A commercial, industrial, or institutional appliance needing a chimney capable of withstanding a continuous flue gas temperature not exceeding 1800°F (982°C).
High-Heat Appliance. A commercial, industrial, or institutional appliance needing a chimney capable of withstanding a continuous flue gas temperature exceeding 1800°F (982°C).

Approved.* Acceptable to the authority having jurisdiction.

Ash. The solid residue that remains after combustion is complete.

Ash Receptacle Door. A door below the grade level providing access to the ash receptacle.

Attic-Type Heating Appliance. A heating appliance designed specifically for installation in an attic or in a space with low headroom that normally is unoccupied.

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

Automatic Electric Igniter. A device for fuel burners designed to utilize electric energy for ignition of a fuel-air mixture at the burner.

Baffle. An object installed in an appliance to change the direction of, or retard airflow, air-fuel mixtures, or flue gases.

Boiler. A closed vessel for heating water or a liquid or for generating steam or vapor by direct application of heat. It is usually an indirect-fired fuel-burning or electrically heated appliance.

Boiler, Combination-Fuel. A single boiler unit designed to burn more than one type of fuel (gas, oil, or solid), either separately or simultaneously, using either separate or common combustion chambers and flues.

Boiler, High-Pressure. A boiler for generating steam at pressures in excess of 15 psig [103 kPa (gauge)], or for heating water to a temperature in excess of 250°F (121°C) or at a pressure in excess of 160 psig [1103 kPa (gauge)].

Boiler, Hot Water Supply. A low-pressure hot water boiler having a volume exceeding 120 gal (454 L), or a heat input exceeding 200,000 Btu/hr (58.6 kWh), or an operating temperature exceeding 200°F (93°C) that provides hot water to be used outside the boiler.

Boiler, Low-Pressure. A boiler for generating steam at pressures not in excess of 15 psig [103 kPa (gauge)] or for furnishing water at a maximum temperature of 250°F (121°C) at a maximum pressure of 160 psig [1103 kPa (gauge)].

Boiler, Supplementary. A boiler designed to burn one type of fuel (gas, oil, or solid) that is intended for supplementing a boiler burning another type of fuel (gas, oil, or solid) by means of a common heat transfer medium.

Bond. Where referring to bricklaying and masonry chimneys, that connection between brick, stone, or other masonry units formed by lapping them upon one another in carrying up the work, thereby forming an inseparable mass.

Breeching. The conduit conveying flue gas from the appliance to the chimney.

Btu. Abbreviation for British thermal unit. The quantity of heat needed to raise the temperature of 1 pound of water 1°F.

Chimney. A structure containing one or more vertical or nearly vertical passageways for conveying flue gases to the outside atmosphere. [*See also Vent, Gas Vent, and Venting System (Flue Gases)*.]

Factory-Built.

*Residential Type and Building Heating Appliance Type***.** A chimney suitable for continuous use at 1000°F (538°C), composed of listed, factory-built components that might be fully enclosed in combustible, residential-type construction, and that is assembled in accordance with the terms of the listing to form the completed chimney.

Building Heating Appliance Type. A heating appliance chimney suitable for continuous use at 1000°F (538°C), composed of listed, factory-built components, designed for open, nonenclosed use at specified minimum clearances to combustibles, and assembled in accordance with the terms of the listing to form the completed chimney.

1400°F Type. A chimney suitable for continuous use at 1400°F (760°C), composed of listed, factory-built components, intended for open, nonenclosed use at specified minimum clearances to combustibles and use in noncombustible locations, and assembled in accordance with the terms of the listing to form the completed chimney.

Medium-Heat Appliance Type. A chimney used with appliances that produce maximum flue gas temperatures of 1800°F (982°C), composed of listed, factory-built components, suitable for open, nonenclosed use at specified minimum clearances to combustibles, and assembled in accordance with the terms of the listing to form the completed chimney.

Masonry Chimney. A field-constructed chimney of solid masonry units, bricks, stones, listed masonry chimney units, or reinforced portland cement concrete that is lined with suitable chimney flue liners and built in accordance with Chapter 4 of NFPA 211, *Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances*.

Unlisted Metal Chimney (Smokestack). A manufactured or field-constructed chimney intended only for nonresidential applications having one or more metal walls, or made of metal with a refractory lining, and that is capable of withstanding the flue gas conditions of its use.

Chimney Cap. A protective covering or housing for the top of a chimney intended to prevent the entry of rain, snow, animals, and birds, and to prevent downdrafts.

Chimney Connector. The pipe that connects a fuel-burning appliance to a chimney.

Chimney Flue Base (Base of Flue). The lowest point of a flue within a chimney.

Cleanout Opening. An opening or hole in a chimney, usually located near its base, designed to allow access to the flue for purposes of removing ash, creosote, soot, and other extraneous matter that becomes trapped.

Clearance. The distance between a heat-producing appliance, chimney, chimney connector, vent, vent connector, or plenum and other surfaces.

Clothes Dryer. A device used to dry wet laundry by means of heat derived from the combustion of fuel or from electric heating elements.

Type 1 Clothes Dryer. A factory-built, mass-produced dryer, primarily used in a family living environment. It might or might not be coin-operated for public use and usually is the smallest unit both physically and in function.

Type 2 Clothes Dryer. A factory-built, mass-produced dryer used in a commercial business. It might or might not be operated by the public or a hired attendant. It might or might not be coin-operated and is not designed for use in an individual family living environment. It can be small, medium, or large in size.

Combustible Material. Material made of or surfaced with wood, compressed paper, plant fibers, plastics, or other material that can ignite and burn, whether flameproofed or not, or whether plastered or unplastered.

Combustion. The rapid oxidation of fuel accompanied by the production of heat or heat and light.

Combustion Products. Effluents resulting from the combustion of a fuel including the inerts, but excluding excess air.

Confined Space. A space whose volume is less than 50 ft^3/1000 Btu/hr (1.42 m^3/293 W) of the aggregate input rating of all appliances installed in that space.

Corbel. Units of masonry projecting from or projecting upward and outward from the face of a wall or chimney in courses to form a support or ledge for a beam, rafter, or other member.

Damper. A valve or plate for controlling draft or the flow of gases, including air.

Damper, Automatically Operated. A damper operated by an automatic control.

Damper, Flue Gas. A damper located on the downstream side of the combustion chamber of a fuel-burning appliance, usually in a flue passage of the appliance or in the chimney or vent connector.

Damper, Manually Operated. An adjustable damper manually set and locked in the desired position.

Direct Vent Appliance (Sealed Combustion System Appliance). A system consisting of an appliance, combustion air and flue gas connections between the appliance and the outside atmosphere, and a vent cap supplied by the manufacturer, and constructed so that all air for combustion is obtained from the outside atmosphere and all flue gases are discharged to the outside atmosphere.

Draft. The pressure differential that causes the flow of air or gases through a chimney, gas vent, or venting system.

Mechanical Draft. Draft produced by a fan or an air or steam jet. When a fan is located so as to push the flue gases through the chimney or vent, the draft is forced. When the fan is located so as to pull the flue gases through the chimney or vent, the draft is induced.

Natural Draft. Draft produced by the difference in the weight of a column of flue gases within a chimney or vent and a corresponding column of air of equal dimension outside the chimney or vent.

Draft Hood. A device built into a gas appliance, or made a part of a chimney connector or vent connector from a gas appliance, that is designed to:

(a) Allow the ready escape of flue gases in the event of zero draft, a backdraft, or stoppage beyond the draft hood;

(b) Allow the ready escape of the back pressure from a backdraft so it does not enter the gas appliance; and

(c) Neutralize the possible effects of excess draft on the operation of the appliance.

Draft Regulator, Barometric. A device built into a fuel-burning appliance, or made a part of a chimney connector or vent connector, that functions to reduce excessive draft through an appliance to a desired value by admitting ambient air into the appliance chimney, chimney connector, vent, or vent connector.

Engineered Venting or Chimney System.* A system that has been sized and configured in accordance with approved engineering methods, such as:

(a) The vent capacity tables in NFPA 54, *National Fuel Gas Code*;

(b) The fuel-burning manufacturers' venting instructions;

(c) Drawings, calculations, and specifications provided by the venting equipment manufacturer or by a professional engineer;

(d) Use of calculations from the ASHRAE *Handbook*, *HVAC Systems and Equipment*, Chapter 31, "Chimney, Gas Vent, and Fireplace Systems";

(e) Application of the VENT II computer program, developed under Gas Research Institute sponsorship for vent design and analysis.

Factory-Built Appliance. A manufactured appliance furnished by the manufacturer as a single assembly or as a package set of subassemblies or parts, and including all the essential components necessary for it to function normally where installed as intended.

Fan. A blower or exhauster assembly comprising blades or runners and housings or casings.

Fireplace. A hearth, fire chamber, or similarly prepared area and a chimney.
Factory-Built Fireplace. A fireplace composed of listed, factory-built components assembled in accordance with the terms of the listing.
Masonry Fireplace. A hearth and fire chamber of solid masonry units, such as bricks, stones, listed masonry units, or reinforced concrete, provided with a suitable chimney.

Fireplace Accessories. Accessories intended for field installation into or attachment to existing masonry fireplaces. These include such items as heat exchangers, door assemblies, tubular grates, and blowers.

Fireplace Insert. A factory-built, field-installed product consisting of a firebox assembly designed to be installed within or partially within the fire chamber of a fireplace that uses the fireplace flue to vent the products of combustion.

Fireplace Stove. A freestanding, chimney-connected, solid fuel-burning appliance that is designed to be operated with the fire chamber either open or closed.

Fireplace Unit, Steel. A unit consisting of a steel firebox and an air chamber adjacent to the sides and rear of the firebox, used to construct a masonry fireplace. The unit usually has ducts to circulate air to and heated air from the air chamber to the living space.

Flame Spread Rating. The flame spread rating of materials as determined by NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*; ASTM E 84, *Surface Burning Characteristics of Building Materials*; and UL 723, *Tests for Surface Burning Characteristics of Building Materials*. Such materials are classified in the Underwriters Laboratories Inc. *Building Materials Directory* under "Surface Burning Characteristics."

Floor Protector. A noncombustible surfacing applied to the floor area underneath and extending in front, to the sides, and to the rear of a heat-producing appliance.

Flue. The general term for a passage through which flue gases are conveyed from the combustion chamber to the outer air.

Appliance Flue. The flue passage within an appliance.

Chimney Flue. The passage in a chimney for conveying the flue gases to the outside atmosphere.

Dilution Flue. A passage designed to effect the dilution of flue gases with air before discharge from an appliance.

Flue Collar. That portion of an appliance designed for attachment of a chimney or vent connector or a draft hood.

Flue Gases. Combustion products from fuel-burning appliances along with excess air.

Furnace, Central Warm-Air. A self-contained indirect-fired or electrically heated appliance designed to supply heated air through ducts to spaces remote from or adjacent to the appliance location.

Forced-Air-Type Central Furnace. A central furnace equipped with a blower that provides the primary means for the circulation of air.

Attic-Type. A forced-air-type furnace designed specifically for installation in an attic or in a space with low headroom that is normally occupied.

Downflow-Type. A forced-air-type furnace designed with airflow essentially in a vertical path, discharging air at or near the bottom of the furnace.

Horizontal-Type. A forced-air-type furnace designed with airflow through the furnace essentially in a horizontal path.

Upflow-Type. A forced-air-type furnace designed with airflow essentially in a vertical path, discharging air at or near the top of the furnace.

Gravity-Type Central Furnace. A central furnace depending primarily on circulation of air by gravity.

Gravity-Type Central Furnace with Booster Fan. A central furnace equipped with a booster fan that does not materially restrict free circulation of air by gravity flow when such a fan is not in operation.

Gravity-Type Central Furnace with Integral Fan. A central furnace equipped with a fan as an integral part of its construction and operable on gravity systems only. The fan is used only to overcome the internal resistance to airflow.

Furnace, Combination-Fuel. A single furnace unit designed to burn more than one type of fuel (gas, oil, or solid), either separately or simultaneously, using either separate or common combustion chambers and flues.

Furnace, Duct. A central furnace designed for installation in a duct of an air distribution system to supply warm air for heating and that depends on a blower not furnished as part of the furnace for air circulation.

Furnace, Floor. A self-contained indirect-fired or electrically heated furnace designed to be suspended from the floor of the space to be heated. A fuel-burning floor furnace is designed to take air for combustion from outside the space being heated and is provided with means for observing the flame and lighting the appliance from such space.

Fan-Type Floor Furnace. A floor furnace equipped with a blower that provides the primary means for circulation of air.

Gravity-Type Floor Furnace. A floor furnace depending primarily on circulation of air by gravity. This classification also includes floor furnaces equipped with booster-type fans that do not materially restrict free circulation of air by gravity flow when such fans are not in operation.

Furnace, Supplementary. A furnace designed to burn one type of fuel (gas, oil, or solid) that is intended for supplementing a central warm-air furnace burning another type of fuel (gas, oil, or solid) by means of a common warm-air supply plenum.

Gas Appliance Categories. Vented gas appliances are classified for venting purposes into four categories as follows:

Category I. An appliance that operates with a non-positive vent static pressure and with a vent gas temperature that avoids excessive condensate production in the vent.

Category II. An appliance that operates with a non-positive vent static pressure and with a vent gas temperature that may cause excessive condensate production in the vent.

Category III. An appliance that operates with a positive vent static pressure and with a vent gas temperature that avoids excessive condensate production in the vent.

Category IV. An appliance that operates with a positive vent static pressure and with a vent gas temperature that may cause excessive condensate production in the vent.

NOTE: For additional information on appliance categorization, see the appropriate Z21 and Z83 American National Standards.

Gas Vent. See Vent, Gas Vent.

Header. Where referring to chimneys, a beam set at right angles to floor or roof joists to provide support and framing around the opening.

Hearth. The floor area within the fire chamber of a fireplace or a fireplace stove.

Hearth Extension. The noncombustible surfacing applied to the floor area extending in front of and at the sides of the hearth opening of a fireplace or a fireplace stove; also where applied to the floor area beneath a fireplace stove or beneath an elevated overhanging fireplace hearth.

Heat Exchanger. A chamber in which heat resulting directly from the combustion of fuel, or heat from a medium such as air, water, or steam, is transferred through the walls of the chamber to air passing through the exchanger; or a chamber in which heat from electric resistors is transferred to the air.

Heat-Producing Appliance. An appliance that produces heat by utilizing electric energy or by burning fuel.

Heat Reclaimer, Chimney Connector-Type. A heat exchanger intended to be installed in a chimney connector between a heating appliance and the chimney to transfer heat from the flue gases through metal to air or water.

Incinerator. An appliance or combustion chamber for the reduction, by burning, of rubbish, garbage, and other wastes.

Residential-Type Incinerator. An incinerator for the burning of ordinary combustible waste material and garbage (Type 2 waste) incidental to residential occupancy and having a firebox or charging compartment not greater than 5 ft^3 (0.142 m^3) in capacity. Residential-type incinerators can be self-contained, factory-built units that do not necessitate field construction, or can be of a built-in type designed to be encased in masonry or installed in a masonry wall or chimney.

Commercial-Industrial-Type Incinerator (Classes III, IV, V, VI, and VII). An incinerator having a charging capacity in excess of 5 ft^3 (0.142 m^3) and suitable for a variety of wastes as follows:

Incinerator Class	Waste Types
Class III	Type 0, Type 1, or Type 2
Class IV	Type 3
Class V	Types 0–4 (municipal incinerators)
Class VI	Type 4
Class VII	Types 5 and 6

Chute-Fed Incinerator (Class IIA). An incinerator designed specifically to be fed refuse from one or more floors above the incinerator directly into the incinerator by a separate chute constructed with a positive means to avoid penetration by smoke or fumes and connected directly over the primary combustion chamber. The incinerator is built with a primary and secondary combustion chamber and a settling chamber. It can include a flue gas washer or scrubber. A separate chimney serves to convey the combustion gases to the outdoors. This class of incinerator is suitable for Type 1 and Type 2 wastes. It generally is used in residential and institutional buildings, including apartments, clubs, dormitories, churches, schools, and other occupancies where Type 1 and Type 2 wastes are to be incinerated.

Flue-Fed Incinerator (Class II). An incinerator served by a single chimney flue that serves also as the charging chute. Refuse is fed directly to the incinerator through this chimney flue from one or more floors above the incinerator. This class of incinerator is suitable for Type 1 and Type 2 waste materials and garbage incidental to residential occupancy in single and multifamily buildings. This class of incinerator is generally used in residential and institutional buildings, including apartments, clubs, dormitories, churches, schools, and other occupancies where Type 1 and Type 2 wastes are to be incinerated.

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.

Lintel. Where referring to masonry fireplaces, that horizontal, noncombustible member, usually of masonry or steel, spanning the opening of a masonry fireplace to support the load above.

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.

Mantel. A shelf or facing ornament above a fireplace opening.

Manufacturer. The company or organization that evidences its responsibility by affixing its name or nationally registered trademark or trade name to the appliance concerned.

Masonry Unit, Solid. A masonry unit whose net cross-sectional area in every plane parallel to the bearing surface is 75 percent or more of its gross cross-sectional area measured in the same plane.

Noncombustible Material. A material that, in the form in which it is used and under the conditions anticipated, does 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 Degrees C*, shall be considered noncombustible materials.

Pellet Fuel. A solid processed fuel of specified size and composition capable of being fed to the appliance combustion system at a controlled rate.

Pellet Fuel-Burning Appliance. A closed combustion pellet vent or chimney-connected solid pellet fuel-burning appliance incorporating a fuel-feed control mechanism.

Pellet Vent. See Vent.

Qualified Agency. Any individual, firm, corporation, or company that, either in person or through a representative, is engaged in and is responsible for the connection, venting, installation, repair, and servicing of heat-producing appliances and who is experienced in such work, is familiar with all precautions required, and has complied with all the requirements of the authority having jurisdiction.

Range. An appliance intended primarily for cooking, including roasting, baking, or broiling or any combination of these functions.

Range, Built-in Residential-Type. A range designed to be recessed into, placed upon, or attached to counters, cabinets, walls, or partitions.

Range, Bungalow Utility-Type. A range having an additional section for gas, liquid, or solid fuel that is designed for space heating and heating a solid top section but not for oven heating.

Range, Residential-Type. A range intended primarily for residential cooking purposes.

Range, Restaurant-Type. A range of the type designed for use primarily in restaurant and hotel kitchens.

Range, Room Heater-Type. A range having a separate room heater section.

Roof Jack. A factory-built assembly for conveying flue gases through a roof and that includes a flue gas passageway, an insulating means, flashing, and a cap.

Room Heater. A self-contained, freestanding, air-heating appliance intended for installation in the space being heated and not intended for duct connection.

Room Heater, Circulating. A room heater with an outer jacket surrounding the heat exchanger arranged with openings at top and bottom so that air circulates between the heat exchanger and the outer jacket. Room heaters that have openings in an outer jacket to allow some direct radiation from the heat exchanger are classified as a radiant type.

Room Heater, Radiant. A room heater designed to transfer heat primarily by direct radiation.

Room Heater, Solid Fuel. A chimney-connected, solid fuel-burning room heater that is designed to be operated with the fire chamber closed.

Room Heater/Fireplace Stove, Combination. A chimney-connected, solid fuel-burning room heater that is designed to be operated with the fire chamber either open or closed.

Room Large in Comparison with the Size of the Appliance. A room having a volume equal to at least 12 times the total volume of a furnace and at least 16 times the total volume of a boiler. The total volume of the furnace or boiler is determined from the exterior dimensions and is to include a fan compartment and burner vestibule, where used. Where the actual ceiling height of a room is greater than 8 ft (2.44 m), the volume of the room is to be figured on the basis of a ceiling height of 8 ft (2.44 m).

Shall. Indicates a mandatory requirement.

Smoke Chamber. The transitional area from the damper opening to the beginning of the flue liner in a fireplace system.

Smoke Developed Rating. The smoke developed rating of materials as determined by NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*; ASTM E 84, *Surface Burning Characteristics of Building Materials*; and UL 723, *Tests for Surface Burning Characteristics of Building Materials*.

Smoke Test. A procedure for ascertaining the tightness of a chimney and for detecting any cracks in a masonry chimney flue or deterioration or breaks in the integrity of a factory-built or metal chimney flue. The procedure involves igniting a smoke bomb or building a smoky fire in a fireplace or solid fuel-burning appliance, covering the chimney termination, and checking for smoke escapage through the chimney walls.

Solid Fuel. Wood, coal, and other similar organic materials and any combination of them.

Solid Fuel-Burning Appliance. A chimney-connected device that burns solid fuel designed for purposes of heating, cooking, or both.

Solid Masonry Construction. A bonded assembly of stones or solid masonry units.

Spark Arresters. Screening material or a screening device attached to a chimney termination to prevent the passage of sparks and brands to the outside atmosphere.

Splay. See Wash.

Steel Fireplace Unit. A unit consisting of a steel firebox and an air chamber adjacent to the sides and rear of the firebox, used to construct a masonry fireplace. The unit usually has ducts to circulate air to and heated air from the air chamber to the living space.

Thimble. A fixed or removable ring, tube, or lining usually located in the hole where the chimney connector or vent connector passes through a wall or enters a chimney or vent.

Trimmer. Where referring to chimneys, the longer floor or roof framing member around a rectangular opening into which the end of a header is joined.

Type B Gas Vent. See Vent, Gas Vent.

Type BW Gas Vent. See Vent, Gas Vent.

Type L Vent. See Vent.

Unit Heater. A self-contained heating appliance that might or might not include an integral fan for circulating air and that can be of the floor-mounted or suspended type that is intended for the heating of the space in which it is installed. A unit heater can be an indirect-fired fuel-burning appliance or might utilize steam, hot water, or electricity.

Vent. A flue gas conveying system intended for use only with appliances that do not produce flue gas outlet temperatures higher than 600°F (315.6°C). Vents are listed systems composed of factory-built components assembled in accordance with the terms of the vent listing, except for certain limited applications of unlisted single wall pipe.

Gas Vent. A passageway composed of listed, factory-built components assembled in accordance with the terms of listing for conveying flue gases from gas appliances or the vent connectors to the outside atmosphere.

Type B Gas Vent. A vertical or nearly vertical gas vent for venting listed gas appliances with draft hoods and other Category I gas appliances listed for use with Type B gas vents.

Type BW Gas Vent. A vertical or nearly vertical gas vent for venting listed gas-fired vented wall furnaces.

Special Gas Vent. A gas vent for venting listed Category II, III, and IV gas appliances.

Pellet Vent. A venting system composed of listed, factory-built components assembled in accordance with the manufacturer's instructions for conveying flue gases from a listed pellet fuel-burning appliance to the outside atmosphere.

Type L Vent. A vertical or nearly vertical composed of listed factory-built components assembled in accordance with the terms of listing for conveying flue gases from oil and gas appliances or their vent connectors to the outside atmosphere.

Vent Cap. A protective covering or housing attached to the vent termination, intended for preventing downdrafts and the entry of rain, snow, and animals.

Vent Connector. The pipe that connects a fuel-burning appliance to a gas vent or Type L vent.

Vent Gases. Products of combustion from fuel-burning appliances along with excess air, plus any dilution air in the venting system above a draft hood or draft regulator.

Vented Appliance. An indirect-fired appliance provided with a flue collar to accommodate a venting system for conveying flue gases to the outer air.

Venting. Removal of combustion products as well as noxious or toxic fumes to the outer air.

Venting System (Flue Gases). A continuous, open passageway from the flue collar or draft hood of a fuel-burning appliance to the outside atmosphere for the purpose of removing flue gases.

Natural Draft. Draft produced by the difference in the weight of a column of flue gases within a chimney or vent and a corresponding column of air of equal dimension outside the chimney or vent.

Mechanical Draft. Draft produced by a fan or an air or steam jet. When a fan is located so as to push the flue gases through the chimney or vent, the draft is forced. When the fan is located so as to pull the flue gases through the chimney or vent, the draft is induced.

Wall Furnace. A self-contained, vented appliance complete with grilles or equivalent, designed for incorporation in or permanent attachment to the structure of a building, manufactured home, or recreational vehicle, and furnishing heated air directly into the space to be heated through openings in the casing. Such appliances should not be provided with duct extensions beyond the vertical and horizontal limits of the casing proper, except that boots not exceeding 10 in. (254 mm) beyond the horizontal of the casing for extension through walls of nominal thickness may be permitted. Where provided, such boots should be supplied by the manufacturer as an integral part of the appliance. This definition excludes floor furnaces, unit heaters, and central furnaces.

Fan-Type Wall Furnace. A wall furnace equipped with a fan for the circulation of air.

Gravity-Type Wall Furnace. A wall furnace dependent on the circulation of air by gravity.

Wall Protector (Shield). Noncombustible surfacing applied to a wall area for the purpose of reducing the clearance between the wall and a heat-producing appliance.

Wash. A slight slope or beveled edge on the top surface of a chimney designed to shed water away from the flue liner.

Water Heater. An indirect-fired fuel-burning or electrically heated appliance for heating water to a temperature not more than 200°F (93°C), having an input not greater than 200,000 Btu or (58.6 kW/hr), and a water-containing capacity not exceeding 120 U.S. gal (454 L).

Wythe. Where referring to masonry chimneys, a course, a thickness, or a continuous vertical section of masonry separating flues in a chimney.

1-6 Dimensions.

Where used to describe building construction components, all minimum dimensions specified in this standard are actual unless otherwise stated. Nominal dimensions shall be permitted to vary from their specified dimensions by no more than $^1/_2$ in. (12.7 mm).

1-7 Draft.

1-7.1 Minimum Performance.

A chimney or vent shall be so designed and constructed to develop a flow sufficient to remove completely all flue or vent gases to the outside atmosphere. The venting system shall satisfy the draft requirements of the connected appliance(s) in accordance with the equipment manufacturers' instructions or the *ASHRAE Handbook*, *HVAC Systems and Equipment,* Chapter 31.

1-7.2 Mechanical Draft Systems.

A mechanical draft system of either forced or induced draft design shall be permitted to be used to increase draft or capacity. Where a mechanical draft system is installed, provision shall be made to prevent the flow of fuel to an automatically fired appliance(s) when that system is not operating.

1-7.3

Chimneys serving incinerators, or other process equipment where the combustion process cannot be stopped completely by fuel shutoff alone, shall be sized for natural draft conditions. Where air pollution control devices or other devices in the chimney system require a mechanical draft system, the chimney system shall be so arranged that, upon a power failure, the natural draft chimney alone can satisfactorily remove the products of combustion until the combustible material is completely consumed.

1-7.4

Forced draft systems and all portions of induced draft systems under positive pressure during operation shall be designed and installed to be gastight or to prevent the leakage of combustion products into a building.

1-7.5

Vent connectors serving appliances vented by natural draft shall not be connected into any portion of mechanical draft systems operating under positive pressure.

1-8 Termination (Height).

1-8.1

Chimneys and vents shall terminate above the roof level in accordance with the requirements of this standard. [*See Figures 1-8.1(a) and (b).*]

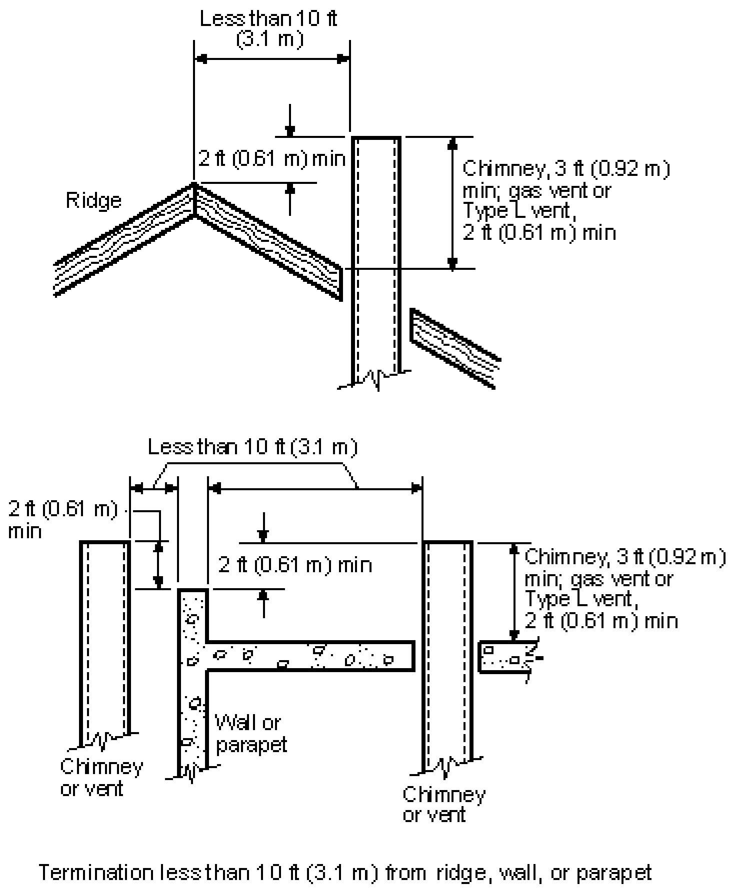


Figure 1-8.1(a) Chimney or vent termination [less than 10 ft (3.1 m)].

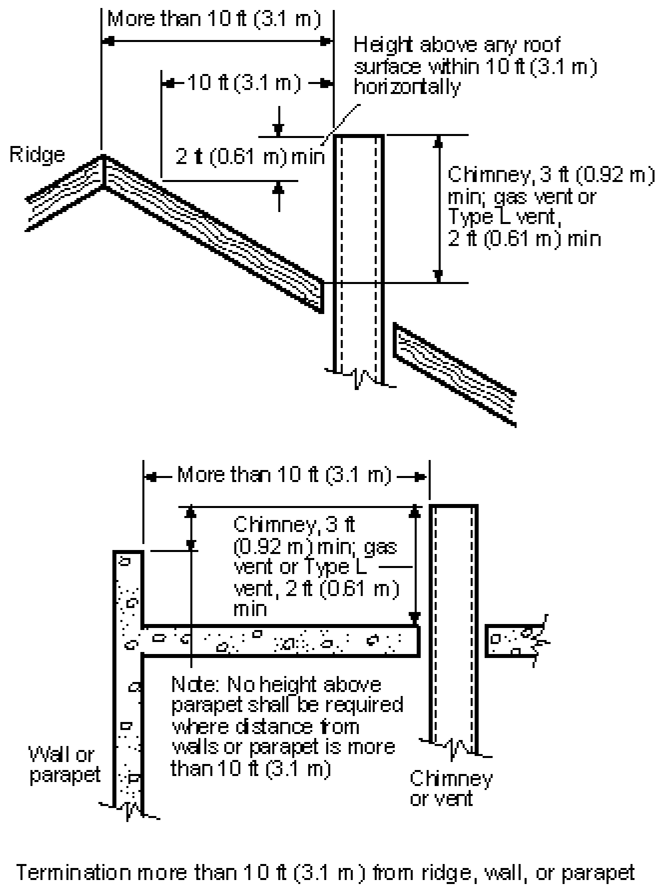


Figure 1-8.1(b) Chimney or vent termination [more than 10 ft (3.1 m)].

1-8.1.1 Masonry chimneys shall extend above the highest point at which they pass through the roof of a building by at least the distance specified in Table 4-2, Column VI, and above any portion of any structure by at least the distance specified in Table 4-2, Column VII, measured horizontally from the vertical chimney line.

Exception: As provided in 5-2.1, Exception, Section 7-4, and Section 7-7.

1-8.1.2 Natural draft chimneys and vents shall not terminate at an elevation less than 5 ft (1.53 m) above the flue collar or the highest connected draft hood outlet.

Exception: As provided in Section 7-7.

1-9 Enclosure.

Interior residential chimneys shall be enclosed where they extend through closets, storage areas, or habitable spaces where the surface of the chimney could be contacted by persons or combustible materials. The space between the chimney and the enclosure shall be at least the minimum air space clearance specified in this standard (*see Table 4-2*) or the clearance specified in the manufacturer's instructions for listed chimneys.

1-10 Flue Lining.

1-10.1

Castable or plastic refractories used to line chimneys or connectors shall be the equivalent in resistance to heat and erosion by flue gases to that of the fireclay brick that would otherwise be specified.

1-10.2

Lining made of castable or plastic refractories shall be secured to the supporting walls by anchors made of corrosion-resistant steel capable of supporting the refractory load at 1500°F (816°C).

1-11 Caps and Spark Arresters for Chimneys and Vents.

1-11.1

Chimney or vent caps, where required for the termination of chimneys or vents, shall be designed to prevent the entry of rain, snow, and animals, including birds.

1-11.2

Screening material attached to chimney or vent caps to prevent the entry of animals and insects shall not adversely affect the chimney or vent draft.

1-11.3

Spark arresters, where required by the authority having jurisdiction for chimneys attached to solid fuel-burning equipment, shall meet the following:

(a) The net-free area of the arrester shall be not less than four times the net-free area of the outlet of the chimney flue it serves.

(b) The arrester screen shall have heat and corrosion resistance equivalent to 19-gauge [0.041-in. (1.04-mm)] galvanized steel or 24-gauge [0.024-in. (0.61-mm)] stainless steel.

(c) Openings shall not allow the passage of spheres having a diameter larger than $^1/_2$ in. (12.7 mm) nor block the passage of spheres having a diameter of less than $^3/_8$ in. (9.5 mm).

(d) The spark screen shall be accessible for cleaning, and the screen or chimney cap shall be removable to allow for cleaning of the chimney flue.

1-11.4

Where part of a listed chimney termination system, spark arresters shall be constructed and installed in accordance with the listing.

Chapter 2 Selection of Chimney and Vent Types

2-1 Chimney Types.

Chimney selection shall be limited to three basic chimney types: factory-built, masonry, and unlisted metal chimneys [*see Figures 2-1(a), (b), and (c)*]. Each basic type is defined in Section 1-5, and the application of each is determined by Table 2-2.1, with specific construction or installation requirements in individual chapters, as follows.

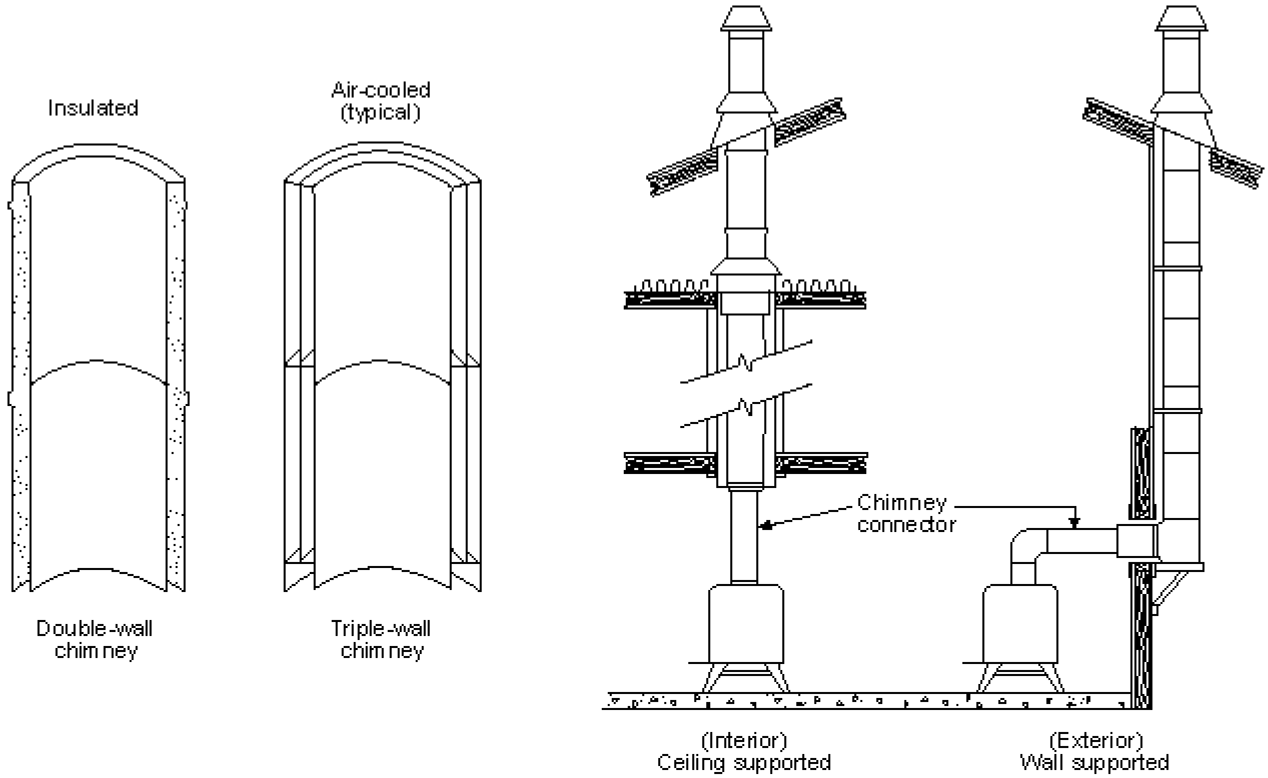


Figure 2-1(a) A typical factory-built chimney installation in a single-family residence; other applications can be determined by the chimney selection chart, Table 2-2.1.

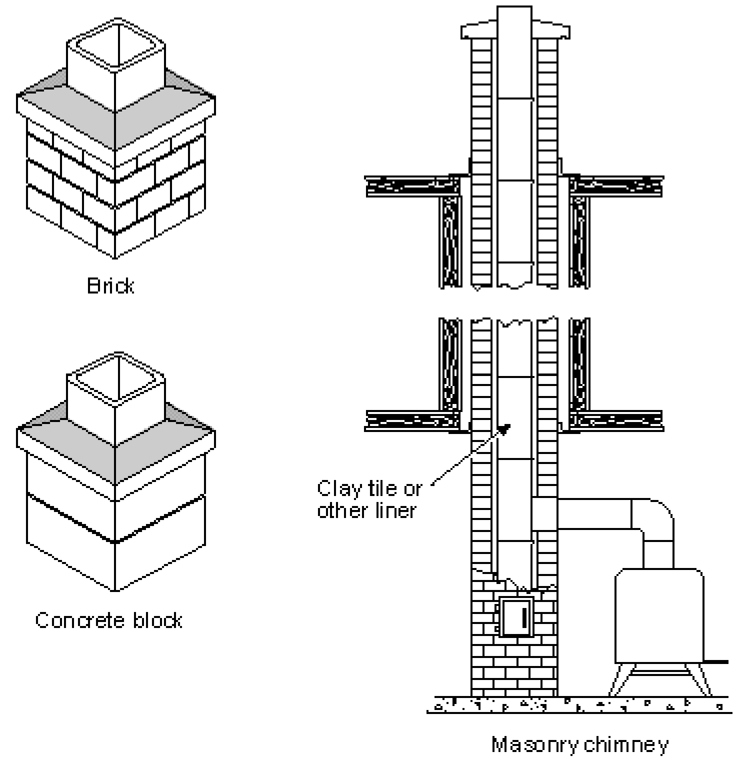


Figure 2-1(b) Masonry chimney.

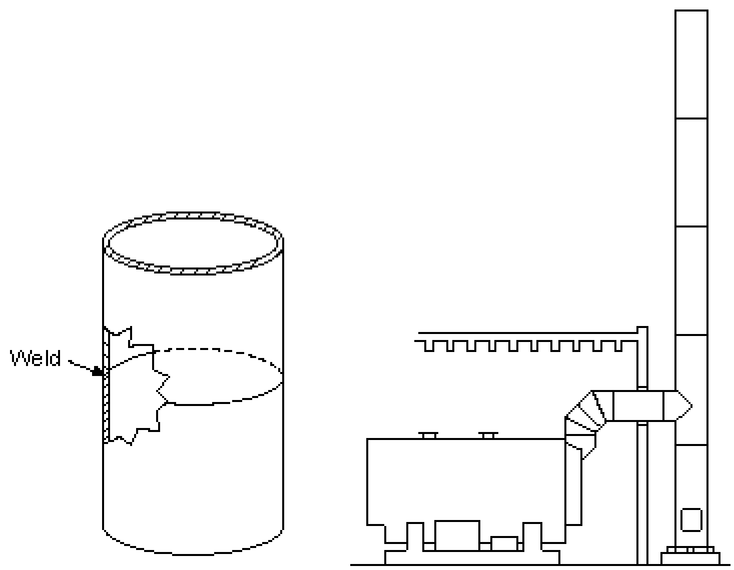


Figure 2-1(c) A typical unlisted metal chimney installation in a commercial or industrial application; unlisted metal chimneys are not suitable for one- and two-family dwellings.

2-2 Chimney or Vent Selection.

The selection of a chimney or vent shall be based on the type of appliance connected thereto, the fuel used by the appliance, and the temperature of the flue gases at the appliance outlet.

2-2.1

The chimney type shall be selected according to Table 2-2.1.

2-2.2

A vent shall be used only where appliances are listed for use with a vent. The vent type shall be selected according to Table 2-2.2.

Table 2-2.1 Chimney Selection Chart

(*See text for definitions and requirements.*)

Column I	**Column II**	**Column III**	**Column IV**	**Column V**
Types of Appliances to Be Used with Each Type Chimney				
Residential-type gas, liquid, and solid fuel-burning applications such as:	1. All appliances shown in Column I	1. All appliances shown in Columns I and II	1. All appliances shown in Columns I, II, and III	1. All appliances shown in Columns I, II, III, and IV
1. All appliances shown in Column I of Table 2-2.2	2. Boilers operating at not over 1000°F (538°C) flue gas temperature	2. 1400°F (760°C) nonresidential appliances	2. Medium-heat nonresidential appliances	2. High-heat nonresidential appliances
2. Dual fuel furnaces	3. Low-heat nonresidential appliances			
3. Fireplace inserts	4. Building heating appliances			
4. Fireplace stoves				
5. Fireplace stoveroom heaters				
6. Freestanding fireplaces				
7. Boilers				
8. Masonry fireplaces				
9. Pellet fuel-burning appliances (*see Note 1*)				
10. Ranges				
11. Residential incinerators				
12. Room heaters				
13. Stoves				
Maximum Continuous Appliance Outlet Flue Gas Temperature				

Under Normal Operating Conditions

1000°F (538°C)	1000°F (538°C)	1400°F (760°C)	1800°F (982°C)	>1800°F (>982°C)
Chimney Type				
[Select chimney type based on appliance type and flue gas temperature (*see Note 4*).]				
1. Factory-built residential-type and building heating appliance (*see Chapter 3 Appendix A and Note 3*)	1. Factory-built residential-type and building heating appliance (*see Chapter 3 and Note 3*)	1. Factory-built 1400°F (*see Chapter 3*)	1. Factory-built medium-heat appliance (*see Chapter 3*)	1. Engineered high-heat type (*see Section 3-2 and Appendix A*)
2. Masonry, residential type (*see Chapter 4*)	2. Masonry, low-heat type (*see Chapter 4*)	2. Masonry, low-heat type, (*see Chapter 4*)	2. Masonry, medium-heat type (*see Chapter 4*)	2. Masonry, high-heat type (*see Chapter 4*)
	3. Unlisted metal low-heat type (*see Chapter 5, Section 5-2, and Note 2*)	3. Unlisted metal 1400°F type (*see Chapter 5, Section 5-2, and Note 2*)	3. Unlisted metal medium-heat type (*see Chapter 5, Section 5-3, and Note 2*)	3. Unlisted metal high-heat type (*see Chapter 5, Section 5-4, and Note 2*)

NOTES

1. See also Table 2-2.2, pellet vent.
2. Single-wall chimneys or unlisted metal chimneys shall not be used inside one- and two-family dwellings. (*See Chapter 5*.)
3. Factory-built listed chimneys for use with all wood- burning appliances used in one- and two-family dwellings shall meet the Type HT requirements of UL 103, *Standard for Safety Chimneys, Factory-Built, Residential Type and Building Heating Appliance,* or the requirements of CAN/ULC-S629-M87, *Standard for 650°C Factory-Built Chimney Systems for Solid Fuel-Burning Appliances.*
4. Chimneys shown in any column shall be permitted to be used on appliances that can use a chimney shown in any column to the left of that column, provided the chimney meets the provisions of Notes 1, 2, and 3.

Table 2-2.2 Vent Selection Chart

(*See Chapter 7 for requirements*.)

Column I	Column II	Column III	Column IV	Column V	Column VI
Types of Appliances to Be Used with Each Type Vent					
All listed gas appliances with draft hoods and other Category I gas appliances listed for use with Type B Vents, such as:	1. Vented wall furnaces listed for use with Type BW vents only	1. Listed Categories II, III, and IV gas appliances and Category I appliances listed for use with special gas vents	1. Low-temperature flue gas appliances listed for use with Type L Vents	1. Incinerators used outdoors, in open sheds, breezeways, or carports as provided in Section 5-2	1. Listed pellet-burning appliances listed for use with pellet vents
1. Central furnaces			2. Gas appliances shown under Column	2. Gas appliances shown under Column	

				I	I	
2. Duct furnaces					3. Listed residential and low-heat gas appliances without draft hoods and unlisted residential and low-heat gas appliances with or without draft hoods.	
3. Floor furnaces						
4. Heating boilers						
5. Ranges, residential and low-heat gas						
6. Built-in ovens						
7. Vented wall furnaces						
8. Room heaters						
9. Water heaters						
10. Horizontal furnaces						
11. Unit heaters						
12. Decorative appliances (gas fireplaces)						

			Vent Type			
	Listed Type B Gas Vent	**Listed Type BW Gas Vent**	**Listed Special Gas Vent**	**Listed Type L Vent**	**Unlisted Single-Wall Metal Pipe**	**Listed Pellet Vent**
					See 7-6.3 for limitations on unlisted single-wall metal pipe	

Chapter 3 Factory-Built Chimneys and Chimney Units

3-1 Type and Installation.

3-1.1

Factory-built chimneys and chimney units shall be listed and shall be installed in accordance with the temperature conditions of the listing and the manufacturer's instructions. Flue gas temperatures in the chimney shall not exceed the limits employed during listing tests.

3-1.2

Factory-built chimneys for use with wood-burning appliances shall comply with the Type HT requirements of UL 103, *Standard for Safety Chimneys, Factory-Built, Residential Type and Building Heating Appliance*, or the requirements of CAN/ULC-S629-M87, *Standard for 650°C Factory-Built Chimney Systems for Solid Fuel-Burning Appliances*.

Exception No. 1: Chimneys for factory-built fireplaces shall meet the requirements of UL 127, Standard for Safety Factory-Built Fireplaces.

Exception No. 2: Freestanding open combustion chamber fireplace stoves listed only to UL 737, Standard for Safety Fireplace Stoves, shall be permitted to use residential-type and building heating appliance chimneys.

Exception No. 3: Engineered appliance-venting systems that have been listed to operate without producing combustible deposits to the venting system shall be installed in accordance with the conditions of their listing and the manufacturer's instructions.

3-1.3

Factory-built chimneys that pass through floors of buildings requiring the protection of vertical openings shall be enclosed with approved walls having a fire resistance rating of not less than 1 hour where such chimneys are located in a building less than four stories in height, and not less than 2 hours where such chimneys are located in a building four or more stories in height.

3-1.4

Decorative shrouds at the termination of a factory-built chimney shall not be permitted.

Exception: Decorative shrouds listed for use with the specific factory-built chimney system.

3-2 Use.

Factory-built chimneys shall be permitted to be used for exhaust systems and ducting from hoods, industrial ovens, furnaces, and process equipment of any temperature classification (*see Table 2-2.1*), provided that the system is engineered so that gas temperatures and pressures do not exceed the applicable limit for the type of chimney.

Chapter 4 Masonry Chimneys

4-1 General Requirements.

4-1.1 Support.

Masonry chimneys shall be supported on properly designed foundations of masonry or reinforced portland or refractory cement concrete or on noncombustible material having a fire resistance rating of not less than 3 hours, provided such supports are independent of the building construction and the load is transferred to the ground.

4-1.2 Corbeling.

Individual and maximum projections of corbels in masonry chimneys shall comply with the requirements of this section. [*See Figures 4-1.2(a), (b), (c), and (d).*]

Exception: Corbeling limitations shall be permitted to be varied for engineered reinforced brick masonry construction.

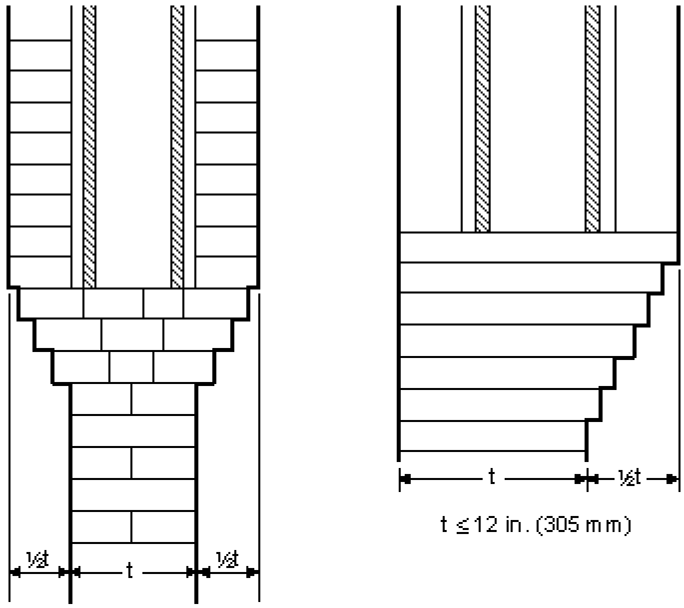
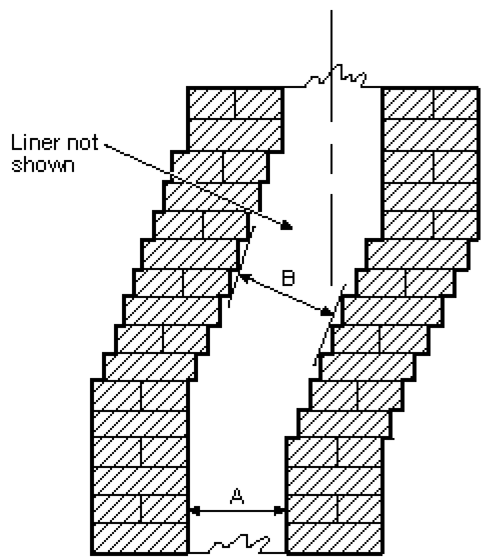


Figure 4-1.2(a) Corbels for supporting chimneys.



Chimney offset construction — centerline of upper flue does not fall beyond center of lower flue wall. Chimney size, A, and offset size, B, are equal.

Figure 4-1.2(b) Corbels to change chimney direction.

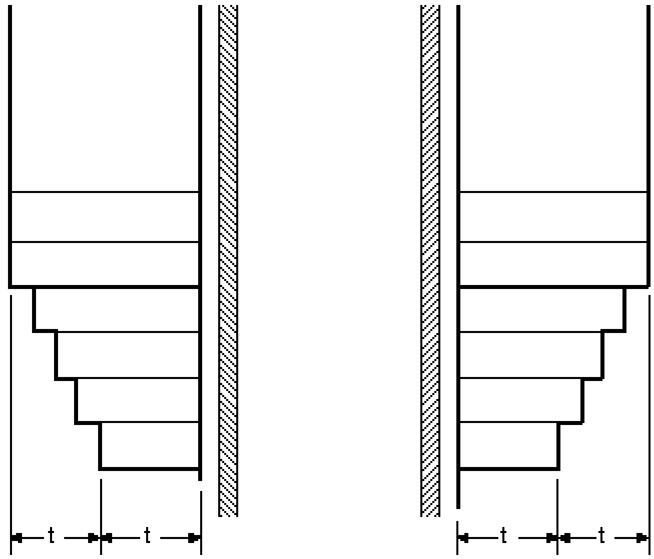


Figure 4-1.2(c) Corbels to increase chimney wall thickness.

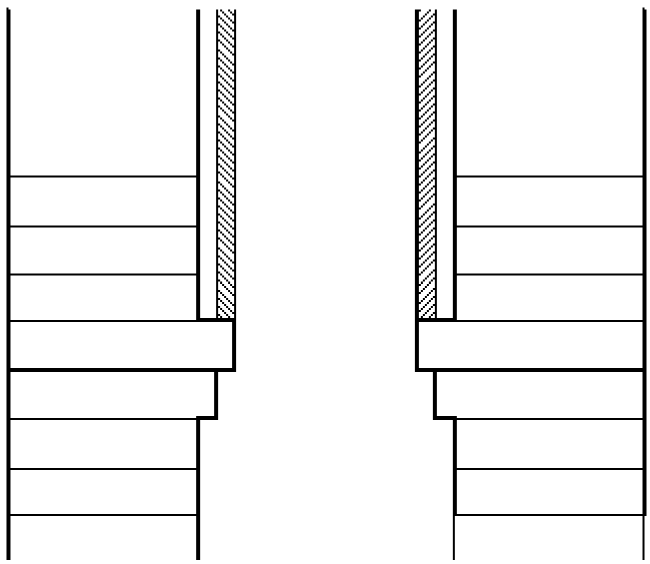


Figure 4-1.2(d) Corbels to support flue lining.

4-1.2.1 Individual corbels occurring at any point within a masonry chimney shall not exceed $^1/_2$ the individual masonry unit height nor $^1/_3$ the thickness.

4-1.2.2 Masonry chimney support shall be permitted to be formed by corbeling from a wall that is not less than 12 in. (305 mm) in thickness to form a maximum total projection of not more than $^1/_2$ the wall thickness.

Exception: Where the corbeling projects equally on each side of the wall, the masonry chimney support shall be permitted to be formed by corbeling from a wall that is not less than 8 in. (203 mm) in thickness to form a maximum total projection on each side of the wall that is not more than $^1/_2$ the wall thickness.

4-1.2.3 Corbeling used to change the direction of a masonry chimney shall have a maximum offset so that the centerline of the upper flue does not fall beyond the center of the lower flue wall. The cross-sectional area of the flue shall not be reduced throughout the offset.

4-1.2.4 Corbeling used to increase the chimney wall thickness shall have a maximum total projection that does not exceed the thickness of the chimney wall.

4-1.2.5 Corbeled or solid masonry shall be provided in masonry chimneys to support the entire perimeter of flue liners.

Exception: Where a flue is constructed of two flue liners without a separation, three sides of each flue liner shall be supported entirely on corbeled masonry.

4-1.2.6 Corbels shall be made with solid units, and, where corbels are located on the walls of hollow masonry units, there shall be not less than three courses of solid masonry units below the corbels.

4-1.3 Change in Size or Shape of Flue at Combustible Members Not Permitted.

A chimney flue shall not change in size or shape within 6 in. (152 mm) above or below any point where the chimney passes through combustible floor, ceiling, or roof components.

4-1.4 Cleanout Openings.

4-1.4.1 Cleanout openings or a means for cleaning shall be provided in all chimney flues. Cleanout openings shall be equipped with ferrous metal, precast cement or other approved noncombustible doors and frames arranged to remain tightly closed and secured when not in use.

4-1.4.2 Interior Cleanout Openings. The lower edge of a cleanout opening inside a building shall be a minimum of 16 in. (406.4 mm) above the lowest accessible floor level.

4-1.4.3 Exterior Cleanout Openings. The lower edge of a cleanout opening located outside a building shall be a minimum of 16 in. (406.4 mm) above grade, provided the cleanout opening is below the lowest chimney connector entrance.

4-1.4.4 Cleanout openings and doors shall not be obstructed. Combustible material located or projected beyond the face of the chimney shall be kept a minimum of 18 in. (457.2 mm) away from the cleanout opening. Cleanout doors shall be permanently marked with the following message: "DO NOT OBSTRUCT. KEEP COMBUSTIBLE MATERIAL AT LEAST 18 IN. (457.2 MM) AWAY FROM THIS DOOR," or equivalent.

Exception: Listed cleanout doors shall be installed in accordance with the terms of their listing and the manufacturer's instructions.

4-1.5

The base of the chimney flue shall start at a point at least 6 in. (152 mm) but not more than 12 in. (305 mm) below the bottom edge of the cleanout door opening. Any space within the chimney below the level of the flue base shall be filled with noncombustible masonry material, mortar, concrete, or sand and topped with a wash or cap that prevents the entry of moisture or creosote.

4-1.6 Firestopping.

All spaces between chimneys and the floors and ceilings through which the chimneys pass shall remain fully open but shall be firestopped with noncombustible material. The firestopping of spaces between chimneys and wood joists, beams, or headers shall be of galvanized steel not less than 26 gauge [0.019 in. (0.483 mm)] thick or of noncombustible sheet material not more than $^1/_2$ in. (12.7 mm) thick.

4-1.7 Smoke Test.

Masonry chimneys shall be proved tight by a smoke test after erection and before being put into use.

4-1.8 Structural Design.

Chimneys shall be designed, anchored, supported, and reinforced as required in this standard. A chimney shall not support any structural load other than its own weight, unless designed to act as a supporting member. Chimney design shall consider seismic and wind loading.

Masonry chimneys shall be permitted to be constructed as part of the masonry or reinforced concrete walls of buildings.

4-1.9 Thimbles.

4-1.9.1 Thimbles for chimneys or vent connectors shall be of fireclay (ASTM C 315, *Standard Specification for Clay Flue Linings*), galvanized steel of a minimum thickness of 24 gauge [0.024 in. (0.61 mm)], or material of equivalent durability. Thimbles shall be installed without damage to the liner. The thimble shall extend through the wall to, but not beyond, the inner face of the liner and shall be cemented firmly to masonry.

4-1.9.2 Thimbles shall be located to provide adequate pitch or rise of chimney or vent connectors, and, where the ceiling above the appliance is constructed of combustible material, the location of the thimble shall provide the minimum clearance required for the connector as specified in Section 6-5.

4-1.9.3 The installation of thimbles through walls or partitions constructed of combustible materials shall conform with the requirements of Section 6-7.

4-1.10 Relining.

4-1.10.1 Where masonry chimneys are relined, the liner shall be listed or of approved material that resists corrosion, softening, or cracking from flue gases at temperatures appropriate to the class of chimney service. Listed liner systems shall be installed in accordance with the listing. Approved materials shall be installed in accordance with Section 4-2.

4-1.10.2 The relined chimney shall meet the requirements of the class of chimney service.

4-2 Construction of Masonry Chimneys.

Masonry chimneys shall be constructed as outlined in Table 4-2 and as detailed in this section.

Table 4-2 Construction, Termination, and Clearances for Masonry Chimneys

(*See text for requirements.*)

Column	I		II		III	IV		V	VI		
Chimney Type	Chimney Wall Thickness				Chimney Liner (*See Note 1.*)				Termina		
	Brick or Concrete		Rubble Stone			Thickness			Highest Point		Ne
	(in.)	(mm)	(in.)	(mm)	Type	(in.)	(mm)	Cement	(ft)	(mm)	(
Residential	4	102	12	305	Fireclay	$^5/_8$	16	Medium duty	3	0.91	
Low-heat	8	203	12	305	Fireclay	$^5/_8$	16	Medium duty	3	0.91	
Medium-heat	8	203	12	305	Fireclay brick	4.5	114	Medium duty	10	3.05	
High-heat	See Note 2				Fireclay brick	4.5	114	High duty	20	6.1	
Column	I		II		III	IV		V	VI		

NOTES

1 Where masonry chimneys are lined with a listed chimney liner system, the system shall be installed in accordance with the listing.
2. Masonry chimneys for high-heat appliances shall be constructed with double walls of solid masonry units or reinforced portland or refractory cement concrete. Each wall shall be not less than 8 in. (203 mm) thick with an air space of not less than 2 in. (51 mm) between walls.
3. Masonry chimneys for high-heat appliances shall have sufficient clearance from buildings and structures to avoid overheating combustible material, to allow inspection and maintenance operations on the chimney, and to avoid the danger of burns to persons. Clearance shall be based on good engineering practice and shall be acceptable to the authority having jurisdiction.

4-2.1

Masonry chimneys shall be constructed of solid masonry or solid, waterproofed, modular concrete blocks in nominal thicknesses not less than those specified in Table 4-2, Column I, or of reinforced portland or refractory cement concrete in actual thicknesses not less than those specified in Table 4-2, Column I, or of rubble stone masonry in actual thicknesses not less than those specified in Table 4-2, Column II. Masonry shall be laid with full, push-filled, head and bed mortar joints.

Exception No. 1: Reinforced masonry chimneys for residential-type appliances shall be permitted to be constructed of hollow masonry units not less than 6 in. (152 mm) nominal thickness, with cells fully filled with mortar.

Exception No. 2: Masonry chimneys for high-heat appliances shall be constructed with double walls of solid masonry or reinforced portland or refractory cement concrete. Each wall shall be not less than 8 in. (203 mm) thick with an air space of not less than 2 in. (51 mm) between walls.

4-2.2

Masonry chimneys shall be lined. The selection of the lining material shall be appropriate for the class of chimney service and the type of appliance connected in accordance with the terms of the appliance listing and the manufacturer's instructions. Listed materials used as chimney linings shall be installed in accordance with the terms of their listings and the manufacturer's instructions. The materials specified in 4-2.2.1 through 4-2.2.6 shall be permitted for the indicated class of chimney service.

4-2.2.1 Low-, Medium-, and High-Heat Appliances (Table 2-2.1, Columns II, III, IV, and V).

(a) Clay flue lining complying with the requirements of ASTM C 315, *Standard Specification for Clay Flue Linings*, or the equivalent, as specified in Table 4-2, Columns III and IV.

(b) Fireclay brick complying with the requirements of ASTM C 27, *Standard Classification of Fireclay and High-Alumina Refractory Brick*, or the equivalent, as specified in Table 4-2, Columns III and IV.

4-2.2.2 Residential-Type and Building Heating Appliances (Table 2-2.1, Columns I and II).

(a) Clay flue lining or fireclay brick complying with 4-2.2.1, as specified in Table 4-2, Columns III and IV.

(b) Listed chimney lining systems.

(c) Factory-built chimneys or chimney units listed for installation within masonry chimneys.

(d) Other approved materials that resist corrosion, erosion, softening, or cracking from flue gases and condensate at temperatures up to 1800°F (982°C).

4-2.2.3 Category I Gas Appliances (Table 2-2.2, Column I).

(a) Chimney liners complying with 4-2.2.2.

(b) Chimney lining systems listed for use with listed gas appliances with draft hoods and other Category I appliances listed for use with Type B vents. (*See 4-2.2.7 for marking*.)

(c) Type B vents listed for installation within masonry chimneys. (*See 4-2.2.7 for marking*.)

4-2.2.4 Categories II, III, and IV Gas Appliances (Table 2-2.2, Column III). Special gas vents listed for installation within masonry chimneys. (*See 4-2.2.7 for marking*.)

4-2.2.5 Pellet Fuel-Burning Appliances (Table 2-2.2, Column VI).

(a) Chimney liners complying with 4-2.2.2.

(b) Pellet vents listed for installation within masonry chimneys. (*See 4-2.2.7 for marking*.)

4-2.2.6 Other materials listed for installation within masonry chimneys for the class of chimney service and for the appliance type shall be permitted. Other approved materials that resist corrosion, erosion, softening, or cracking from flue gases and condensate at temperatures appropriate for the class of chimney service and appliance type shall be permitted.

4-2.2.7 Notice of Usage. Where a Type B gas vent, special gas vent, pellet vent, or other material not suitable for use under Columns I and II of Table 2-2.1 is used as a liner for a masonry chimney, the chimney shall be plainly and permanently identified by a label attached to the wall or ceiling or at another conspicuous location adjacent to the point where the connector enters the chimney. The label shall read: "This (type of product) Is For (type or category of appliance) Appliances that Burn (type of fuel) Only. Do Not Connect Other Types of Appliances," or Equivalent Language.

4-2.3

Fireclay flue liners shall be installed ahead of the construction of the chimney as it is carried up, carefully bedded one on the other in a medium-duty, nonwater-soluble calcium aluminate refractory cement mixture, or its equivalent, with close-fitting joints left smooth on the inside. Portland cement bonded mixtures shall not be used.

4-2.4

Fireclay brick flue liners shall be installed laid in full-width refractory mortar as specified in Table 4-2, Column V, or the equivalent.

4-2.5

Fireclay flue lining for residential and low-heat masonry chimneys shall be separated from the chimney wall by a minimum of $^{1}/_{2}$ in. (12.7 mm) and a maximum of 4 in. (102 mm) of air space. The air space shall not be filled, and only enough mortar shall be used to make a good joint and hold the liners in position.

Exception: Where masonry chimneys are lined with a listed chimney liner system, the system shall be installed in accordance with the listing.

4-2.6

The fireclay flue liner shall start at or below the base of the chimney flue and shall be supported by solid masonry. The lining shall be carried up as nearly vertically as possible, with a maximum slope no greater than 30 degrees from the vertical. The lining shall extend for the entire height of the chimney to a level not less than 2 in. (51 mm) above the splay or wash. The splay or wash shall be constructed to allow for unrestricted vertical movement of the flue lining due to thermal expansion without allowing the introduction of moisture into the chimney.

4-2.7

Where a chimney contains more than one flue, a separation shall be provided between adjacent flues. The separation shall be constructed of solid masonry wythes (partitions) not less than 4 in. (102 mm), nominal, in thickness or of reinforced portland or refractory cement concrete not less than 4 in. (102 mm), actual, in thickness, and the partitions shall be bonded or securely tied to the chimney walls.

Exception No. 1: Where two flues are used to vent a single fireplace or appliance, this separation shall not be required.

Exception No. 2: Multiple flues in one chimney shall not be permitted for medium-heat appliances, high-heat appliances, or commercial and industrial incinerators.

4-3 Clearance from Combustible Material.

4-3.1

The minimum air space clearance between interior masonry chimneys (where any portion of the chimney is located within the exterior wall of the building) and combustible materials shall be at least the distance specified in Table 4-2, Column VIII. The minimum air space clearance between exterior masonry chimneys (where the chimney is located completely outside the exterior wall of the building, excluding the soffit or cornice area) and combustible material shall be at least the distance specified in Table 4-2, Column IX. The air space shall not be filled; however, this shall not eliminate the firestopping requirements in 4-1.6.

Exception No. 1: For residential and low-heat chimneys, noncombustible trim shall be permitted to be used to prevent the entry of debris into the air space.

Exception No. 2: Masonry chimneys for high-heat appliances shall have sufficient clearance from buildings and structures to avoid overheating combustible material, to allow inspection and maintenance operations on the chimney, and to avoid the danger of burns to persons. Clearances shall be based on good engineering practice and acceptable to the authority having jurisdiction.

4-3.2

Chimneys constructed with listed chimney liners shall be built with clearances in conformance with the listing of the liner system.

4-4 Masonry Chimneys for Incinerators.

In addition to the requirements in Sections 4-1 through 4-3, masonry chimneys for incinerators shall meet the requirements of 4-4.1 through 4-4.3.

4-4.1

Chute-fed incinerators shall meet the requirements of NFPA 82, *Standard on Incinerators and Waste and Linen Handling Systems and Equipment*.

4-4.2

Masonry chimneys for commercial and industrial incinerators shall be supported on properly designed foundations of masonry or reinforced portland or refractory cement concrete or on noncombustible material having a fire resistance rating of not less than 3 hours, provided such supports are independent of the building construction and the load is transferred to the ground.

Exception: Chimneys shall be permitted to be supported on incinerator walls if the incinerator foundation and walls are built to support the load imposed. They shall be constructed to prevent excessive stress upon the roof of the combustion chamber.

4-4.3

The terminus of the chimney for commercial and industrial incinerators shall be equipped with an approved spark arrester if the incinerator does not include effective means for arresting sparks and fly ash. (*See NFPA 82, Standard on Incinerators and Waste and Linen Handling Systems and Equipment*.)

Chapter 5 Unlisted Metal Chimneys (Smokestacks) for Nonresidential Applications

5-1 General Requirements.

5-1.1

Single-wall metal chimneys or unlisted metal chimneys shall not be used inside or outside of one- and two-family dwellings.

5-1.2

Unlisted metal chimneys shall be constructed of steel or cast iron. Sheet steel shall have a thickness not less than that indicated in Table 5-1.2.

Table 5-1.2 Minimum Thickness of Sheet Steel Chimneys

Manufacturer Standard	Minimum Thickness		Area		Equiv. Round Diameter	
Gauge No.	(in.)	(mm)	(in.^{2})	(m^2)	(in.)	(mm)
16	0.053	1.35	≤ 154	≤ 0.0994	≤ 14	≤ 356
14	0.067	1.70	155 to 201	0.0999 to 0.1296	> 14 to ≤ 16	> 356 to ≤ 406
12	0.093	2.36	202 to 254	0.1303 to 0.1638	> 16 to ≤ 18	> 406 to ≤ 457
10	0.123	3.12	> 254	> 0.1638	> 18	> 457

NOTE: Regardless of minimum thicknesses specified in this table, the thickness of sheet metal shall be adequate to meet the requirements of 5-1.3.

5-1.3

Unlisted metal chimneys shall be properly riveted, welded or bolted, securely supported, and constructed in accordance with good engineering practice as necessary to provide the following:

(a) Strength to resist stresses due to steady or gusting wind loads;

(b) Adequate anchoring, bracing, and inherent strength to withstand seismic and wind-induced vibrational stresses;

(c) Proper material thickness for durability considering fuel analysis, gas temperature, and exposure;

(d) Security against leakage of flue gases under positive pressure;

(e) Allowance for thermal expansion of breeching and vertical sections.

5-1.4

Unlisted metal chimneys shall not be used inside of ventilating ducts.

5-1.5

Unlisted metal chimneys shall have sufficient clearance from buildings and structures to avoid heating combustible material to a temperature in excess of 90°F (50°C) above ambient and to allow inspection and maintenance operations on the chimney. They shall be located or shielded to avoid the danger of burns to persons.

5-1.6

Unlisted metal chimneys shall be supported on properly designed foundations of masonry or reinforced portland or refractory cement concrete or on noncombustible material having a fire resistance rating of not less than 3 hours, provided such supports are independent of the building construction and the load is transferred to the ground. An unlisted metal chimney also can be supported at intervals by the building structure, in which case expansion joints shall be provided at each support level. All joints shall be liquidtight or of a design that allows liquid to drain to the interior of the chimney.

5-1.7

Unlisted metal chimneys serving residential-type or low-heat appliances and producing flue gases having a temperature below 350°F (165.5°C) at the entrance to the chimney at full load or partial load shall be lined with acid- and condensate-resistant metal or refractory material, constructed of suitable stainless steel, or otherwise protected to minimize or prevent condensation and corrosion damage.

5-2 Unlisted Metal Chimneys for Residential-Type or Low-Heat Appliances.

5-2.1 Termination (Height).

5-2.1.1 Unlisted metal chimneys for residential-type or low-heat appliances shall extend at least 3 ft (0.92 m) above the highest point where they pass through the roof of a building and at least 2 ft (0.61 m) higher than any portion of a building within 10 ft (3.1 m). [*See Figures 1-8.1(a) and (b)*.]

Exception: The outlet of an unlisted metal chimney for residential-type and low-heat appliances equipped with a mechanical exhaust system shall be permitted to terminate at a location not less than 3 ft (0.92 m) from an adjacent building or building opening and at least 10 ft (3.1 m) above grade or walkways.

5-2.1.2 In any case, the outlet shall be so arranged that the flue gases are not directed so that they jeopardize people, overheat combustible structures, or enter building openings in the vicinity of the outlet.

5-2.2 Clearances.

5-2.2.1 Exterior.

5-2.2.1.1 Exterior unlisted metal chimneys used only for residential-type or low-heat appliances as identified in Table 2-2.1 shall have a clearance of not less than 18 in. (457 mm) from a wall of wood frame construction and from any combustible material.

5-2.2.1.2 Exterior unlisted metal chimneys over 18 in. (457 mm) in diameter shall have a clearance of not less than 4 in. (102 mm) from a building wall of other than wood frame construction.

5-2.2.1.3 Exterior unlisted metal chimneys 18 in. (457 mm) or less in diameter shall have a clearance of not less than 2 in. (51 mm) from a building wall of other than wood frame construction.

5-2.2.1.4 An unlisted metal chimney erected on the exterior of a building shall not be installed less than 24 in. (610 mm) from any door or window or from any walkway.

Exception: Where the chimney is insulated in an approved manner to avoid the danger of burns to persons.

5-2.2.2 Interior.

5-2.2.2.1 Where an unlisted metal chimney extends through any story(ies) of a building above that in which the appliances connected to the chimney are installed, it shall be enclosed in those upper stories within a continuous enclosure constructed of noncombustible materials (*see definition in Section 1-5*). The enclosure shall comply with the following:

(a) The enclosure shall extend from the ceiling of the appliance room to or through the roof so that it maintains the integrity of the fire separations required by the applicable building code provisions.

(b) The enclosure walls shall have a fire resistance rating of not less than 1 hour where the building is less than four stories in height.

(c) The enclosure walls shall have a fire resistance rating of not less than 2 hours where the building is four stories or more in height.

(d) The enclosure walls shall provide a space on all sides of the chimney sufficient to allow inspection and repair, but it shall not be less than 12 in. (305 mm) under any circumstances.

(e) The enclosure walls shall be without openings.

Exception: Doorways equipped with approved self-closing fire doors shall be permitted to be installed at various floor levels for inspection purposes.

5-2.2.2.2 Where an unlisted metal chimney serving only residential-type or low-heat appliances as identified in Table 2-2.1 is located in the same story of a building as that story in which the appliances connected thereto are located, it shall have a clearance of not less than 18 in. (457 mm) from a wall of wood frame construction and from any combustible material.

5-2.2.2.3 Interior unlisted metal chimneys over 18 in. (457 mm) in diameter shall have a clearance of not less than 4 in. (102 mm) from a building wall of other than wood frame construction.

5-2.2.2.4 Interior unlisted metal chimneys 18 in. (457 mm) or less in diameter shall have a clearance of not less than 2 in. (51 mm) from a building wall of other than wood frame construction.

5-2.2.2.5 Where an unlisted metal chimney serving only residential-type or low-heat appliances as identified in Table 2-2.1 passes through a roof constructed of combustible material, it shall be guarded by a ventilating thimble of galvanized steel or approved corrosion-resistant metal not less than 0.024 in. (0.61 mm) in thickness, extending not less than 9 in. (229 mm) below and 9 in. (229 mm) above the roof construction.

Exception: Where combustible material in the roof construction is cut away to provide not less than 18 in. (457 mm) clearance on all sides of the chimney, using entirely noncombustible material to close such an opening, the requirements of 5-2.2.2.5 shall not apply.

5-2.2.2.6 The ventilating thimble metal material shall be of galvanized steel not less than 24 gauge [0.024 in. (0.61 mm)] in thickness and shall provide a clearance of not less than 9 in. (229 mm) from the chimney surface to the nearest combustibles. The thimble shall provide a minimum 1-in. (25.4-mm) air space between the thimble wall and combustible material. The space between the chimney and the thimble wall shall be ventilated. (*See Figure 5-2.2.2.6*.)

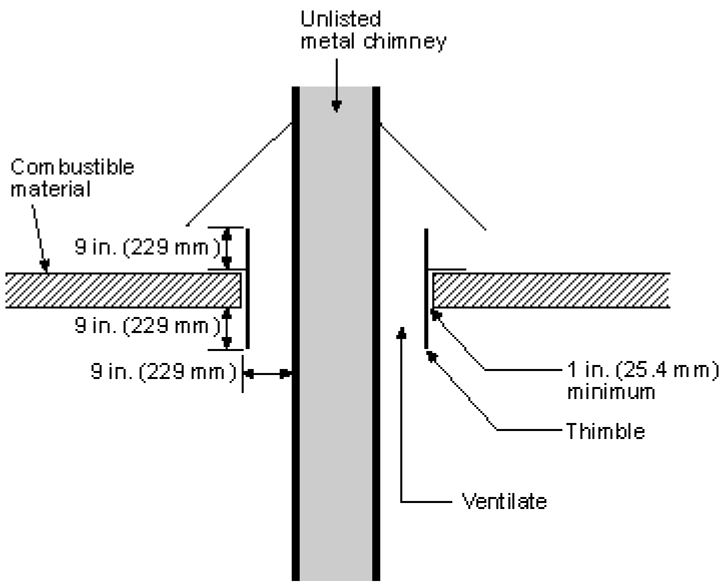


Figure 5-2.2.2.6 Ventilating thimble.

5-3 Unlisted Metal Chimneys for Medium-Heat Appliances.

5-3.1 Construction.

Unlisted metal chimneys serving medium-heat appliances as identified in Table 2-2.1 shall be lined with medium-duty fireclay brick (ASTM C 27, *Standard Classification of Fireclay and High-Alumina Refractory Brick*), or its equivalent, laid in medium-duty refractory mortar (ASTM C 199, *Standard Test Method for Pier Test for Refractory Mortars*), or its equivalent.

5-3.1.1 The lining shall be at least 2 in. (64 mm) thick for chimneys having a diameter or greatest cross-sectional dimension of 18 in. (457 mm) or less.

5-3.1.2 The lining shall have a thickness of not less than 4 in. (114 mm) laid on a full-width bed for chimneys having a diameter or greatest cross-sectional dimension greater than 18 in. (457 mm).

5-3.1.3 The lining shall start 2 ft (0.61 m) or more below the lowest chimney connector entrance and shall extend to a height of at least 25 ft (7.6 m) above the highest chimney connector entrance. Chimneys terminating 25 ft (7.6 m) or less above a chimney connector entrance shall be lined to the top.

5-3.2 Termination (Height).

Unlisted metal chimneys for medium-heat appliances shall extend not less than 10 ft (3.1 m) higher than any portion of any building within 25 ft (7.6 m).

5-3.3 Clearances.

5-3.3.1 Exterior.

5-3.3.1.1 Exterior unlisted metal chimneys used for medium-heat appliances as identified in Table 2-2.1 shall have a clearance of not less than 24 in. (610 mm) from a wall of wood frame construction and from any combustible material.

5-3.3.1.2 Exterior unlisted metal chimneys over 18 in. (457 mm) in diameter shall have a clearance of not less than 4 in. (102 mm) from a building wall of other than wood frame construction.

5-3.3.1.3 Exterior unlisted metal chimneys 18 in. (457 mm) or less in diameter shall have a clearance of not less than 2 in. (51 mm) from a building wall of other than wood frame construction.

5-3.3.1.4 An unlisted metal chimney erected on the exterior of a building shall not be installed less than 24 in. (610 mm) from any door or window or from any walkway.

Exception: Where the chimney is insulated or shielded in an approved manner to avoid the danger of burns to persons.

5-3.3.2 Interior.

5-3.3.2.1 Where an unlisted metal chimney extends through any story(ies) of a building above that story in which the appliances connected to the chimney are installed, it shall be enclosed in those upper stories within a continuous enclosure constructed of noncombustible materials (*see definition in Section 1-5*). The enclosure shall comply with the following:

(a) The enclosure shall extend from the ceiling of the appliance room to or through the roof so that it maintains the integrity of the fire separations required by the applicable building code provisions.

(b) The enclosure walls shall have a fire resistance rating of not less than 1 hour where the building is less than four stories in height.

(c) The enclosure walls shall have a fire resistance rating of not less than 2 hours where the building is four stories or more in height.

(d) The enclosure walls shall provide a space on all sides of the chimney to allow inspection and repair, but it shall not be less than 12 in. (305 mm) under any circumstances.

(e) The enclosure walls shall be without openings.

Exception: Doorways equipped with approved self-closing 1-hour fire doors shall be permitted to be installed at various floor levels for inspection purposes.

5-3.3.2.2 Where an unlisted metal chimney serving a medium-heat appliance as identified in Table 2-2.1 passes through a roof constructed of combustible material, it shall be guarded by a ventilating thimble of galvanized steel or approved corrosion-resistant metal extending not less than 9 in. (229 mm) below and 9 in. (229 mm) above the roof construction and shall be of a size that allows a minimum clearance of 18 in. (457 mm) on all sides of the chimney.

5-3.3.2.3 Where an unlisted metal chimney serving medium-heat appliances as identified in Table 2-2.1 is located in the same story of a building as that story in which the appliances connected thereto are located, it shall have a clearance of not less than 36 in. (914 mm) from a wall of wood frame construction and from any combustible material.

5-3.3.2.4 Interior unlisted metal chimneys over 18 in. (457 mm) in diameter shall have a clearance of not less than 4 in. (102 mm) from a building wall of other than wood frame construction.

5-3.3.2.5 Interior unlisted metal chimneys 18 in. (457 mm) or less in diameter shall have a clearance of not less than 2 in. (51 mm) from a building wall of other than wood frame construction.

5-4 Unlisted Metal Chimneys for High-Heat Appliances.

5-4.1 Construction.

5-4.1.1 Unlisted metal chimneys for high-heat appliances as identified in Table 2-2.1 shall be lined with high-duty fireclay brick (ASTM C 27, *Standard Classification of Fireclay and High-Alumina Refractory Brick),* or its equivalent, not less than 4 in. (114 mm) thick, laid on a full-width bed in high-duty refractory mortar (ASTM C 199, *Standard Test Method for Pier Test for Refractory Mortars),* or its equivalent.

5-4.1.2 The lining shall start 2 ft (0.61 m) or more below the lowest chimney connector entrance and shall extend to a height of at least 25 ft (7.6 m) above the highest chimney connector entrance. Chimneys terminating 25 ft (7.6 m) or less above a chimney connector entrance shall be lined to the top.

5-4.2 Termination (Height).

Unlisted metal chimneys for high-heat appliances shall extend not less than 20 ft (6.1 m) higher than any portion of any building within 50 ft (15.3 m).

5-4.3 Clearance from Combustible Material.

Unlisted metal chimneys for high-heat appliances shall have sufficient clearance from buildings and structures to avoid heating combustible material to a temperature in excess of 90°F (50°C) above ambient and to allow inspection and maintenance operations on the chimney. They shall be located or shielded to avoid the danger of burns to persons.

Chapter 6 Chimney Connectors and Vent Connectors

6-1 Connectors Required.

Connectors shall be used to connect appliances to the vertical chimney or vent unless the chimney or vent is attached directly to the appliance.

6-2 Materials.

6-2.1

Connectors shall be made of noncombustible, corrosion-resistant material capable of withstanding the flue gas condensate and temperatures produced by the appliances and shall be of sufficient thickness to withstand physical damage.

6-2.2

Connectors for residential-type appliances shall conform to the requirements of this chapter.

6-2.2.1 Appliances Installed in Attics. Vent connectors for listed gas appliances and appliances listed for use with Type B gas vents that are installed in attics shall be of Type B or Type L vent material.

6-2.2.2 Appliances Not Installed in Attics.

6-2.2.2.1 Vent connectors for appliances listed for use with Type B gas vents and for appliances with draft hoods and equipped with listed conversion burners and that are not installed in attics shall be of Type B or Type L material or other material listed for use as connectors, or smooth interior-wall metal pipe having strength and resistance to heat and corrosion equivalent to that of galvanized sheet steel not less than 0.018 in. (0.46 mm) thick, aluminum (1100 or 3003 alloy or the equivalent) not less than 0.027 in. (0.69 mm) thick, or stainless steel not less than 0.012 in. (0.31 mm) thick.

6-2.2.2.2 Listed vent connectors shall be installed in accordance with the terms of their listing and the connector manufacturer’s installation instructions.

6-2.2.3 Connectors for oil appliances, solid fuel-burning appliances, domestic-type incinerators, and gas appliances other than those specified in 6-2.2.1 and 6-2.2.2 shall be of factory-built chimney material, Type L vent material, or steel pipe having resistance to corrosion and heat not less than that of galvanized pipe specified in Table 6-2.2.3.

Table 6-2.2.3 Metal Thickness for Galvanized Steel Pipe Connectors

Diameter of Connector		Galvanized Sheet	Minimum Thickness	
(in.)	(mm)	Gauge No.	(in.)	(mm)
< 6	< 152	26	0.019	0.48
≥ 6 to ≤ 10	≥ 152 to ≤ 254	24	0.024	0.61
> 10 to ≤ 16	> 254 to ≤ 406	22	0.029	0.74
> 16	> 406	16	0.056	1.42

6-2.3

Connectors for low-heat appliances shall be of listed factory-built chimney material or of steel pipe having resistance to corrosion and heat not less than that of galvanized pipe specified in Table 6-2.2.3.

6-2.4

Connectors for medium-heat appliances and commercial and industrial incinerators shall be constructed of listed medium-heat chimney sections or of steel not lighter than that designated for unlisted metal chimneys in Table 5-1.2 and shall conform to the requirements of 6-2.4.1 through 6-2.4.2.2.

6-2.4.1 Connector sections of listed medium-heat chimneys shall be joined together using continuous welds, flanges, or couplings.

6-2.4.2 Steel connectors shall be lined with medium-duty fireclay brick (ASTM C 27, *Standard Classification of Fireclay and High-Alumina Refractory Brick*) laid in medium-duty refractory mortar (ASTM C 199, *Standard Test Method for Pier Test for Refractory Mortars*), or the equivalent.

6-2.4.2.1 The lining shall be at least 2 in. (64 mm) thick for connectors having an inside diameter or greatest inside cross-sectional dimension of 18 in. (457 mm) or less.

6-2.4.2.2 The lining shall be at least 4 in. (114 mm) thick laid on the 4-in. (114-mm) bed for connectors having an inside diameter or greatest inside cross-sectional dimension greater than 18 in. (457 mm).

6-2.5

Metal connectors for high-heat appliances shall conform to the requirements of 6-2.5.1 and 6-2.5.2.

6-2.5.1 Metal connectors for high-heat appliances shall be made of steel not lighter than that designated for chimneys in Table 5-1.2.

6-2.5.2 The connectors shall be lined with high-duty fireclay brick (ASTM C 27, *Standard Classification of Fireclay and High-Alumina Refractory Brick*) or its equivalent having a thickness of not less than 4 in. (114 mm) laid on the 4-in. (114-mm) bed in high-duty refractory mortar (ASTM C 199, *Standard Test Method for Pier Test for Refractory Mortars*), or its equivalent.

6-2.6

Masonry connectors or breeching shall be made of refractory material equivalent in resistance to heat and corrosion to high-duty fireclay brick (ASTM C 27, *Standard Classification of Fireclay and High-Alumina Refractory Brick*) not less than 4 in. (114 mm) thick.

6-3 Length.

A connector shall be as short and straight as practicable. The appliance shall be located as close as practicable to the chimney or vent.

6-3.1*

The horizontal length of a connector to a natural draft chimney, or vent, serving a single appliance shall be not more than 75 percent of the height of the vertical portion of the chimney or vent above the connector.

Exception No. 1: Where part of an engineered venting system.

Exception No. 2: The horizontal length of a connector for a single Category I or draft hood-equipped gas appliance shall be in accordance with the applicable table in Part 11 of NFPA 54, National Fuel Gas Code, for the type of vent or chimney material, or in accordance with other approved engineering methods. The horizontal length of the connector shall be permitted to exceed 75 percent of the vertical height above the connector where so indicated by the applicable table or engineering method.

6-3.2

The horizontal length, design, and construction of combined connectors, or connectors to a manifold joining two or more appliances to a chimney or vent, shall be determined in accordance with approved engineering methods.

6-4 Size.

6-4.1

The connector shall be sized for its entire length in accordance with approved engineering methods.

6-4.2

As an alternate to 6-4.1, the requirements of 6-4.2.1 through 6-4.2.3 shall be permitted to be applied.

6-4.2.1 The effective area of a connector for a single appliance shall be not less than the area of the appliance flue collar.

6-4.2.2 A connector or manifold serving two or more appliances shall have an effective area equivalent to the combined areas of the appliance flue collars or individual connectors.

6-4.2.3 Linings, if used, shall not reduce the required effective area of the connector.

6-5 Clearance.

6-5.1

Clearances from connectors to combustible material shall be in accordance with the requirements of 6-5.1.1 through 6-5.6 for both unprotected and protected installations.

6-5.1.1 Clearances from connectors to unprotected combustible material shall be in accordance with Table 6-5.1.1 and Figure 6-5.1.1.

Table 6-5.1.1 Chimney Connector and Vent Connector Clearances from Combustible Materials

	Minimum Clearance (*See Note 1.*)	
Description of Appliance	**(in.)**	**(mm)**
Residential-Type Appliances		

Single-Wall Metal Pipe Connectors		
Gas appliances without draft hoods	18	457
Electric, gas, and oil incinerators	18	457
Oil and solid-fuel appliances	18	457
Unlisted gas appliances with draft hoods	9	229
Boilers and furnaces equipped with listed gas burners and with draft hoods	9	229
Oil appliances listed as suitable for use with Type L vents	9	229
Listed gas appliances with draft hoods and other Category I gas appliances listed for use with Type B vents (*see Note 3*)	6	152
Type L Vent Piping Connectors		
Gas appliances without draft hoods	9	229
Electric, gas, and oil incinerators	9	229
Oil and solid-fuel appliances	9	229
Unlisted gas appliances with draft hoods	6	152
Boilers and furnaces equipped with listed gas burners and with draft hoods	6	152
Oil appliances listed as suitable for use with Type L vents	(*See Note 2*)	
Listed gas appliances with draft hoods and other Category I gas appliances listed for use with Type B vents	(*See Note 3*)	
Type B Gas Vent Piping Connectors		
Listed gas appliances with draft hoods and other Category I gas appliances listed for use with Type B vents	(*See Note 3*)	
Low-Heat Appliances		
Single-Wall Metal Pipe Connectors		
Gas, oil, and solid-fuel boilers, furnaces, and water heaters	18	457
Ranges, restaurant-type	18	457
Oil unit heaters	18	457

Unlisted gas unit heaters	18	457
Listed gas unit heaters with draft hoods	6	152
Other low-heat nonresidential appliances	18	457
Medium-Heat Appliances		
Single-Wall Metal Pipe Connectors		
All gas, oil, and solid-fuel appliances	36	914
High-Heat Appliances		
Masonry or Metal Connectors		
All gas, oil, and solid-fuel appliances	(*See Note 4*)	

NOTES

1. These clearances apply, except if the listing of an appliance specifies different clearance, in which case the listed clearance takes precedence.
2. If listed Type L vent piping is used, the clearance shall be permitted to be in accordance with the vent listing.
3. If listed Type B or Type L vent piping is used, the clearance shall be permitted to be in accordance with the appliance and vent listing.
4. Clearances shall be based on good engineering practice and acceptable to the authority having jursidiction. The clearances from connectors to combustible materials shall be permitted to be reduced, provided the combustible material is protected in accordance with Table 6-5.1.2.

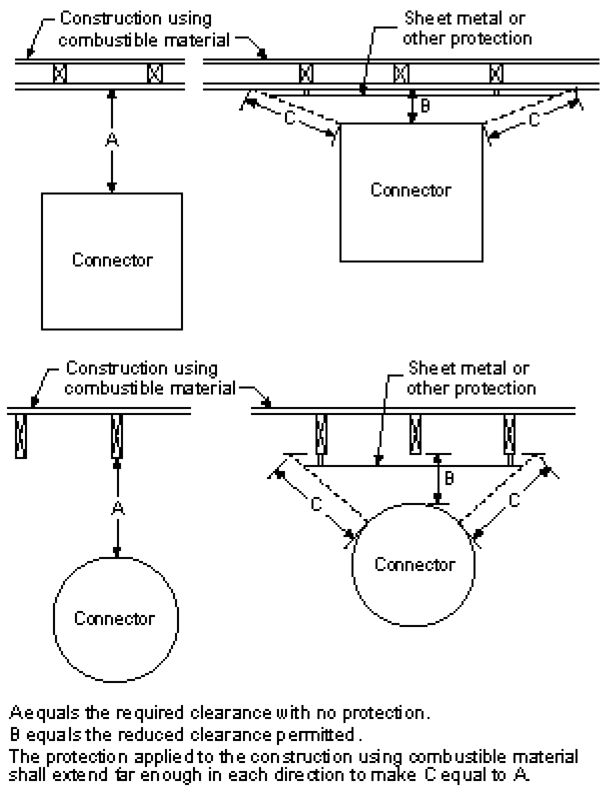


Figure 6-5.1.1 Extent of protection required to reduce clearances from chimney or vent connectors.

6-5.1.2 Clearances from connectors to combustible material shall be permitted to be reduced, provided the combustible material is protected by an engineered protection system acceptable to the authority having jurisdiction, by the use of materials or products listed for protection purposes, or in accordance with Table 6-5.1.2 and Figure 6-5.1.1.

Table 6-5.1.2 Reduction of Connector Clearance with Specified Forms of Protection[1-8]

Clearance Reduction Applied to and Covering All Combustible Surfaces within the Distance Specified as Required Clearance with No Protection (*See 6-5.1*	Maximum Allowable Reduction in Clearance (%)		Where the required clearance with no protection is 18 in. (457 mm), the clearances below are the minimum allowable clearances. For other required clearances, calculate minimum allowable clearance from maximum allowable reduction.[8]	
	As Wall Protector	As Ceiling Protector	As Wall Protector	As Ceiling Protector

and Table 6-5.1.1.).	(%)	(%)	(in.)	(mm)	(in.)	(mm)
(a) $3^1/_2$-in. (90-mm) thick masonry wall without ventilated air space	33	-	12	305	-	-
(b) $^1/_2$-in. (13-mm) thick noncombustible insulation board over 1-in. (25.4-mm) glass fiber or mineral wool batts without ventilated air space	50	33	9	229	12	305
(c) 0.024-in. (0.61-mm), 24-gauge sheet metal over 1-in. (25.4-mm) glass fiber or mineral wool batts reinforced with wire, or equivalent, on rear face with ventilated air space	66	50	6	152	9	229
(d) $3^1/_2$-in. (90-mm) thick masonry wall with ventilated air space	66	-	6	152	-	-
(e) 0.024-in. (0.61-mm), 24-gauge sheet metal with ventilated air space	66	50	6	152	9	229
(f) $^1/_2$-in. (13-mm) thick noncombustible insulation board with ventilated air space	66	50	6	152	9	229
(g) 0.024-in. (0.61-mm), 24-gauge sheet metal with ventilated air space over 0.024-in.(0.61-mm), 24-gauge sheet metal with ventilated air space	66	50	6	152	9	229
(h) 1-in. (25.4-mm) glass fiber or mineral wool batts sandwiched between two sheets 0.024-in. (0.61-mm), 24-gauge sheet metal with ventilated air space	66	50	6	152	9	229

[1]Spacers and ties shall be of noncombustible material. No spacers or ties shall be used directly behind appliance or connector.

[2]With all clearance reduction systems using a ventilated air space, adequate air circulation shall be provided as described in 6-5.5. There shall be at least 1 in. (25.4 mm) between the clearance reduction system and combustible walls and ceilings for clearance reduction systems using a ventilated air space.

[3]Mineral wool batts (blanket or board) shall have a minimum density of 8 lb/ft^3 (128.7 kg/m^3) and have a minimum melting point of 1500°F (816°C).

[4]Insulation material used as part of clearance reduction system shall have a thermal conductivity of 1.0 (Btu-in.)/(ft^2-hr-°F) or less. Insulation board shall be formed of noncombustible material.

[5]If a single-wall connector passes through a masonry wall used as a wall shield, there shall be at least $^1/_2$ in. (13 mm) of open, ventilated air space between the connector and the masonry.

[6]There shall be at least 1 in. (25.4 mm) between the connector and the protector. In no case shall the clearance between the connector and the wall surface be reduced below that allowed in the table.

[7]All clearances and thicknesses are minimum; larger clearances and thicknesses shall be permitted.

[8]To calculate the minimum allowable clearance, the following formula can be used: $C_{pr} = C_{un} \times (1 -$

R/100). C_{pr} is the minimum allowable clearance, C_{un} is the required clearance with no protection, and R is the maximum allowable reduction in clearance.

6-5.2

Engineered systems installed for the protection of combustible materials shall reduce the temperature rise of such materials to 90°F (50°C) above ambient. The system design shall be based on applicable heat transfer principles, taking into account the geometry of the system, the heat loss characteristics of the structure behind the combustible material, and the possible abnormal operating conditions of heat-producing sources.

6-5.3

All clearances shall be measured from the outer surface of the connector to the combustible material, disregarding any intervening protection applied to the combustible material. However, in no case shall the clearance interfere with the requirement for accessibility.

6-5.4

Materials and products listed for the purpose of reducing clearance to combustibles shall be installed in accordance with the conditions of the listing and the manufacturer's instructions.

6-5.5

For clearance reduction systems using an air space between the combustible wall and the wall protector, adequate air circulation shall be provided by one of the methods specified in 6-5.5.1 through 6-5.5.3.

6-5.5.1 Adequate air circulation can be provided by leaving all edges of the wall protector open with at least a 1-in. (25.4-mm) air gap.

6-5.5.2 If the wall protector is mounted on a single flat wall away from corners, adequate air circulation can be provided by leaving only the bottom and top edges or only the side and top edges open with at least a 1-in. (25.4-mm) air gap.

6-5.5.3 Wall protectors that cover two walls in a corner shall be open at the bottom and top edges with at least a 1-in. (25.4-mm) air gap.

6-5.6

All clearances shall be measured from the outer surface of the combustible material to the nearest point on the surface of the connector, disregarding any intervening protection applied to the combustible material.

6-6 Location.

Where the connector used for a gas appliance having a draft hood or for Category I appliances is located in or passes through an attic, crawl space, or other cold area, that portion of the connector shall be of listed Type B or Type L vent material or provided with equivalent means of insulation.

6-7 Installation.

6-7.1

A connector to a masonry chimney shall extend through the wall to the inner face or liner, but not beyond, and shall be firmly cemented to masonry.

Exception: A thimble shall be permitted to be used to facilitate removal of the chimney connector *for cleaning, in which case the thimble shall be permanently cemented in place with high-temperature cement.*

6-7.2

A chimney connector or vent connector shall not pass through any floor or ceiling, nor through a fire wall or fire partition.

6-7.3

Connectors for listed gas appliances with draft hoods, other listed Category I gas appliances (Table 2-2.2, Column I), and oil appliances listed for Type L vents (Table 2-2.2, Column III) shall be permitted to pass through walls or partitions constructed of combustible material, provided:

(a) They are made of listed Type B or Type L vent material for gas appliances, or listed Type L vent material for oil appliances, and are installed with not less than listed clearances to combustible material; or

(b) They are made of single-wall metal pipe and guarded by a ventilated metal thimble not less than 4 in. (102 mm) larger in diameter than the vent connector.

6-7.4

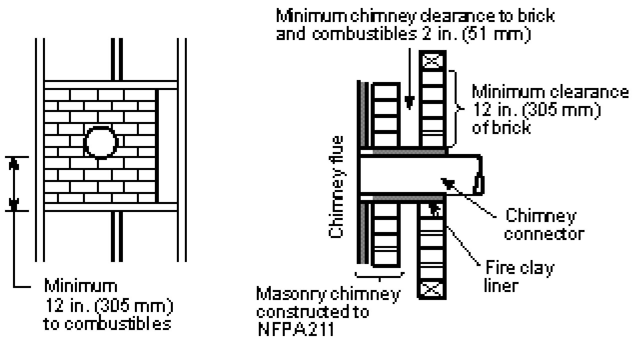
Connectors for residential-type appliances (Table 2-2.1, Column I) shall be permitted to pass through walls or partitions constructed of combustible material if the connector is either listed for wall pass-through, or is routed through a device listed for wall pass-through, and is installed in accordance with the conditions of the listing.

6-7.5

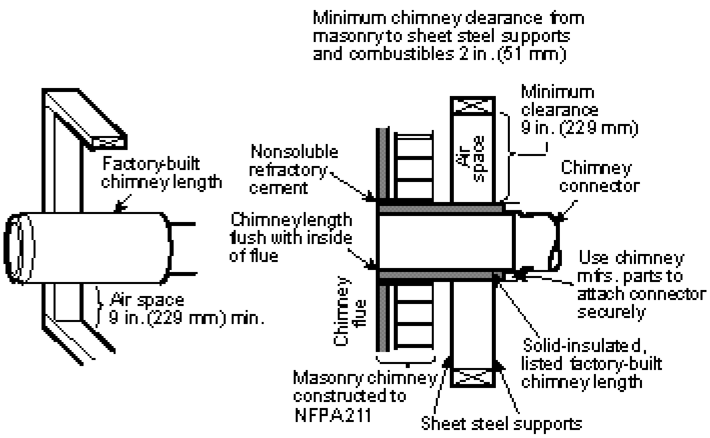
Connectors for residential-type appliances (Table 2-2.1, Column I) with inside diameters less than or equal to 10 in. (254 mm) shall be permitted to pass through walls or partitions constructed of combustible material to a masonry chimney, provided the connector system selected or fabricated is installed in accordance with the conditions and clearances in Table 6-7.5. Any unexposed metal that is used as part of a wall pass-through system and is exposed to flue gases shall be constructed of stainless steel or other equivalent material that resists corrosion, softening, or cracking from flue gases at temperatures up to 1800°F (982°C).

Table 6-7.5 Chimney Connector Systems and Clearances from Combustible Walls for Residential Heating Appliances

System



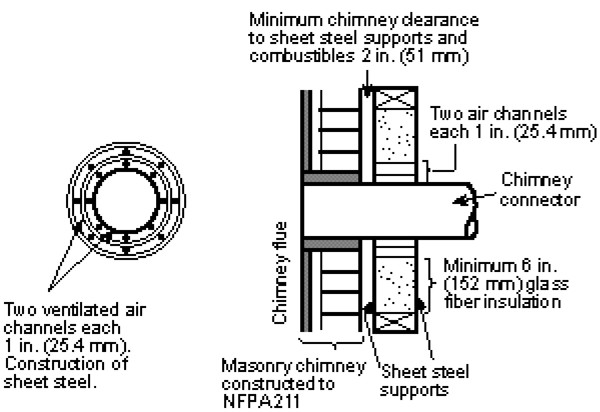
A Minimum 3.5-in. (90-mm) thick brick masonry wall framed into combustible wall with a minimum of 12-in. (305-mm) brick separation from clay liner to combustibles. Fireclay liner (ASTM C 315, *Standard Specification for Clay Fire Linings*, or equivalent), minimum ⅝-in. (16-mm) wall thickness, shall run from outer surface of brick wall to, but not beyond, the inner surface of chimney flue liner and shall be firmly cemented in place.



B Solid-insulated, listed factory-built chimney length of the same inside diameter as the chimney connector and having 1 in. (25.4 mm) or more of insulation with a minimum 9-in. (229-mm) air space between the outer wall of the chimney length and combustibles.

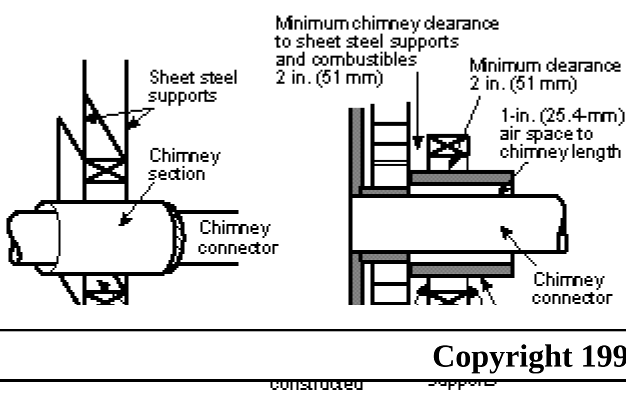
The inner end of the chimney length shall be flush with the inside of the masonry chimney flue and shall be sealed to the flue and to the brick masonry penetration with non-water-soluble refractory cement. Supports shall be securely fastened to wall surfaces on all sides.

Fasteners between supports and the chimney length shall not penetrate the chimney liner.



C Sheet steel chimney connector, minimum 24 gauge [0.024 in. (0.61 mm)] in thickness, with a ventilated thimble, minimum 24 gauge [0.024 in. (0.61 mm)] in thickness, having two 1-in. (25.4-mm) air channels, separated from combustibles by a minimum of 6 in. (152 mm) of glass fiber insulation. Opening shall be covered, and thimble supported with a sheet steel support, minimum 24 gauge [0.024 in. (0.61 mm)] in thickness.

Supports shall be securely fastened to wall surfaces on all sides and shall be sized to fit and hold chimney section. Fasteners used to secure chimney section shall not penetrate chimney flue liner.



D Solid-insulated, listed factory-built chimney length with an inside diameter 2 in. (51 mm) larger than the chimney connector and having 1 in. (25 mm) or more of insulation, serving as a pass-through for a single wall sheet steel chimney connector of minimum 24 gauge [0.024 in. (0.61 mm)] thickness, with a minimum 2-in. (51-mm) air space between the outer wall of chimney section and combustibles.

Minimum length of chimney section shall be 12 in. (305 mm). Chimney section concentric with and spaced 1 in. (25.4 mm) away from connector by means of sheet steel support plates on both ends of chimney section. Opening shall be covered, and chimney section supported on both sides with sheet steel supports of minimum 24 gauge [0.024 in. (0.61 mm)] thickness. ... urfaces on all sides ... ction. Fasteners ... netrate chimney ... lue liner.

Additional requirements:

1. Insulation material used as part of wall pass-through system shall be of noncombustible material and shall have a thermal conductivity of 1.0 Btu-in./hr-ft^2-°F (4.88 kg-cal/hr-m^2-°C) or less.
2. All clearances and thicknesses are minimums; larger clearances and thicknesses shall be permitted.
3. Any material used to close up an opening for the connector shall be of noncombustible material.

6-7.6

A connector for a medium- or high-heat appliance (Table 2-2.1, Columns IV and V) shall not pass through walls or partitions constructed of combustible material.

6-7.7

Connectors shall maintain a pitch or rise of at least $^1/_4$ in./ft (6.4 mm/305 m) of horizontal length of pipe from the appliance to the chimney.

6-7.8

Connectors shall be installed to avoid sharp turns or other construction features that would create excessive resistance to the flow of flue gases.

6-7.9

A device, other than a damper, that can obstruct the free flow of flue gas shall not be installed in a connector, chimney, or vent. For requirements regarding dampers, see Section 6-9.

Exception No. 1: This requirement shall not be construed to prohibit the use of devices specifically listed for installation in a connector in accordance with the fuel-burning appliance listing, such as heat reclaimers, draft regulators, and safety controls.

Exception No. 2: Approved economizers, heat reclaimers, and recuperators in venting systems of equipment, not required to be equipped with draft hoods in accordance with the fuel-burning appliance listing, provided performance is in accordance with Section 1-7.

6-7.10

Connectors shall be supported securely and joints fastened using sheet-metal screws, rivets, or other approved means.

6-7.11

The entire length of a connector shall be readily accessible for inspection, cleaning, and replacement.

6-7.12

A connector serving a gas or oil appliance shall not be connected to a chimney flue serving a factory-built fireplace.

Exception: Where the gas or oil appliance is listed for such installation and is installed in accordance with the listing.

6-7.13

A connector serving a gas or oil appliance shall be permitted to be connected to a masonry fireplace flue, provided the fireplace opening is sealed or the chimney flue that vents the fireplace is permanently sealed below the connection.

Exception: Listed gas or oil appliances shall be installed in accordance with the listing.

6-7.14

Vent and chimney connectors shall not be covered with insulation.

Exception: Listed insulated vent and chimney connectors shall be installed in accordance with *the terms of their listing.*

6-8 Interconnection.

6-8.1

Connectors serving appliances operating under natural draft shall not be connected into any portion of a mechanical draft system operating under positive pressure.

6-8.2

Unless listed for such connection, solid fuel-burning appliances shall not be connected to a chimney flue serving another appliance burning other fuels.

6-8.3

Gas utilization appliances and appliances burning liquid fuel shall be permitted to be connected to one chimney flue through separate openings or shall be permitted to be connected through a single opening, provided they are joined by a suitable fitting located as close as practicable to the chimney and provided:

(a) Sufficient draft is available for the safe combustion of each appliance and for the removal of all products of combustion; and

(b) The appliances so connected are equipped with primary safety controls.

6-8.4

If two or more openings are provided into one chimney flue, they shall be at different levels, and the smaller connector shall enter at the highest level consistent with available head room or clearance to combustible material.

6-9 Dampers.

6-9.1

Manually operated dampers shall not be placed in chimneys, vents, or connectors of stoker-fired, liquid, or gas-burning appliances. Fixed baffles on the appliance side of draft hoods and draft regulators shall not be classified as dampers. Manually operated dampers shall be permitted to be installed in the chimney connector of hand-fired solid fuel-burning appliances, provided such dampers do not obstruct more than 80 percent of the connector area.

6-9.2

Automatically operated dampers shall be listed and shall be installed by a qualified agency in accordance with the terms of the damper and appliance listings. The installation of dampers on gas appliances shall be in accordance with NFPA 54, *National Fuel Gas Code*.

6-10 Draft Hoods.

For information concerning the use and installation of draft hoods, see NFPA 54, *National Fuel Gas Code*.

6-11* Draft Regulators.

See A-6-11.

6-11.1

Gas appliances connected to chimneys, other than those required to be installed with draft hoods by NFPA 54, *National Fuel Gas Code*, shall be permitted to be installed with draft regulators if in accordance with the appliance manufacturer's instructions.

6-11.2

Solid fuel-burning appliances shall be permitted to be installed with draft regulators to reduce draft intensity. Such regulators shall be installed and set in accordance with the instructions furnished with the appliance or the draft regulator.

6-11.3

A barometric draft regulator, if used, shall be installed in the same room or enclosure as the appliance in such a manner that no difference in pressure between the air in the vicinity of the regulator and the combustion air supply will be permitted.

Chapter 7 Vents

7-1 Types and Uses.

See Table 2-2.2.

7-1.1

Type B gas vents shall be used to vent only listed gas appliances with draft hoods and other Category I gas appliances listed for use with Type B gas vents. Type B gas vents shall not be used for venting the following:

(a) Vented wall furnaces listed for use with Type BW gas vents only;

(b) Incinerators;

(c) Appliances that can be converted readily to the use of solid or liquid fuels;

(d) Combination gas/oil-burning appliances;

(e) Appliances listed for use with chimneys only;

(f) Listed Categories II, III, and IV gas appliances.

7-1.2

Type BW vents shall be used only with listed vented gas wall furnaces having a capacity not greater than that of the listed Type BW gas vent.

7-1.3

A special gas vent shall be listed and used in accordance with the terms of its listing and the appliance and vent manufacturers' instructions.

7-1.4

Type L vents shall be used only with appliances listed as suitable for such use and gas appliances listed as suitable for use with Type B gas vents.

7-1.5

Single-wall metal pipe other than special gas vents used to vent Categories II, III, and IV gas appliances shall conform to the requirements of 7-1.5.1 through 7-1.5.4.

7-1.5.1 Single-wall metal pipe shall not be used to vent incinerators.

7-1.5.2 The pipe shall be of sheet copper with a thickness not less than 24 B & S gauge [0.0201 in. (0.51 mm)] or of galvanized steel with a thickness not less than 20 gauge [0.036 in. (0.914 mm)].

7-1.5.3 Single-wall metal pipe shall be used only for runs directly from the space in which the appliance is located through the roof or exterior wall to the outer air.

7-1.5.4 Single-wall metal pipe shall not originate in any unoccupied attic or concealed space and shall not pass through any attic, inside wall, concealed space, or any floor or ceiling.

7-2 Size.

7-2.1 General.

Vents shall be sized and configured in accordance with approved methods and the appliance and vent manufacturers' instructions.

7-2.2 Gas Vents.

Gas vents shall be sized in accordance with Part 11 of NFPA 54, *National Fuel Gas Code*, or other approved methods, and the appliance and vent manufacturers' instructions.

7-3 Location.

Single-wall outside vents for appliances used in cold climates shall be insulated.

7-4 Termination (Height).

7-4.1

All vents shall terminate above the roof surface.

Exception: Pellet vents and other vents as provided in 7-4.5 and Section 7-7.

7-4.1.1 Vents installed with mechanical exhausters shall terminate not less than 12 in. (305 mm) above the highest point where they pass through the roof surface.

7-4.1.2 Vents installed with a listed cap shall terminate in accordance with the terms of the cap's listing.

7-4.1.3 Vents installed without listed caps or mechanical exhausters shall extend 2 ft (0.61 m) above the highest point where they pass through the roof surface of a building and at least 2 ft (0.61 m) higher than any portion of a building within 10 ft (3.1 m). [*See Figures 1-8.1(a) and (b).*]

7-4.2

Natural draft vents for gas appliances shall terminate at an elevation not less than 5 ft (1.53 m) above the highest connected appliance outlet.

Exception: As provided in 7-4.3 and 7-7.2.

7-4.3

Natural draft gas vents serving vented wall furnaces shall terminate at an elevation not less than 12 ft (3.7 m) above the bottom of the furnace.

7-4.4

Vents passing through roofs shall extend through the roof flashing.

7-4.5

Mechanical draft systems shall not be required to comply with 7-4.1 and 7-4.3, provided they comply with the following:

(a) The exit terminal of a mechanical draft system, other than a direct vent appliance (sealed combustion system appliance) shall be located as follows:

1. Not less than 3 ft (0.91 m) above any forced air inlet located within 10 ft (3 m);

2. Not less than 4 ft (1.2 m) below, 4 ft (1.2 m) horizontally from, or 1 ft (305 mm) above any door, window, or gravity air inlet into any building; and

3. Not less than 2 ft (0.61 m) from an adjacent building and not less than 7 ft (2.1 m) above grade where located adjacent to public walkways.

(b) The exit terminal shall be so arranged that flue gases are not directed so that they jeopardize people, overheat combustible structures, or enter buildings.

(c) Forced draft systems and all portions of induced draft systems under positive pressure during operation shall be designed and installed to be gastight or to prevent leakage of combustion products into a building.

(d) Through-the-wall vents for gas appliances shall not terminate over public walkways or over an area where condensate or vapor could create a nuisance or hazard or could be detrimental to the operation of regulators, relief valves, or other equipment.

7-5 Notice of Usage.

7-5.1

In those localities where solid and liquid fuels are used extensively, gas vents shall be plainly and permanently identified by a label attached to the wall or ceiling at a point where the vent connector enters the gas vent. The label shall read: "This Gas Vent Is for Appliances that Burn Gas. Do Not Connect to Solid or Liquid Fuel-Burning Appliances or Incinerators."

7-5.2

Where a Type B gas vent, special gas vent, or pellet vent is used as the liner for a masonry chimney, the chimney shall be plainly and permanently identified by a label attached to the wall or ceiling or conspicuous location adjacent to the point where the connector enters the chimney that reads as follows: "This Chimney Liner Is for (name type; category of appliance) Appliances that Burn (type of fuel) Only. Do Not Connect Other Types of Appliances."

7-6 Installation.*

7-6.1

Type B, Type BW, and Type L vents shall be installed in full compliance with the terms of their listing.

7-6.2

Vents that pass through the floors of buildings requiring the protection of vertical openings shall be enclosed within an approved enclosure.

7-6.2.1 The enclosure walls shall have a fire resistance rating of not less than 1 hour where a vent as described in 7-6.2 is located in a building less than four stories in height.

7-6.2.2 The enclosure walls shall have a fire resistance rating of not less than 2 hours where a vent as described in 7-6.2 is located in a building four or more stories in height.

7-6.3

Unlisted single-wall metal pipe shall be installed as specified in 7-6.3.1 through 7-6.3.3.

7-6.3.1 Unlisted single-wall metal pipe shall be installed with minimum clearances from combustible material as follows:

(a) Unlisted gas appliances without draft hoods — 18 in. (457 mm);

(b) Unlisted gas appliances equipped with draft hoods — 9 in. (229 mm);

(c) Boilers and furnaces equipped with listed conversion gas burners and with draft hoods — 9 in. (229 mm);

(d) Listed gas appliances with draft hoods and other Category I gas appliances listed for use with Type B vents — 6 in. (152 mm).

Exception: Residential incinerators.

7-6.3.2 Where a single-wall metal pipe passes through an exterior wall constructed of combustible material, it shall be guarded at the point of passage by a ventilating metal thimble not smaller than the following:

Exception: Where all combustible material in the wall is cut away from the pipe a sufficient distance to provide the clearance required by 7-6.3.1 from such pipe to combustible material, with entirely noncombustible material used to close such an opening.

(a) For listed gas-burning appliances with draft hoods and other Category I gas appliances listed for use with Type B vents, the thimble shall be 4 in. (102 mm) larger in diameter than the pipe.

Exception No. 1: Residential incinerators.

Exception No. 2: Where there is a run of not less than 6 ft (1.8 m) of pipe in the open between the draft hood outlet or flue collar and the thimble, the thimble shall be permitted to be 2 in. (51 mm) larger in diameter than the pipe.

(b) For unlisted gas-burning appliances with draft hoods, the thimble shall be 6 in. (152 mm) larger in diameter than the pipe.

(c) For unlisted gas appliances without draft hoods, the thimble shall be 12 in. (305 mm) larger in diameter than the pipe.

7-6.3.3 Where an unlisted single-wall metal pipe passes through a roof constructed of combustible material, it shall be guarded at the point of passage as follows:

(a) As specified for passage through a combustible exterior wall by 7-6.3.2; or

(b) With listed gas appliances that can be connected to Type B gas vents by a noncombustible, nonventilating thimble not less than 4 in. (102 mm) larger in diameter than the vent pipe and extending not less than 18 in. (457 mm) above and 6 in. (152 mm) below the roof with the annular space open at the bottom and closed only at the top.

7-7 Special Venting Arrangements.

7-7.1 Direct Vent Appliances (Sealed Combustion System Appliances).

7-7.1.1 Direct vent appliances (sealed combustion system appliances) shall be listed and installed in accordance with their listing and the manufacturer's instructions.

7-7.1.2 The vent terminal of a direct vent appliance with an input of 10,000 Btu/hr (2930 W) or less shall be located at least 6 in. (152 mm) from any opening into a building, and such an appliance with an input of over 10,000 Btu/hr (2930 W) but not over 50,000 Btu/hr (14650 W) shall be located not less than 9 in. (229 mm) from any opening through which vent gases could enter a building, and the vent terminal of such appliance having an input over 50,000 Btu/hr (14650 W) shall be located not less than 12 in. (305 mm) from the opening. The bottom of the vent terminal and the air intake shall be located at least 12 in. (305 mm) above grade.

7-7.2 Ventilating Hoods and Exhaust Systems.

7-7.2.1* Where ventilating hoods and exhaust systems serving commercial cooking appliances are used to vent gas-burning appliances installed in commercial applications, the connector from the appliance shall terminate under the hood not less than 18 in. (457 mm) from any grease filter or screen installed in the hood.

7-7.2.2 Where automatically operated appliances, such as water heaters, are vented through natural draft ventilating hoods, dampers shall not be installed in the ventilating system.

7-7.2.3 Where automatically operated appliances, such as water heaters, are vented through a ventilating hood or exhaust system equipped with a mechanical exhaust system, the appliance control system shall be interlocked to allow appliance operation only when the mechanical exhaust system is in operation. [*See 7-4.5(c).*]

7-7.2.4 A ventilating hood shall be installed above an open-top broiler in a residence.

7-7.2.4.1 The hood shall be made with tight joints and shall be constructed of copper with a thickness not less than 24 B & S gauge [0.0201 in. (0.51 mm)] or galvanized steel with a thickness not less than 28 gauge [0.016 in. (0.406 mm)].

7-7.2.4.2 A clearance of not less than $^1/_4$ in. (6.4 mm) between the hood and the underside of combustible material or metal cabinets shall be provided.

7-7.2.4.3 The vertical clearance above the broiler to the underside of combustible material or a metal cabinet protected by the hood shall be not less than 24 in. (610 mm).

7-7.2.4.4 The width and breadth of the hood shall be not less than that of the open-top broiler unit.

7-7.2.4.5 The hood shall be centered over the unit.

7-7.2.4.6 The hood shall be exhausted directly through an outside wall to the outside or connected to a suitable chimney flue used for no other purpose. The connecting duct shall conform to the following:

(a) Connecting ducts shall be made of galvanized steel not less than 28 gauge [0.016 in. (0.406 mm)].

(b) A clearance of not less than 6 in. (152 mm) shall be provided between the exhaust duct and unprotected combustible material.

Exception: This clearance shall be permitted to be reduced where the combustible material is protected in accordance with Table 6-5.1.2.

7-7.3 Clothes Dryers.

7-7.3.1 All ducts expelling lint shall be provided with a lint collector.

Exception: Where the dryer is so equipped.

7-7.3.2 Requirements for Type 1 gas-fired clothes dryer exhaust shall be in accordance with NFPA 54, *National Fuel Gas Code*.

7-7.3.3 Type 2 clothes dryers shall be exhausted to the outside air.

7-7.3.4 Provision for makeup air shall be provided for Type 2 clothes dryers, with a minimum free area of 1 in.^{2} (645.2 mm^2) for each 1000 Btu/hr (1055 kJ/hr) total input rating of the dryer(s) installed.

7-7.3.5 A clothes dryer exhaust duct shall not be connected into any chimney connector, vent connector, chimney, or vent.

7-7.3.6 Ducts for exhausting clothes dryers shall not be put together with sheet-metal screws or other fastening means that extend into the duct, thereby catching lint and reducing the efficiency of the exhaust.

7-7.3.7 Exhaust ducts for Type 2 clothes dryers shall be constructed of sheet metal or other noncombustible material. Such ducts shall be of adequate strength to meet the conditions of service with a minimum thicknesses equivalent to No. 24 galvanized steel gauge [0.024 in. (0.61 mm)].

7-7.3.8 Exhaust ducts for Type 2 clothes dryers shall have a clearance of at least 6 in. (152 mm) to combustible material. If such a duct passes through a wall, floor, or partition constructed of combustible material, all such material in the wall, floor, or partition shall be cut away from the duct for a sufficient distance to provide a clearance of at least 6 in. (152 mm) and the opening shall be closed in accordance with 7-7.3.9.

Exception: Exhaust ducts for Type 2 clothes dryers shall be permitted to be installed with reduced clearances to combustible material, provided the combustible material is protected as described in Table 6-5.1.2.

7-7.3.9 Where ducts pass through walls, floors, or partitions, the space around the duct shall be sealed with noncombustible material.

7-7.3.10 Multiple installations of Type 1 and Type 2 clothes dryers shall be made in a manner to prevent adverse operation due to back pressures that might be created in the exhaust. Common exhaust vents that pass through floors of buildings requiring the protection of vertical openings shall be enclosed with approved walls having a fire resistance rating of not less than 1 hour where such chimneys are located in a building less than four stories in height, and not less than 2 hours where such chimneys are located in a building four or more stories in height.

7-7.4 Equipment with Integral Vents.

Gas utilization appliances incorporating integral venting means shall be considered properly vented where installed in accordance with the terms of their listing.

Chapter 8 Fireplaces

8-1 Factory-Built Fireplaces.

8-1.1

Factory-built fireplaces shall be listed and shall be installed in accordance with the terms of the listing. Hearth extensions shall be provided in accordance with the manufacturer's instructions or shall be of masonry on noncombustible construction in accordance with Section 8-3.

8-1.2

Factory-built fireplaces shall be secured to the floor or structural framing of the building in order to prevent shifting.

8-1.3

Decorative shrouds at the termination of a factory-built fireplace chimney shall not be permitted.

Exception: Decorative shrouds listed for use with the specific factory-built fireplace.

8-2 Masonry Fireplaces.

8-2.1 Construction.

8-2.1.1 Fireplaces shall be constructed of solid masonry units or of reinforced portland or refractory cement concrete. Masonry fireplaces shall be supported on properly designed foundations of masonry or reinforced portland or refractory cement concrete or on other noncombustible constructions having a fire resistance rating of not less than 3 hours, provided such supports are adequate for the load.

8-2.1.2 Where a lining of low-duty fireclay brick (ASTM C 27, *Standard Classification of Fireclay and High-Alumina Refractory Brick*), firebox brick (ASTM C 1261, *Standard Specification for Firebox Brick for Residential Fireplaces*), or the equivalent, at least 2 in. (51 mm) thick laid in medium-duty refractory mortar (ASTM C 199, *Standard Test Method for Pier Test for Refractory Mortars*), or the equivalent, or other approved lining is provided, the total thickness of back and sides, including the lining, shall be not less than 8 in. (203 mm).

8-2.1.3 Where the lining described in 8-2.1.2 is not provided, the thickness of back and sides shall be not less than 12 in. (305 mm).

8-2.1.4 Where the masonry supporting a fireplace is designed to support vertical loads from the building and corbels are used to support beams or girders, corbeling shall be as described in 4-1.2 for masonry chimneys. The lintel spanning the fireplace shall be designed and constructed to support safely the additional concentrated load transferred by the member.

8-2.1.5 Where a lining of low-duty fireclay brick (ASTM C 27, *Standard Classification of Fireclay and High-Alumina Refractory Brick*), firebox brick (ASTM C 1261, *Standard Specification for Firebox Brick for Residential Fireplaces*), or the equivalent, at least 2 in. (51 mm) thick laid in medium-duty refractory mortar (ASTM C 199, *Standard Test Method for Pier Test for Refractory Mortars*), or the equivalent, or other approved lining is provided, the total thickness of the smoke chamber walls, including the lining, shall be not less than 6 in. (152 mm).

Where unlined, the smoke chamber wall thickness shall be not less than 8 in. (203 mm).

The smoke chamber height shall not be greater than the inside width of the fireplace room opening. The smoke chamber depth shall not be greater than the depth of the fireplace fire chamber. (*See Figure 8-2.1.5.*)

The inner surfaces of the smoke chamber shall be smooth and not inclined more than 45 degrees from vertical.

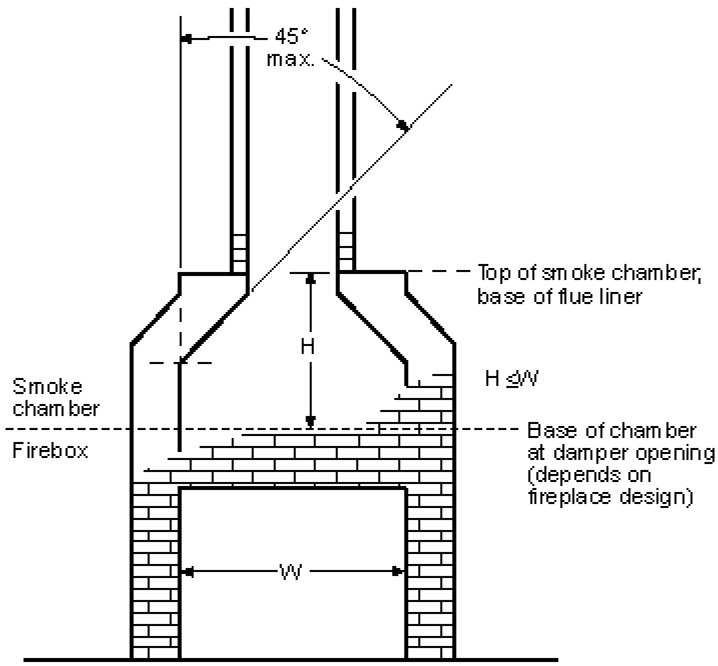


Figure 8-2.1.5 Sectional view of fireplace showing smoke chamber.

8-2.1.6 Masonry fireplaces shall be provided with chimneys designed and constructed in accordance with the requirements for construction of masonry chimneys (*see Section 4-2*), or, where permitted by the individual listing, approved factory-built chimneys having approved adapters in accordance with the requirements for factory-built chimneys (*see Chapter 2*).

8-2.2 Steel Fireplace Units.

8-2.2.1 Steel fireplace units incorporating a firebox liner of not less than $^1/_4$-in. (6.4-mm) thick steel and an air chamber shall be installed with masonry to provide a total thickness at the back and sides of not less than 8 in. (203 mm), not less than 4 in. (102 mm) of which shall be solid masonry.

Exception: Listed firebox liners shall be installed in accordance with the terms of the listing.

8-2.2.2 Warm-air ducts employed with steel fireplace units of the circulating air type shall be constructed of metal or masonry.

8-2.3 Clearance.

8-2.3.1 All wood beams, joists, studs, and other combus- tible material shall have a clearance of not less than 2 in. (51 mm) from the front faces and sides of masonry fireplaces and not less than

4 in. (102 mm) from the back faces of masonry fireplaces. (*See Figure 8-2.3.1.*)

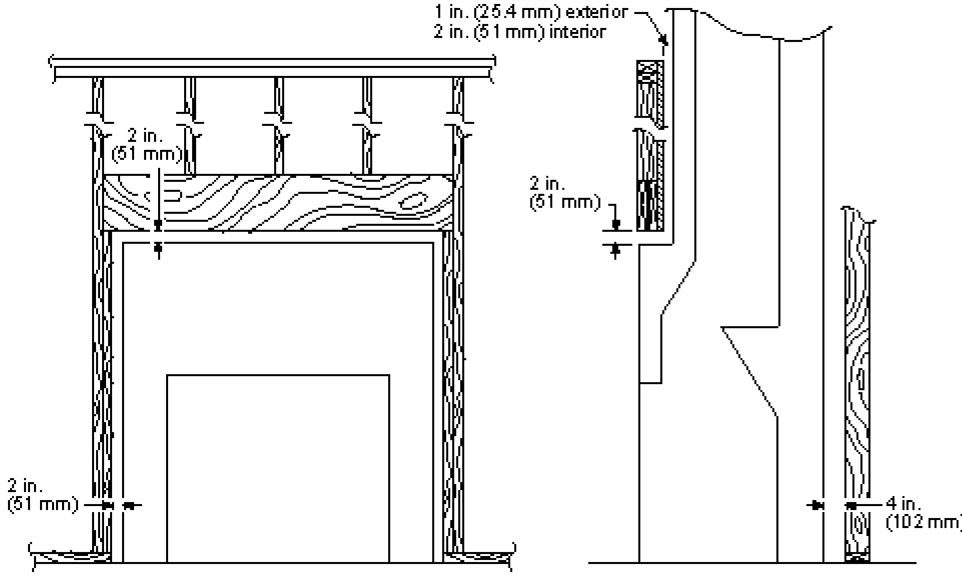


Figure 8-2.3.1 Fireplace clearance to combustible material.

8-2.3.2 Spaces between headers or trimmers of combustible material and masonry fireplaces shall be firestopped with noncombustible material. The material used for firestopping shall be galvanized steel not less than 26 gauge [0.19 in. (0.483 mm)] in thickness or noncombustible sheet material not more than $^1/_2$ in. (12.7 mm) thick.

8-2.3.3 Woodwork, such as wood trim, mantels, and other combustible material, shall not be placed within 6 in. (152 mm) of a fireplace opening. Combustible material above and projecting more than $1^1/_2$ in. (38 mm) from a fireplace opening shall not be placed less than 12 in. (305 mm) from the top of the fireplace opening. (*See Figure 8-2.3.3.*)

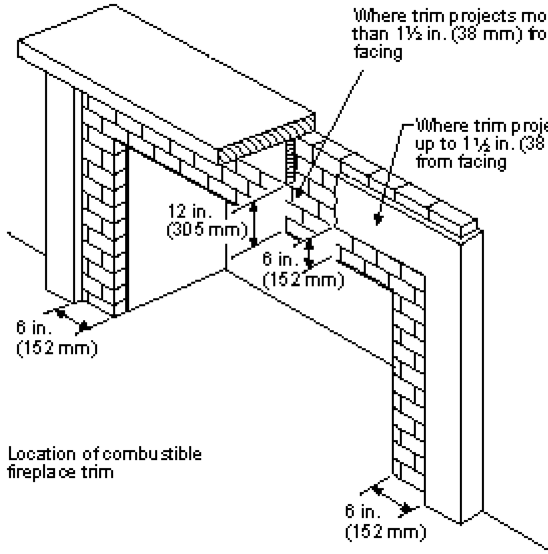


Figure 8-2.3.3 Fireplace clearance to combustible material.

8-2.4 Accessibility.

For cleaning purposes, means shall be provided for access to the venting area above and immediately behind any movable damper valve plate in masonry fireplaces and steel fireplace units.

8-3 Hearth Extensions.

8-3.1

Masonry fireplaces shall have hearth extensions of brick, concrete, stone, tile, or other approved noncombustible material properly supported and with no combustible material against the underside thereof. Wooden forms used during the construction of hearth and hearth extension shall be removed when the construction is completed.

8-3.2

Where the fireplace opening is less than 6 ft^2 (0.56 m^2), the hearth extension shall extend at least 16 in. (406 mm) in front of the facing material and at least 8 in. (203 mm) beyond each side of the fireplace opening. (*See Figure 8-3.2.*)

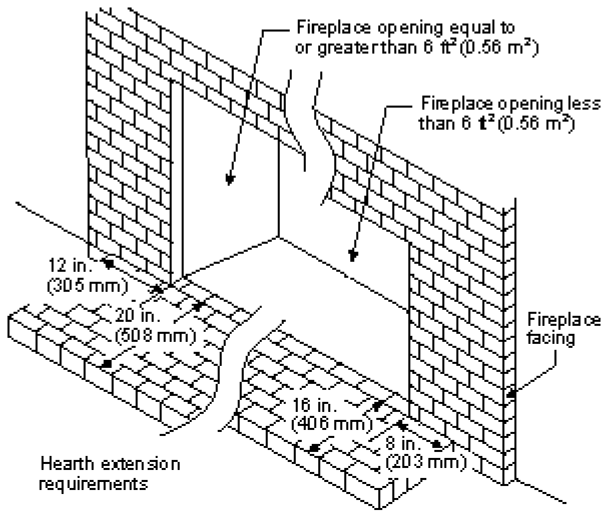


Figure 8-3.2 Fireplace hearth extension details.

8-3.3

Where the fireplace opening is 6 ft^2 (0.56 m^2) or larger, the hearth extension shall extend at least 20 in. (508 mm) in front of the facing material, and at least 12 in. (305 mm) beyond each side of the fireplace opening. (*See Figure 8-3.2.*)

8-3.4

Where a fireplace is elevated above or overhangs a floor, the hearth extension also shall extend over the area under the fireplace.

8-4 Accessories.

Factory-built accessories for fireplaces include such devices as fireplace heater inserts and heat exchangers circulating air or water that could alter the combustion or heating characteristics of the fireplace. Such accessories shall be listed and installed in accordance with the terms of their listing.

Exception: Unlisted accessories that are acceptable to the authority having jurisdiction shall be permitted to be installed as approved and in accordance with the manufacturer's installation instructions.

8-5 Combustion Air Ducts.

8-5.1

Where required by the authority having jurisdiction, combustion air ducts shall be installed in accordance with this section.

Exception No. 1: Combustion air ducts for factory-built fireplaces shall be a listed component of the fireplace and shall be installed according to the manufacturer's instructions.

Exception No. 2: Listed combustion air duct systems for masonry fireplaces shall be installed according to the terms of their listing and the manufacturer's instructions.

8-5.2

Combustion air ducts shall extend as directly as practicable from the outdoors (inlet) to a termination outside the fire chamber (outlet). Combustion air ducts shall be constructed of masonry, galvanized steel with a thickness not less than 26 gauge [0.019 in. (0.483 mm)], or other approved noncombustible material and shall be equipped with a damper that is capable of being fully closed.

8-5.3

Combustion air ducts that terminate outside the fire chamber but within 6 in. (152 mm) of the fire chamber shall be designed and installed to prevent the direct entry of flame, embers, or ashes from the fire chamber into the duct.

8-5.4

Unlisted combustion air ducts shall be installed with a minimum 1-in. (25.4-mm) clearance to combustibles for all parts of the duct construction within 5 ft (1.5 m) of the duct outlet.

8-5.5

The exterior inlet of the combustion air duct shall be screened.

8-5.6

Combustion air ducts shall not originate in an attic, basement, garage, or other interior space.

Chapter 9 Solid Fuel-Burning Appliances

9-1 Appliances.

Solid fuel-burning appliances shall be listed and installed in accordance with the terms of their listing.

Exception: Unlisted appliances approved by the authority having jurisdiction shall be installed as specified in this chapter. Such installations also shall be in accordance with the manufacturer's installation instructions if such instructions specify the use of increased protection or greater clearances than specified in this chapter. This exception shall not apply to mobile home installations.

9-2 Location of Appliances.

9-2.1

Every appliance shall be located with respect to building construction and other equipment to allow access to the appliance. Sufficient clearance shall be maintained to allow cleaning of surfaces; the replacement of air filters, blowers, motors, controls, and chimney connectors; the lubrication and servicing of moving parts; and the adjustment and servicing of stokers, if provided.

9-2.2

Solid fuel-burning appliances shall not be installed in confined spaces. The space or room shall be of ample size to allow adequate circulation of heated air. Appliances shall be so located as not to interfere with the proper circulation of air within the heated space.

Exception: Solid fuel-burning appliances listed for installation in confined spaces such as alcoves shall be installed in accordance with the terms of the listing and the manufacturer's *instructions.*

9-2.3

Solid fuel-burning appliances shall not be installed in any location where gasoline or any other flammable vapors or gases are likely to be present.

9-2.4

Solid fuel-burning appliances shall not be installed in any residential garage.

9-3 Air for Combustion and Ventilation.

Solid fuel-burning appliances shall be installed in a location and manner to provide adequate ventilation and combustion air supply to allow satisfactory combustion of fuel, proper chimney draft, and maintenance of safe temperatures. Where buildings are so tight that normal infiltration does not provide the necessary air, outside air shall be introduced.

9-4 Chimney Connections and Usage.

9-4.1

All solid fuel-burning appliances shall be connected to chimneys in accordance with Chapter 6. The chimney provided shall be in accordance with Table 2-2.1.

9-4.2

The clearance of chimney connectors to combustible material shall be as specified in Table 6-5.1.1.

9-4.3

Connectors and chimneys for solid fuel-burning appliances shall be designed, located, and installed to allow ready access for internal inspection and cleaning.

9-4.4

For residential-type solid fuel-burning appliances, the cross-sectional area of the flue shall not be less than the cross-sectional area of the appliance flue collar. The cross-sectional area of the flue shall not be more than three times the cross-sectional area of the appliance flue collar.

9-4.5 Connection to Masonry Fireplaces.

A solid fuel-burning appliance such as a stove or insert shall be permitted to use a masonry fireplace flue where the following conditions are met:

Exception: Listed fireplace accessories shall be permitted to use a masonry fireplace flue.

(a) There is a connector that extends from the appliance to the flue liner.

(b) The cross-sectional area of the flue is no more than three times the cross-sectional area of the flue collar of the appliance.

(c) If the appliance vents directly through the chimney wall above the smoke chamber, there shall be a noncombustible seal below the entry point of the connector.

(d) The installation shall be such that the chimney system can be inspected and cleaned.

(e) Means shall be provided to prevent dilution of combustion products in the chimney flue with air from the habitable space.

9-4.6

Another solid fuel-burning appliance shall not be installed using an existing flue serving a factory-built fireplace unless the appliance is specifically listed for such installation.

9-5 Mounting.

9-5.1 Mounting for Residential-Type Appliances.

9-5.1.1 General Requirements.

9-5.1.1.1 Residential-type solid fuel-burning appliances that are tested and listed by a recognized testing laboratory for installation on floors constructed of combustible materials shall be placed on floors in accordance with the requirements of the listing and the conditions of approval. Such appliances that are not listed by a recognized testing laboratory shall be provided with floor protection in accordance with the provisions of 9-5.1.2 or 9-5.1.3.

Exception: Residential-type solid fuel-burning appliances shall be permitted to be placed without floor protection in any of the following manners:

(a) On concrete bases adequately supported on compacted soil, crushed rock, or gravel;

(b) On concrete slabs or masonry arches that do not have combustible materials attached to the underside;

(c) On approved assemblies constructed of only noncombustible materials and having a fire resistance rating of not less than 2 hours, with floors constructed of noncombustible material;

(d) On properly stabilized ground that can support the load of the appliance.

9-5.1.1.2 Any floor assembly, slab, or arch shall extend not less than 18 in. (457 mm) beyond the appliance on all sides.

9-5.1.1.3 In lieu of the requirements for floor protection specified herein, a floor protector listed by a recognized testing laboratory and installed in accordance with the installation instructions shall be permitted to be employed.

9-5.1.1.4 Concrete bases, concrete slabs, masonry arches, and floor-ceiling assemblies and their supports shall be designed and constructed to support the appliances.

9-5.1.2 Room Heaters, Fireplace Stoves, Room Heater/Fireplace Combinations, and Ranges.

9-5.1.2.1 Room heaters, fireplace stoves, room heater/fireplace stove combinations, or ranges that are set on legs or pedestals that provide not less than 6 in. (152 mm) of ventilated open space beneath the fire chamber or base of the appliance shall be permitted to be placed on floors of combustible construction, provided the floor under the appliance is protected with closely spaced solid masonry units not less than 2 in. (51 mm) in thickness. The top surface of the masonry shall be covered with sheet metal not less than 24 gauge [0.024 in. (0.61 mm)]. The floor protection shall extend not less than 18 in. (457 mm) beyond the appliance on all sides.

9-5.1.2.2 Room heaters, fireplace stoves, room heater/fireplace stove combinations, or ranges that are set on legs or pedestals providing 2 in. to 6 in. (51 mm to 152 mm) of ventilated open space beneath the fire chamber or base of the appliance shall be permitted to be placed on floors of combustible construction, provided the floor under the appliance is protected with one course of hollow masonry units not less than 4 in. (102 mm) in thickness. The masonry units shall be laid with ends unsealed and joints matched in such a way as to provide a free circulation of air through the core spaces of the masonry. The top surface of the masonry shall be covered with sheet metal not less than 24 gauge [0.024 in. (0.61 mm)]. The floor protection shall extend not less than 18 in. (457 mm) beyond the appliance on all sides.

9-5.1.2.3 Room heaters, fireplace stoves, room heater/fireplace stove combinations, or ranges with legs or pedestals that provide less than 2 in. (51 mm) of ventilated open space beneath the fire chamber or base of the appliance shall not be placed on floors of combustible construction.

9-5.1.3 Furnaces and Boilers.

9-5.1.3.1 Furnaces or boilers with legs or pedestals that provide not less than 6 in. (152 mm) of ventilated open space beneath the fire chamber or base of the appliance shall be permitted to be placed on floors of combustible construction, provided the floor under the appliance is protected with one course of hollow masonry units not less than 4 in. (102 mm) in thickness. The masonry units shall be laid with ends unsealed and joints matched in such a way as to provide a free circulation of air through the core spaces of the masonry. The top surface of the masonry shall be covered with a steel plate not less than $^3/_{16}$ in. (4.8 mm) in thickness. The floor protection shall extend not less than 18 in. (457 mm) beyond the appliance on all sides.

9-5.1.3.2 Furnaces or boilers that are set on legs or pedestals that provide 2 in. to 6 in. (51 mm to 152 mm) of ventilated open space beneath the fire chamber or base of the appliance shall be permitted to be placed on floors of combustible construction, provided the floor under the appliance is protected with two courses of hollow masonry units each not less than 4 in. (102 mm) in thickness. The masonry units shall be laid with ends unsealed and joints matched in such a way as to provide a free circulation of air through the core spaces of the masonry. The top surface of the masonry shall be covered with a steel plate not less than $^3/_{16}$ in. (4.8 mm) in thickness. The floor protection shall extend not less than 18 in. (457 mm) beyond the appliance on all sides.

9-5.1.3.3 Furnaces or boilers with legs or pedestals that provide less than 2 in. (51 mm) of ventilated open space beneath the fire chamber or base of the appliance shall not be placed on floors of combustible construction.

9-5.2 Mounting for Low-Heat Nonresidential Appliances.

9-5.2.1 Low-heat nonresidential solid fuel-burning appliances that have been tested and listed by a recognized testing laboratory for placement on floors constructed with a combustible material shall be placed on floors in accordance with the requirements of the listing and conditions of approval. Such appliances that are not listed by a recognized testing laboratory shall be provided with floor protection in accordance with the provisions of 9-5.2.3 or 9-5.2.4.

Exception: Low-heat nonresidential solid fuel-burning appliances shall be permitted to be placed without floor protection in any of the following manners:

(a) On floors constructed of noncombustible materials and having a fire resistance rating of not less than 2 hours; this construction shall extend not less than 18 in. (457 mm) beyond the appliance on all sides;

(b) On concrete bases adequately supported on compacted soil, crushed rock, or gravel;

(c) On properly stabilized ground that can support the load of the appliance.

9-5.2.2 Concrete bases, concrete slabs, and floors shall be designed and constructed to support the appliances.

9-5.2.3 Low-heat nonresidential solid fuel-burning appliances that are set on legs or pedestals that provide not less than 18 in. (457 mm) of ventilated open space beneath the fire chamber or base of the appliance shall be permitted to be placed on floors of combustible construction, provided the floor under the appliance is protected with one course of hollow masonry units not less than 4 in. (102 mm) in thickness. The masonry units shall be laid with ends unsealed and joints matched in such a way as to provide free circulation of air through the core spaces of the masonry. The top surface of the masonry shall be covered with a steel plate not less than $^3/_{16}$ in. (4.8 mm) in thickness. The floor protection shall extend not less than 18 in. (457 mm) beyond the appliance on all sides.

9-5.2.4 Low-heat nonresidential solid fuel-burning appliances that are set on legs or pedestals that provide 6 in. to 18 in. (152 mm to 457 mm) of ventilated open space beneath the fire chamber or base of the appliance shall be permitted to be placed on floors of combustible construction, provided the floor under the appliance is protected with two courses of hollow masonry units, each not less than 4 in. (102 mm) in thickness. The masonry units shall be laid with ends unsealed and joints matched in such a way as to provide a free circulation of air through the core spaces of the masonry. The top surface of the masonry shall be covered with a steel plate not less than $^3/_{16}$ in. (4.8 mm) in thickness. The floor protection shall extend not less than 18 in. (457 mm) beyond the appliance on all sides.

9-5.2.5 Low-heat nonresidential solid fuel-burning appliances with legs or pedestals that provide less than 6 in. (152 mm) of ventilated open space beneath the fire chamber or base of the appliance shall not be placed on floors of combustible construction.

9-5.3 Mounting for Medium-Heat Nonresidential Appliances.

9-5.3.1 Medium-heat nonresidential solid fuel-burning appliances that have been tested and listed by a recognized testing laboratory for placement on floors constructed with a combustible material shall be placed on floors in accordance with the requirements of the listing and conditions of approval. Such appliances that are not listed by a recognized testing laboratory shall be provided with floor protection in accordance with the provisions of 9-5.3.3 or 9-5.3.4.

Exception: Medium-heat nonresidential solid fuel-burning appliances shall be permitted to be placed without floor protection in any of the following manners:

(a) On concrete bases adequately supported on compacted soil, crushed rock, or gravel;

(b) On floors constructed of noncombustible materials and having a fire resistance rating of not less than 2 hours; this construction shall extend not less than 3 ft (0.92 m) beyond the appliance on all sides and 8 ft (2.45 m) beyond the front or side where ashes are removed;

(c) On properly stabilized ground that can support the load of the appliance.

9-5.3.2 Concrete bases, concrete slabs, and floors shall be designed and constructed to support the appliances.

9-5.3.3 Medium-heat nonresidential solid fuel-burning appliances that are set on legs or pedestals that provide not less than 24 in. (610 mm) of ventilated open space beneath the fire chamber or base of the appliance shall be permitted to be placed on floors of combustible construction, provided the floor under the appliance is protected with one course of hollow masonry units not less than 4 in. (102 mm) in thickness. The masonry units shall be laid with ends unsealed and joints matched in such a way as to provide a free circulation of air through the core spaces of the masonry. The top surface of the masonry shall be covered with a steel plate not less than $^{3}/_{16}$ in. (4.8 mm) in thickness. The floor protection shall extend not less than 3 ft (0.92 m) beyond the appliance on all sides and 8 ft (2.45 m) beyond the front or side where ashes are removed.

9-5.3.4 Medium-heat nonresidential solid fuel-burning appliances that are set on legs or pedestals that provide 18 in. to 24 in. (457 mm to 610 mm) of ventilated open space beneath the fire chamber or base of the appliance shall be permitted to be placed on floors of combustible construction, provided the floor under the appliance is protected with two courses of hollow masonry units, each not less than 4 in. (102 mm) in thickness. The masonry units shall be laid with ends unsealed and joints matched in such a way as to provide a free circulation of air through the core spaces of the masonry. The top surface of the masonry shall be covered with a steel plate not less than $^{3}/_{16}$ in. (4.8 mm) in thickness. The floor protection shall extend not less than 3 ft (0.92 m) beyond the appliance on all sides and 8 ft (2.45 m) beyond the front or side where ashes are removed.

9-5.3.5 Medium-heat nonresidential solid fuel-burning appliances with legs or pedestals that provide less than 18 in. (457 mm) of ventilated open space beneath the fire chamber or base of the appliance shall not be placed on floors of combustible construction.

9-5.4 Mounting of High-Heat Nonresidential Appliances.

9-5.4.1 High-heat nonresidential solid fuel-burning appliances shall be placed in one of the following manners:

(a) On concrete bases adequately supported on compacted soil, crushed rock, or gravel;

(b) On floors constructed of noncombustible materials and having a fire resistance rating of not less than 2 hours; this construction shall extend not less than 10 ft (3.1 m) beyond the appliance on all sides and not less than 30 ft (9.2 m) beyond the front or side where hot products are removed;

(c) On properly stabilized ground that can support the load of the appliance.

9-5.4.2 Concrete bases and floors shall be designed and constructed to support the appliances.

9-5.4.3 High-heat nonresidential solid fuel-burning appliances shall not be placed on floors of combustible construction.

9-6 Clearances from Solid Fuel-Burning Appliances.

9-6.1

Solid fuel-burning appliances shall be installed so that their use cannot create a hazard to persons or property. The clearance shall be not less than specified in Table 9-6.1.

Exception No. 1: Appliances listed for installation with clearances less than specified in Table 9-6.1 shall be permitted to be installed in accordance with the terms of their listing and the manufacturer's instructions.

Exception No. 2: Heating furnaces and boilers and water heaters specifically listed for *installation in spaces such as alcoves shall be permitted to be so installed in accordance with the terms of their listing, provided the specified clearance is maintained regardless of whether the enclosure is of combustible or noncombustible material.*

For reduced clearances, see Table 9-6.2.1. These clearances apply to appliances installed in rooms that are large in comparison with the size of the appliances.

Table 9-6.1 Standard Clearances for Solid Fuel-Burning Appliances

	Above Top of Casing or Appliance Above Top and Sides of Furnace Plenum or Bonnet		From Front		From Back[3]		From Side	
Kind of Appliance	**(in.)**	**(mm)**	**(in.)**	**(mm)**	**(in.)**	**(mm)**	**(in.)**	**(m**
Residential Appliances	6	152	48	1219	6[2]	152[2]	6[2]	15
Steam boilers — 15 psi (103 kPa)								
Water boilers — 250°F (121°C) max.								
Water boilers — 200°F (93°C) max.								
All water walled or jacketed								
Furnaces								
Gravity and forced air[4]	18	457	48	1219	18	457	18	45
Room Heaters, Fireplace Stoves, Combinations	36	914	36	914	36	914	36	91
					Firing Side		**Opposite Si**	
Ranges								
Lined fire chamber	30[1]	762[1]	36	914	24	610	18	45
Unlined fire chamber	30[1]	762[1]	36	914	36	914	18	45

[1]To combustible material or metal cabinets. If the underside of such combustible material or metal cabinet is protected with sheet metal of not less then 24 gauge [0.024 in. (0.61 mm)], spaced out 1 in. (25.4 mm), the distance shall be permitted to be reduced to not less than 24 in. (610 mm).

[2]Adequate clearance for cleaning and maintenance shall be provided.

[3]Provisions for fuel storage shall be located at least 36 in. (914 mm) from any side of the appliance.

[4]For clearances from air ducts, see NFPA 90B, *Standard for the Installation of Warm Air Heating and Air Conditioning Systems*.

9-6.2 Clearance Reduction.

9-6.2.1 Clearances from listed and unlisted solid fuel-burning appliances to combustible material shall be permitted to be reduced if the combustible material is protected as described in Table 9-6.2.1 and in Figures 9-6.2.1(a) through (d).

After reduction, clearance shall be not less than 12 in. (305 mm) to combustible walls and not less than 18 in. (457 mm) to combustible ceilings.

Exception: Appliances listed for installation with a clearance of less than 12 in. (305 mm) to a combustible wall or less than 18 in. (457 mm) to a combustible ceiling shall be installed in accordance with the terms of their listing and the manufacturer's instructions.

Table 9-6.2.1 Reduction of Appliance Clearance with Specified Forms of Protection[1-10]

	Maximum Allowable Reduction in Clearance (%)		Where the required clearance with no protecti is 36 in. (914 mm), the clearances below are t minimum allowable clearances. For other required clearances with no protection, calcul minimum allowable clearance from maximu allowable reduction.[9,10]			
Clearance Reduction System Applied to and Covering All Combustible Surfaces within the Distance Specified as Required	**As Wall Protector**	**As Ceiling Protector**	**As Wall Protector**		**As Ceiling Protector**	
Clearance with No Protection (*See 9-6.1.*)	**(%)**	**(%)**	**(in.)**	**(mm)**	**(in.)**	**(mm)**
(a) 31/2-in. (90-mm) thick masonry wall without ventilated air space	33		24	610		
(b) 1/2-in. (13-mm) thick noncombustible insulation board over 1-in. (25.4 mm) glass fiber or mineral wool batts without ventilated air space	50	33	18	457	24	610
(c) 0.024-in. (0.61-mm), 24-gauge sheet metal over 1-in. (25.4-mm) glass fiber or mineral wool batts reinforced with wire, or equivalent, on rear face with ventilated air space	66	50	12	305	18	457
(d) 31/2-in. (90-mm) thick masonry wall with ventilated air space	66		12	305		
(e) 0.024-in. (0.61-mm), 24-gauge sheet metal with ventilated air space	66	50	12	305	18	457
(f) 1/2-in. (13-mm) thick noncombustible insulation board with ventilated air space	66	50	12	305	18	457
(g) 0.024-in. (0.61-mm), 24-gauge sheet metal with ventilated air space over 0.024-in. (0.61-mm), 24-gauge	66	50	12	305	18	457

sheet metal with ventilated air space						
(h) 1-in. (25.4- mm) glass fiber or mineral wool batts sandwiched between two sheets 0.024-in. (0.61-mm), 24-gauge sheet metal with ventilated air space	66	50	12	305	18	457

[1]Spacers and ties shall be of noncombustible material. No spacers or ties shall be used directly behind appliance or conductor.

[2]With all clearance reduction systems using a ventilated air space, adequate air circulation shall be provided as described in 9-6.2.4. There shall be at least 1 in. (25.4 mm) between the clearance reduction system and combustible walls and ceilings for clearance reduction systems using a ventilated air space.

[3]Mineral wool batts (blanket or board) shall have a minmum density of 8 lb/ft^3 (128.7 kg/m^3) and have a minimum melting point of 1500°F (816°C).

[4]Insulation material used as part of clearance reduction system shall have a thermal conductivity of 1.0 (Btu-in.)/(ft^2-hr-°F) or less. Insulation board shall be formed of noncombustible material.

[5]If a single-wall connector passes through a masonry wall used as a wall shield, there shall be at least 1/2 in. (13 mm) of open, ventilated air space between the connector and the masonry.

[6]There shall be at least 1 in. (25.4 mm) between the appliance and the protector. In no case shall the clearance between the appliance and the wall surface be reduced below that allowed in the table.

[7]Clearances in front of the loading door or ash removal door, or both, of the appliance shall not be reduced from those in Section 9-5.

[8]All clearances and thicknesses are minimums; larger clearances and thicknesses shall be permitted.

[9]To calculate the minimum allowable clearance, the following formula can be used: $C_{pr} = C_{un} \times (1 - R/100)$.

C_{pr} is the minimum allowable clearance, C_{un} is the required clearance with no protection, and R is the maximum allowable reduction in clearance.

[10]Refer to Figures 9-6.2.1(e) and 9-6.2.1(f) for other reduced clearances using materials found in (a) through (h) of this table.

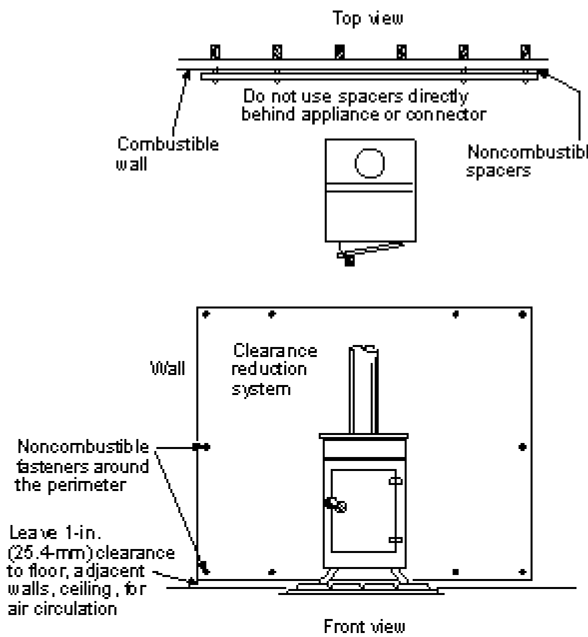


Figure 9-6.2.1(a) Clearance reduction system — fastener location.

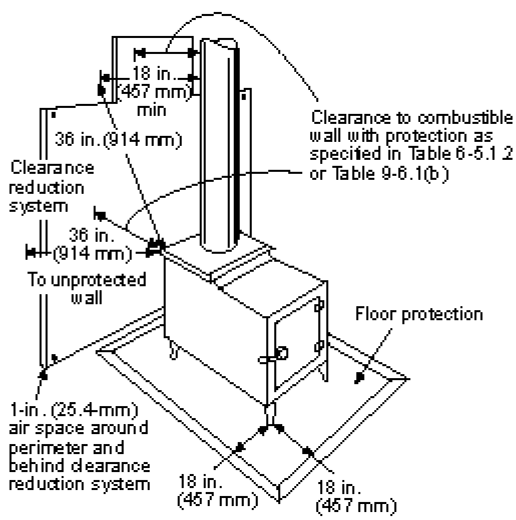


Figure 9-6.2.1(b) Distance to combustible wall/floor.

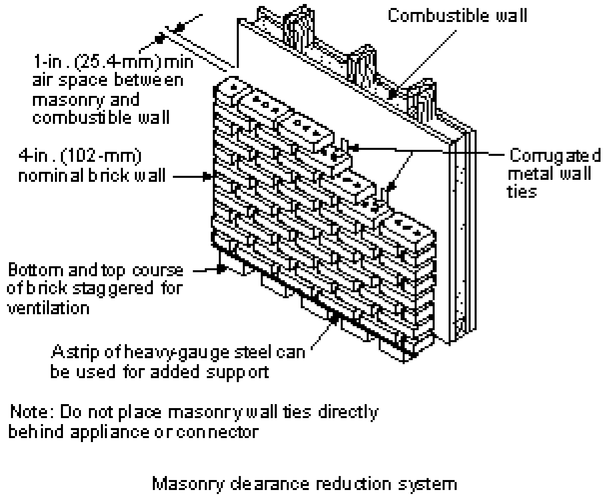


Figure 9-6.2.1(c) Masonry clearance reduction system.

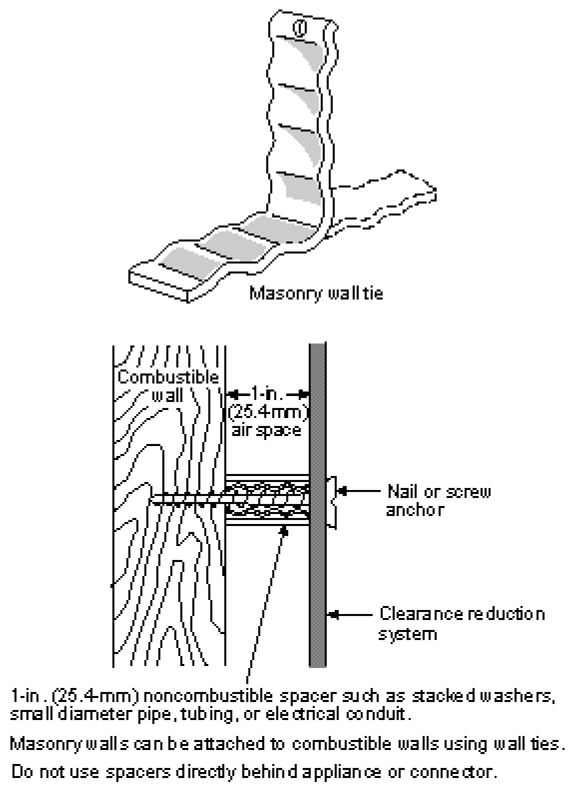


Figure 9-6.2.1(d) Fastener detail.

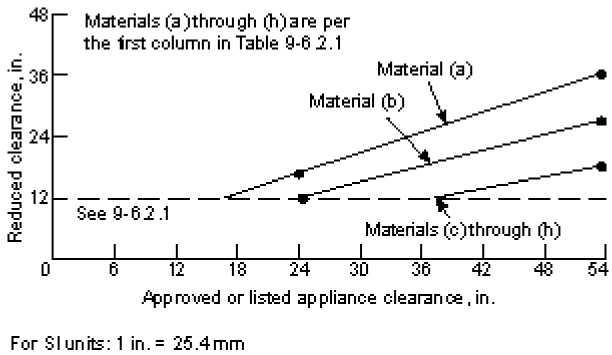


Figure 9-6.2.1(e) Wall protection using materials in Table 9-6.2.1.

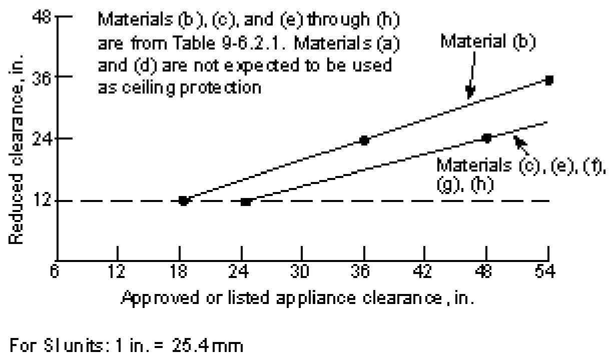


Figure 9-6.2.1(f) Ceiling protection using materials in Table 9-6.2.1.

9-6.2.2 Clearances from solid fuel-burning appliances to combustible material shall be permitted to be reduced, provided the combustible material is protected by an engineered protection system acceptable to the authority having jurisdiction. Engineered systems installed for the protection of combustible material shall reduce the temperature of such materials to 90°F (50°C) rise above ambient. System design shall be based upon applicable heat transfer principles, taking into account the geometry of the system, the heat loss characteristics of the structure behind the combustible material, and the possible abnormal operating conditions of the heat-producing sources.

9-6.2.3 Clearances from solid fuel-burning appliances to combustible material shall be permitted to be reduced by the use of materials or products listed for protection purposes. Materials and products listed for the purpose of reducing clearance to combustibles shall be installed in accordance with the conditions of the listing and the manufacturer's instructions.

9-6.2.4 For clearance reduction systems using an air space between the combustible wall and the wall protector, adequate air circulation shall be provided by one of the following methods as shown in Figure 9-6.2.4.

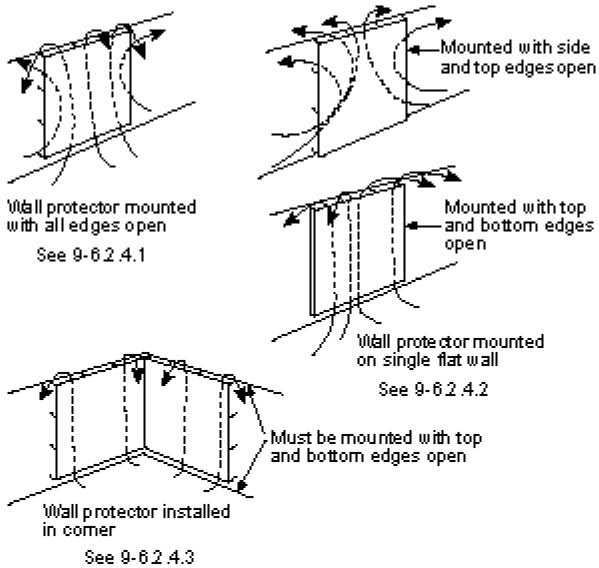


Figure 9-6.2.4 Air circulation methods.

9-6.2.4.1 Adequate air circulation shall be permitted to be provided by leaving all edges of the wall protector open with at least a 1-in. (25.4-mm) air gap.

9-6.2.4.2 If the wall protector is mounted on a single flat wall away from corners, adequate air circulation shall be permitted to be provided by leaving only the bottom and top edges or only the side and top edges open with at least a 1-in. (25.4-mm) air gap.

9-6.2.4.3 Wall protectors that cover two walls in a corner shall be open at the bottom and top edges with at least a 1-in. (25.4-mm) air gap.

9-6.2.5 All clearances shall be measured from the outer surface of the combustible material to the nearest point on the surface of the solid fuel-burning appliance, disregarding any intervening protection applied to the combustible material.

9-6.2.6 All clearances provided between solid fuel-burning appliances and combustible materials shall be large enough to maintain sufficient clearances between chimney connectors and combustible material as required in Section 6-5.

9-7 Accessories.

Factory-built accessories for solid fuel-burning appliances such as heat exchangers, stove mats, floor pads, and protection shields shall be listed and shall be installed in accordance with the terms of their listing.

Exception: Unlisted accessories that are acceptable to the authority having jurisdiction shall be permitted to be installed in accordance with the approval of the authority having jurisdiction and the appliance and accessory manufacturers' installation instructions.

Chapter 10 Maintenance

10-1 Initial Installation.

Initial installation of chimneys, fireplaces, and vents shall allow inspection of the surroundings to determine that the required clearances have been maintained and that correct provisions for support, stabilization, future inspection, and maintenance are in place.

10-2 Inspection — Chimneys.

Chimneys, fireplaces, and vents shall be inspected at least once a year for soundness, freedom from deposits, and correct clearances. Cleaning, maintenance, and repairs shall be done if necessary.

Exception: Type B and Type BW gas and special venting systems.

10-3 Inspection — Connections.

Connectors, spark arresters, cleanouts, and tee fittings for chimneys and for oil and pellet venting systems shall be inspected at least once a year for soundness and freedom from deposits.

Exception: Connectors for Type B gas venting systems.

10-4 Appliance Replacement.

Before replacing an existing appliance or connecting a vent connector to a chimney, the chimney passageway shall be cleaned, lined, or repaired as necessary.

10-5 Cleanout Doors.

After any inspection or maintenance operation, cleanout doors and caps or plugs for cleanout tee fittings shall be closed tightly or secured in place.

10-6 Cleaning Methods.

Cleaning of chimneys, if necessary, shall be done by methods that do not impair structural or thermal performance.

10-7 Evidence of Damage.

Chimneys, vents, and fireplaces shall be inspected, cleaned, and repaired if there is any evidence of damage to the chimney, fireplace, or vent or to the surroundings.

10-8 Operating Malfunction.

When inspection or an operating malfunction shows that an existing chimney, fireplace, or vent is damaged, unsuitable, or improperly sized, it shall be repaired, rebuilt, or resized to the construction and functional requirements of this standard.

10-9* Damaged or Deteriorated Liners.

If the flue liner in a chimney has softened, cracked, or otherwise deteriorated so that it no longer has the continued ability to contain the products of combustion (i.e., heat, moisture, creosote, and flue gases), it shall be either removed and replaced, repaired, or relined with a listed liner system or other approved material that will resist corrosion, softening, or cracking from flue gases at temperatures appropriate to the class of chimney service. (*See Table 2-2.1*.)

Chapter 11 Referenced Publications

11-1

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.

11-1.1 NFPA Publications.

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

NFPA 54, *National Fuel Gas Code*, 1996 edition.

NFPA 82, *Standard on Incinerators and Waste and Linen Handling Systems and Equipment,* 1994 edition.

NFPA 96, *Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations*, 1994 edition.

NFPA 97, *Standard Glossary of Terms Relating to Chimneys, Vents, and Heat-Producing Appliances*, 1996 edition.

NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, 1996 edition.

11-1.2 Other Publications.

11-1.2.1 ASHRAE Publication. American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., 1791 Tullie Circle, NE, Atlanta, GA 30329.

ASHRAE Handbook, HVAC Systems and Equipment, 1992.

11-1.2.2 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM C 27, *Standard Classification of Fireclay and High-Alumina Refractory Brick*, 1993.

ASTM C 199, *Standard Test Method for Pier Test for Refractory Mortars*, 1994.

ASTM C 315, *Standard Specification for Clay Flue Linings*, 1991.

ASTM C 1261, *Standard Specification for Firebox Brick for Residential Fireplaces*, 1994.

ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, 1995.

ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750 Degrees C*, 1994.

11-1.2.3 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 103, *Standard for Safety Chimneys, Factory-Built, Residential Type and Building Heating Appliance*, 1994.

UL 127, *Standard for Safety Factory-Built Fireplaces*, 1988.

UL 723, *Standard for Safety Test for Surface Burning Characteristics of Building Materials*, 1993.

UL 737, *Standard for Safety Fireplace Stoves*, 1995.

UL *Building Materials Directory*, 1995.

11-1.2.4 ULC Publication. Underwriters Laboratories of Canada, 7 Crouse Road, Scarborough, Ontario M1R 3A9 Canada.

CAN/ULC-S629-M87, *Standard for 650°C Factory-Built Chimney Systems for Solid Fuel-Burning Appliances*, 1987.

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-1-5.2 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-1-5.2 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-1-5.2 Engineered Venting or Chimney System. Approved engineering methods can include the following:

(a) The vent capacity tables in NFPA 54, *National Fuel Gas Code;*

(b) The fuel-burning equipment manufacturers' venting instructions;

(c) Drawings, calculations, and specifications provided by the venting equipment manufacturer or by a professional engineer;

(d) Use of calculations from the *ASHRAE Handbook*, *HVAC Systems and Equipment*, Chapter 31;

(e) Application of the VENT II (version 4.1 or more current) computer program, developed under Gas Research Institute sponsorship for vent design and analysis.

A-1-5.2 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-6-3.1 A list of engineering methods referred to in the exceptions can be found in A-1-5.2, "Engineered Venting."

A-6-11 For information concerning the use and installation of draft regulators with oil-burning appliances, see NFPA 31, *Standard for the Installation of Oil-Burning Equipment*.

A-7.6 Additional requirements for the installation of venting systems serving gas appliances appear in NFPA 54, *National Fuel Gas Code*.

A-7-7.2.1 For information on ventilation of restaurant cooking equipment, see NFPA 96, *Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations*.

A-10-9 Deterioration of the interior surface of a liner that results in softening or corrosion of liner materials (e.g., powdering or crumbling of liner materials or attack on metal surfaces resulting in perforation) is indicative of an inability of the liner to continue to perform its intended function.

Damage to liners from either structural or thermal causes that results in cracks that would allow moisture to penetrate the liner or would preclude the liner from containing flames or the products of combustion, or both, is indicative of an inability of the liner to continue to perform its intended function.

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 31, *Standard for the Installation of Oil-Burning Equipment*, 1992 edition.

NFPA 54, *National Fuel Gas Code*, 1996 edition.

NFPA 82, *Standard on Incinerators and Waste and Linen Handling Systems and Equipment*, 1994 edition.

NFPA 90B, *Standard for the Installation of Warm Air Heating and Air Conditioning Systems*, 1996 edition.

NFPA 96, *Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations*, 1994 edition.

B-1.2 Other Publications.

B-1.2.1 ASHRAE Publication. American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., 1791 Tullie Circle, NE, Atlanta, GA 30329.

ASHRAE Handbook, HVAC Systems and Equipment, 1992.

B-1.2.2 ASTM Publication. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM C 1283, *Standard Practice for Installing Clay Flue Lining*, 1994.

Formal Interpretation

NFPA 211

Chimneys, Fireplaces, Vents, and Solid Fuel Burning Appliances

1996 Edition

Reference : 9-4.6
F.I. 84-1

Question: Is it the intention of 9-4.6 that another solid fuel burning appliance, such as a fireplace insert or heat exchanger, installed using an existing flue serving a factory-built fireplace be listed for use with a specific model factory-built fireplace?

Answer: Yes.

Issue Edition: 1984
Reference: 8-5.5
Date: September 1984

NFPA 214

1996 Edition

Standard on Water-Cooling Towers

1996 Edition

This edition of NFPA 214, *Standard on Water Cooling Towers*, was prepared by the Technical Committee on Water-Cooling Towers 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 214 was approved as an American National Standard on July 26, 1996.

Origin and Development of NFPA 214

The subject of the protection of water-cooling towers was first considered by the NFPA Committee on Building Construction in 1957, and a progress report on that subject was published in the Advance Reports of that year. In 1958, a new Committee on Water-Cooling Towers was appointed and a Tentative Standard on Fire Protection of Water-Cooling Towers proposed by the Committee was adopted by the Association in that year. Final adoption was secured in 1959. Revised editions were published in 1961, 1966, 1968, 1971, 1976, 1977, 1983, and 1988. The 1992 edition incorporates a variety of technical and editorial revisions. The 1996 edition of the standard reinforces a performance-based approach to fire protection for water-cooling towers. The scope was also changed to include protection of field-erected, water-cooling towers.

Technical Committee on Water-Cooling Towers

Steven F. Vieira, Grinnel Corp., RI

Alternates

Kenneth E. Isman, Nat'l Fire Sprinkler Assn., NY
(Alt. to D. Dixon)

Robert J. Smith, Jr., M&M Protection Consultants, IL
(Alt. to J. M. Connolly)

Terry L. Victor, Grinnell Fire Protection Systems, Co., MD
(Alt. to S. F. Vieira)

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 the design, construction, protection, and maintenance of water-cooling towers.

NFPA 214
Standard on
Water-Cooling Towers

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 C.

Foreword

The fire record of water-cooling towers indicates the failure to recognize the extent or seriousness of the potential fire hazard of these structures both while in operation or when temporarily shut down. Cooling towers of combustible construction, especially those of the induced draft type, present a potential fire hazard even when in full operation because of the existence of relatively dry areas within the towers.

A significant percentage of fires in water-cooling towers of combustible construction are caused by ignition from outside sources such as incinerators, smokestacks, or exposure fires. Fires in cooling towers may create an exposure hazard to adjacent buildings and processing units. Therefore, distance separation from buildings and sources of ignition or the use of noncombustible construction are primary considerations in preventing these fires.

Ignition within these structures can be caused by welding or cutting operations, smoking, overheated bearings, electrical failures, and other heat- or spark-producing sources.

Fires have also occurred during the construction of cooling towers. Measures must be taken during construction to prevent the accumulation of combustible waste materials such as wood borings, shavings, scrap lumber, or other easily ignited materials. “No Smoking” regulations and strict control of welding and other heat- or spark-producing operations must be enforced. Wetting down combustible portions of the tower during idle periods of construction is a good fire prevention practice.

Cooling water supplied to heat exchangers, which are used for cooling flammable gases or liquids or combustible liquids where the cooling water pressure is less than that of the material being cooled, may constitute an unusual hazard to the cooling tower by the return of the flammables or combustibles to the cooling tower water distribution system.

Chapter 1 General

1-1 Scope.

1-1.1*

This standard applies to fire protection for field-erected and factory-assembled water-cooling towers of combustible construction or those in which the fill is of combustible material.

1-1.2

No standard can be promulgated that will guarantee the elimination of fires in water-cooling towers. Technology in this area is under constant development and will be reflected in revisions to this standard. The user of this standard must recognize the complexity of fire protection requirements for water-cooling towers. Therefore, the designer is cautioned that the standard is not a design handbook. The standard does not do away with the need for the engineer or competent, engineering judgment. 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 such designs. In such cases, the designer is responsible for demonstrating the validity of the approach.

1-1.3* Fire Risk Analysis.

The following are some of the factors that shall be considered in determining the extent and method of fire protection of induced-draft and natural-draft cooling towers:

(a) Importance to continuity of operation.

(b)* Size and construction of tower.

(c) Type of tower.

(d) Location of tower.

(e) Water supply.

(f) Value of tower.

(g) Climate.

(h)* Water delivery time.

(i) Environment.

(j) Rooftop towers.

(k) Limited access.

(l) Construction of materials. (*See 1-1.4*.)

1-1.4 Construction Materials of Cooling Towers.

When the cooling towers' structure, fan and distribution decks, louvers, and fill materials are all of noncombustible materials, no fire protection is required. If any of these are combustible materials and the factors in 1-1.3 necessitate it, fire protection shall be provided in accordance with Chapter 3 and towers shall be located in accordance with Chapter 2. All other chapters shall be considered mandatory requirements.

1-2 Definitions.

Air Travel. The horizontal distance through the fill measured just below the distribution basin.

Approved.* Acceptable to the authority having jurisdiction.

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

Cell. The smallest tower subdivision that can function as an independent unit with regard to air and water flow. Each cell may have one or more fans or stacks and one or more distribution systems. For the purposes of this standard, a cell within a hyperbolic tower is considered the area bounded by fire-resistant partitions.

Combustible. Material other than noncombustible material.

Cooling Tower Classifications. (*See Figures B-1 through B-5, Appendix B.*)

Counterflow. A cooling tower in which the water flows countercurrent to the airflow.

Crossflow. A cooling tower in which the airflow is essentially perpendicular to the flow of water.

Film Fill. Water-cooling media made of formed plastic sheets and placed parallel to tower air travel at evenly spaced intervals.

Fire-Resistant Partition.* A tight, continuous partition suitable for use in a cooling tower environment having a fire-resistance rating of 20 minutes or more when tested in accordance with NFPA 251, *Standard Methods of Fire Tests of Building Construction and Materials*. The partition shall extend from 1 ft below the operating water level of the cold water basin to the underside of the fan deck (counterflow towers) or distribution basin (crossflow towers).

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.

Mechanical Draft. A cooling tower in which air movement depends on fans or blowers. When the fans or blowers are at the air inlet, the tower is considered forced-draft. When the fans or blowers are at the air exit, the tower is considered induced-draft.

Natural Draft. A cooling tower in which air movement depends on the difference in densities of the heated air inside the tower and the cooler air outside. Natural-draft towers contain no fans or blowers.

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. Examples of noncombustible materials are concrete, masonry, tile, and metal.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Chapter 2 Location of Cooling Towers

2-1 Combustible Exterior Surfaces.

Cooling towers with combustible exterior surfaces, including the deck, distribution basins, etc., shall be located at least 100 ft (30.5 m) from the following hazards:

(a) Structures or processes that emit sparks or flying brands under ordinary circumstances, such as chimneys, incinerators, flare stacks, or cob burners; and

(b) Materials or processes of severe fire hazard, such as petroleum-processing and storage tanks, explosives manufacturing or storage, and petroleum product pipelines and pumping stations.

2-2 Combustible Surfaces with Fixed Protection.

Towers with combustible exterior surfaces and provided with fixed exposure protection in accordance with 3-2.10 of this standard may be located closer than 100 ft (30.5 m) from the hazards listed in Section 2-1(a) and (b).

2-3 Noncombustible Exterior Surfaces.

Towers with noncombustible exterior surfaces shall be located 40 ft (12.2 m) or more from the hazards listed in Section 2-1(a) and (b).

2-4 Noncombustible Surfaces with Fixed Protection.

Towers with noncombustible exterior surfaces and provided with fixed interior fire protection installed in accordance with Chapter 3 of this standard shall be permitted to be located closer than 40 ft (12.2 m) from the hazards listed in Section 2-1(a) and (b).

2-5 Combustible Towers on Building Roofs.

Combustible cooling towers located on building roofs or other locations to which access for manual fire fighting is restricted or difficult shall be provided with a protection system in accordance with Chapter 3 of the standard.

2-6 Screening.

Open areas or space between a combustible cold-water basin and the ground or roof of a building upon which it is located shall be effectively screened to prevent the accumulation of waste combustible material under the tower, or to prevent the use of such areas or space under the tower for the storage of combustible material. Fire protection shall be permitted to be installed in lieu of screening.

Chapter 3 Fire Protection

3-1 General.

3-1.1* Types of Suppression Systems.

If the fire risk analysis in 1-1.3 requires a fire protection system, one of the following general types of systems shall be used:

(a) Open-head deluge system.

(b) Closed-head dry-pipe system.

(c) Wet-pipe automatic sprinkler system.

(d) Closed-head preaction system.

3-1.2 Complete Plans and Data Required.

A complete plan showing piping arrangement, location of sprinklers, fixed detectors, and operating equipment such as valves, deluge valves, etc., together with hydraulic calculations, water requirements, and water supply information, shall be submitted to the authority having jurisdiction for approval before installation. Plans shall be drawn to scale and include the details necessary to indicate clearly all of the equipment and its arrangement. Plans shall show location of new work with relation to existing structures, cooling towers, and water supplies. Plans shall include a note listing the types of materials used in the system.

3-2 Fire Protection System Design.

3-2.1 Sprinkler and Water Spray.

Fire protection systems shall be designed, installed, and tested in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems,* and NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection,* except as modified by this standard.

3-2.2 Types of Systems.

3-2.2.1 The counterflow tower design lends itself to either closed- or open-head systems. Therefore, wet-pipe, dry-pipe, preaction, or deluge systems shall be permitted to be used. A deluge system provides a higher degree of protection where water supplies are adequate. In climates that are subject to freezing temperatures, a deluge system minimizes the possibility of failure due to pipes freezing.

3-2.2.2 The crossflow design is such that it is difficult to locate sprinklers in the most desirable spots for both water distribution and heat detection. This situation can be solved by separating these two functions and using separate water discharge and detection systems. The open-head deluge system does this and, therefore, shall be used in crossflow towers.

3-2.3 Minimum Rate of Application.

3-2.3.1 Under the fan decks of counterflow towers, the rate of application of water shall be 0.5 gpm/ft^2 (20.4 L/min/m^2) (including fan opening).

3-2.3.2 Under the fan decks of crossflow towers, the rate of application of water shall be 0.33 gpm/ft^2 (13.45 L/min/m^2) (including fan opening).

3-2.3.3 Over the fill areas of crossflow towers, the rate of application of water shall be 0.5 gpm/ft^2 (20.4 L/min/m^2).

3-2.4 Types and Locations of Discharge Outlets.

3-2.4.1* Counterflow Towers.

3-2.4.1.1 The discharge outlets shall be located under the fan deck and fan opening.

3-2.4.1.2 Except under the fan opening, all discharge outlets shall have deflector distances installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

3-2.4.1.3 Closed-head discharge outlets for dry-pipe and preaction systems shall be installed in the upright position only.

3-2.4.2* Crossflow Towers.

3-2.4.2.1 The discharge outlets protecting the plenum area shall be located under the fan deck and in the fan opening.

3-2.4.2.2 Discharge outlets protecting the fill shall be located under the distribution basin on either the louver or drift eliminator side, discharging horizontally through the joist channels.

3-2.4.2.3 Towers with a fill area longer than the maximum allowable for the discharge device being used shall have discharge devices placed on both sides of the fill area in each joist channel. The pressure at each discharge device shall be adequate to provide protection for half of the length of the fill area.

3-2.4.2.4 Where joist channels are wider than 2 ft (0.6 m), more than one discharge device shall be required per joist channel.

Exception: If the discharge device being used is listed for the width of the joist channel being protected.

3-2.4.3* On towers having extended fan decks that completely enclose the distribution basin, the discharge outlets protecting the fill area shall be located over the basin, under the extension of the fan deck. These discharge outlets shall be open directional spray nozzles or other approved spray devices arranged to discharge 0.35 gpm/ft^2 (14.26 L/min/m^2) directly on the distribution basin and 0.15 gpm/ft^2 (6.11 L/min/m^2) on the underside of the fan deck extension. On towers having extended fan decks that do not completely enclose the hot water basin, outlets protecting the fill shall be located under the distribution basin as set out in 3-2.4.2 of this standard.

3-2.4.4 For deluge systems using directional spray nozzles in the pendant position, provisions shall be made to protect the underside of a combustible fan deck at a minimum of 0.15 gpm/ft^2 (6.11 L/min/m^2), which shall be included as part of the application rate specified in 3-2.3.

3-2.4.5* On film-filled towers that have solid, hot-water basin covers over the complete basin, the discharge outlets protecting the fill area shall be permitted to be located under the basin covers. These discharge outlets shall be open directional spray nozzles or other approved devices arranged to discharge 0.35 gpm/ft^2 (14.26 L/min/m^2) directly on the distribution basin, and 0.15 gpm/ft^2 (6.11 L/min/m^2) on the underside of the water basin covers. On towers having basin covers that do not completely enclose the hot water basin, outlets protecting the fill shall be located under the distribution basin as set out in 3-2.4.2 of this standard.

3-2.5 Pipe, Fittings, and Hangers.

3-2.5.1* Piping shall be installed in accordance with the requirements of NFPA 13, *Standard for the Installation of Sprinkler Systems*.

3-2.5.2* Piping or tubing used within the cooling tower shall be metallic and approved for fire protection use.

Exception: Piping or tubing used for pneumatic detection systems shall be permitted to be of other materials suitable for use in a cooling tower environment.

3-2.5.3 Hydraulic calculations shall be made in accordance with Chapter 6 of NFPA 13, *Standard for the Installation of Sprinkler Systems*.

3-2.5.4 All fittings shall be of a type specifically approved for fire protection use. In dry sections of the system piping, which may be exposed to possible fire conditions, ferrous fittings shall be of steel, malleable iron, or ductile iron.

Exception: Cast-iron fittings shall be permitted to be used in pneumatic detection piping.

3-2.5.5 Approved, gasketed, groove-type fittings are acceptable to connect pipe in fire-exposed areas where the fire protection system is automatically operated.

3-2.5.6 Where piping is supported from structural members of a cooling tower, the attachment shall be made so that the structural member is not split or otherwise damaged.

3-2.6 Valves.

3-2.6.1 General. Valves shall be installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, and NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, where applicable. Shutoff valves and automatically operated water control valves, if provided, shall be located:

(a) Outside the fire-exposed area;

(b) As close to the cooling tower as possible to minimize the amount of pipe to the discharge device; and

(c) Where they will be accessible during a fire emergency.

3-2.6.2 Manual Release Valve. Remote manual release valves, where required, shall be conspicuously located and readily accessible during a fire emergency. If remote, manual release valves are not required, an inspector's test valve shall be provided for each pilot-head-operated system.

3-2.7 Strainers.

Strainers are required for systems utilizing discharge devices with waterways of less than 0.375-in. (9.5-mm) diameter. (*See NFPA 15, Standard for Water Spray Fixed Systems for Fire Protection, for further details.*)

3-2.8* Heat Detectors.

3-2.8.1 Where deluge or preaction systems are used, heat detectors shall be installed in accordance with the applicable sections of NFPA 72, *National Fire Alarm Code*.

3-2.8.2 In mechanical induced-draft towers, heat detectors shall be located under the fan deck at the circumference of the fan opening and under the fan opening where necessary to comply with the following spacing requirements. (*For extended fan decks, see 3-2.8.3.*)

3-2.8.2.1 Fixed-temperature detectors shall be spaced not more than 8 ft (2.4 m) apart in any direction including the fan opening. Temperature ratings shall be selected in accordance with operating conditions, but shall be no less than intermediate.

3-2.8.2.2 Rate-of-rise detectors shall be spaced not more than 15 ft (4.6 m) apart in any direction. In pneumatic-type systems, for detectors inside the tower, there shall be no more than one detector for each mercury check in towers operating in cold climates, and two detectors for each mercury check in towers used during the warm months only or year-round in warm climates. There shall be no more than four detectors for each mercury check where the detectors are located outside the tower.

3-2.8.3 On towers having extended fan decks that completely enclose the distribution basin, detectors shall be located under the fan deck extension in accordance with standard, indoor-spacing rules for the type detectors used. (*See NFPA 72, National Fire Alarm Code.*)

Exception: Where the fan deck extension is 16 ft (4.9 m) or less and this dimension is the length of the joist channel, then only one row of detectors centered on and at right angles to the joist channels shall be required. Spacing between detectors shall be in accordance with NFPA 72, National Fire Alarm Code.

On towers having extended fan decks that do not completely enclose the hot water basin, detectors shall not be required under the fan deck extension.

3-2.8.4* Where the total number of deluge systems exceeds the number for which the water supply was designed, heat barriers shall be installed under the extended fan deck to separate the systems. Heat barriers shall extend from the fan deck structure to the distribution basin dividers.

3-2.8.5 Where heat detectors are inaccessible during tower operation, an accessible test detector shall be provided for each detection zone.

3-2.8.6 Heat detector components exposed to corrosive vapors or liquids shall be protected by materials of suitable construction or by suitable, protective coatings applied by the equipment manufacturer.

3-2.9 Protection for Fan Drive Motor.

3-2.9.1 A heat detector and water discharge outlet shall be provided over each fan drive motor when the motor is located so that it is not within the protected area of the tower.

3-2.9.2 Provision shall be made to interlock the fan motors with the fire protection system so that the cooling tower fan motors will be stopped in the cell(s) for which the system is actuated. Where the continued operation of the fans is vital to the process, a manual override switch may be provided to reactivate the fan when it is determined that there is no fire.

3-2.10 Exposure Protection.

3-2.10.1 Where any combustible exterior surfaces of a tower, including the fan deck, distribution basins, etc., are less than 100 ft (30.5 m) from significant concentrations of combustibles such as structures, piled material, etc., the combustible exposed surfaces of the tower shall be protected by an automatic water spray system.

3-2.10.2 Systems for exterior protection shall be designed with the same attention and care as interior systems. Pipe sizing shall be based on hydraulic calculations. Water supply and discharge rate shall be based on a minimum 0.15 gpm/ft^2 (6.11 L/min/m^2) for all surfaces being protected.

3-2.11 Suppression Design.

The design and installations shall comply with the applicable sections of NFPA 13, *Standard for the Installation of Sprinkler Systems*.

3-3 Corrosion Protection.

3-3.1*

Piping, fittings, hangers, braces, and attachment hardware including fasteners shall be hot-dip galvanized steel per ASTM A 153, *Standard Specification for Zinc Coating (Hot Dip) on Iron and Steel Hardware*, or other materials having a superior corrosion resistance. Exposed pipe threads and bolts on fittings shall be protected against corrosion. All other components shall be corrosion resistant or protected against corrosion by a suitable coating.

3-3.2

Approved discharge devices are made of nonferrous material and are corrosion resistant to normal atmospheres. Some atmospheres require special coatings on the discharge devices. Wax-type coatings shall not be used on devices without fusible elements.

3-3.3

Special care shall be taken in the handling and installation of wax-coated or similar sprinklers to avoid damaging the coating. Corrosion-resistant coatings shall not be applied to the sprinklers by anyone other than the manufacturer of the sprinklers, except that in all cases any damage to the protective coating occurring at the time of installation shall be repaired at once using only the coating of the manufacturer of the sprinkler in an approved manner so that no part of the sprinkler will be exposed after the installation has been completed. Otherwise, corrosion will attack the exposed metal and will, in time, creep under the wax coating.

3-4* Hydrant Protection.

Hydrants shall not be located closer than 40 ft (12.2 m) from towers.

3-5* Standpipe Protection.

Towers with any combustible construction located on a building 50 ft (15.3 m) or more in height shall be provided with Class III standpipe protection (as defined in NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*) with hose connections within 200 ft (61.0 m) of all parts of the tower. Sufficient hose shall be provided to reach all parts of the tower. Provision shall be made for completely draining all exposed standpipe lines during winter. Hose equipment at each standpipe hose connection on the roof shall be protected from the weather in a suitable cabinet or enclosure. (*See NFPA 14, Standard for the Installation of Standpipe and Hose Systems, for further details.*)

3-6 Water Supply.

3-6.1 Deluge Systems.

3-6.1.1* Where all cells of a cooling tower are protected by a single deluge system, the water supply shall be adequate to supply all discharge outlets on that system.

3-6.1.2 Where two or more deluge systems are used to protect a cooling tower and fire-resistant partitions are not provided between the deluge systems, the water supply shall be adequate to supply all discharge outlets in the two most hydraulically demanding adjacent systems.

3-6.1.3* Where two or more deluge systems are separated by fire-resistant partitions, the water supply shall be adequate to supply all discharge outlets in the single most hydraulically demanding system.

3-6.2 Wet, Dry, and Preaction Systems.

3-6.2.1* Where each cell of the cooling tower is separated by a fire-resistant partition, the water supply shall be adequate to supply all discharge outlets in the hydraulically most demanding single cell.

3-6.2.2* Where fire-resistant partitions are not provided between each cell of a cooling tower, the water supply shall be adequate to supply all discharge outlets in the two most hydraulically demanding adjoining cells.

3-6.3 Hose Streams.

Water supplies shall be sufficient to include a minimum of 500 gpm (1892.5 L/min) for hose streams in addition to the sprinkler requirements.

3-6.4 Duration.

An adequate water supply of at least 2-hour duration shall be provided for the combination of the water supply specified in 3-6.1 or 3-6.2, plus the hose stream demand specified in 3-6.3.

3-7* Lightning Protection.

Lightning protection, where provided, shall be installed in accordance with the provisions of NFPA 780, *Standard for the Installation of Lightning Protection Systems*.

3-8 Earthquake Protection.

Where provided, earthquake-resistant construction shall be in accordance with applicable sections of NFPA 13, *Standard for the Installation of Sprinkler Systems*.

Chapter 4 Electrical Equipment and Wiring

4-1 Installation.

Installation of all electrical equipment and wiring pertaining to water-cooling towers shall be in accordance with NFPA 70, *National Electrical Code*®□.

4-2* Overcurrent Protection.

Electric motors that are driving fans shall be provided with overcurrent protective devices as mandated by NFPA 70, *National Electrical Code*.

4-3 Stop Fan.

A remote fan-motor switch shall be provided to stop the fan in case of fire.

4-4 Interlock.

When a fire protection system is installed, provisions shall be made to interlock the fan motors with the sprinkler system (*see Chapter 3*).

4-5 Vibration-Controlled Switch.

An automatic vibration-controlled switch shall be provided to automatically shut down fan motors.

Chapter 5 Internal Combustion Engine-Driven Fans

5-1 Internal Combustion Engines.

Electric motors or steam turbines are the preferred drives to operate fans on cooling towers. When neither is available, internal combustion engines shall be permitted to be used, provided they are installed, used, and maintained in accordance with NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*.

Chapter 6 Maintenance

6-1 Housekeeping.

Areas around towers located on the ground shall be kept free of grass, weeds, brush, or combustible waste materials.

6-2 Smoking.

Smoking shall not be permitted on or adjacent to any cooling tower of combustible construction. Signs to this effect shall be posted and maintained and this regulation shall be strictly enforced.

6-3 Mechanical Inspection.

Forced- and induced-draft towers in continuous operation shall be checked frequently for excessive heating in motors and for excessive fan vibration.

6-4 Inspection Frequency.

At least semiannually, the fan assemblies, including the motors and speed reducers, shall be checked, both during operation and when shut down, for excessive wear or vibration, improper lubrication, corrosion, or other features that could result in failure. Where conditions require, corrective action shall be taken.

6-5 Welding and Cutting.

Where work on the tower requires welding or cutting, it shall be done in accordance with NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*.

6-6* Down Time.

Combustible cooling towers are particularly susceptible to ignition when they are shut down for repairs or other reasons and the wood becomes dried out. During these periods, all automatic fire protection on the tower shall be operable, or if the tower is not so protected, special protection shall be provided until the tower is back in service.

6-7 Access.

Access to the tops of water-cooling towers for fire fighting and maintenance shall be provided by an approved stairway or ladder. Towers in excess of 120 ft (36.6 m) in any dimension shall be provided with not less than two means of access remote from each other.

6-8 Lockout.

Motors, speed reduction units, and drive shafts shall be accessible for servicing and maintenance. Provisions shall be made for lockout or tagout of electric motors when maintenance work is being performed in the area of fans.

6-9 Temporary Supports. After maintenance work is completed, all scaffolding, boards, temporary supports, and other temporary materials shall be removed from the tower.

6-10 Maintenance of Fire Protection Systems.

For proper maintenance of fire protection systems see NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*.

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 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 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, 1995 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 70, *National Electrical Code*, 1996 edition.

NFPA 72, *National Fire Alarm Code*, 1996 edition.

NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*, 1995 edition.

NFPA 780, *Standard for the Installation of Lightning Protection Systems*, 1995 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 A 153/A 153M, *Standard Specification for Zinc Coating (Hot Dip) on Iron and Steel Hardware*, 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-1-1.1 The standard does not apply more or less strictly to factory-assembled units than past revisions. Because these units have typically been steel frame/structure with PVC fill, one should evaluate protection requirements in accordance with 1-1.3, with item (b) being specifically noted. In all cases, 1-1.3 should be reviewed for making the determination with regard to the installation of fire suppression. In some cases no fire suppression may be appropriate.

A-1-1.3 Fire experience for mechanical forced-draft towers does not indicate the general need for automatic fire protection systems. However, exposure protection may be necessary as provided in 3-2.10.

A-1-1.3(b) There are several fire tests that can be used to evaluate the fire risk related to water-cooling tower materials. The most suitable tests are those that demonstrate low fire risk when tested in a configuration that approximates that large scale of the installation. Tests such as ASTM E 136 and ASTM E 84 have limitations. The test methods do not duplicate the larger extent of the hazard in its final installation and are not necessarily suitable or generally satisfactory for materials that soften, flow, or melt under fire conditions.

A-1-1.3(h) Where applicable, piping arrangements, system capacities, and supervisory air pressures should be designed such that the time for water delivery to the most remote discharge device is minimized. For all water suppression systems using detection, the detection system should be designed to cause actuation of the special water control valve within 20 seconds under expected exposure conditions (*see NFPA 15, Standard for Water Spray Fixed Systems for Fire Protection, Section 8-6*).

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 concerned with product evaluations that 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, 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 Fire-Resistant Partition. Examples of some types of construction that meet this requirement are $^1/_2$-in. (12.7-mm) asbestos cement board, $^1/_2$-in. (12.7-mm) plywood, or $^3/_4$-in. (19.1-mm) tongue and groove boarding when installed on both sides of wood studs. Other types of materials should be tested in accordance with NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials.*

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-3-1.1 Antifreeze Sprinkler Systems. The use of antifreeze sprinkler systems in cooling towers is not recommended. While in theory this type of system would function, the use of antifreeze systems in cooling towers presents problems not encountered in usual antifreeze applications.

Due to the inaccessibility of the piping during normal operation of the cooling tower, it is practically impossible to do any maintenance work or to make routine inspections. The corrosion problem can be quite serious in cooling towers, and leaks in the system will not readily become apparent. This would result in loss of the antifreeze solution and could result in freezing of the system.

Local ordinances in many areas prohibit the use of these systems.

A-3-2.4.1 See Figures A-3-2.4.1(a)-(d).

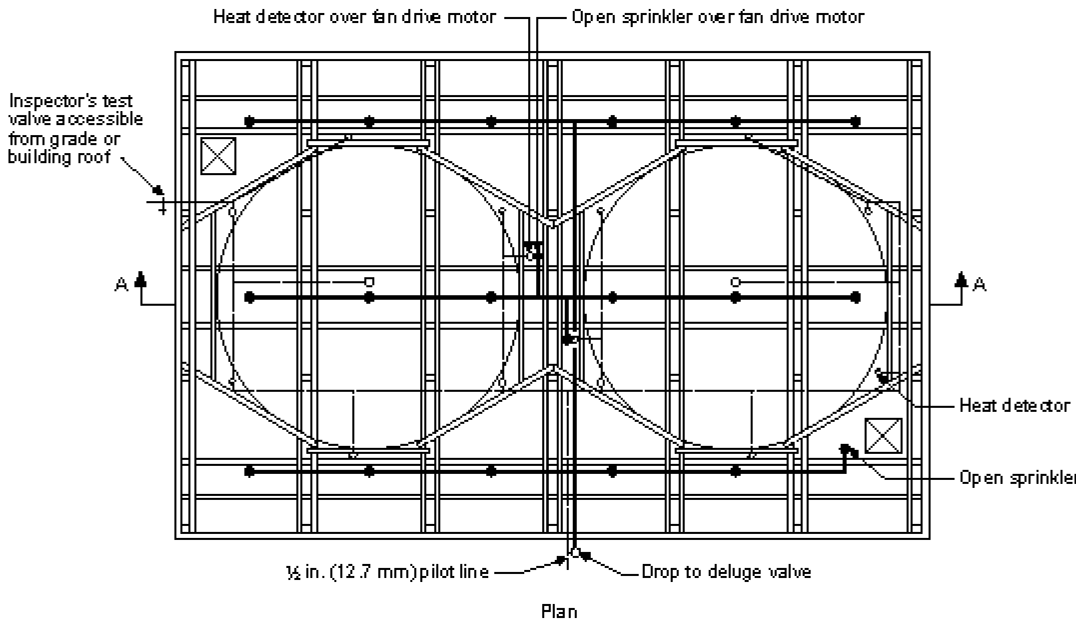


Figure A-3-2.4.1(a) Typical deluge fire protection arrangement for counterflow towers.

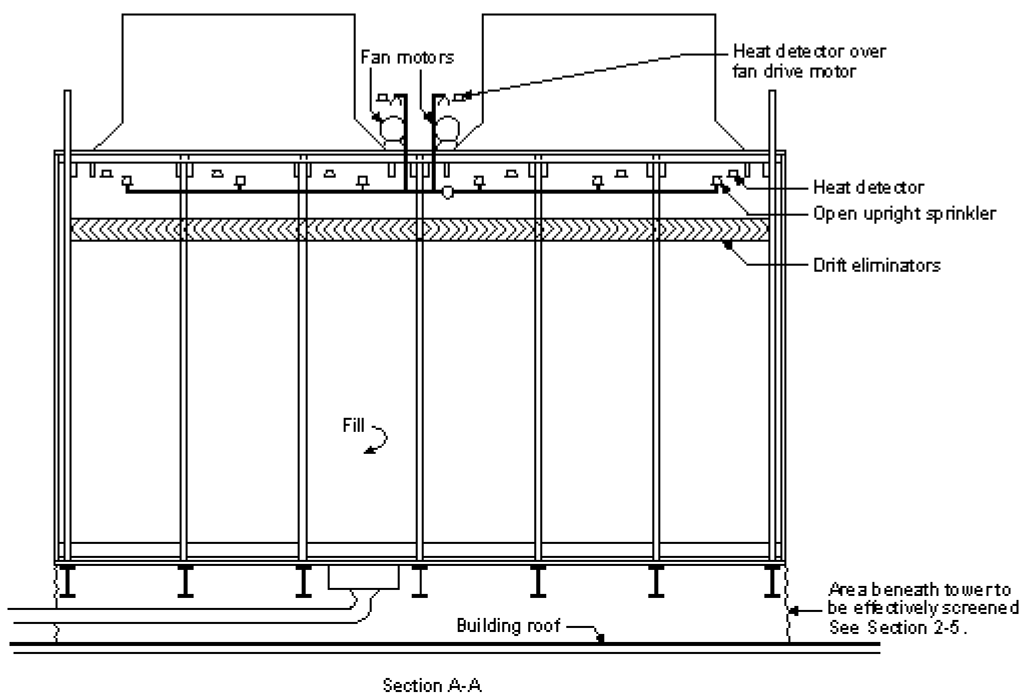


Figure A-3-2.4.1(b) Typical deluge fire protection arrangement for counterflow towers.

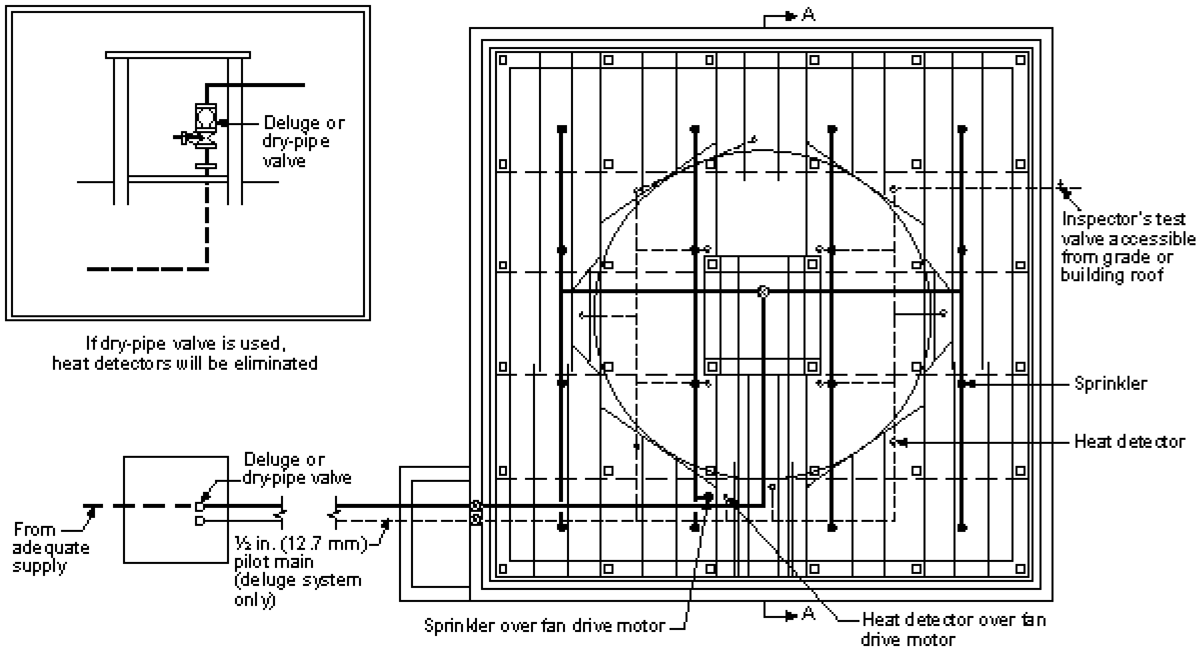


Figure A-3-2.4.1(c) Typical deluge or dry pipe fire protection arrangement for counterflow towers.

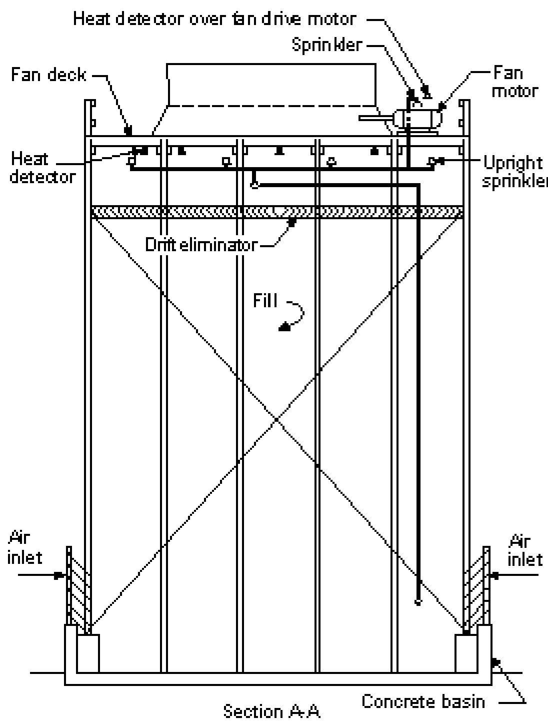


Figure A-3-2.4.1(d) Typical deluge or dry pipe fire protection arrangement for counterflow towers.

A-3-2.4.2 See Figures A-3-2.4.2(a)-(d).

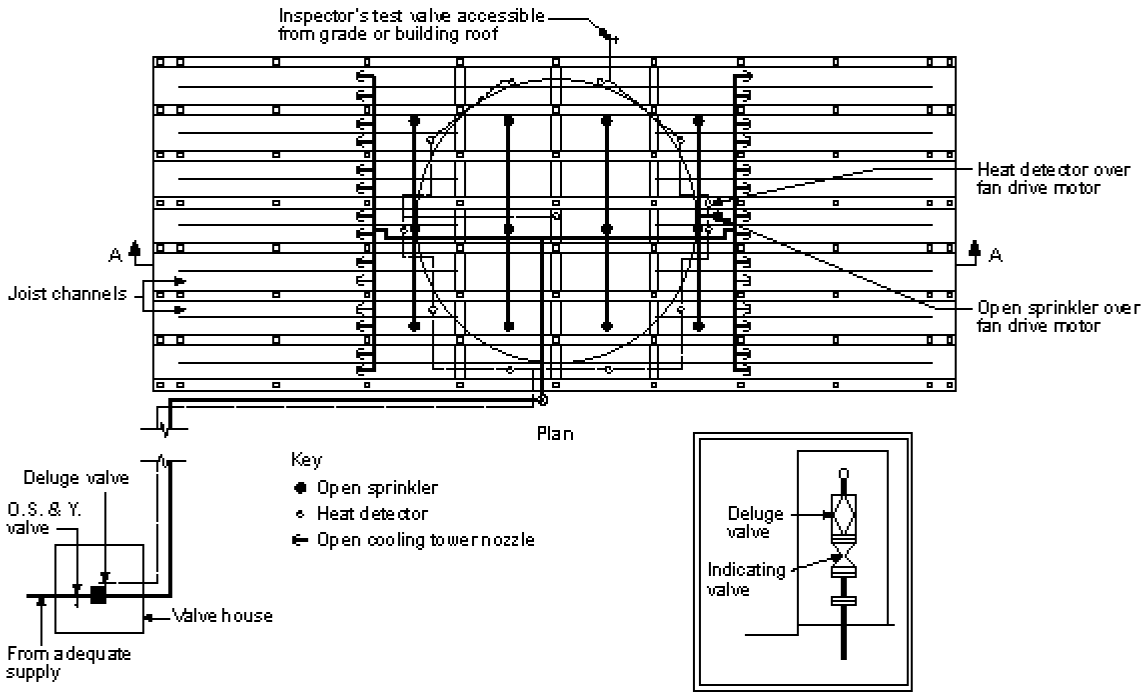


Figure A-3-2.4.2(a) Typical deluge fire protection arrangement for crossflow towers.

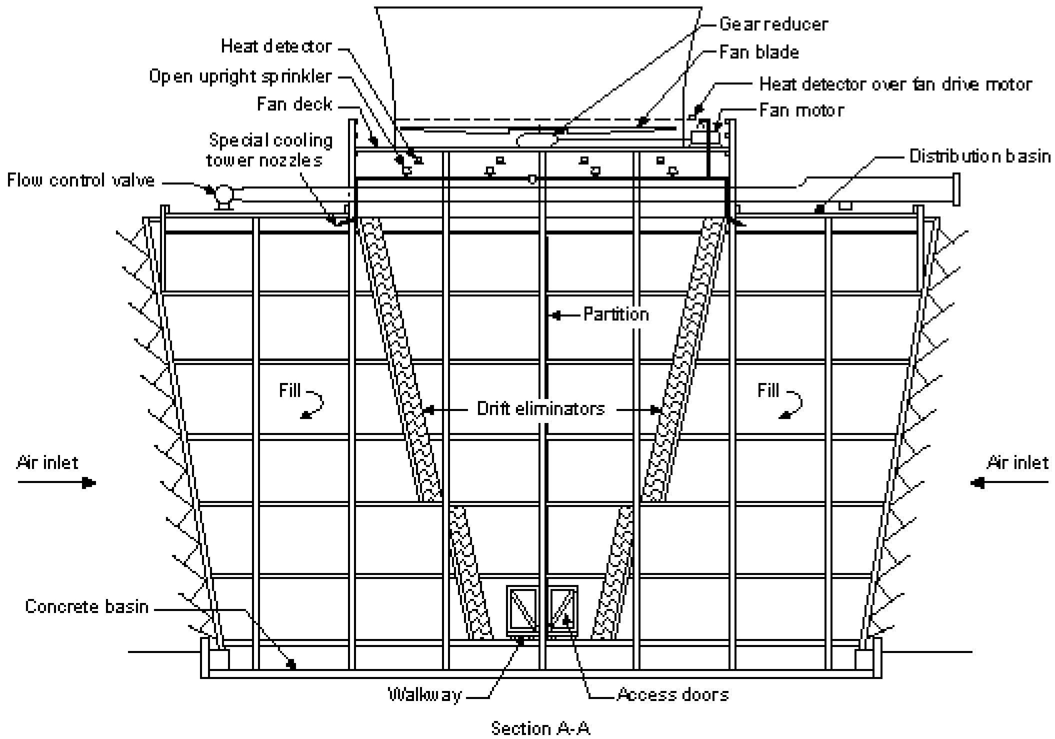
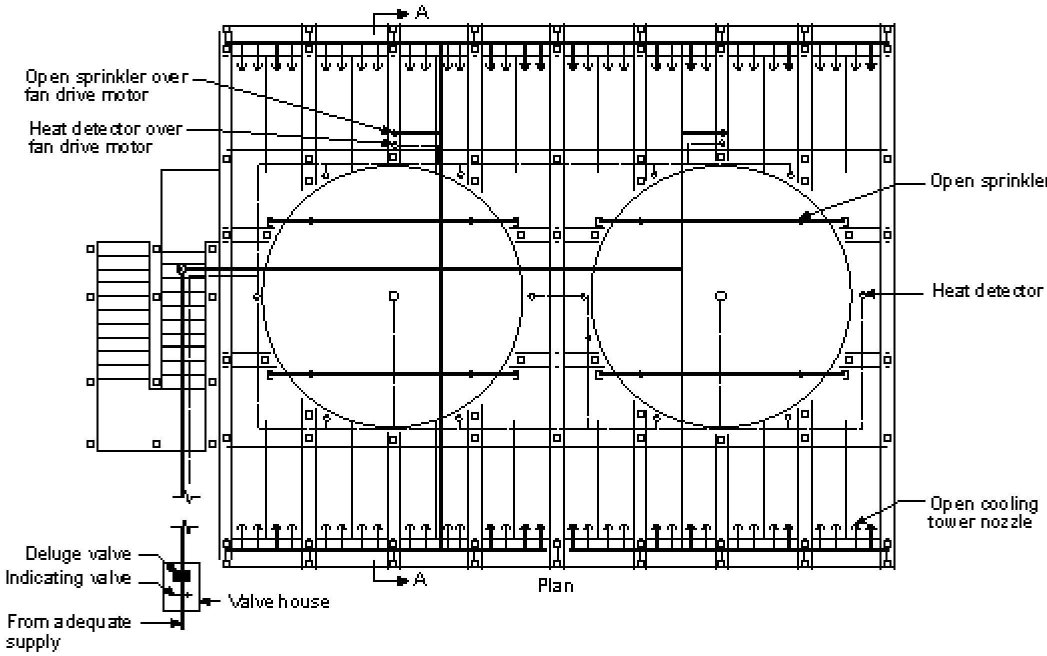
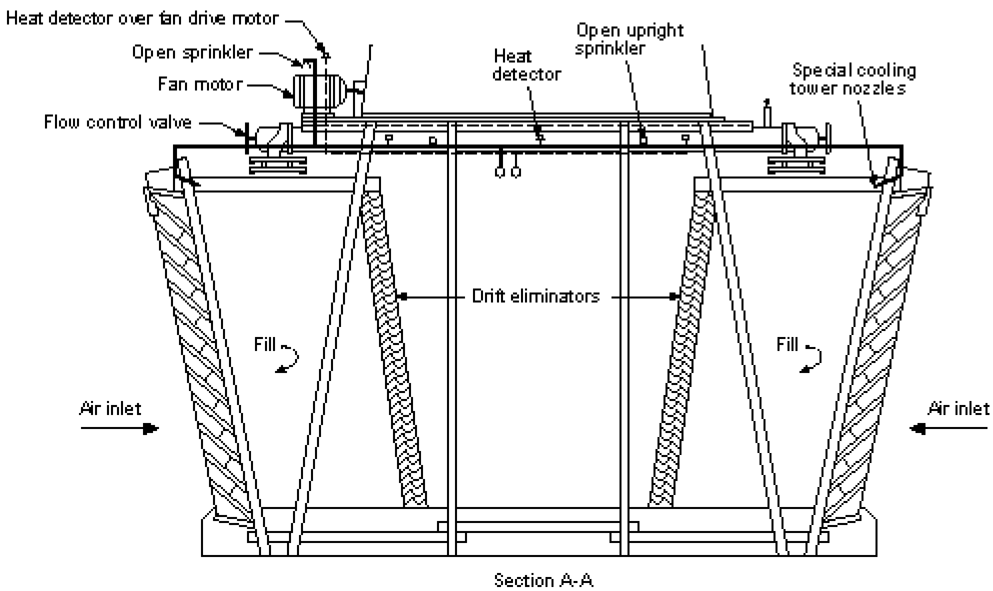


Figure A-3-2.4.2(b) Typical deluge fire protection arrangement for crossflow towers.



Note: Where air seal boards prevent installation of cooling tower nozzles on drift eliminator side of fill, this nozzle location should be used.

Figure A-3-2.4.2(c) Typical deluge fire protection arrangement for crossflow towers.



Note: Where air seal boards prevent installation of cooling tower nozzles on drift eliminator side of fill, this nozzle location should be used.

Figure A-3-2.4.2(d) Typical deluge fire protection arrangement for crossflow towers.

A-3-2.4.3 Location of the nozzle relative to surfaces to be protected shall be determined by the particular nozzle's discharge characteristics. Care should also be taken in the selection of nozzles to obtain waterways not easily obstructed by debris, sediment, sand, etc., in the water. Refer to Figures A-3-2.4.3(a) and (b).

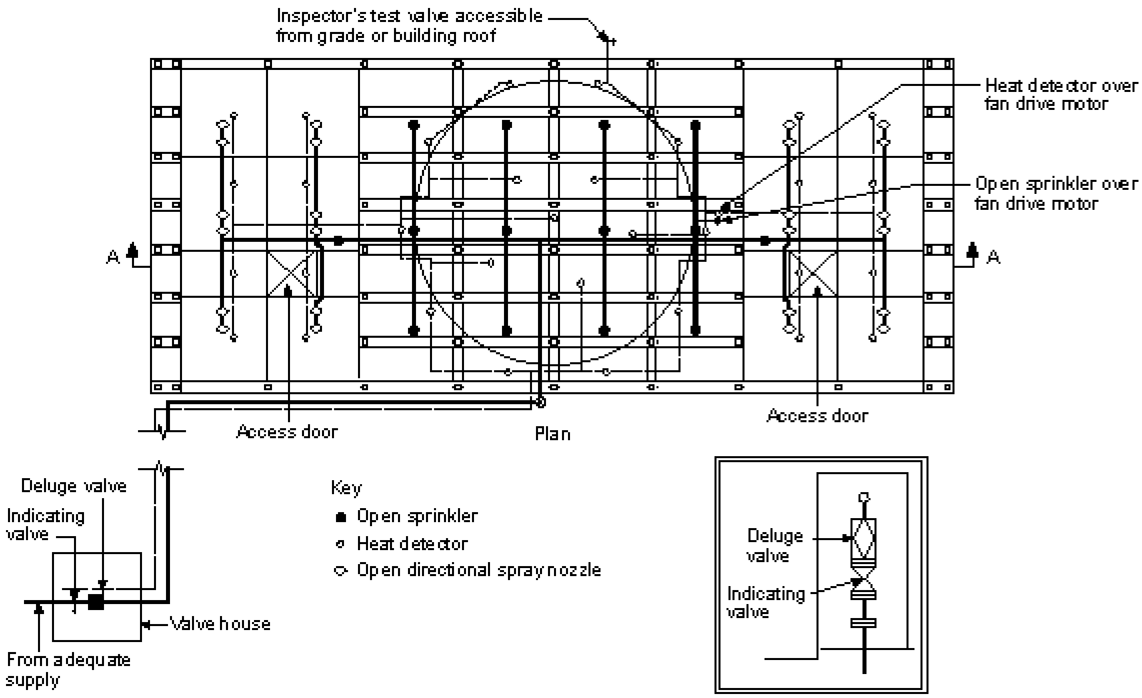


Figure A-3-2.4.3(a) Typical deluge fire protection arrangement for crossflow towers with completely enclosed distribution basins.

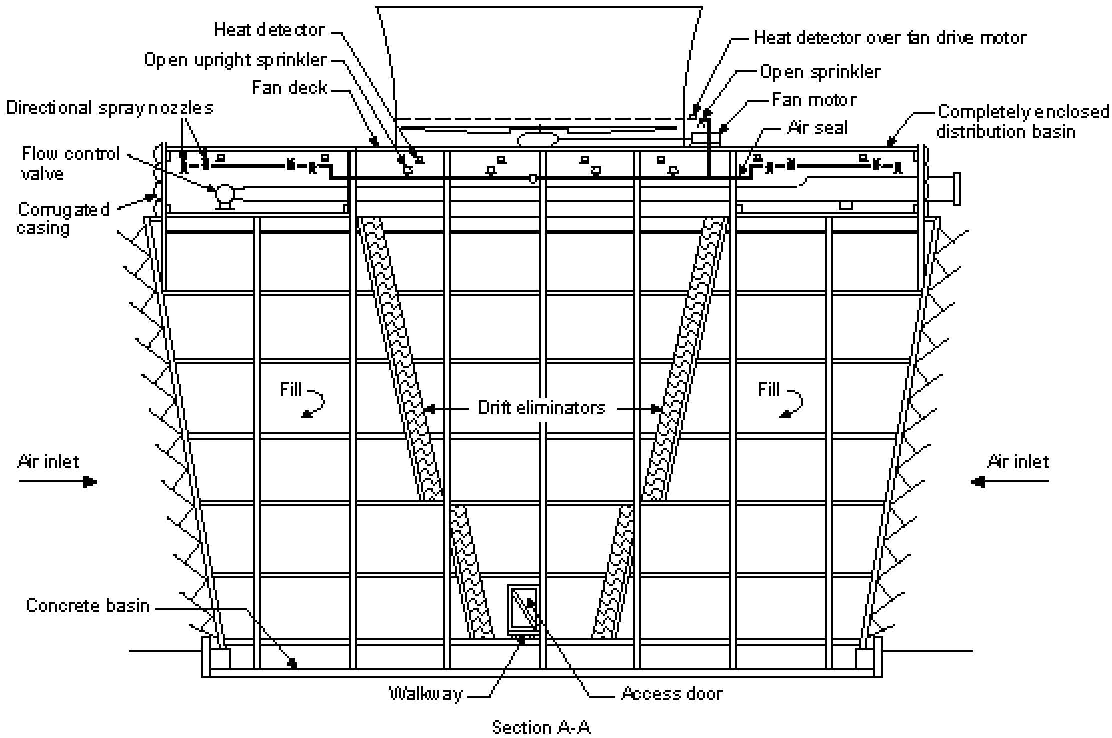


Figure A-3-2.4.3(b) Typical deluge fire protection arrangement for crossflow towers with completely enclosed distribution basins.

A-3-2.4.5 See Figure A-3-2.4.5.

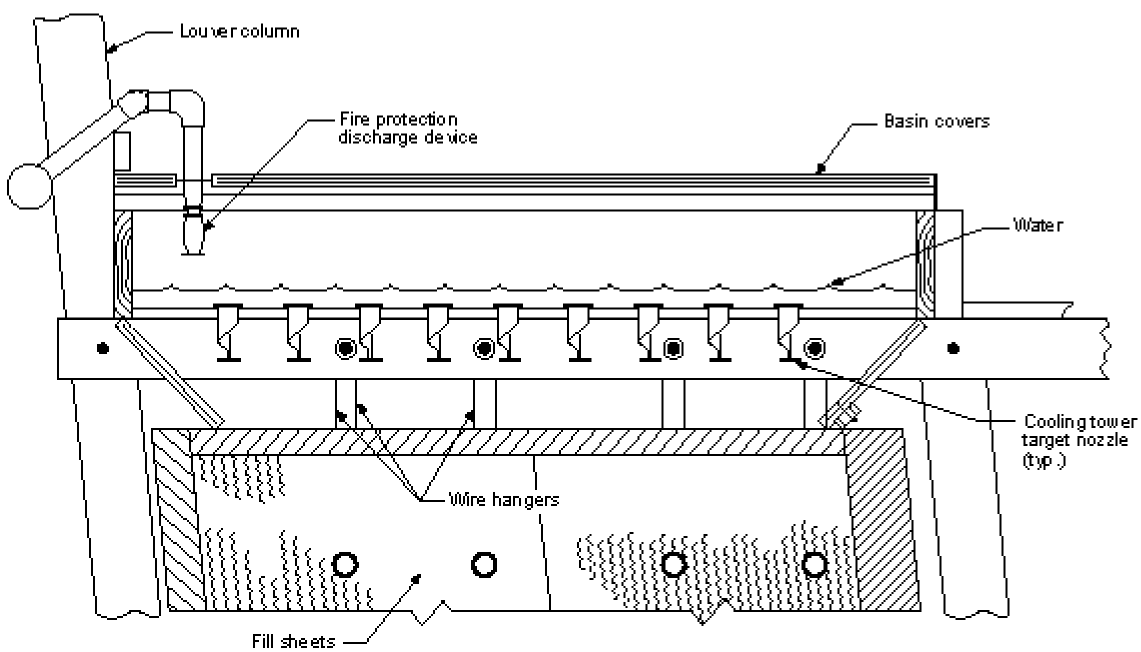


Figure A-3-2.4.5 Typical deluge fire protection arrangement for crossflow towers with covers completely enclosing distribution basins.

A-3-2.5.1 In towers where sufficient vibration is anticipated which will cause movement of the fire protection system resulting in wear of water or detection piping or tubing at the hangers, it may be necessary to install vibration absorbers between the hangers and the pipe.

Special consideration should be given to the support of detection piping or tubing due to its small diameter. Thin-wall or nonmetallic pipe or tubing usually requires closer spacing of hangers for adequate support.

A-3-2.5.2 Where plastic piping or tubing is used for pneumatic detection systems, consideration should be given to the effects of ultraviolet radiation.

A-3-2.8 Due to the extremely humid atmosphere and potentially corrosive conditions in cooling towers, it is very difficult to maintain electrical detection equipment. Experience has shown that even with weatherproof equipment and wiring practices an electrical system will malfunction frequently. Therefore, the information in the subparagraphs of this section is based on the use of detectors operating on pneumatic or hydraulic principles.

A-3-2.8.4 Acceptable materials are $^3/_8$-in. (9.5-mm) plywood or $^3/_{16}$-in. (4.8-mm) asbestos cement board on one side of studs.

A-3-3.1 Corrosion of exposed pipe threads and bolts on fittings is a concern. Therefore, care should be taken to ensure corrosion protection is as equivalent to hot dipped galvanized as possible. Experience has shown that cadmium-plated components corrode at an accelerated rate as compared to hot-dipped galvanized components.

If circulating tower water quality has the following characteristics, an upgrade of hot-dipped, galvanized, sprinkler components should be considered:

Calcium, as CaCo(3) < 50 ppm
Chloride > 450 ppm as Cl- (270 ppm as NaCl)
pH < 6.5
pH > 9.0
Hot water temperature >140°F.

Other unusual water uses include geothermal power, paper processing, and Stretford process, each of which may require component material upgrade.

A-3-4 Hydrant protection should be provided within 200 ft (61.0 m) of all parts of towers having combustible construction located on the ground or on buildings less than 50 ft (15.3 m) in height. A hose house and standard hose house equipment should be provided at each hydrant. (*See NFPA 24, Standard for the Installation of Private Fire Service Mains and Their Appurtenances, for further details.*)

A-3-5 Standpipes should preferably be located in stair towers. If located on an open roof, they should not be closer than 40 ft (12.2 m) to the cooling tower.

A-3-6.1.1 Where a single deluge system protects an entire water-cooling tower, regardless of the number of cells, the water supply needs to be based on the entire deluge system coverage. Refer to Figure A-3-6.1.1.

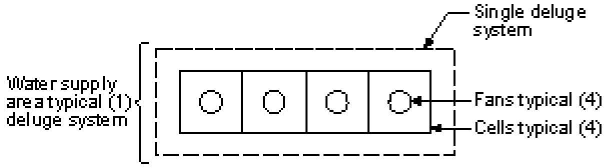


Figure A-3-6.1.1 Single deluge system.

A-3-6.1.3 Deluge systems separated by fire-resistant partitions can be treated independently as worst-case water supply situations. Refer to Figure A-3-6.1.3.

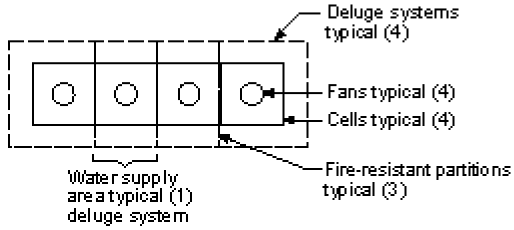


Figure A-3-6.1.3 Multiple deluge systems.

A-3-6.2.1 Water-cooling towers with each cell separated by a fire-resistant partition and protected by wet, dry, or preaction system(s) should have the water supply based on the most demanding individual cell. Refer to Figure A-3-6.2.1.

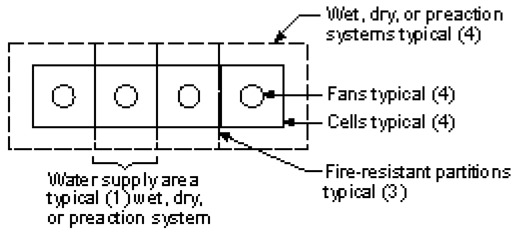


Figure A-3-6.2.1 Multiple wet, dry, or preaction systems with fire-resistant partitions.

A-3-6.2.2 Without fire-resistant partitions between cells, the worst-case situation involves the most demanding adjoining cells. Refer to Figure A-3-6.2.2.

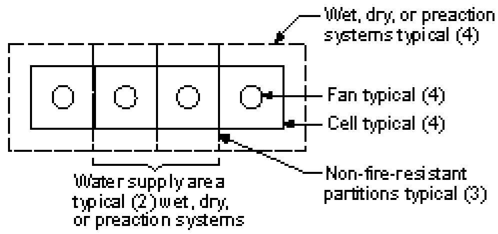


Figure A-3-6.2.2 Multiple wet, dry, or preaction systems with no fire-resistant partitions.

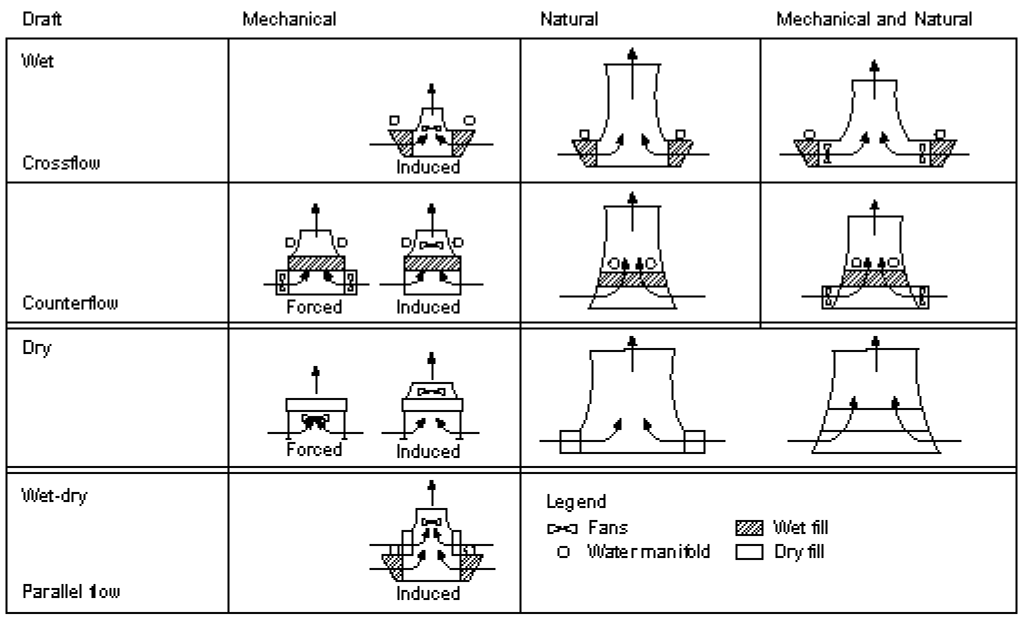
A-3-7 Towers located on roofs of buildings in certain geographical locations may be particularly susceptible to lightning damage.

A-4-2 Motors should be totally enclosed to protect them from dirt or moisture and to prevent sparks from reaching adjacent combustible construction.

A-6-6 Examples of special protection are watch service or intermittent wetting, or both.

Appendix B Water-Cooling Tower Types

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



Reprinted with permission of Factory Mutual Engineering and Research.

Figure B-1 Summary of typical cooling towers.

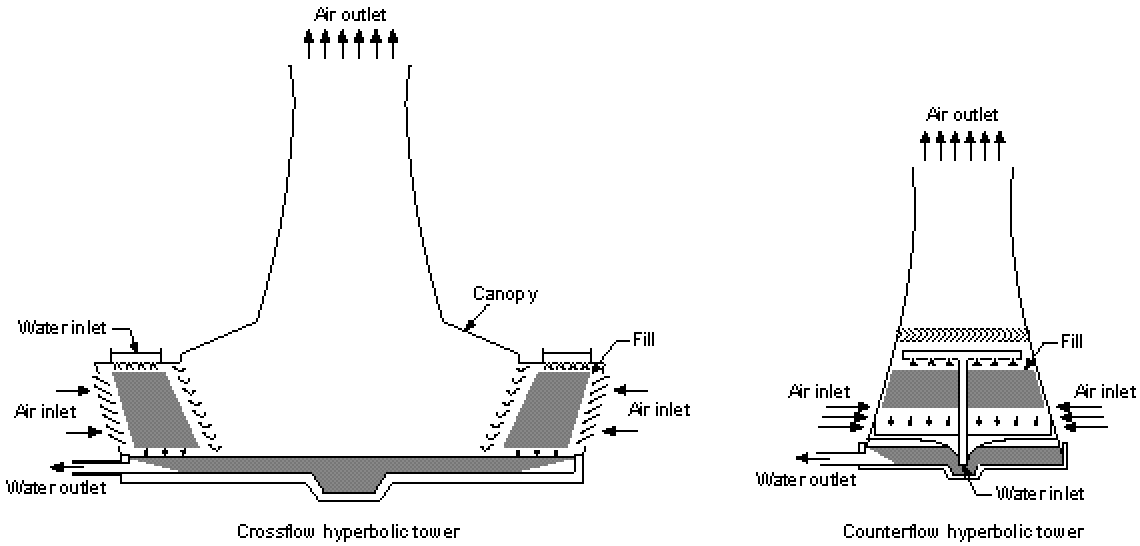


Figure B-2 Types of natural-draft towers.

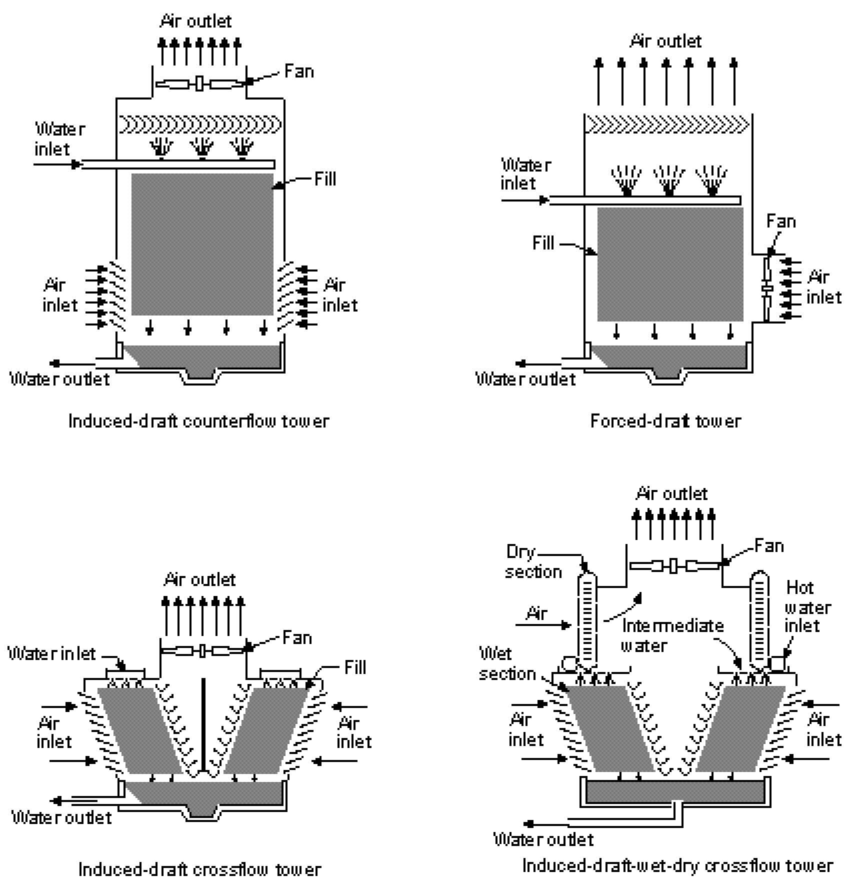


Figure B-3 Types of mechanical-draft towers.

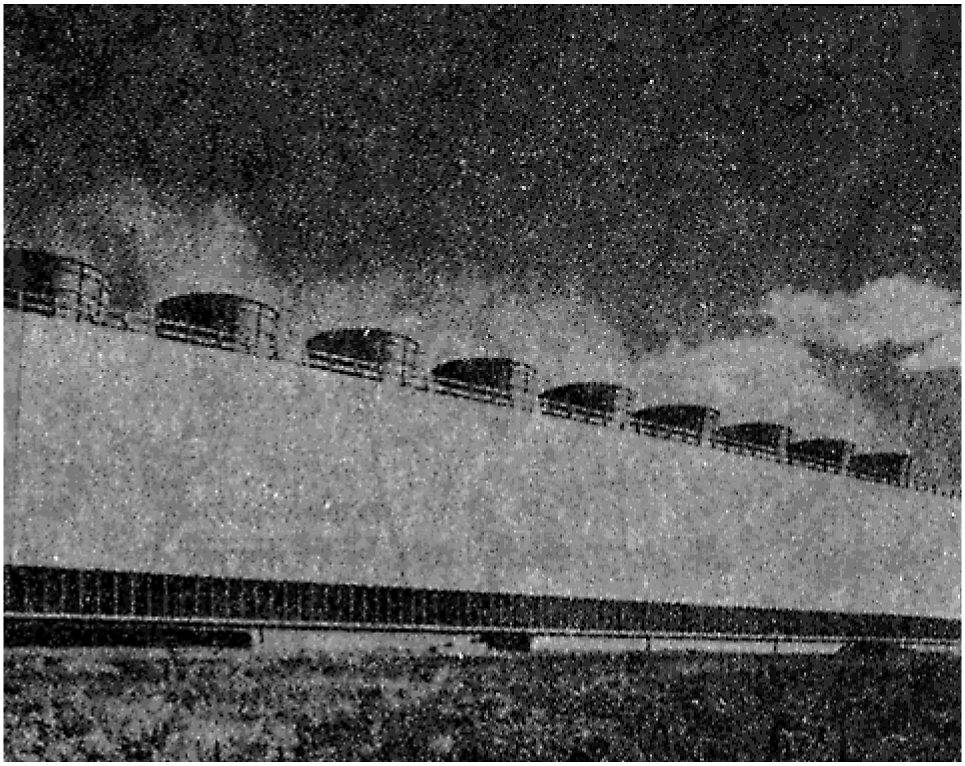


Figure B-4 Typical induced-draft counterflow water-cooling tower.

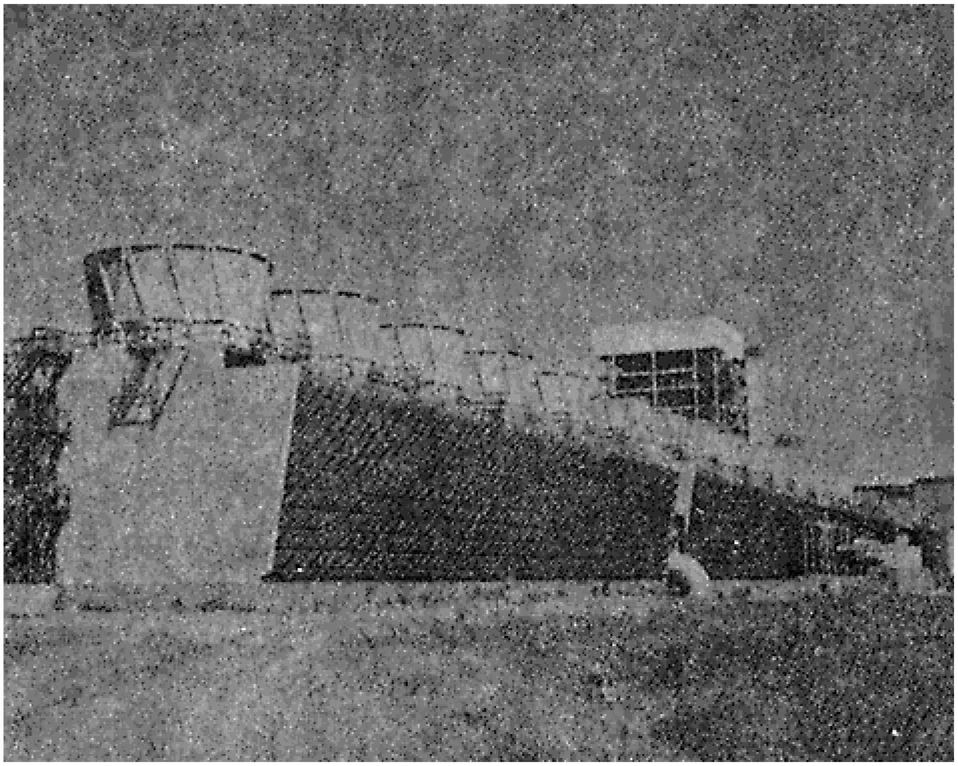


Figure B-5 Typical induced-draft crossflow water-cooling tower.

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*, 1996 edition.

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, 1995 edition.

C-1.2 Other Publications.

C-1.2.1 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, 1995 edition.

ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, 1994 edition.

NFPA 220

1995 Edition

Standard on Types of Building Construction

1995 Edition

This edition of NFPA 220, *Standard on Types of Building Construction*, 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 220 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 220

In 1952, the Committee on Building Construction secured tentative adoption of NFPA 220, *Standard Types of Building Construction*, at the NFPA Annual Meeting. At the 1954 NFPA Annual Meeting, revisions of the 1952 tentative text were adopted by the Association and, in 1955, minor revisions also were acted on favorably. A new definition of noncombustibility and editorial changes in the description of the fire resistance rating of structural members (under the definition of fire-resistive construction) were adopted at the 1956 NFPA Annual Meeting on the recommendation of the Committee on Building Construction.

In 1958, with the development of the use of plastics in building construction, recommendations on the types of standard fire tests to be used in evaluating the fire safety of these materials were adopted and inserted in the appendix.

In 1961, an appendix was adopted to furnish a guide to NFPA committees, regulatory officials, and others that addressed the classification of air-supported structures.

In 1975, a more fundamental definition of noncombustible was added, including the introduction of a definition of the term limited-combustible, based on potential heat value limitations and more generalized definitions for types of building construction.

In 1979, the standard was extensively rewritten to introduce the nomenclature related to construction Type I through Type V, which include parenthetically placed hourly fire resistance designations of the structural components.

The 1985 edition included the addition of a new Chapter 4, which provided referenced publications whose use is mandated within this standard.

The 1992 edition provided changes in technical terminology.

Further editorial changes have been made to the 1995 edition to increase its user-friendliness.

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Todd E. Schumann, Industrial Risk Insurers, IL
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Stephen V. Skalko, Portland Cement Assn., GA
(Alt. to J. J. Messersmith, Jr.)

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 220
Standard on
Types of Building Construction

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 D.

Chapter 1 General

1-1* Scope.

This standard defines types of building construction based on the combustibility and the fire resistance rating of a building’s structural elements. Fire walls; nonbearing exterior walls; nonbearing interior partitions; fire barrier walls; shaft enclosures; and openings in walls, partitions, floors, and roofs are not related to the types of building construction and are regulated by other standards and codes, where appropriate.

1-2 Purpose.

This standard provides definitions for standard types of building construction.

1-3 Guide to Classification of Types of Building Construction.

The types of construction include five basic types designated by Roman numerals as Type I, Type II, Type III, Type IV, and Type V. This system of designating types of construction also includes a specific breakdown of the types of construction through the use of Arabic numbers. These numbers follow the Roman numeral notation where identifying a type of construction (e.g., Type I-443, Type II-111, Type III-200).

The Arabic numbers following each basic type of construction (e.g., Type I, Type II) indicate the fire resistance rating requirements for certain structural elements as follows:

(a) *First Arabic Number:* Exterior bearing walls.

(b) *Second Arabic Number:* Columns, beams, girders, trusses and arches, supporting bearing walls, columns, or loads from more than one floor.

(c) *Third Arabic Number:* Floor construction.

Specific fire resistance requirements are found in Table 3-1.

Chapter 2 Definitions

2-1 Definitions.

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*.

Flame Spread Index.* A number obtained according to NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*.

Limited-Combustible. A building construction 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 (8141 kJ/kg), where tested in accordance with NFPA 259, *Standard Test Method for Potential Heat of Building Materials*, and complies with (a) or (b) below. Materials subject to increase in combustibility or flame spread index 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) that has a flame spread index not greater than 50.

(b) Materials, in the form and thickness used, other than as described in (a), having neither a flame spread index 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 index greater than 25 nor evidence of continued progressive combustion.

Noncombustible Material. A material that, in the form in which it is used and under the conditions anticipated, does 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 Degrees C*, shall be considered noncombustible materials.

Chapter 3 Types of 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	111	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 roofs 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 roofs 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 roofs 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	1½	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]

Those members that shall be permitted to be of approved combustible material.

[1] See A-3-1 (Table).
[2] "H" indicates heavy timber members; see text 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.

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.

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 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 259, *Standard Test Method for Potential Heat of Building Materials*, 1993 edition.

4-1.2 Other Publication.

4-1.2.1 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 Degrees C*, 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-1-1

It is necessary for the user to consider the influence of location, occupancy, exterior exposure, possibility of mechanical and physical damage to fire-resistant material, and other features that could impose additional requirements for safeguarding life and property, as commonly covered in building codes.

For information on the construction of fire walls and fire barrier walls, see NFPA 221, *Standard for Fire Walls and Fire Barrier Walls*. For the installation of opening protection, see NFPA 80, *Standard for Fire Doors and Fire Windows*, and NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*.

A-2-1

These definitions apply to the materials used in the construction of buildings but do not apply to furnishings, the contents of buildings, or the fire hazard evaluation of materials.

A-2-1 Fire Resistance Rating.

The fire resistance of building construction varies with the susceptibility to damage by fire of the building materials used and the degree of fire protection, if any, provided for the structural members. (*See also ASTM E119, Standard Test Method of Fire Tests of Building Construction, and UL 263, Standard for Safety Fire Tests of Building Construction and Materials*.)

A-2-1 Flame Spread Index.

Under the criteria of NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, the flame spread index 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. (*See also ASTM E84, Standard Test Method for Surface Burning Characteristics of Building Materials, and UL 723, Standard for Safety Test for Surface Burning Characteristics of Building Materials*.)

A-3-1 (Table) Requirements for fire resistance of exterior walls located in close proximity to property lines, other buildings, or exposures, the provision of spandrell wall sections, and the limitation or protection of wall openings are not related to type of construction. They might be specified in other standards and codes, where appropriate, and might be required in addition to the requirements of this standard for the type of construction.

A-3-4

The dimensions used for sawn and glued laminated lumber in Section 3-4 are nominal dimensions.

Appendix B Recommendations on Plastics in Building Codes and Standards

This Appendix is not a part of the requirements of this NFPA document but is included for

informational purposes only.

This appendix is prepared to furnish guidance to NFPA committees and for the drafting of provisions applying to plastics that might be permitted to be used in building codes.

Small-scale fire tests may provide misleading results for use in evaluating plastics for building materials. The exemption of plastics from recommendations on fire hazard characteristics specified by building codes and standards for other building materials should not be permitted.

The use of standard fire tests for all building materials, including plastics, is recommended, particularly those for fire resistance of structural assemblies (*see NFPA 251*, *Standard Methods of Fire Tests of Building Construction and Materials*) and those for surface flame spread and other features (*see NFPA 255, Standard Method of Test of Surface Burning Characteristics of Building Materials*).

Appendix C Potential Heat of Selected Building Materials

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

NOTE: See ASTM, *Proceedings.*

Material	**Thickness (in.)**	**Density (lb/ft^3)**	**Potential Heat, Weight Basis, (Btu/lb)**
1. Woods			
a. Douglas fir, untreated	$^3/_4$	38.0	8400
b. Douglas fir (retardant treatment “A”)	$^3/_4$	37.2	8290
c. Douglas fir (retardant treatment “B”)	$^3/_4$	47.2	7850
d. Douglas fir (retardant treatment “C”)	$^3/_4$	38.8	7050
e. Maple soft, untreated	1	39.5	7940
f. Hardboard, untreated	$^1/_4$	59.8	8530
2. Plastics			
a. Polystyrene, wall tile	0.075	65.4	17,420
b. Rigid, polyvinyl chloride, retardant treated	0.147	86.0	9290
c. Phenolic laminate	0.063	76.4	7740
d. Polycarbonate resin	$^1/_4$	78.7	13,330
3. Insulation			

a. Glass fiber, semirigid, no vapor barrier	1	3.0	3040
b. Rock wool batting, paper enclosure	3	2.4	1050
c. Roof insulation board	1	10.4	3380
d. Cork (reconstituted cork sheet)	$^1/_4$	14.8	11,110
e. Cellulose mineral board	2	47.8	2250
4. Concrete			
a. Cinder aggregate		93.0	3080
b. Slag aggregate		110.1	80
c. Shale aggregate		80.5	10
d. Calcareous gravel aggregate		133.1	-250
e. Siliceous gravel aggregate		166.8	- 40
5. Cement Board			
a. Asbestos cement board	$^3/_{16}$	117.0	80
b. Asbestos cement board + 20 mil paint	$^3/_{16}$	159.2	390
6. Gypsum			
a. $CaSO_4 \bullet H_2O$ hydrated neat gypsum	0.41	137.9	- 290
b. Perlite aggregate plaster, 21 percent aggregate	1	53.2	70
c. Sand aggregate plaster, 15 percent aggregate	1	101.8	- 50
d. Vermiculite aggregate plaster, 15 percent aggregate	1	51.2	- 90
e. Gypsum board “A”	$^3/_8$	50.5	760
f. Gypsum board “A” with paper removed	$^3/_8$	46.6	- 270
g. Gypsum board “A” + alkyd gloss paint	$^3/_8$	46.7	880
h. Gypsum board “B”	$^1/_2$	51.2	650
7. Lath			
a. Gypsum A	$^3/_8$	55.3	310
b. Metal diamond mesh	0.025	405	1230
c. Metal diamond mesh, paint removed	0.019	401	660

8. Metals			
a. Structural steel, unpainted	0.060	489	230
b. Magnesium	0.128	122	10,800
c. Aluminum	0.004	165	30
d. Brass	0.004	534	100
e. Copper	0.024	556	60
f. Lead	0.036	710	280
g. Zinc		415	760
9. Miscellaneous			
a. Paint "E" (dried paint film)	0.05		3640
b. Asphalt shingles (fireretardant)	$^1/_4$	70.7	8320
c. Building paper (asphalt-impregnated)	0.042	42.8	13,620
d. Building paper (rosin-sized)	0.018	23.6	7650
e. Linoleum tile	$^1/_8$	86.0	7760
f. Brick, red-face	$2^1/_4$	139.1	20
g. Charcoal, coconut			13,870

NOTE: All weights and percentages refer to original air-dry weight.

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 80, *Standard for Fire Doors and Fire Windows*, 1995 edition.

NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, 1993 edition.

NFPA 221, *Standard for Fire Walls and Fire Barrier Walls*, 1994 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.

D-1.2 Other Publications.

D-1.2.1 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM *Proceedings*, Vol. 61, 1961, pp. 1336-1348.

ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, 1991.

ASTM E119, *Standard Test Method of Fire Tests of Building Construction and Materials*, 1988.

D-1.2.2 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 263, *Standard for Safety Fire Tests of Building Construction and Materials*, Eleventh Edition, 1992.

UL 723, *Standard for Safety Test for Surface Burning Characteristics of Building Materials*, Seventh Edition, 1993.

Formal Interpretation

NFPA 220

Types of Building Construction

1995 Edition

Reference : Chapter 3

F.I. 75-11

Question: Is it the intent of NFPA 220, with respect to secondary roof elements, to prohibit the installation of skylights in secondary roof construction, regardless of the size of the skylight?

Answer: No. Regulation or control of skylights is outside the scope of NFPA 220. NFPA 220 is concerned with the structural integrity of building construction assemblies, including roofs, in order to define types of building construction; it is not, therefore, the intent of NFPA 220 to prohibit skylights of any size, provided said integrity is maintained. Other codes or standards may, however, place restrictions on the use and protection of skylights.

Issue Edition: 1975
Reference:– 3-1
Date: April 1978

NFPA 221

1994 Edition

Standard for Fire Walls and Fire Barrier Walls

1994 Edition

This edition of NFPA 221, *Standard for Fire Walls and Fire Barrier Walls*, 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 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 221

In 1991, the NFPA Technical Committee on Building Construction asked the Standards Council to consider approval of a new document on fire walls. This request was approved, and the committee developed NFPA 221, *Standard for Fire Walls and Fire Barrier Walls*.

Technical Committee on Building Construction

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Elaine B. Gall, VA State Fire Marshal’s Office, VA

Daniel F. Gemeny, Rolf Jensen & Assoc., Inc., CA

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Karl D. Houser, Gypsum Assn., DC

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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.

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 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., that are handled by other committees.)

NFPA 221
Standard for
Fire Walls and Fire Barrier Walls

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.

This standard specifies requirements for the design and construction of fire walls and fire barrier walls.

1-2 Purpose.

1-2.1

This standard prescribes minimum requirements for fire walls and fire barrier walls for use in providing safety to life and protection of property from fire. These requirements shall apply to walls that are required to separate buildings or subdivide a building to prevent the spread of fire.

1-2.2

Nothing in this standard is intended to prevent the use of alternate materials or devices, provided sufficient technical data is submitted to the authority having jurisdiction to demonstrate that the alternate method of construction or device provides equivalent strength and fire resistance.

1-3 Definitions.

Angle Walls. Exterior walls intersecting at angles of 135 degrees or less at the end of a fire wall.

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.

End Walls. Exterior walls intersecting at angles of more than 135 degrees at the end of a fire wall.

Fire Barrier Wall. A wall, other than a fire wall, having a fire resistance rating.

Fire Damper. A device, installed in an air distribution system, designed to close automatically upon detection of heat to interrupt migratory airflow and to restrict the passage of flame.

Fire Resistance Rating.* The time, in minutes or hours, that materials or assemblies have withstood a fire test exposure as established in accordance with the test procedures of NFPA 251, *Standard Methods of Fire Tests of Building Construction and Materials*.

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.

High Hazard Materials. Materials that are combustible or flammable liquids; flammable gases; and combustible dusts.

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.

Non-load-bearing Wall. A wall supporting only its own weight and no other vertical loads such as a floor or roof.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Chapter 2 Fire Walls

2-1 Types of Fire Walls.

Fire walls shall meet the requirements of Chapters 2, 4, 5, 6, and 7 and shall be:

(a) Cantilevered/freestanding fire walls; or

(b) Tied fire walls; or

(c) Double fire walls.

2-2 Structural Stability and Strength.

2-2.1

Fire walls shall be designed and constructed to remain stable after the collapse due to fire of the structure on either side of the wall. Fire walls constructed in compliance with the requirements of Section 2-3, 2-4, or 2-5 shall be deemed to provide the required stability.

2-2.2* Design Loads.

All fire walls and their supports shall be designed to withstand a minimum uniform load of 5 psf (0.24 kPa) from either direction applied perpendicular to the face of the wall. All fire walls shall be non-load-bearing. Structural framing within the plane of the wall shall be permitted to be load-bearing.

2-2.3*

Where the fire wall or fire protective covering of a structural member is subject to impact damage from moving vehicles or the handling of merchandise or other activity, protection against impact damage shall be provided for an appropriate height but not less than 5 ft (1.5 mm) from the finished floor.

2-3* Cantilevered/Freestanding Fire Walls.

Cantilevered or freestanding fire walls shall be entirely self-supported and non-load-bearing. There shall be no connections to the building(s) or contents on either side other than to the flashing. Such walls shall be erected where there is a complete break in the structural framework. The wall shall be secured to the foundation to resist overturning due to design loads.

2-4* Tied Fire Walls.

Tied fire walls shall be centered on a single column line or constructed between a double column line. Structural framing on either side of the wall shall line up horizontally and vertically and shall support the roof. The framework on each side of the fire wall shall be continuous or tied together through the wall. The framework on each side shall be designed so that it can resist the maximum lateral pull that can be developed due to framework collapse in a fire on the opposite side. Tied fire walls shall be laterally supported by the building framework with flexible anchors. Where centered on a single column line, structural framing (columns and beams or trusses) at the column line shall have a fire resistance rating of not less than the required fire resistance rating of the fire wall. Where the wall is installed between double column lines, framing along the first column line immediately on each side of the fire wall shall have a fire resistance rating of not less than the required fire resistance rating of the fire wall.

2-5* Double Fire Walls.

A double fire wall [*see Figure 2-5(a)*] consists of two back-to-back walls. There shall be no connections, other than to the flashing, between the walls. [*See Figures 2-5(b) and (c).*]

Each fire wall shall be laterally supported by the building frame on its respective side and shall be independent of the fire wall and framing on the opposite side.

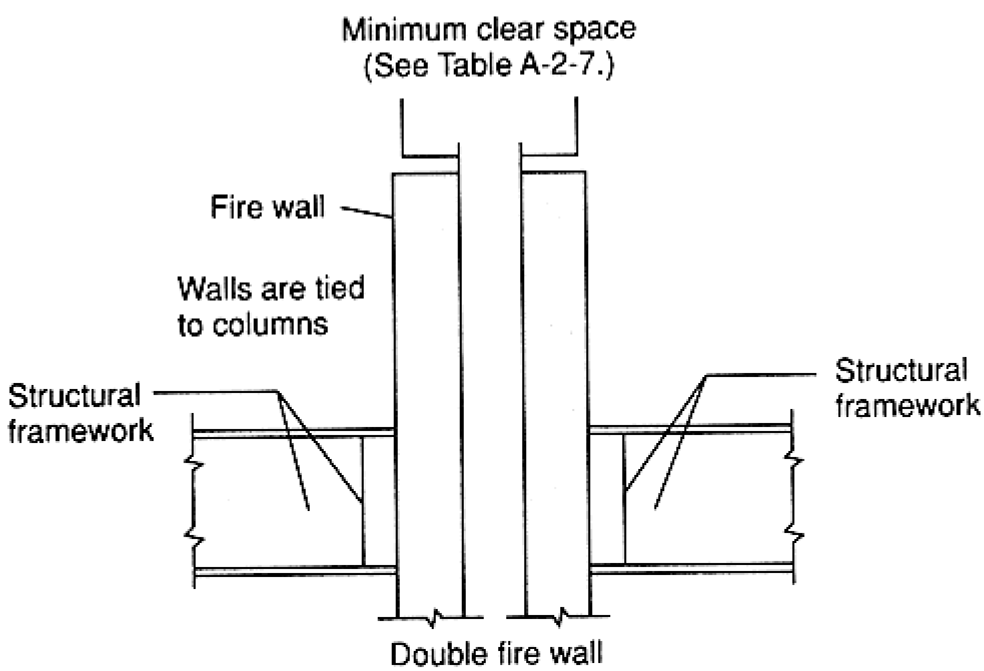

Figure 2-5(a) Double fire wall.

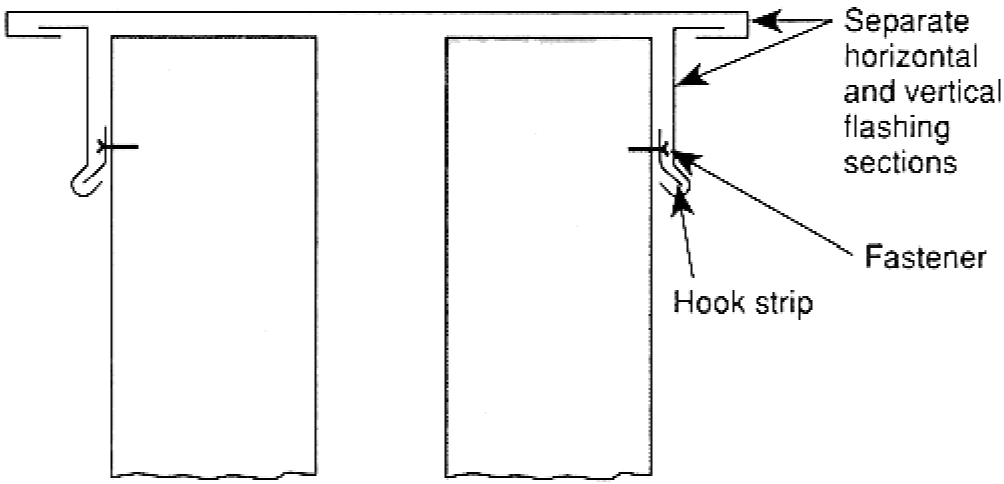

Figure 2-5(b) Double fire wall.

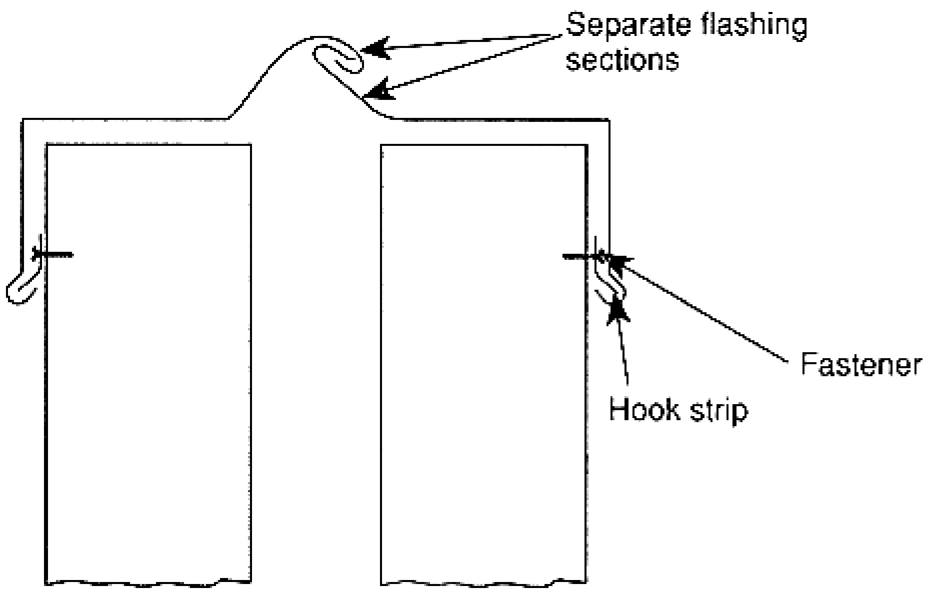

Figure 2-5(c) Double fire wall.

2-6 Fire Walls at Elevation Differences.

Where the roofs on opposite sides of a fire wall are not of the same elevation, the fire wall assembly shall be arranged in either of two ways:

(a) The two buildings shall be separated by a double fire wall; or

(b)* A cantilevered fire wall shall be constructed from the foundation to the top of the parapet for the lower roof. The upper wall section shall be permitted to have an exterior fire resistance rating of one hour less than the required fire resistance rating of the lower cantilevered portion but not less than a 2-hr rating. The upper wall shall be connected to the framework of the higher building and shall be structurally independent of the cantilevered wall.

2-7* Clearance.

Clearance to allow for expansion of unprotected structural framework shall be provided. This space shall be provided between cantilevered walls and structural framework on each side and between double walls.

2-8 Expansion, Seismic, and Control Joints.

Joints shall be provided to prevent cracking due to drying, shrinkage, or normal building temperature change. The integrity of the fire resistance rating of the wall shall be maintained by the protection of these joints. Protection for expansion and seismic joints shall be installed in accordance with tested design specifications.

Chapter 3 Fire Barrier Walls

3-1 Design Requirements.

A fire barrier wall shall meet the requirements of Chapter 3, Chapter 4, 5-1.1, and 6-2.1.

3-2 Termination Points.

A fire barrier wall shall extend from the foundation or floor below to the underside of the roof or floor deck above.

Exception: The fire barrier wall shall be permitted to terminate at the underside of an individually protected structural member in the same plane. The structural member shall have a fire resistance rating of not less than that required for the fire barrier wall and shall prevent the passage of flame and hot gases.*

3-2.1 Design Loads.

All fire barrier walls and their supports shall be designed to withstand a minimum uniform load of 5 psf (0.24 kPa) from either direction applied perpendicular to the face of the wall.

3-3 Expansion, Seismic, and Control Joints.

Joints shall be provided to prevent cracking due to drying, shrinkage or normal building temperature change. The integrity of the fire resistance rating of the wall shall be maintained by the protection of these joints. Protection for expansion and seismic joints shall be installed in accordance with tested design specifications.

Chapter 4 Fire Resistance

4-1* Wall Materials.

The fire resistance rating of the wall assembly shall be as required by the applicable code or standard. Assemblies shall be tested and rated in accordance with NFPA 251, *Standard Methods of Fire Tests of Building Construction and Materials*.

Exception: Assemblies calculated to have equivalent fire resistance shall be permitted, provided that the calculations are based on the conditions of acceptance and the fire exposure specified in NFPA 251, Standard Methods of Fire Tests of Building Construction and Materials.

4-2 Penetration Seals.

All through-penetration protection systems shall be tested and rated in accordance with ASTM E814, *Standard Test Method for Fire Tests of Through-Penetration Fire Stops*. The positive pressure difference between the exposed and unexposed surfaces of the test assembly shall not be less than 0.01 in. water gauge (2.5 Pa). A through-penetration protection system shall have an F rating (as defined by ASTM E814) not less than the required fire resistance rating of the fire wall or fire barrier wall.

Exception: Concrete, mortar, or grout shall be permitted with maximum 6-in. (153-mm) nominal diameter steel or copper pipe, or steel conduit. Concrete, mortar, or grout shall be the thickness required to maintain the required fire resistance rating of the wall being penetrated. The maximum opening size shall be 144 in.^{2} (0.094 m^2).

4-3 Double Wall Assemblies.

Double wall assemblies shall be considered to have a combined assembly fire rating as specified in Table 4-3.

Table 4-3 Fire Resistance Ratings for Double Wall Assemblies

Fire Resistance Rating of Each Wall of	Equivalent to Single Wall of
3 hr	4 hr
2 hr	3 hr
1 hr	2 hr

Chapter 5 Protection of Openings

5-1 General.

5-1.1

All openings in fire walls and fire barrier walls shall be protected in accordance with NFPA 80, *Standard for Fire Doors and Fire Windows*. The aggregate width of openings in each floor level shall not exceed 25 percent of the wall length.

5-1.2

Fire walls having a required fire resistance rating of 4 hr shall have each opening protected with two fire door assemblies, each having a minimum 3-hr fire resistance rating.

5-2* Double Fire Walls.

Openings in double fire walls shall be protected using one fire door in each separate wall or two fire doors in a freestanding, fire-resistive vestibule.

Chapter 6 Penetrations

6-1* Pipes, Conduit, and Cables.

Pipes, conduit, and cable trays (regardless of size) penetrating fire walls having a required 3-hr or greater fire resistance rating shall be positioned to pass through the wall no more than 3 ft (1.0 m) above the finished floor level. A steel sleeve of adequate size to allow an approximate 1-in. (25-mm) clearance between the sleeve and the pipe or conduit shall be provided for each pipe or conduit. The space between the sleeve and penetrating item (annular space) shall be filled as required in Section 4-2. Joint reinforcement shall be provided in the horizontal mortar joints immediately above and below sleeves in concrete masonry walls, and all hollow spaces of concrete masonry walls immediately adjacent to the sleeve shall be filled with concrete, mortar, or grout.

The center-to-center spacing between adjacent pipes or conduit shall be not less than three times the larger pipe or conduit outside diameter.

Exception: The limitation on the height of penetrations above the floor and other requirements of Section 6-1 shall not apply where the structural framework of the building has a fire resistance rating equal to or greater than the required fire resistance rating of the fire wall; only compliance with Section 4-2 shall be required.

6-2 Heating, Ventilating, and Air Conditioning Systems.

6-2.1

Fire dampers shall be installed and maintained in accordance with NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*.

6-2.2

Fire walls having a required fire resistance rating of 4 hr shall be protected with two minimum 3-hr rated fire damper assemblies.

6-2.2.1 One fire damper shall be provided in each wall assembly with a fire rating suitable for the respective wall of a double fire wall, and a slip joint connecting the sleeves between the walls shall be provided. The minimum fire resistance rating of each damper shall be $1^1/_2$ hr.

6-3* Piping or Ductwork for High Hazard Materials.

6-3.1

Piping or ductwork used to convey high hazard materials shall not penetrate fire walls that have a required fire resistance rating of 4 hr.

6-3.2

Piping or ductwork that penetrates fire walls with a required fire resistance rating of less than 4 hr used to convey high hazard materials shall be protected with approved devices or systems designed to terminate the flow or movement of the materials through the fire wall upon fire detection.

Chapter 7 Exterior Protection

7-1* Parapets.

Fire walls shall be provided with parapets at least 30 in. (0.76 m) high. The parapet height shall be measured from the top surface of the roof being protected. Roofs sloped greater than $^1/_4$ in. per ft (6 mm per 305 mm) downward toward the wall shall be provided with a minimum 36-in. (0.9-m) parapet.

7-2* Roof Surface Protection.

7-2.1

Built-up roofs shall be surfaced for at least 25 ft (7.6 m) on both sides of the fire wall with gravel or slag. The application rate shall be at least 4 lb/ft^2 (19 kg/m^2).

7-2.2

All single-ply membrane roof coverings shall be protected by noncombustible paver blocks or ASTM D448, *Standard Classification for Sizes of Aggregate for Road and Bridge Construction*, No. 3 [nominal 1-in. to 2-in. (2.54-cm to 5.08-cm) diameter] gravel ballast. Complete membrane coverage shall be provided at a rate not less than 10 lb/ft^2 (48.8 kg/m^2) for at least 25 ft (7.6 m) on both sides of the fire wall.

7-3* Roof-mounted Structures.

Combustible structures or equipment such as monitors, penthouses, or cooling towers not more than 20 ft (6.1 m) in height above roofs shall be located at least 50 ft (15.2 m) from fire walls required to have a fire resistance rating exceeding 2 hr. Roof-mounted structures over 20 ft (6.1 m) high shall be provided with a greater separation distance acceptable to the authority having jurisdiction.

7-4 Roof Penetrations.

Heat and smoke vents, skylights, and unprotected roof penetrations for air-handling equipment or smoke control systems shall be located at least 25 ft (7.6 m) from fire walls requiring a fire resistance rating of more than 2 hr and at least 4 ft (1.3 m) from fire walls requiring a fire resistance rating of 2 hr or less.

7-5* End Walls.

The length and arrangement of end walls shall be in accordance with Table 7-5 and Figure 7-5(a) or (b). The fire resistance rating of the end walls shall be from the outside and shall be a minimum of 1 hr but shall be not more than two hours less than that of the fire wall.

Table 7-5 Length of End Wall Protection*

Height of Exposing Area [ft (m)]	Length of End Wall Protection* [ft (m)]

Up to 40 (12.2)	6 (1.8)
41 to 70 (21.3)	10 (3.1)
71 (21.6) and over	14 (4.3)

* Protection shall consist of blank, fire-rated construction.

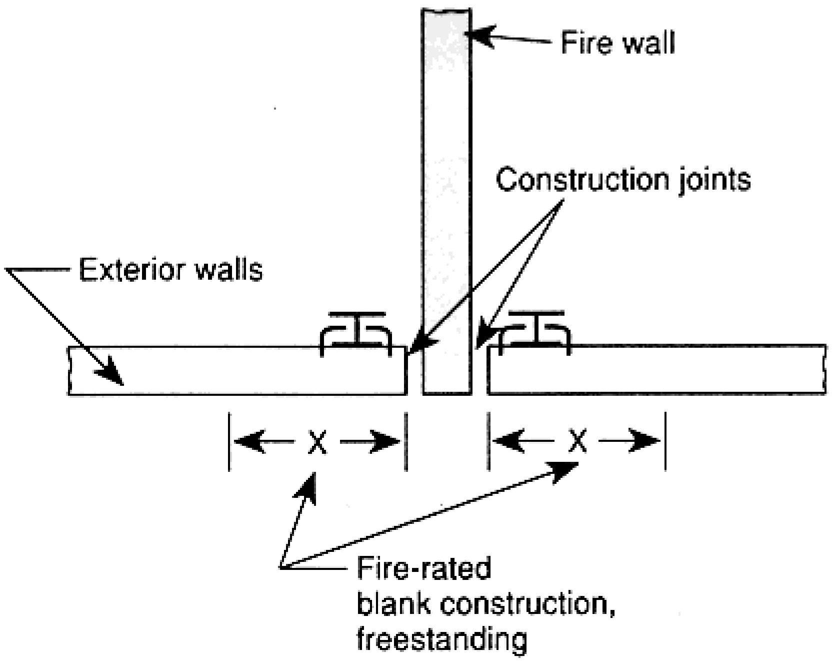

Figure 7-5(a) End wall exposure protection — end walls tied to structural framing.

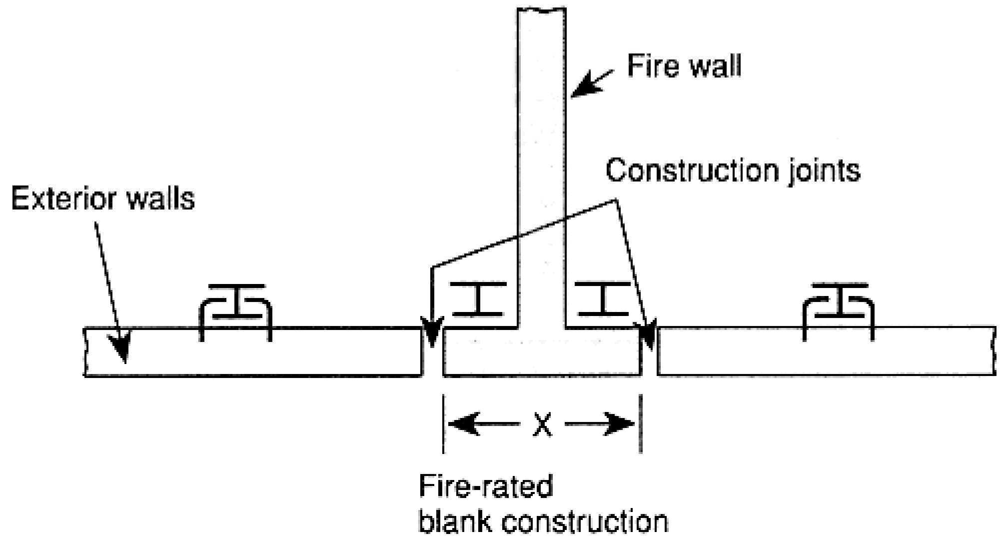

Figure 7-5(b) End wall exposure protection — end walls not tied to structural framing.

7-6 Angle Walls.

The length of fire-resistive angle walls, Y, [*see Figure 7-6(a)*] shall be 20 ft to 35 ft (6.1 m to 10.7 m), depending on the severity of exposure (*see Table 7-6*). The fire resistance rating of the angle walls shall be from the outside and shall be not more than one hour less than that of the fire wall. In addition, construction of each wall and eave shall be noncombustible beyond the fire-resistive construction for the minimum distances outlined in Table 7-6.

Elevation differences perpendicular to fire walls shall be protected as angle walls. [*See Figure 7-6(a)*.]

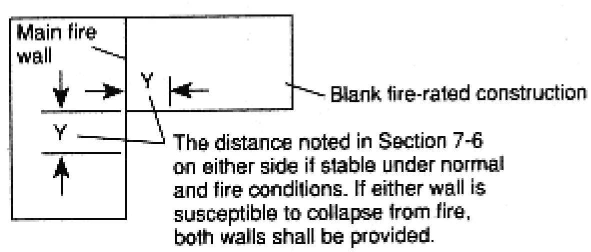

Figure 7-6(a) Angular wall exposure protection.

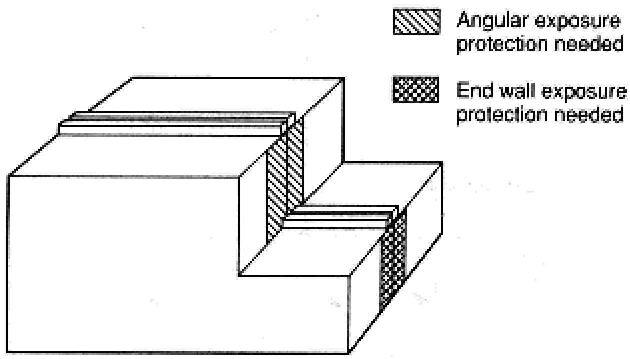

Figure 7-6(b) Exterior wall protection.

Table 7-6 Angle Wall Protection

Occupancy Hazard*	Length of Fire-resistive Angle Walls [ft (m)]	Length of Noncombustible Construction Beyond Fire-resistive Construction [ft (m)]
Light	20 (6.1)	60 (18.3)
Ordinary Group 1	30 (9.1)	75 (22.9)
Ordinary Group 2	35 (10.7)	100 (30.5)
Extra Group 1 and 2		

* As defined in NFPA 13, *Standard for the Installation of Sprinkler Systems*.

7-7 Railroad Sidings and Truck Docks.

Railroad sidings parallel to end walls and truck dock openings shall not be located within 20 ft (6.1 m) on either side of a fire wall.

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 13, *Standard for the Installation of Sprinkler Systems*, 1994 edition.

NFPA 80, *Standard for Fire Doors and Fire Windows*, 1992 edition.

NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, 1993 edition.

NFPA 251, *Standard Methods of Fire Tests of Building Construction and Materials*, 1990 edition.

8-1.2 Other Publications.

8-1.2.1 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM D448, *Standard Classification for Sizes of Aggregate for Road and Bridge Construction*, 1986.

ASTM E814, *Standard Test Method for Fire Tests of Through-Penetration Fire Stops*, 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-1-3 Fire Resistance Rating.

ASTM E119, *Standard Test Methods for Fire Tests of Building Construction and Materials*, and UL 263, *Fire Tests of Building Construction and Materials*, are similar to NFPA 251, *Standard Methods of Fire Tests of Building Construction and Materials*.

A-2-2.2

Other loads, such as seismic loads or interior pressure differences due to wind, can govern and should be considered in accordance with local code requirements. Parapets should be designed for wind loads, including appropriate pressure coefficients.

A-2-2.3

Where the potential exists for the collapse of building materials or contents or the impact of vehicles on a fire wall requiring a fire resistance rating of 4 hr, the fire wall should be constructed of materials that are of adequate strength.

A-2-3

Walls intended to be used as cantilever fire walls in the future and used as temporary exterior walls will be vulnerable to wind damage. Such walls should be designed to resist required wind loads. If the future cantilevered wall is temporarily fastened to the building frame until the additional building is built, care should be taken to ensure that all ties to the wall are fully cut when new construction is completed.

A-2-4

Tied fire walls [*see Figure A-2-4(a)*] are fastened to and usually encase members of the structural frame of the building. To remain stable, the pull of the collapsing structural members on the fire side of the wall must be resisted by the strength of the structure on the other side.

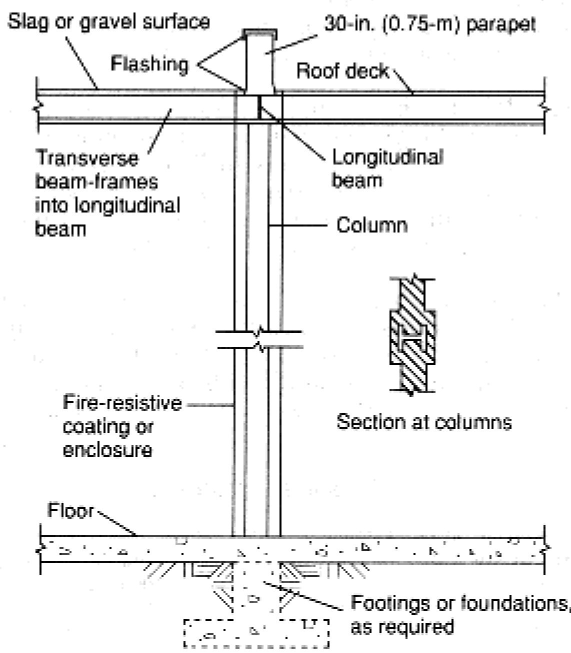

Figure A-2-4(a) Typical tied fire wall used with continuous building framework.

Since a fire can occur on either side of the wall, the wall preferably should be located at the center of strength of the building frame. The center of strength is the plane within the building frame in which the structural framing on either side has equal resistance. In small structures, the center of strength generally is in the middle of the building [*see Figure A-2-4(b)*]. In large buildings, the center of strength might lie midway between two double-column expansion joints [*see Figures A-2-4(c) and (d)*]. Single-column line expansion joints utilizing beams with slotted connections do not break the continuity of the building frame. [*See Figure A-2-4(e)*.]

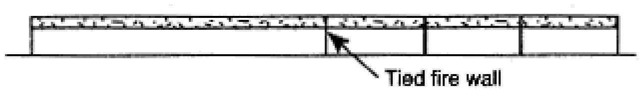

Figure A-2-4(b) A tied wall at the center of a continuous steel frame. The pull from collapsing steel on either side must be resisted by the lateral strength of steel on the other side.

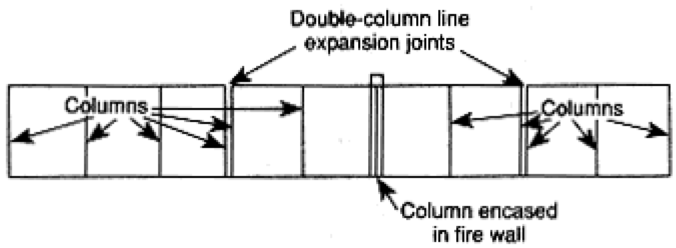

Figure A-2-4(c) Tied wall where framing is not continuous throughout the building.

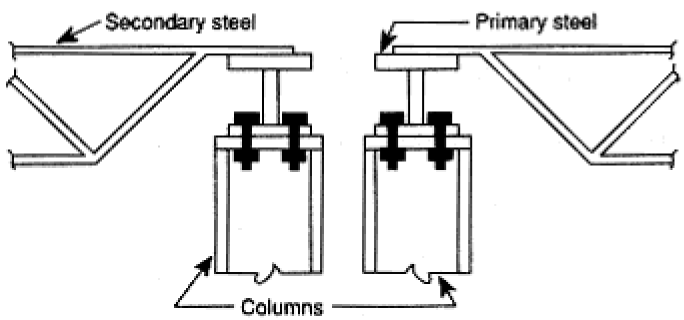

Figure A-2-4(d) Double-column line expansion joint.

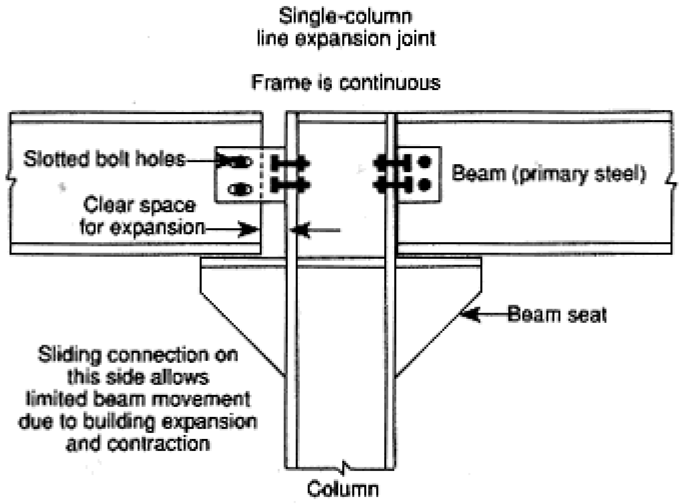

Figure A-2-4(e) Single-column line expansion joint frame is continuous.

Bolts with nuts and washers may be permitted to be used to tie framework across a double-column line. In order to prevent the defeat of the purpose of the expansion joint created by the double-column line, nuts should be backed off slightly about $^{3}/_{4}$ in. (19 mm). Where the primary roof framing is perpendicular to the fire wall, two bolts should tie the roof framing together over each column to provide concentric load distribution. Where the primary roof framing is parallel to the fire wall, single bolts may be permitted to be used; however, intermediate ties might be needed between column lines. A registered civil or structural engineer should be consulted to provide more exact details. [*See Figures A-2-4(f) and (g)*.]

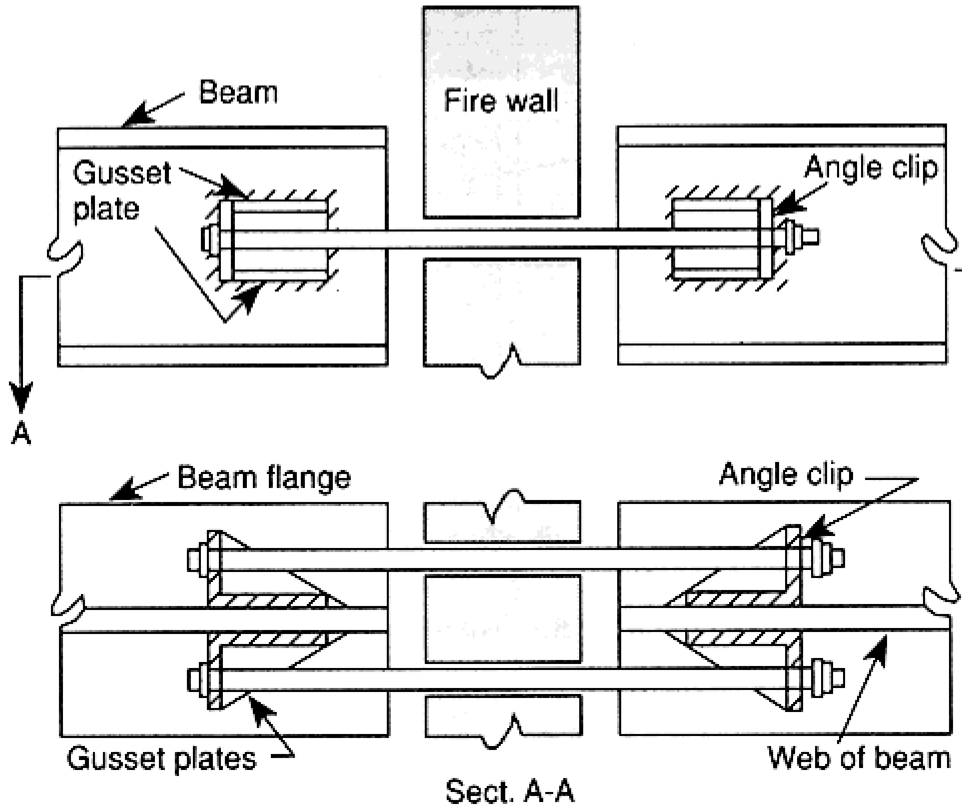

Figure A-2-4(f) Through-wall tie — primary roof framing perpendicular to wall.

NOTE: Columns are needed but not illustrated.

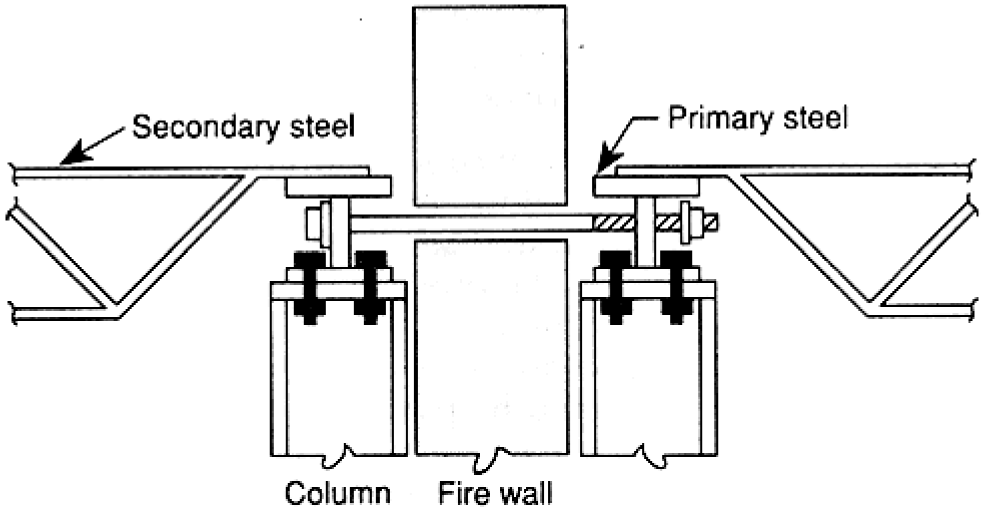

Figure A-2-4(g) Through-wall tie — primary steel parallel to fire wall.

If the wall is not located at the center of strength, the lateral resistance of the frame on either side of the wall should be sufficient to resist the maximum horizontal component of the force that could result from collapsing structural framework on the opposite side. The horizontal force at each tie should be computed by using the formula following Figure A-2-4(h).

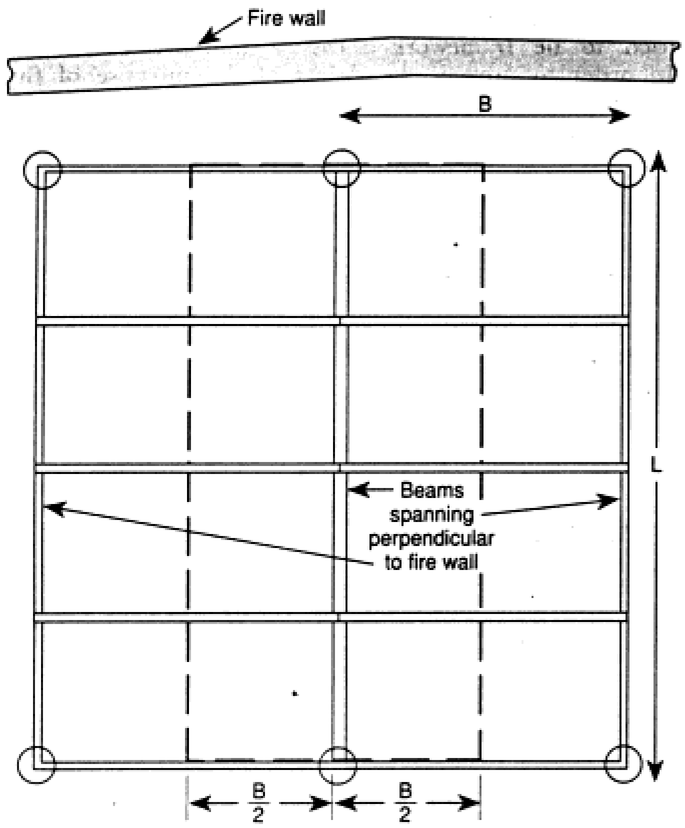

Figure A-2-4(h) Tied fire wall with ties at each beam.

$$H = \frac{wBL^2}{8S}$$

where:

H = Horizontal pull per tie [lb (kg)].
w = Dead load plus 25 percent of the live load of the roof [lb/ft^2 (kg/m^2)].
L = Span of the structural member running perpendicular to the wall [ft (m)].
B = Distance between ties [ft (m)].
S = Sag in ft (m) that may be assumed as:
0.07L for open-web trusses.
0.09L for solid beams.
0.06L for wood trusses.

A-2-5

Where there is an uncontrolled fire on either side of a double wall, one building frame will collapse, pulling the wall on that side with it. The other wall, supported by structural framework on the protected side, will remain in place to stop the spread of fire.

Since there should be no connections between the walls, particular attention should be paid to the details at openings in the walls.

A double fire wall is most adaptable where an addition to a plant requires a fire wall between an existing structure and a new building. The existing wall, which is secured to the building frame, is altered, if necessary, to provide the proper fire resistance. Another fire wall is then constructed adjacent to the existing one and secured to the new building frame.

A-2-6(b) The exterior fire-rated wall above the cantilevered wall should not overlap the cantilevered wall on the side of the lower building. It may be permitted to be installed above the cantilevered wall or overlap the cantilevered wall on the side of the higher building [*see Figures A-2-6(a) and (b)*]. In either case, the integrity of the fire resistance rating of the fire wall should be maintained by protecting the joint between the cantilevered wall and the exterior fire wall attached to the higher building. In some cases, the parapet may be permitted to be omitted from the higher wall only; however, such a judgment should consider the severity of exposure from the occupancy in the lower building and the elevation difference between the exposure and the top of the higher wall.

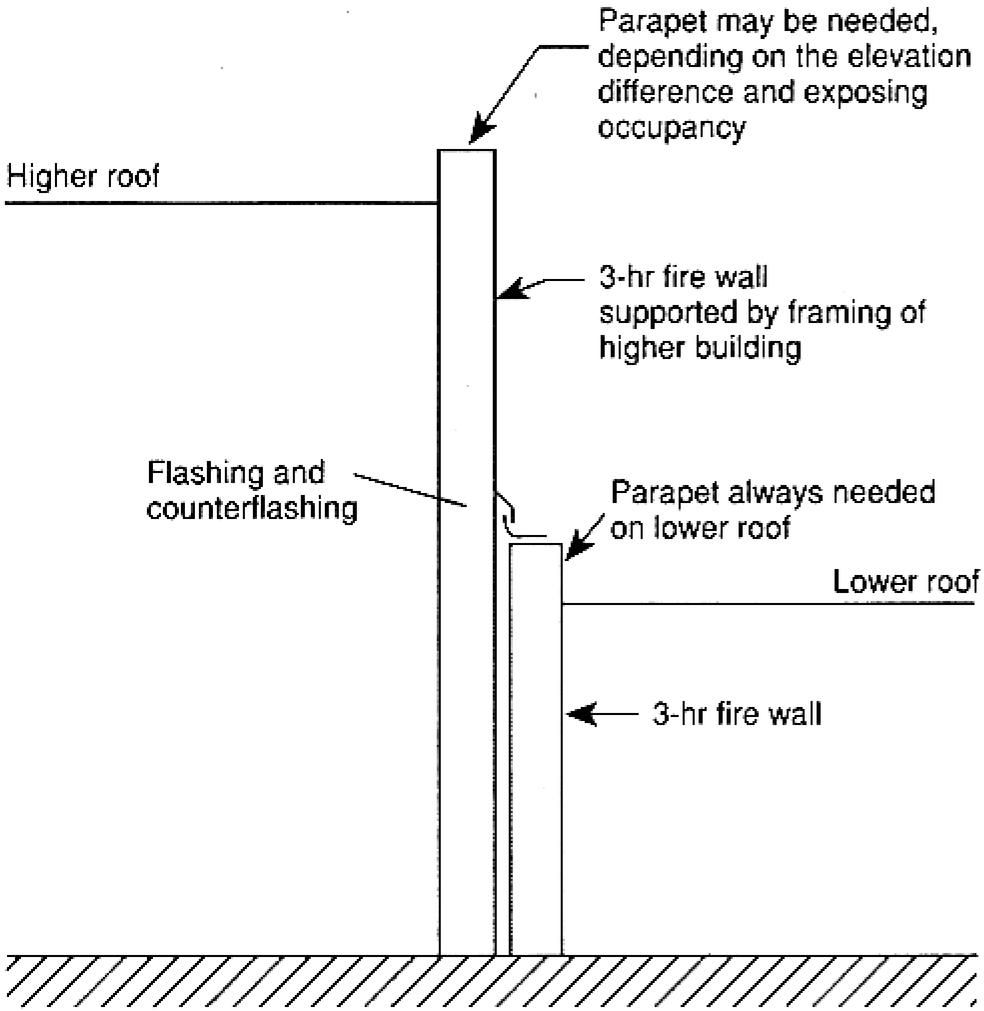

Figure A-2-6(a) Fire wall arrangement at elevation difference (double wall).

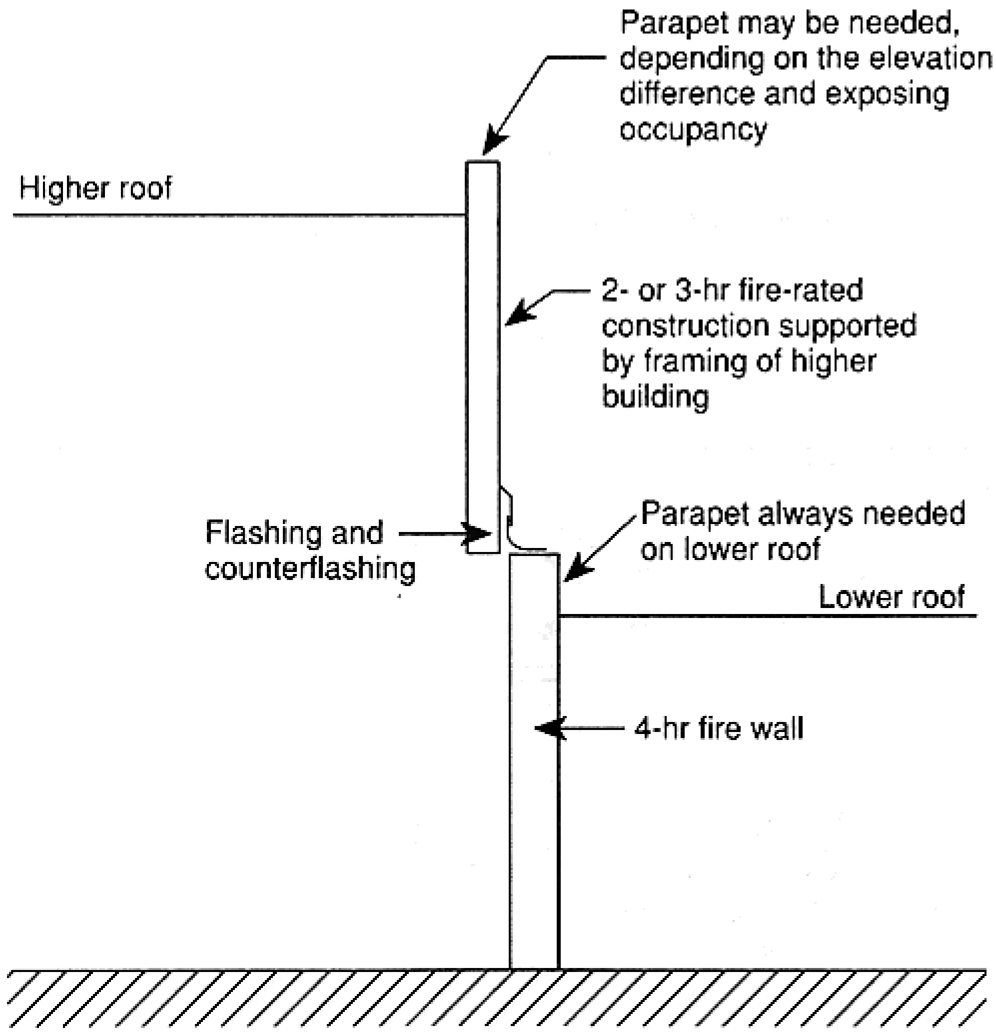

Figure A-2-6(b) Fire wall arrangement at elevation difference (cantilever wall).

A-2-7

Adequate clearance should be provided between storage and fire walls to prevent damage to the wall that might result from swelling of absorbent materials due to contact with water.

In areas of moderate and high seismic risk, sufficient separation should be provided as follows:

(a) Between cantilevered walls and adjacent framing on each side;

(b) Between double walls;

(c) Between one-way walls and building framework to which they are not tied.

This allows independent movement of the elements without contact.

Table A-2-7 Minimum Recommended Clearance Between Unprotected Structural Framework and Fire Walls, or Between

Double Fire Walls

Length of Bay Perpendicular to the Fire Wall		Minimum Clearance Between Wall and Structural Framework, and Between Double Walls	
(ft)	(m)	(in.)	(cm)
20	(6.1)	$2^1/_2$	(6.4)
25	(7.6)	$3^1/_4$	(8.3)
30	(9.1)	$3^3/_4$	(9.5)
35	(10.7)	$4^1/_2$	(11.4)
40	(12.2)	5	(12.7)
45	(13.7)	$5^3/_4$	(14.6)
50	(15.2)	$6^1/_4$	(15.9)
55	(16.8)	7	(17.8)
60 or longer	(18.3)	$7^1/_2$	(19.1)

Table A-2-7 is based on steel framework. This table provides clearances that are conservative for other types of framework materials. This table is based on an average temperature of 800°F (427°C) in two adjacent bays. [Source: FMRC DS 1-22, *Criteria for Maximum Foreseeable Loss Fire Walls and Space Separations*.]

A-3-2 Exception.

The fire resistance rating of the fire barrier wall is based on specific criteria in NFPA 251, *Standard Methods of Fire Tests of Building Construction and Materials*. It is based on both structural stability under the fire and hose stream tests and criteria for temperature transmission through the wall that are designed to prevent ignition of combustible materials on the unexposed side of the wall. The exception recognizes that fire barrier walls may be permitted to terminate at the underside of an individually protected structural member that has the same fire resistance rating as the wall. In the case where the fire resistance rating for the structural member is the same as that for the wall, no additional temperature transmission criteria to prevent ignition of combustible materials is needed.

However, in the event that the structural member does not have a solid web or solid surface along its length for the full height of the structural member, such as an open-web member, the fire protective covering for the structural member must be continuous for the full height of the structural member to prevent the passage of flame and hot gases over the top of the fire barrier wall.

A-4-1

Methods for calculating the fire endurance of assemblies can be found in the following publications:

(a) Concrete and Masonry.

ACI 216R, *Guide for Determining the Fire Endurance of Concrete Elements*.

Concrete and Masonry Industry Firesafety Committee, *Analytical Methods of Determining Fire Endurance of Concrete and Masonry Members — Model Code Approved Procedures*.

CRSI, *Reinforced Concrete Fire Resistance*.

PCI, *Design for Fire Resistance of Precast Prestressed Concrete*.

(b) Steel.

AISI, *Designing Fire Protection for Steel Columns*.

AISI, *Designing Fire Protection for Steel Beams*.

AISI, *Designing Fire Protection for Steel Trusses*.

(c) Wood.

National Forest Products Assn., *Design of Fire-Resistive Exposed Wood Members*.

UBC, *Methods for Calculating Fire Resistance of Wood-Framed Walls, Floors and Roofs*.

A-5-2

An example of an arrangement where the alternative of providing two fire doors on a freestanding, fire-resistive vestibule is used, and the opening is not used as part of the means of egress, is shown in Figure A-5-2. Where this alternative is used and the opening is used for egress, the vestibule should be long enough to allow both doors to swing in the same direction and open completely.

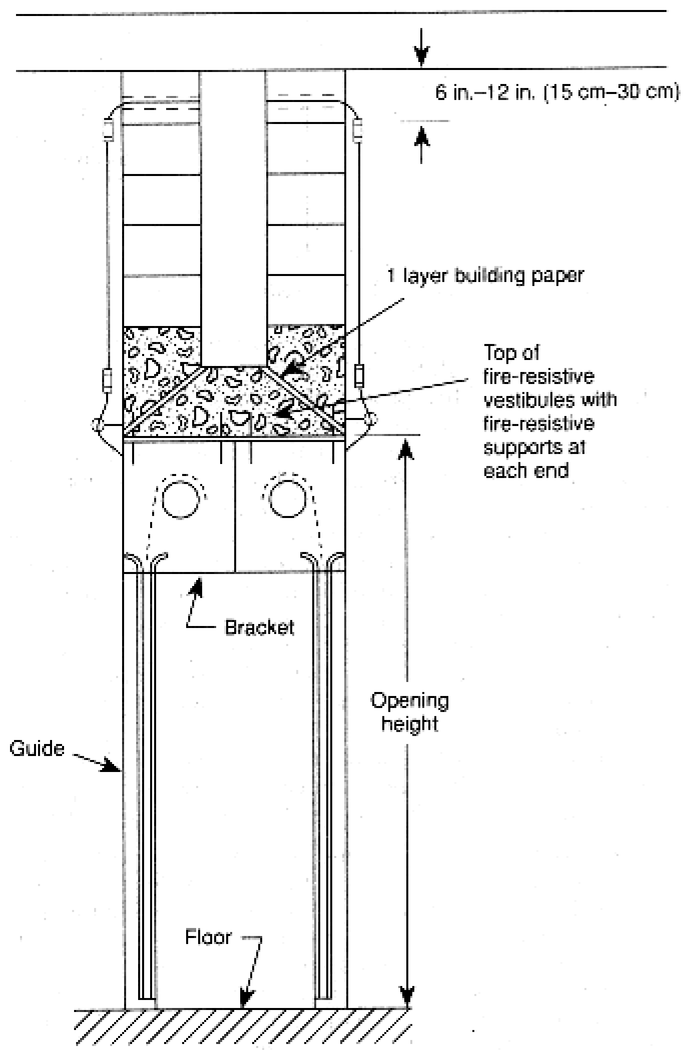

Figure A-5-2 Double doors on a freestanding vestibule.

A-6-1 Location of Combustibles.

Combustibles should be kept at least 1 ft (0.3 m) away from pipes, ducts, plates, and conduit where they penetrate the wall. Alternatively, a penetration seal with a T rating (as defined by ASTM E814, *Standard Test Method for Fire Tests of Through-Penetration Fire Stops*) of not less than 1 hr should be provided.

Mechanical connections, such as double-threaded elbows (*see Figure A-6-1*) or flexible braided steel pipe that are acceptable to the authority having jurisdiction and that will limit stress on the wall should be considered.

Steel-faced fire walls with gypsum board core or gypsum board on stud fire walls should be provided with a concrete stanchion where pipe, conduit, or cables penetrate fire walls with a required fire resistance rating of 4 hr.

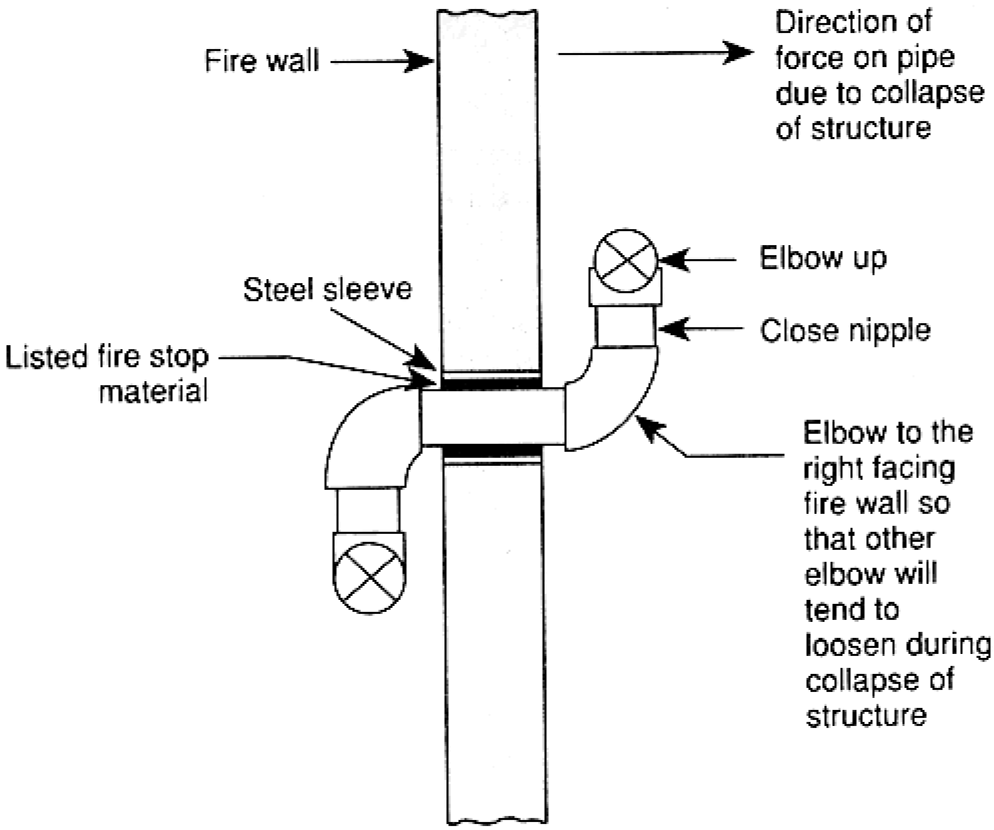

Figure A-6-1 Pipe penetration.

A-6-3

High hazard materials transported by piping or ductwork passing through fire walls have been shown to be a significant avenue of fire propagation across the fire wall and should be avoided. Where necessary for these systems to penetrate a fire wall with a fire resistance rating of less than 4 hr, the flow of the high hazard materials must be interrupted or otherwise protected by engineered devices or systems specifically designed for such purpose and approved by the authority having jurisdiction. Devices that may be permitted to be used for this protection include, but are not limited to, excess-flow valves and fire-safe shutoff valves, pneumatic knife or gate dampers, blower/vacuum shutdown devices, or encapsulation of the piping or ductwork and its supports with material having a fire resistance rating at least equal to that required of the fire wall.

Combustible and flammable materials include flammable gases and combustible and flammable liquids used in piping systems and combustible dusts used in air conveying systems.

A-7-1

Where a higher building or higher portion of a building adjoins a lower building at a fire wall, the lower building should always have a minimum 30-in. (9.76-m) high parapet. A parapet may be permitted to be omitted on the higher building if there is at least a 15-ft to 50-ft (4.6-m to 15.2-m) elevation difference, depending on the severity of the fire exposure from the lower building. Also, see NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures,* Table 2-4. Where the parapet is not needed, the exterior fire-rated wall construction should extend at least up to the gravel stop. Gravel surfacing or equivalent is still recommended for at least 25 ft (7.6 m) from the fire wall in each direction on the higher and lower roof.

A-7-2

For existing construction where the roof strength is not adequate to support gravel surfacing, the roof should be structurally reinforced to support the gravel. As an alternative, or for new or existing construction where the roof slope is excessive for gravel, the roof should be coated with an approved, lightweight, exterior grade, fire-resistant coating.

For single-ply roofs, where the roof is not adequate to support the specified weight of the ballast stone or paver blocks, it should be similarly reinforced, or the top surface of the roof should be protected with an approved coating as described previously if the roof membrane is totally adhered. Mechanically-attached, single-ply roof covers normally flex between fasteners, which could cause cracking of a coating.

A-7-3

Where required separation is not practical, a minimum of 25 ft (7.6 m) of separation should be provided, and fire-rated barriers should be constructed on the exposed side of the roof projection. The fire resistance rating should be a minimum of 2 hr if a 4-hr fire wall is required and 1 hr where fire walls of 3 hr or less are required.

A-7-5

An example of such an end wall configuration is a 4-hr fire wall with 2-hr end walls.

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 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*, 1993 edition.

NFPA 251, *Standard Methods of Fire Tests of Building Construction and Materials*, 1990 edition.

B-1.2 Other Publications.

B-1.2.1 ACI Publication. American Concrete Institute, 22400 W. Seven Mile Road, Box 19150, Redford Station, Detroit, MI 48219.

ACI 216R, *Guide for Determining the Fire Endurance of Concrete Elements*, 1989.

B-1.2.2 AISI Publications. American Iron and Steel Institute, 1133 15th Street NW, Suite 300, Washington, DC 20005.

Designing Fire Protection for Steel Columns, 1980.

Designing Fire Protection for Steel Beams, 1984.

Designing Fire Protection for Steel Trusses, 1981.

B-1.2.3 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM E119, *Standard Test Methods for Fire Tests of Building Construction and Materials*, 1988.

ASTM E152, *Standard Methods of Fire Tests of Door Assemblies*, 1981.

ASTM E814, *Standard Test Method for Fire Tests of Through-Penetration Fire Stops*, 1988.

B-1.2.4 Concrete and Masonry Industry Firesafety Committee, 5420 Old Orchard Road, Skokie, IL 60077-1083.

Document No. SR267, *Analytical Methods of Determining Fire Endurance of Concrete and Masonry Members — Model Code Approval Procedures*.

B-1.2.5 CRSI Publication. Concrete Reinforcing Steel Institute, 933 Plum Grove Road, Schaumburg, IL 60173.

Reinforced Concrete Fire Resistance, 1980.

B-1.2.6 FMRC Publications. Factory Mutual Research Corporation, 1151 Boston-Providence Turnpike, Norwood, MA 02061-9102.

Approval Guide, 1977.

Data Sheet 1-21, *Fire Resistance of Building Assemblies*, 1977.

Data Sheet 1-22, *Criteria for Maximum Forseeable Loss Fire Walls and Space Separations*, 1993.

Data Sheet 1-23, *Protection of Openings*, 1976.

Specification Tested Products Guide.

B-1.2.7 GA Publications. Gypsum Association, 810 First Street, NE, Suite 510, Washington, DC 20002.

GA 219, *Recommendations for Installation of Steel Fire Door Frames in Steel Stud-Gypsum Board Fire-Rated Partitions*, 1989.

GA 600, *Fire Resistance Design Manual*, 1992.

B-1.2.8 IRI Information Publications. Industrial Risk Insurers, 85 Woodland Street, Hartford, CT 06102.

IRI Information IM.2.2.1, *Fire Walls, Fire Barriers and Fire Partitions*, 1992.

IRI Information IM.2.2.2, *Fire Doors and Through-Penetration Protection*, 1991.

B-1.2.9 National Forest Products Association Publication. National Forest Products

Association, 1250 Connecticut Avenue, NW, Suite 200, Washington, DC 20036.

Design of Fire-Resistive Exposed Wood Members, 1985.

B-1.2.10 PCI Publication. Precast Prestressed Concrete Institute, 175 West Jackson Boulevard, Chicago, IL 60604.

Design for Fire Resistance of Precast Prestressed Concrete, 1989.

B-1.2.11 UBC Publication. Uniform Building Code, 5360 South Workman Mill Road, Whittier, CA 90601.

Methods for Calculating Fire Resistance of Wood-Framed Walls, Floors and Roofs.

B-1.2.12 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 10B, *Fire Tests of Door Assemblies*, 1993.

UL 263, *Fire Tests of Building Construction and Materials*, 1992.

UL 1479, *Fire Tests of Through-Penetration Firestops*, 1993.

Fire Resistance Directory, Vol. I, 1993.

Fire Resistance Directory, *Vol. II*, 1993.

B-1.2.13 Warnock Hersey, 8431 Murphy Drive, Middleton, WI 53562.

Listings, 1993 Certification.

NFPA 231

1995 Edition

Standard for General Storage

1995 Edition

This edition of NFPA 231, *Standard for General Storage*, was prepared by the Technical Committee on General Storage 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.

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 231

In 1943, the U.S. War Production Board promulgated *General Storage Specifications for Critical-Strategic Materials*. These were based largely on existing NFPA standards and upon generally accepted good practice in fire protection. They were published for convenient reference in NFPA *National Fire Codes for Building Construction and Equipment* in 1944, and an NFPA Committee on General Storage was appointed that same year. On the recommendation of that committee, a general storage standard was adopted at the NFPA Annual Meeting in 1946. This covered both indoor and outdoor storage. A revision of the standard was tentatively adopted in 1953.

In 1955, the committee presented a draft of a new document, *Recommended Safe Practices for General Storage*, No. 231-T, covering indoor storage, outdoor storage, and refrigerated warehouses. This was tentatively adopted, leaving the 1946 general storage standard still official. With a few amendments, NFPA 231, *Recommended Safe Practices for General Storage*, was adopted in 1956.

In 1965, the document was changed from a recommended practice to a standard, and the current title was introduced. The sections of the 1965 edition pertaining to outdoor storage and refrigerated warehouses were deleted, and an appendix on pallets and palletized storage was added.

In the 1970 edition, amendments included doubling the maximum recommended area for Type I and Type II storage, placing height limitations on empty wooden pallet storage, and reducing the water requirements for Type II storage.

In 1972, protection requirements for empty combustible pallets and design curves for sprinkler water demands were added.

In 1974, the height of storage to which this standard applies was increased from 25 ft (7.6 m) to 30 ft (9.1 m).

The standard was partially revised in 1979, and again in 1985.

The 1987 edition incorporated minor revisions and superseded the 1985 edition.

The 1990 edition of the standard was modified to include the requirements of Early Suppression Fast Response (ESFR) Sprinklers. In addition, Chapter 6 was modified to include encapsulated commodities up to 15 ft (4.6 m).

This 1995 edition of the standard was revised to include recent developments with regard to miscellaneous storage, extra-large orifice sprinklers, large drop sprinklers, and ESFR sprinklers. Efforts were made to increase the user friendliness of the document throughout. However, Chapters 6 and 7 underwent significant modification.

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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.

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 safeguarding general warehousing and commodities stored indoors or outdoors against fire. Storage specifically covered by other NFPA standards is not within the scope of this committee.

NFPA 231

Standard for General Storage

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 11 and Appendix D.

Chapter 1 Introduction

1-1 Scope.

1-1.1

This standard shall apply to the storage of materials representing the broad range of combustibles, including plastics that are stored palletized, solid-piled, in bin boxes, or on shelves.

Exception: Miscellaneous storage shall be permitted to be protected in accordance with NFPA 13, Standard for the Installation of Sprinkler Systems.

1-1.2 Outdoor Storage of a Broad Range of Combustibles.

(*See Appendix C.*)

1-1.3

This standard shall not apply to:

(a) Unsprinklered buildings.

(b) Storage of commodities that, with their packaging and storage aids, would be classified as noncombustible.

(c) Unpackaged bulk materials such as grain, coal, or similar commodities.

(d) Inside or outside storage of commodities covered by other NFPA standards, except where specifically mentioned herein (e.g., pyroxylin plastics.)

(e) Storage on racks.

1-1.4

Nothing in this standard is intended to restrict new technologies or alternate arrangements, provided the level of safety prescribed by the standard is not reduced.

1-2 Retroactivity Clause.

The provisions of this document shall be 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.

1-3 Definitions.

Unless expressly stated elsewhere, for the purpose of this standard, the terms in this section shall be defined as follows:

Array.

Closed Array. A storage arrangement where air movement through the pile is restricted because of 6 in. (152 mm) or less vertical flues.

Open Array.* A storage arrangement where air movement through the pile is enhanced because of vertical flues larger than 6 in. (152 mm).

Available Height for Storage.* The maximum height at which commodities can be stored above the floor and still maintain adequate clearance from structural members and the required clearance below sprinklers.

Bin Box Storage. Storage in five-sided wood, metal, or cardboard boxes with open face on the aisles. Boxes are self-supporting or supported by a structure so designed that little or no horizontal or vertical space exists around boxes.

Ceiling Height. The distance between the floor and the underside of the ceiling above (or roof deck) within the storage area.

Clearance. The distance from the top of storage to the ceiling sprinkler deflectors.

Commodity. Combinations of products, packing material, and container.

Compartmented.* The rigid separation of the products in a container by dividers that form a stable unit under fire conditions.

Container (shipping, master, or outer container).* A receptacle strong enough, by reason of material, design, and construction, to be shipped safely without further packaging.

Early Suppression Fast Response (ESFR) Sprinklers. A listed ESFR sprinkler is a thermosensitive device designed to react at a predetermined temperature by automatically releasing a stream of water and distributing it in a specified pattern and quantity over a designated area so as to provide early suppression of a fire where installed on the appropriate sprinkler piping.

Encapsulated. A method of packing consisting of a plastic sheet completely enclosing the sides and top of a pallet load containing a combustible commodity or combustible packages.

NOTE: Banding (i.e., stretch-wrapping) around the sides only of a pallet load is not considered to be encapsulation.

Expanded (foamed or cellular) Plastics. Those plastics, the density of which is reduced by the presence of numerous small cavities (cells), interconnecting or not, dispersed throughout their mass.

Exposed Group A Plastic Commodities. Those plastics not in packaging or coverings that absorb water or otherwise appreciably retard the burning hazard of the commodity (paper wrapped or encapsulated, or both, should be considered exposed).

Free-Flowing Plastic Materials. Those plastics that fall out of their containers during a fire, fill flue spaces, and create a smothering effect on the fire. Examples: powder, pellets, flakes, or random-packed small objects [e.g., razor blade dispensers, 1-oz to 2-oz (28-g to 57-g) bottles].

Large Drop Sprinkler. A listed large drop sprinkler is characterized by a K factor between 11.0 and 11.5, and a proven ability to meet prescribed penetration, cooling, and distribution criteria prescribed in the large drop sprinkler examination requirements. The deflector/discharge characteristics of the large drop sprinkler generate large drops of such size and velocity as to enable effective penetration of the high-velocity fire plume.

Miscellaneous Storage. Storage that does not exceed 12 ft (3.7 m) in height and is incidental to another occupancy use group as defined in NFPA 13, *Standard for the Installation of Sprinkler Systems*. Such storage shall not constitute more than 10 percent of the building area or 4000 ft^2 (372 m^2) of the sprinklered area, whichever is greater. Such storage shall not exceed 1000 ft^2 (93 m^2) in one pile or area, and each such pile or area shall be separated from other storage areas by at least 25 ft (7.6 m).

Noncombustible. Commodities, packaging, or storage aids that do not ignite, burn, or liberate flammable gases when heated to a temperature of 1380°F (749°C) for 5 minutes.

Packaging. A commodity wrapping, cushioning, or container.

Palletized Storage. Storage of commodities on pallets or other storage aids that form horizontal spaces between tiers of storage.

Pile Stability.*

Stable Piles. Those arrays where collapse, spillage of content, or leaning of stacks across flue spaces is not likely to occur soon after initial fire development.

NOTE: Storage on pallets, compartmented storage, and plastic components that are held in place by materials that do not deform readily under fire conditions are examples of stable storage.

Unstable Piles. Those arrays where collapse, spillage of contents, or leaning of stacks across flue spaces occurs soon after initial fire development.

NOTE: Leaning stacks, crushed bottom cartons, and reliance on combustible bands for stability are examples of potential pile instability under a fire condition. An increase in pile height tends to increase instability.

Roof Height. The distance between the floor and the underside of the roof deck within the storage area.

Shall. Indicates a mandatory requirement.

Shelf Storage. Storage on structures less than 30 in. (76.2 cm) deep with shelves usually 2 ft (0.6 m) apart vertically and separated by approximately 30-in. (76.2-cm) aisles.

Should. Indicates a recommendation or that which is advised but not required.

Solid Unit Load of a Nonexpanded Plastic (either cartoned or exposed). A load that does not have voids (air) within the load and that burns only on the exterior of the load; water from sprinklers might reach most surfaces available to burn.

Spray Sprinkler. A type of sprinkler listed for its capability to provide fire control for a wide range of fire hazards.

Sprinkler Temperature Rating.

(a) Ordinary-temperature rated sprinklers include temperature ratings between 135°F and 170°F (57°C and 77°C).

(b) High-temperature rated sprinklers include temperature ratings between 250°F and 300°F (121°C and 149°C).

Storage Aids. Commodity storage devices, such as pallets, dunnage, separators, and skids.

Unit Load. A pallet load or module held together in some manner and normally transported by material-handling equipment.

Chapter 2 Classification of Storage

2-1 Commodity Classification.

2-1.1

Class I commodities are defined as essentially noncombustible products on combustible pallets, in ordinary corrugated cartons with or without single-thickness dividers, or in ordinary paper wrappings with or without pallets.

Examples of Class I commodities include:

Foods. Noncombustible foodstuffs and beverages; foods in noncombustible containers; frozen foods; meats; fresh fruits and vegetables in nonplastic trays or containers; liquid dairy products in nonwax-coated paper containers or in plastic-coated paper containers; beer and wine, up to 20 percent alcohol, in metal, glass, or ceramic containers in ordinary corrugated cartons.

Glass Products. Glass bottles, empty or filled with noncombustible liquids; mirrors.

Metal Products. Metal desks with plastic tops and trim; electrical coils; electrical devices in their metal enclosures; pots and pans; electrical motors; dry cell batteries; metal parts; empty cans; stoves; washers; dryers; metal cabinets.

Others. Oil-filled and other types of distribution transformers; cement in bags; electrical insulators; gypsum board; inert pigments; dry insecticides.

2-1.2

Class II commodities are defined as Class I products in slatted wooden crates, solid wooden boxes, multiple thickness paperboard cartons, or equivalent combustible packaging material with or without pallets.

Examples of Class II commodities include:

Thinly coated fine wire such as radio coil wire on reels or in cartons; incandescent or fluorescent light bulbs; book signatures; beer or wine up to 20 percent alcohol in wood containers; Class I commodities, if in small cartons or small packages placed in ordinary paperboard cartons.

2-1.3

Class III commodities are defined as wood, paper, natural fiber cloth, or Group C plastics or products thereof, with or without pallets. Products shall be permitted to contain a limited amount of Group A or B plastics. Metal bicycles with plastic handles, pedals, seats, and tires are examples of a commodity with a limited amount of plastic.

Examples of Class III commodities include:

Leather Products. Shoes; jackets; gloves; luggage.

Paper Products. Books; magazines; newspapers; stationery; plastic-coated paper food containers; paper or cardboard games; tissue products.

Textiles. Natural fiber upholstered nonplastic furniture; wood or metal furniture with plastic padded and covered armrests; mattresses without expanded plastic or rubber; absorbent cotton in cartons; natural fiber and viscose yarns, thread, and products; synthetic thread and yarn; natural fiber clothing or textile products.

Wood Products. Doors; windows; door and window frames; combustible fiberboard; wood cabinets and furniture; other wood products.

Others. Tobacco products in paperboard cartons; nonflammable liquids such as soaps, detergents and bleaches, and nonflammable pharmaceuticals in plastic containers; non-negative-producing film packs in sealed metal foil wrappers in paperboard packages; combustible foods or cereal products.

2-1.4

Class IV commodities are defined as Class I, II, or III commodities containing an appreciable amount of Group A plastics in ordinary corrugated cartons and Class I, II, and III commodities in corrugated cartons with Group A plastic packing, with or without pallets. Group B plastics and free-flowing Group A plastics also are included in this class. An example of packing material is a metal typewriter in a foamed plastic cocoon in an ordinary corrugated carton. *(See Note to Figure 7-1.1.)*

Examples of Class IV commodities include:

Small appliances, typewriters, and cameras with plastic parts; plastic-backed tapes; nonviscose synthetic fabrics or clothing; telephones; vinyl floor tiles; wood or metal frame upholstered furniture or mattresses with plastic covering or padding, or both; plastic-padded metal bumpers and dashboards; insulated conductor and power cable on wood or metal reels or in cartons; inert solids in plastic containers; building construction insulating panels of polyurethane sandwiched between nonplastic material.

2-1.5* Classification of Plastics, Elastomers, and Rubber.

NOTE: The following categories are based on unmodified plastic materials. The use of fire- or flame-retarding modifiers or the physical form of the material could change the classification.

2-1.5.1 Group A.

ABS (acrylonitrile-butadiene-styrene copolymer)
Acetal (polyformaldehyde)
Acrylic (polymethyl methacrylate)
Butyl rubber
EPDM (ethylene-propylene rubber)
FRP (fiberglass reinforced polyester)
Natural rubber (if expanded)
Nitrile rubber (acrylonitrile-butadiene rubber)
PET (thermoplastic polyester)
Polybutadiene
Polycarbonate
Polyester elastomer
Polyethylene
Polypropylene
Polystyrene
Polyurethane
PVC (polyvinyl chloride — highly plasticized, e.g., coated fabric, unsupported film)
SAN (styrene acrylonitrile)
SBR (styrene-butadiene rubber)

2-1.5.2 Group B.

Cellulosics (cellulose acetate, cellulose acetate butyrate, ethyl cellulose)
Chloroprene rubber
Fluoroplastics (ECTFE — ethylene-chlorotrifluoroethylene copolymer; ETFE — ethylene-tetrafluoroethylene copolymer; FEP — fluorinated ethylene-propylene copolymer)
Natural rubber (not expanded)
Nylon (nylon 6, nylon 6/6)
Silicone rubber

2-1.5.3 Group C.

Fluoroplastics (PCTFE — polychlorotrifluoroethylene; PTFE — polytetrafluoroethylene)
Melamine (melamine formaldehyde)
Phenolic
PVC (polyvinyl chloride — rigid or lightly plasticized, e.g., pipe, pipe fittings)
PVDC (polyvinylidene chloride)
PVDF (polyvinylidene fluoride)
PVF (polyvinyl fluoride)
Urea (urea formaldehyde)

Chapter 3 Building Construction

3-1 Construction.

3-1.1*

Buildings used for storage of materials that are stored and protected in accordance with this standard shall be of any of the types described in NFPA 220, *Standard on Types of Building Construction.*

3-1.2

Adequate access shall be provided to all portions of the premises for fire-fighting purposes.

3-2* Emergency Smoke and Heat Venting.

Protection outlined in this standard shall apply to buildings with or without roof vents and draft curtains.

Chapter 4 Storage Arrangement

4-1 Piling Procedures and Precautions.

4-1.1

Any commodities that are hazardous in combination with each other shall be stored so they cannot come into contact with each other.

4-1.2*

Safe floor loads shall not be exceeded. For water absorbent commodities, normal floor loads shall be reduced to take into account the added weight of water that can be absorbed during fire-fighting operations.

4-2 Commodity Clearance.

4-2.1

The clearance between top of storage and sprinkler deflectors shall conform to NFPA 13, *Standard for the Installation of Sprinkler Systems*, except as modified by this standard.

4-2.2*

If the commodity is stored above the lower chord of roof trusses, at least 1 ft (30.5 cm) of clear space shall be maintained to permit wetting of the truss unless the truss is protected with 1-hour fireproofing.

4-2.3

Storage clearance from ducts shall be maintained in accordance with NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*, Section 2-18.

4-2.4

The clearance between stored materials and unit heaters, radiant space heaters, duct furnaces, and flues shall not be less than 3 ft (0.9 m) in all directions or shall be in accordance with the clearances shown on the approval agency label.

4-2.5*

Clearance shall be maintained to lights or light fixtures to prevent possible ignition.

4-2.6

Sufficient clearance shall be maintained around the path of fire door travel to ensure proper operation and inspection.

4-3 Aisles.

4-3.1

Wall aisles shall be at least 24 in. (61 cm) wide in warehouses used for the storage of commodities that expand with the absorption of water.

4-3.2*

Aisles shall be maintained to retard the transfer of fire from one pile to another and to permit convenient access for fire fighting, salvage, and removal of storage.

4-4* Storage of Idle Pallets.

4-4.1 Wood Pallets.

4-4.1.1* Pallets shall be stored outside or in a detached structure.

Exception: Indoor pallet storage shall be permitted in accordance with 4-4.1.2.

4-4.1.2 Pallets, where stored indoors, shall be protected as indicated in Table 4-4.1.2, unless the following conditions are met:

(a) Pallets shall be stored no higher than 6 ft (1.8 m); and

(b) Each pallet pile of no more than four stacks shall be separated from other pallet piles by at least 8 ft (1.4 m) of clear space or 25 ft (7.6 m) of commodity.

NOTE: No additional protection is necessary, provided the requirements of 4-4.1.2(a) and (b) are met.

Table 4-4.1.2 Protection for Indoor Storage of Wood Idle Pallets or Nonexpanded Polyethylene Solid Deck Idle Pallets

Height of Pallet Storage ft (m)	Sprinkler Density Requirements gpm/ft^2 [(L/s)/m^2]	Area of Sprinkler Demand ft^2 (m^2) Temperature Rating 286°F (141°C)	165°F (74°C)
Up to 6 (1.8)	.20 (.14)	2000 (186)	3000 (279)
6 to 8 (1.8 to 2.4)	.30 (.20)	2500 (232)	4000 (372)
8 to 12 (2.4 to 3.7)	.60 (.41)	3500 (325)	6000 (557)
12 to 20 (3.7 to 6.1)	.60 (.41)	4500 (418)	-

4-4.2* Plastic Pallets.

4-4.2.1 Plastic pallets shall be stored outside or in a detached structure.

Exception No. 1: Indoor plastic pallet storage shall be permitted in accordance with 4-4.2.2.

Exception No. 2: Indoor nonexpanded polyethylene solid deck pallets shall be permitted to be *protected in accordance with 4-4.1.2.*

4-4.2.2 Plastic pallets where stored indoors shall be protected as follows:

(a) Where stored in cutoff rooms:

(1) The cutoff rooms shall have at least one exterior wall.

(2) The plastic pallet storage shall be separated from the remainder of the building by 3-hour rated fire walls.

(3) The storage shall be protected by sprinklers designed to deliver 0.60 gpm/ft^2 [0.41 (L/s)/m^2] for the entire room or by high-expansion foam and sprinklers as indicated in Section 5-2.

(4) The storage shall be piled no higher than 12 ft (3.7 m).

(5) Any steel columns shall be protected by 1-hour fireproofing or a sidewall sprinkler directed to one side of the column at the top or at the 15-ft (4.6-m) level, whichever is lower. *(See A-4-2.2.)*

(b) Where stored without cutoffs from other storage:

(1) Plastic pallet storage shall be piled no higher than 4 ft (1.2 m).

(2) Sprinkler protection shall employ high-temperature rated sprinklers.

(3) Each pallet pile of no more than two stacks shall be separated from other pallet piles by at least 8 ft (2.4 m) of clear space or 25 ft (7.6 m) of stored commodity.

4-5 Flammable and Combustible Liquids.

Only limited quantities of flammable and combustible liquids shall be permitted in general storage warehouses. Any such storage shall be segregated from other stored combustible material.

NOTE: For further information, see Chapter 4 of NFPA 30, *Flammable and Combustible Liquids Code*.

Chapter 5 Fire Protection — General

5-1 Automatic Sprinkler Systems.

5-1.1

Sprinkler systems installed in buildings used for solid pile, bin box, shelf, or palletized storage shall be in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

Exception: Where modified by this standard.

5-1.2

The design density shall not be less than 0.15 gpm/ft^2 [0.10 (L/s)/m^2], and the design area shall not be less than 2000 ft^2 (186 m^2) for wet systems or 2600 ft^2 (242 m^2) for dry systems for any commodity, class, or group.

5-1.2.1 The sprinkler design density for any given area of operation for a Class III or Class IV commodity, calculated in accordance with Chapter 6, shall not be less than the density for the corresponding area of operation for Ordinary Hazard Group 2 in NFPA 13, *Standard for the Installation of Sprinkler Systems*.

5-1.2.2 The water supply requirements for sprinklers only shall be based on the actual calculated demand for the hazard in accordance with Chapter 6, Chapter 7, Chapter 8, or Chapter 9, depending on the type of sprinkler selected and the commodity being protected.

5-1.3

Where palletized or solid pile storage is placed on top of racks, the provisions of NFPA 231C, *Standard for Rack Storage of Materials*, shall apply to the entire height of storage with regard to sprinkler requirements and water supplies for ceiling and rack sprinklers.

5-1.4

In warehouses with areas containing rack storage and other areas containing palletized, solid pile, bin box, or shelf storage, the standard applicable to the storage configuration shall apply.

5-1.5

Standard response standard orifice $^{1}/_{2}$-in. (12.7-mm) or standard response large orifice $^{17}/_{32}$-in. (13.5-mm) sprinklers shall be used in applying the curves and tables in Chapters 6 and 7.

Exception No. 1: Use of these curves and tables with quick response sprinklers shall be permitted at the discretion of the authority having jurisdiction.

Exception No. 2: The use of extra-large orifice (ELO) sprinklers [$^{5}/_{8}$ in. (15.9 mm)] shall be permitted where listed for such use and where installed at a minimum design pressure of 10 psi (69 kPa).

5-1.6

In buildings occupied in part for storage, within the scope of this standard, the required sprinkler protection shall extend 15 ft (4.6 m) beyond the perimeter of the storage area.

5-2 High-Expansion Foam.

5-2.1

High-expansion foam systems installed in addition to automatic sprinklers shall be installed in accordance with NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*.

Exception: Where modified by this standard.

5-2.2

High-expansion foam used to protect the idle pallets shall have a maximum fill time of 4 minutes.

5-2.3

High-expansion foam systems shall be automatic in operation.

5-2.4

Detectors for high-expansion foam systems shall be listed and shall be installed at no more than one-half listed spacing.

5-2.5

Detection systems, concentrate pumps, generators, and other system components essential to the operation of the system shall have an approved standby power source.

5-2.6

A reduction in ceiling density to one-half that required for Class I through Class IV commodities, idle pallets, or plastics (using the secondary demand point) shall be permitted without revising the design area, but shall be not less than 0.15 gpm/ft^2 [0.10 (L/s)/m^2].

5-3 Manual Inside Protection.

5-3.1 Small Hose Systems.

Small hose lines [1$^1/_2$ in. (38 mm)] shall be available to reach all portions of the storage area, giving due consideration to access aisle configuration with maximum anticipated storage in place. Such small hose shall be supplied from one of the following:

(a) Outside hydrants

(b) A separate piping system for small hose stations

(c) Valved hose connections on sprinkler risers where such connections are made upstream of sprinkler control valves

(d) Adjacent sprinkler systems.

NOTE: For further information on adjacent sprinkler systems, see NFPA 13, *Standard for the Installation of Sprinkler Systems*.

5-3.2 Portable Fire Extinguishers.

Portable fire extinguishers shall be provided in accordance with NFPA 10, *Standard for Portable Fire Extinguishers.* Up to one-half of the required complement of portable fire extinguishers for Class A fires shall be permitted to be omitted in storage areas where fixed small hose lines [1$^1/_2$ in (38 mm)] are available to reach all portions of the storage area.

5-4* Hydrants.

At locations without public hydrants, or where hydrants are not within 250 ft (76.2 m), private hydrants shall be installed in accordance with NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances.*

5-5* Fire Organization.

5-5.1

Arrangements shall be made to permit rapid entry into the premises by the municipal fire department, police department, or other authorized personnel in case of fire or other emergency.

5-5.2

Plant emergency organizations, where provided, shall be instructed and trained in the following procedures:

(a) Maintenance of the security of the premises

(b) Means of summoning outside aid immediately in an emergency

(c) Use of hand extinguishers and hose lines on small fires and mop-up operations

(d) Operation of the sprinkler system and water supply equipment

(e) Use of material-handling equipment while sprinklers are operating to effect final extinguishment

(f) Supervision of sprinkler valves after system is turned off so that system can be reactivated if rekindling occurs

(g) Need for breathing apparatus

(h) Proper operation of emergency smoke and heat venting systems where these have been provided.

5-5.3

A fire watch shall be maintained when the sprinkler system is not in service.

5-6 Alarm Service.

A central station, auxiliary, remote station, or proprietary sprinkler waterflow alarm shall be provided. A local waterflow alarm shall be permitted where recorded guard service is provided.

NOTE: For further information, see NFPA 72, *National Fire Alarm Code*.

Chapter 6* Fire Protection for Commodity Classes I through IV—Spray Sprinklers

6-1 General.

6-1.1

Class I through Class IV commodities of the following configurations protected by spray sprinklers shall be in accordance with this chapter.

(a) Nonencapsulated commodities that are solid pile, palletized, or bin box storage up to 30 ft (9.1 m) in height;

(b) Nonencapsulated commodities on shelf storage up to 15 ft (4.6 m) in height;

(c)* Encapsulated commodities that are solid pile, palletized, bin box, or shelf storage up to 15 ft (4.6 m) in height.

6-1.2

Bin box and shelf storage over 12 ft (3.7 m) and provided with walkways at not over 12-ft (3.7-m) vertical intervals shall be provided with automatic sprinklers under the walkways as well as at the ceiling. The design density for ceiling and walkway sprinklers shall be permitted to be in accordance with the height adjustment of Figure 6-2.2.4.

6-2 Water Supplies.

6-2.1

The water supply shall be capable of providing the sprinkler system demand determined in accordance with 6-2.3, including the hose stream demand of 6-2.4 for the duration requirements of 6-2.5.

6-2.2

The area and density for the hydraulically remote area shall be determined as specified in 6-2.2.1 through 6-2.2.7.

6-2.2.1 Storage 12 ft (3.7 m) or less in height of Class I and Class II commodities shall be in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, for Ordinary Hazard Group 1. Storage 12 ft (3.7 m) or less in height of Class III and Class IV commodities shall be in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, for Ordinary Hazard Group 2.

6-2.2.2 Where using ordinary-temperature rated sprinklers, a single point shall be selected from the appropriate commodity curve on Figure 6-2.2.2.

6-2.2.3 Where using high-temperature rated sprinklers, a single point shall be selected from the appropriate commodity curve on Figure 6-2.2.3.

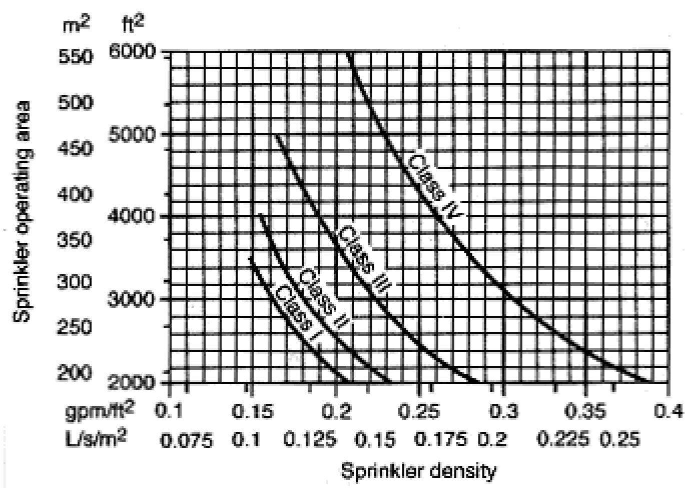

Figure 6-2.2.2 Sprinkler system design curves, 20-ft (6.1-m) high storage — ordinary-temperature rated sprinklers.

NOTE: Sprinkler demand for 20-ft (6.1-m) high storage shall be selected from any point on the appropriate class curve in Figure 6-2.2.3.
Figure 6-2.2.3 provides protection curves for sprinkler systems using only high-temperature rated sprinklers.

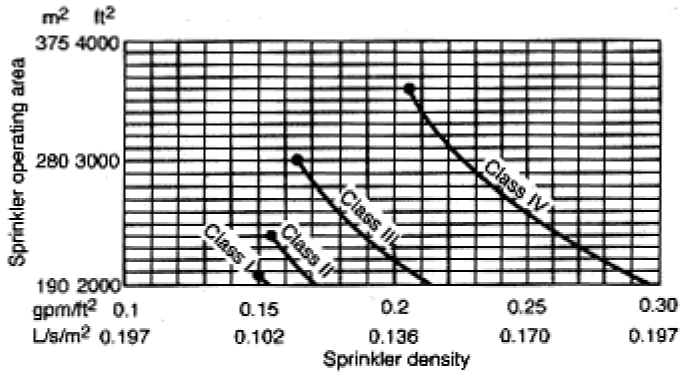

Figure 6-2.2.3 Sprinkler system design curves, 20-ft (6.1-m) high storage — high-temperature rated sprinklers.

6-2.2.4 The densities selected in accordance with 6-2.2.2 or 6-2.2.3 shall be modified in accordance with Figure 6-2.2.4 without revising the design area.

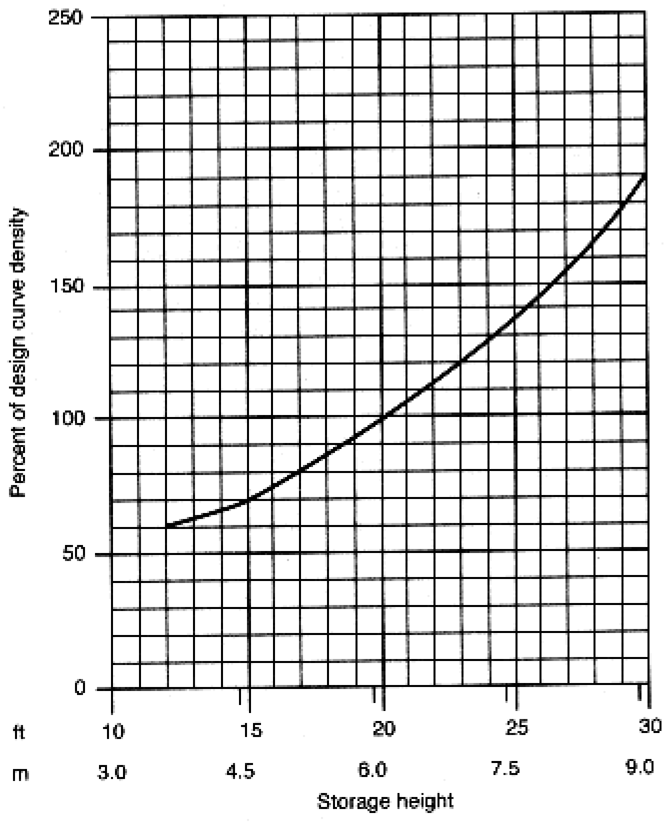

Figure 6-2.2.4 Ceiling sprinkler density vs storage height.

6-2.2.5 Where dry-pipe systems are used, the areas of operation indicated in the design curves shall be increased by 30 percent.

6-2.2.6 For bin boxes and closed shelves constructed of metal with a face area not exceeding 16 ft^2 (1.5 m^2), the area of application shall be permitted to be reduced by 50 percent, provided the minimum requirements of Chapter 5 are met.

6-2.2.7 The final area and density shall not be less than the minimum specified in Chapter 5.

6-2.3

Given the area and density determined in accordance with 6-2.2, the fire sprinkler system shall be hydraulically calculated in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

6-2.4*

A minimum of 500 gpm (32 L/s) shall be added to the sprinkler demand for combined large and small hose stream demand.

6-2.5

Water supply duration shall be in accordance with Table 6-2.5.

Table 6-2.5 Duration (hours)

Storage Height ft (m)	Commodity Class	
	Classes I, II, and III	Class IV
over 12 (3.7) up to 20 (6.1)	1 1/2	2
over 20 (6.1) up to 30 (9.1)	2	2 1/2

6-3 High-Expansion Foam.

See Section 5-2.

Chapter 7 Fire Protection for Plastic and Rubber Commodities—Spray Sprinklers

7-1* General.

See Appendix B.

7-1.1*

Plastics stored up to 25 ft (7.62 m) in height protected by spray sprinklers shall be in accordance with Chapter 7. The decision tree (Figure 7-1.1) shall be used to determine the protection in each specific situation.

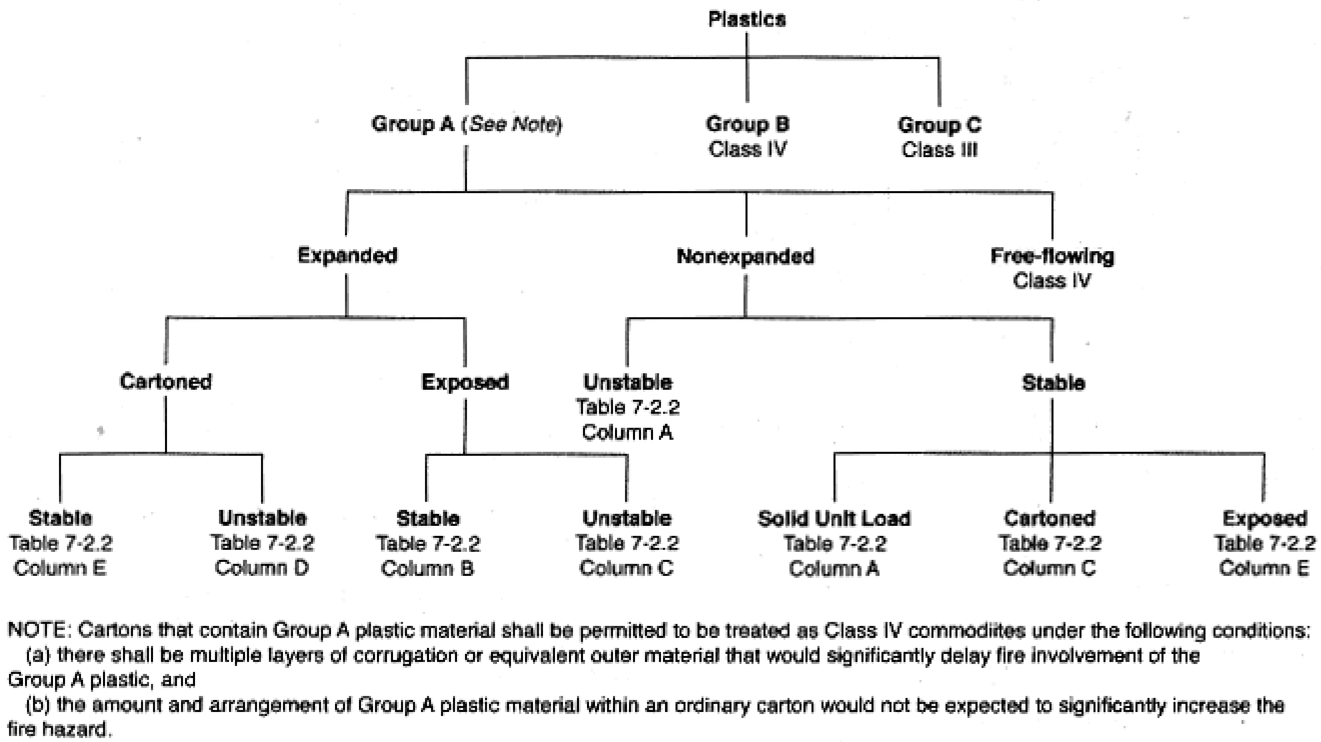

Figure 7-1.1 Decision tree.

7-1.2*

Factors affecting protection requirements such as closed/open array, clearance between storage and sprinklers, and stable/unstable piles, shall be applicable only to storage of Group A plastics. The factors contained in 7-2.1, A-7-2.1, and Appendix B shall be given serious consideration prior to determining the final protection requirements. This decision tree also shall be used to determine protection for commodities that are not wholly Group A plastics but contain such quantities and arrangements of the same that they are deemed more hazardous than Class IV commodities.

7-1.3

Group B plastics and free-flowing Group A plastics shall be protected in the same manner as a Class IV commodity. Storage 12 ft (3.7 m) or less in height shall be protected in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, for Ordinary Hazard Group 2.

7-1.4

Group C plastics shall be protected in the same manner as a Class III commodity. Storage 12 ft (3.7 m) or less in height shall be protected in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, for Ordinary Hazard Group 2.

7-2 Water Supplies.

7-2.1*

The design of the sprinkler system shall be based on those conditions that routinely or periodically exist in a building that create the greatest water demand.

These conditions include:

(a) Pile height

(b) Clearance

(c) Pile stability

(d) Array.

7-2.2*

Design areas and densities shall be selected for the appropriate storage configuration from Table 7-2.2.

Table 7-2.2

Storage Height ft (m)	Roof/Ceiling Height ft (m)	Density (gpm/ft²) [(L/s)/m²]				
		A	B	C	D	E
5 (1.52)	15 (4.57) 20 (6.10) 25 (7.62)	OH-2 OH-2 OH-2	OH-2 OH-2 OH-2	OH-2 OH-2 OH-2	OH-2 OH-2 OH-2	OH-2 OH-2 OH-2
12 (3.66)	15 (4.57) 20 (6.10) 25 (7.62)	0.2 (0.14) 0.3 (0.20) 0.4 (0.27)	EH-2 0.6 (0.41) 0.8 (0.54)	0.3 (0.20) 0.5 (0.34) 0.6 (0.41)	EH-1 EH-2 0.45 (0.31)	EH-2 EH-2 0.7 (0.4
15 (4.57)	20 (6.10) 25 (7.62) 30 (9.14)	0.25 (0.17) 0.4 (0.27) 0.45 (0.31)	0.5 (0.34) 0.8 (0.54) 0.9 (0.61)	0.4 (0.27) 0.6 (0.41) 0.7 (0.48)	0.3 (0.20) 0.45 (0.31) 0.55 (0.37)	0.45 (0.3 0.7 (0.4 0.85 (0.5
20 (6.1)	25 (7.62) 30 (9.14) 35 (10.67)	0.3 (0.20) 0.45 (0.31) 0.6 (0.41)	0.6 (0.41) 0.9 (0.61) 1.2 (0.82)	0.45 (0.31) 0.7 (0.48) 0.85 (0.58)	0.35 (0.24) 0.55 (0.37) 0.7 (0.48)	0.55 (0.3 0.85 (0.5 1.1 (0.7
25 (7.62)	30 (9.14) 35 (10.67) 40 (12.19)	0.4 (0.27) 0.6 (0.41) N/A	0.75 (0.51) 1.2 (0.82) N/A	0.55 (0.37) 0.85 (0.58) N/A	0.45 (0.31) 0.7 (0.48) N/A	0.7 (0.4 1.1 (0.7 N/A

NOTE 1: For Table 7-2.2, the design areas are a minimum of 2500 ft² (Exception: OH-2).
NOTE 2: For closed array, areas shall be reduced from 500 ft² to 2000 ft².
NOTE 3: Interpolation of densities/areas between storage heights shall be permitted. Interpolation of ceiling/roof heights shall not be permitted.
NOTE 4: For density demands of 0.4 gpm/ft² or greater, large orifice or extra-large orifice (ELO) sprinklers shall be used.
NOTE 5: It is recommended that high-temperature rated sprinklers be installed, since most tests upon which this standard is based used high-tempera rated sprinklers.
NOTE 6: Column designations correspond to the configuration of plastics storage as follows:
A: (1) Nonexpanded, unstable
(2) Nonexpanded, stable, solid unit load
B: Expanded, exposed, stable
C: (1) Expanded, exposed, unstable
(2) Nonexpanded, stable, cartoned
D: Expanded, cartoned, unstable
E: (1) Expanded, cartoned, stable
(2) Nonexpanded, stable, exposed
NOTE 7:
OH-2 = Density required for Ordinary Hazard Group 2 occupancies.
EH-1 = Density required for Extra Hazard Group 1 occupancies.
EH-2 = Density required for Extra Hazard Group 2 occupancies as specified in NFPA 13, *Standard for the Installation of Sprinkler Systems*.
Hose streams shall be provided in accordance with 7-2.3.
N/A: Not applicable.

7-2.3

Where sprinkler protection has been designed for Group A plastics, at least 500 gpm (32 L/s) shall be added to the density/area demand for hose streams.

7-2.4

Water supply duration (sprinkler demand plus hose streams) shall be 2-hour duration for 5 ft to 20 ft (1.5 m to 6.1 m) and 2$^1/_2$-hour duration for 20 ft to 25 ft (6.1 m to 7.6 m).

7-2.5*

Where dry-pipe systems are used for Group A plastics, the operating area shall be increased by 30 percent without revising the density.

Chapter 8 Fire Protection—Large Drop Sprinklers

8-1 General.

8-1.1

Large drop sprinklers shall be permitted for use with the hazards listed in Table 8-1.

Table 8-1 Large Drop Sprinkler Data Pressure and Number of Design Sprinklers Required for Various Hazards for Large Drop Sprinklers

Hazard	Type of System	Minimum Operating Pressure [psi (bars)] (See Note 1.) 25 (1.7)	50 (3.4)	75 (5.2)	Hose Stream Demand gpm (dm³/min)	Water Supply Duration (hr)
		Number of Design Sprinklers				
Palletized Storage Classes I, II, and III commodities up to 25 ft (7.6 m) with maximum 10-ft (3.0-m) clearance to ceiling	Wet	15	Note 2	Note 2	500 (1900)	2
	Dry	25	Note 2	Note 2		
Class IV commodities up to 20 ft (6.1 m) with maximum 10-ft (3.0-m) clearance to ceiling	Wet	20	15	Note 2	500 (1900)	2
	Dry	N/A	N/A	N/A		
Unexpanded plastics up to 20 ft (6.1 m) with maximum 10-ft (3.0-m) clearance to ceiling	Wet	25	15	Note 2	500 (1900)	2
	Dry	N/A	N/A	N/A		
Expanded plastics commodities up to 18 ft (5.5 m) with maximum 8-ft (2.4-m) clearance to ceiling	Wet	N/A	15	Note 2	500 (1900)	2
	Dry	N/A	N/A	N/A		
Idle wood pallets up to 20 ft (6.1 m) with maximum 10-ft (3.0-m) clearance to ceiling	Wet	15	Note 2	Note 2	500 (1900)	1½
	Dry	25	Note 2	Note 2		
Solid Pile Storage Classes I, II, and III commodities up to 20 ft (6.1 m) with maximum 10-ft (3.0-m) clearance to ceiling	Wet	15	Note 2	Note 2	500 (1900)	1½
	Dry	25	Note 2	Note 2		
Class IV commodities and unexpanded plastics up to 20 ft (6.1 m) with maximum 10-ft (3.0-m) clearance to ceiling	Wet	N/A	15	Note 2	500 (1900)	1½
	Dry	N/A	N/A	N/A		

NOTE 1: Open wood joist construction. Each joist channel shall be fully firestopped to its full depth at intervals not exceeding 20 ft (6.1 m). In unfirestopped open wood joist construction or if firestops are installed at intervals not exceeding 20 ft (6.1 m), the minimum operating pressures of Table 8-1 shall be increased by 40 percent.

NOTE 2: The high pressure shall be permitted to be used, but the required number of design sprinklers shall not be permitted to be reduced from that required for the lower pressure.

N/A: Not applicable.

8-2 Water Supplies.

8-2.1

Sprinkler water demand for large drop sprinklers shall be in accordance with Table 8-1.

8-2.2

A minimum of 500 gpm (32 L/s) shall be added to the sprinkler demand for combined large and small hose stream demand.

8-2.3

Water supply duration shall be as indicated in Table 8-1.

8-3 Sprinkler System Design.

8-3.1

All requirements contained in NFPA 13, *Standard for the Installation of Sprinkler Systems*, pertaining to large drop sprinklers shall apply.

Exception: Where modified by this standard.

Chapter 9 Fire Protection—Early Suppression Fast Response (ESFR) Sprinklers

9-1* General.

9-1.1

ESFR sprinklers shall be permitted for the protection of commodities in accordance with Table 9-1.

Table 9-1 ESFR Sprinkler Data

Type of Storage	Commodity	Maximum Height of Storage ft (m)	Maximum Height of Building (See Note 1.) ft (m)	Nominal K factor	Sprinkler Design Pressure psi (bars)	Commodity Limitation
Palletized and solid pile storage (no open-top containers or solid shelves)	Cartoned unexpanded plastic; cartoned expanded plastic; uncartoned unexpanded plastic; and Class I, II, III, or IV commodities encapsulated or unencapsulated	25 (7.6)	30 (9.1)	13.5–14.5	50 (3.4)	
	Cartoned unexpanded plastic; and Class I, II, III, or IV commodities, encapsulated or unencapsulated	35 (10.7)	40 (12.2)	13.5–14.5	75 (5.2)	(See Note 2.)
		20 (6.1)	25 (7.6)	11.0–11.5	50 (3.4)	

NOTE 1: Maximum building height shall be measured to the underside of the roof deck or ceiling.
NOTE 2: Only ESFR sprinklers specifically listed for 40-ft (12.2-m) high buildings shall be used in buildings higher than 30 ft (9.1 m) up to 40 ft (12.2 m).

9-1.2*

ESFR sprinklers shall be permitted for use in buildings with the following types of roof construction:

(a) Smooth ceiling

(b) Bar joist

(c) Beam and girder

(d) Panel.

9-1.3

Roof slope shall not exceed 1 in./ft.

9-2* Water Supplies.

9-2.1

The design area shall consist of the most hydraulically demanding area of 12 sprinklers, consisting of 4 sprinklers on each of 3 branch lines. The design shall include a minimum of 960 ft^2 (89.2 m^2).

9-2.2

A minimum of 250 gpm (946 L/min) shall be added to the sprinkler demand for combined large and small hose streams.

9-2.3

Water supply duration shall be at least 1 hour.

9-2.4

ESFR sprinklers shall be limited to wet-pipe systems.

9-3 Sprinkler System Design.

9-3.1

All requirements contained in NFPA 13, *Standard for the Installation of Sprinkler Systems*, shall apply.

Exception: Where modified by this standard.

Chapter 10 Building Equipment, Maintenance, and Operations

10-1* Mechanical Handling Equipment.

10-1.1* Industrial Trucks.

Power-operated industrial trucks shall comply with NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance, and Operation.*

10-2 Building Service Equipment.

10-2.1

Electrical equipment shall be installed in accordance with the provisions of NFPA 70, *National Electrical Code®*.

10-3 Cutting and Welding Operations.

10-3.1*

Where welding or cutting operations are necessary, the requirements of NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, shall apply. Where possible, work shall be removed to a safe area.

10-3.2

Welding, soldering, brazing, and cutting shall be permitted to be performed on building components that cannot be removed, provided no storage is located below and within 25 ft (7.6 m) of the working area and flameproof tarpaulins enclose this area. During any of these operations, the sprinkler system shall be in service. Extinguishers suitable for Class A fires with a minimum rating of 2A and charged and attended inside hose lines, where provided, shall be located in the working area. A fire watch shall be maintained during these operations and for not less than 30 minutes following completion of open-flame operation.

10-4 Waste Disposal.

Rubbish, trash, and other waste material shall be disposed of at regular intervals.

10-5 Smoking.

Smoking shall be strictly prohibited. "No Smoking" signs shall be posted in prohibited areas.

Exception: Smoking shall be permitted in locations prominently designated as smoking areas.

10-6 Maintenance and Inspection.

10-6.1

Fire walls, fire doors, and floors shall be maintained in good repair at all times.

10-6.2

The sprinkler system and the water supplies shall be inspected, tested, and maintained in accordance with NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*.

10-7 Refrigeration Systems.

Refrigeration systems, if used, shall conform to ASHRAE 15-70, *Safety Code for Mechanical Refrigeration*.

Chapter 11 Referenced Publications

11-1

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.

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 11A, *Standard for Medium- and High-Expansion Foam Systems*, 1994 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1994 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 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1994 edition.

NFPA 70, *National Electrical Code*, 1993 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*, 1995 edition.

NFPA 220, *Standard on Types of Building Construction*, 1995 edition.

NFPA 231C, *Standard for Rack Storage of Materials*, 1995 edition.

NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance, and Operation*, 1992 edition.

11-1.2 Other Publication.

11-1.2.1 ASHRAE Publication. American Society of Heating, Refrigerating and Air Conditioning Engineers, United Engineering Center, 345 East 49th Street, New York, NY 10017.

ASHRAE 15, *Safety Code for Mechanical Refrigeration*, 1992.

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 Array, Open.

Fire tests conducted to represent a closed array utilized 6-in. (152-mm) longitudinal flues and no transverse flues. Fire tests conducted to represent an open array utilized 12-in. (305-mm) longitudinal flues.

A-1-3 Available Height for Storage.

For new sprinkler installations, maximum height of storage is the height at which commodities can be stored above the floor where the minimum required unobstructed space below sprinklers is maintained. For the evaluation of existing situations, maximum height of storage is the maximum existing height, if space between sprinklers and storage is equal to or greater than required.

A-1-3 Compartmented.

Cartons used in most of the Factory Mutual-sponsored plastic tests involved an ordinary 200-lb (90.7-kg) test of outside corrugated cartons with five layers of vertical pieces of corrugated carton used as dividers on the inside. There were also single horizontal pieces of corrugated carton between each layer. Other tests sponsored by the Society of Plastics Industry, Industrial Risk Insurers, Factory Mutual, and Kemper used two vertical pieces of carton (not corrugated) to form an "X" in the carton for separation of product. This was not considered compartmented, as the pieces of carton used for separations were flexible (not rigid), and only two pieces were in each carton.

A-1-3 Container.

The term container includes items such as cartons and wrappings. Fire retardant containers or tote boxes do not of themselves create a need for automatic sprinklers unless coated with oil or grease. Containers can lose their fire retardant properties if washed. For obvious reasons, they should not be exposed to rainfall.

A-1-3 Pile Stability.

Pile stability performance has been shown to be a difficult factor to judge prior to being subjected to an actual fire. In the test work completed, compartmented cartons (*see A-1-2, "Compartmented*") have been shown to be stable under fire conditions. Those tests on cartons that were not compartmented tended to be unstable under fire conditions.

A-2-1.5

The classes of plastics used in this standard basically were derived from a series of large-scale and laboratory-type small-scale fire tests using a variety of expanded and nonexpanded plastic materials. It is recognized that not all plastics in a class exhibit exactly the same characteristics while burning.

A-3-1.1

With protection installed in accordance with this standard, fire protection of overhead steel and steel columns might not be necessary.

Consideration should be given to subdividing large-area warehouses in order to reduce the amount of merchandise that could be affected by a single fire.

It is recommended that walls or partitions be provided to separate the storage area from mercantile, manufacturing, or other occupancies to prevent the possibility of transmission of fire or smoke between the two occupancies. Door openings should be equipped with automatic-closing fire doors appropriate for the fire resistance rating of the wall or partition.

A-3-2

Smoke removal is important to manual fire fighting and overhaul. Since most fire tests were conducted without smoke and heat venting, protection specified in Sections 5-1, 6-1, and 7-1 was developed without the use of such venting. However, venting through eaveline windows, doors, monitors, gravity, or mechanical exhaust systems is essential to smoke removal after control of the fire is achieved. (*See NFPA 204M, Guide for Smoke and Heat Venting*.)

A-4-1.2

Commodities that are particularly susceptible to water damage should be stored on skids, dunnage, pallets, or elevated platforms in order to maintain at least 4 in. (10.2 cm) clearance from the floor.

A-4-2.2

Protection for exposed steel structural roof members might be needed and should be provided as indicated by the authority having jurisdiction.

A-4-2.5

Incandescent light fixtures should have shades or guards to prevent the ignition of commodity from hot bulbs where possibility of contact with storage exists.

A-4-3.2

Storage should be separated by aisles so that piles are not more than 50 ft (15.2 m) wide or 25 ft (7.6 m) wide if they abut a wall. Main and cross aisles should be located opposite window or door openings in exterior walls. This is of particular importance in buildings where few exterior openings exist. Aisle width should be at least 8 ft (2.4 m). In judging the adequacy of existing sprinkler protection, aisle spacing and frequency should be given consideration.

A-4-4

Idle pallet storage introduces a severe fire condition. Stacking idle pallets in piles is the best arrangement of combustibles to promote rapid spread of fire, heat release, and complete combustion. After pallets are used for a short time in warehouses, they dry out and edges become frayed and splintered. In this condition they are subject to easy ignition from a small ignition source. Again, high piling increases considerably both the challenge to sprinklers and the probability of involving a large number of pallets when fire occurs. Therefore, it is preferable to store pallets outdoors where possible.

A-4-4.1.1 See Table A-4-4.1.1.

Table A-4-4.1.1 Recommended Clearance Between Outside Idle Pallet Storage and Building

Wall Construction		Minimum Distance [ft (m)] of Wall from Storage of		
Wall Type	**Openings**	**Under 50 Pallets**	**50 to 200 Pallets**	**Over 200 Pallets**
Masonry	None	0	0	0
	Wired glass with outside sprinklers 1-hr doors	0	10 (3.0)	20 (6.1)
	Wired or plain glass with outside sprinklers $^3/_4$-hr doors	10 (3.0)	20 (6.1)	30 (9.1)
Wood or metal with outside sprinklers				
Wood, metal, or other		20 (6.1)	30 (9.1)	50 (15.2)

Notes:
1. Fire-resistive protection comparable to that of the wall also should be provided for combustible eave

lines, vent openings, etc.

2. Where pallets are stored close to a building, the height of storage should be restricted to prevent burning pallets from falling on the building.

3. Manual outside open sprinklers generally are not a reliable means of protection unless property is attended to at all times by plant emergency personnel.

4. Open sprinklers controlled by a deluge valve are preferred.

A-4-4.2

A fire in stacks of idle plastic and wooden pallets is one of the greatest challenges to sprinklers. The undersides of the pallets create a dry area on which a fire can grow and expand to other dry or partially wet areas. This process of jumping to other dry, closely located, parallel, combustible surfaces continues until the fire bursts through the top of the stack. Once this happens, very little water is able to reach the base of the fire. The only practical method of stopping a fire in a large concentration of pallets with ceiling sprinklers is by means of prewetting. In high stacks, this cannot be done without abnormally high water supplies. The storage of empty wood pallets should not be permitted in an unsprinklered warehouse containing other storage.

A-5-4

At windowless warehouses and where windows are scant, hydrants should be located at or in the vicinity of entrances.

A-5-5

Manual fire-fighting operations in a storage warehouse are not a substitute for sprinkler operation. The sprinkler system should be kept in operation during manual fire-fighting operations until visibility has cleared so that the fire can be seen clearly and the extent of fire reduced to a stage that needs only mopping up. It is essential that charged hose lines be available before venting is started because of a possible increase in fire intensity. Where a sprinkler valve has been closed, a responsible person should remain at the valve so it can be opened promptly if necessary. The water supply for the sprinkler system should be augmented where possible and care exercised that the water supply for the sprinkler system is not rendered ineffective by the use of excessive hose streams.

Where a private fire brigade is provided, sufficient large hose [$2^1/_2$ in. (64 mm)] and related equipment should be available.

Information on emergency organization and pre-incident planning is provided in the following publications:

NFPA *Industrial Fire Brigades Training Manual*.

NFPA 600, *Standard on Industrial Fire Brigades*.

NFPA 1420, *Recommended Practice for Pre-Incident Planning for Warehouse Occupancies*.

A-6

The following procedure should be followed in determining the proper density and area as specified in Chapter 6.

1. Determine the commodity class.
2. Select the density and area of application from Figure 6-2.2.2 or Figure 6-2.2.3.
3. Adjust the required density for storage height in accordance with Figure 6-2.2.4.
4. Increase the operating area by 30 percent in accordance with 6-2.2.5 where a dry-pipe

system is used.

5. Satisfy the minimum densities and areas as indicated in 5-1.2 and 5-1.2.1.

Example:

Storage — greeting cards in boxes in cartons on pallets

Height — 22 ft (6.7 m)

Clearance — 6 ft (1.8 m)

Sprinklers — 165°F (74°C)

System type — dry

1. Classification — Class III

2. Selection of density/area — 0.225 gpm/ft^2 over 3000 ft^2 [0.014 (L/s)/m^2 over 276 m^2] from Figure 6-2.2.2

3. Adjustment for height of storage using Figure 6-2.2.4 - 1.15 $\times$ 0.225 = 0.259 gpm/ft^2; round up to 0.26 gpm/ft^2

4. Adjustment of area of operation for dry system - 1.3 $\times$ 3000 ft^2 = 3900 ft^2 (363 m^2)

5. Confirmation that minimum densities and areas have been achieved

In 5-1.2, the minimum design density for a dry sprinkler system is 0.15 gpm/ft^2 over 2600 ft^2 [0.10 (L/s)/m^2 over 242 m^2] (this has been satisfied) for Class III.

Paragraph 5-1.2.1 refers to Ordinary Hazard Group 2 of NFPA 13, *Standard for the Installation of Sprinkler Systems*. That density at 3000 ft^2 (279 m^2) is 0.17 gpm/ft^2 [0.12 (L/s)/m^2] (this minimum has been satisfied) 3000 ft^2 $\times$ 1.3 = 3900 ft^2 (363 m^2), 0.17 gpm/ft^2 over 3900 ft^2 [0.12 (L/s)/m^2 over 363 m^2].

The design density and area of application equals 0.26 gpm/ft^2 [0.18 (L/s)/m^2] over 3900 ft^2 (363 m^2).

A-6-1.1

(c) Full-scale tests show no appreciable difference in the number of sprinkler heads that open for either nonencapsulated or encapsulated products up to 15 ft (4.6 m) high. Test data is not available for encapsulated products stored higher than 15 ft (4.6 m). However, in rack storage tests involving encapsulated storage 20 ft (6 m) high, increased protection was needed over that for nonencapsulated storage.

The protection specified in Chapter 6 contemplates a maximum of 10-ft (3-m) clearances from top of storage to sprinkler deflectors for storage heights of 15 ft (4.6 m) and higher.

A-6-2.4

Recommended water supplies anticipate successful sprinkler operation. Because of the small, but still significant, number of uncontrolled fires in sprinklered properties, which have various causes, there should be an adequate water supply available for fire department use.

A-7-1

The densities and area of application have been developed from fire test data. Most of these tests were conducted with large orifice [$^{17}/_{32}$ in. (13.5 mm)] sprinklers and 80-ft^2 or 100-ft^2 (7.4-ft^2 or 9.3-m^2) sprinkler spacing. These and other tests have indicated that, with densities of 0.40 gpm/ft^2 [0.27 (L/s)/m^2] and higher, better results are obtained with large orifice and 70 ft^2

to 100 ft^2 (7.4 m^2 to 9.3 m^2) sprinkler spacing than where using $^1/_2$-in. (12.7-mm) orifice sprinklers at 50-ft^2 (4.6-m^2) spacing. A discharge pressure of 100 psi (689 kPa) was used as a starting point on one of the fire tests. It was successful, but has a $1^1/_2$-ft (0.5-m) clearance between the top of storage and ceiling sprinklers. A clearance of 10 ft (3.0 m) could have produced a different result due to the tendency of the higher pressure to atomize the water and the greater distance that the fine water droplets had to travel to the burning fuel.

A-7-1.1

Two direct comparisons between ordinary-temperature and high-temperature rated sprinklers are possible:

(a) With nonexpanded polyethylene 1-gal (3.8-L) bottles in corrugated cartons, a 3-ft (0.9-m) clearance, and the same density, approximately the same number of sprinklers operated [9 at 286°F (141°C) versus 7 at 165°F (74°C)].

(b) With exposed, expanded polystyrene meat trays, a 9.5-ft (1.9-m) clearance, and the same density, three times as many ordinary-temperature rated sprinklers operated as did high-temperature rated sprinklers [11 at 286°F (141°C) versus 33 at 165°F (74°C)].

The cartoned plastics requirements of this standard are based to a great extent on test work that used a specific commodity — 16-oz (0.473-L) polystyrene plastic jars individually separated by thin carton stock within a large corrugated carton [$3^1/_2$ ft^2 (0.32 m^2)]. [*See Figure A-7-1.1(a).*]

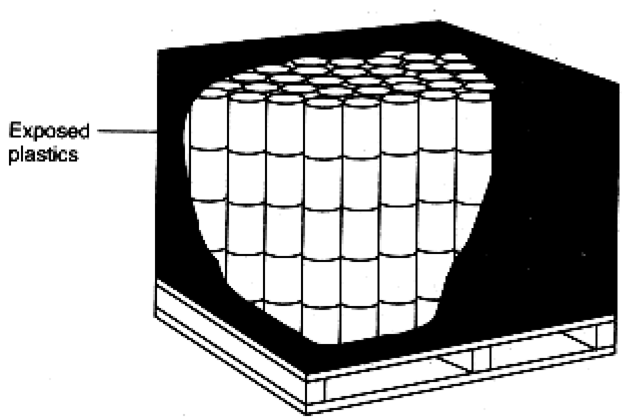

Figure A-7-1.1(a) Corrugated carton containing individually separated plastic jars.

Other Group A plastic commodities can be arranged in cartons so that they are separated by multiple thicknesses of carton material. In such arrangements, less plastic becomes involved in the fire at any one time. This could result in a less vigorous fire that can be controlled by Class IV commodity protection.

Other situations exist in which the plastics component is surrounded by several layers of less hazardous material and is therefore temporarily protected or insulated from a fire involving adjacent plastic products. Such conditions also could produce a less vigorous fire and be successfully handled by Class IV protection. [*See Figure A-7-1.1(b).*]

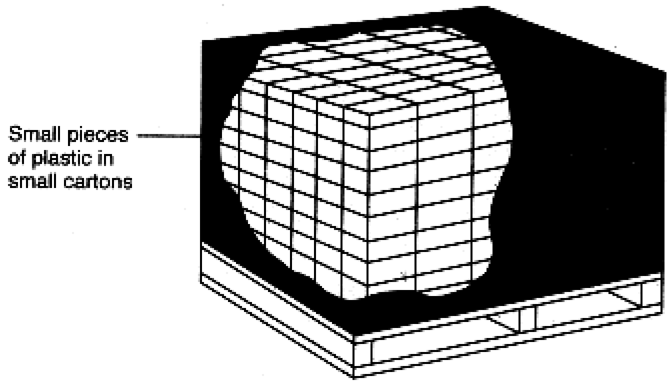

Figure A-7-1.1(b) Corrugated carton containing plastic pieces individually separated by carton material.

The decision to protect as a Class IV commodity, however, should be made only based on experienced judgment and only with an understanding of the consequences of underprotecting the storage segment.

A-7-1.2

There are few storage facilities in which the commodity mix or storage arrangement remains constant, and a designer should be aware that the introduction of different materials can change protection requirements considerably. Design should be based on higher densities and areas of application, and the various reductions allowed should be applied cautiously. For evaluation of existing situations, however, the allowances can be quite helpful.

A-7-2.1

An evaluation for each field situation should be made to determine the worst applicable height-clearance relationship that can be expected to appear in a particular case. Fire tests have shown that considerably greater demands occur where clearance is 10 ft (3.0 m) as compared to 3 ft (0.9 m), and where a pile is stable as compared to an unstable pile. Since a system is designed for a particular clearance, the system could be inadequate when significant areas do not have piling to the design height and larger clearances exist between stock and sprinklers. This can also be true where the packaging or arrangement is changed so that stable piling is created where unstable piling existed. Recognition of these conditions is essential to avoid installation of protection that is inadequate or becomes inadequate because of changes.

No tests were conducted simulating a peaked roof configuration. However, it is expected that the principles of Chapter 7 still apply. The worst applicable height-clearance relationship that can be expected to occur should be found, and protection designed for it. If storage is all at the same height, the worst height-clearance relationship creating the greatest water demand would occur under the peak. If commodities are stored higher under the peak, the various height-clearance relationships should be tried and the one creating the greatest water demand used for designing protection.

A-7-2.2

Test data is not available for all combinations of commodities, storage heights, and clearances. Some of the protection criteria in this standard are based on extrapolations of test data for other commodities and storage configurations, as well as available loss data.

For example, there is very limited test data for storage of expanded plastics higher than 20 ft (6 m). The protection criteria in this standard for expanded plastics higher than 20 ft (6 m) are extrapolated from test data for expanded plastics storage 20 ft (6 m) and less in height and test data for unexpanded plastics above 20 ft (6 m).

Further examples can be found in the protection criteria for clearances up to 15 ft (4.6 m). Test data is limited for clearances greater than 10 ft (3.0 m). It should be assumed that, if protection is adequate for a given storage height in a building of a given height, the same protection will protect storage of any lesser height in the same building. For example, protection adequate for 20-ft (6.1-m) storage in a 30-ft (10-m) building [10-ft (3.0-m) clearance] would also protect 15-ft (4.6-m) storage in a 30-ft (10-m) building [15-ft (4.6-m) clearance]. Therefore, the protection criteria in Table 7-2.2 for 15-ft (4.6-m) clearance are based on the protection criteria for storage 5 ft (1.5 m) higher than the indicated height with 10-ft (3.0-m) clearance.

A-7-2.5

Wet systems are recommended for storage occupancies. Dry-pipe systems may be permitted only where it is impractical to provide heat.

A-9-1

ESFR sprinklers were designed to respond quickly to growing fires and deliver heavy discharge to suppress fires rather than to control them. ESFR sprinklers should not be relied upon to provide suppression if they are used outside these design parameters.

A-9-1.2

Storage in single-story or multistory buildings may be permitted, provided the maximum ceiling/roof height as specified in Table 9-1 is satisfied for each storage area.

A-9-2

Design parameters were determined from a series of full-scale fire tests conducted as a joint effort between Factory Mutual Research Corporation and the National Fire Protection Research Foundation. (Copies of the test reports are available from the NFPRF.)

A-10-1

Locomotives should not be allowed to enter storage areas.

A-10-1.1

Industrial trucks using gas or liquid fuel should be refueled outside of the storage building at a location designated for that purpose.

A-10-3.1

The use of welding, cutting, soldering, or brazing torches in the storage areas introduces a severe fire hazard. The use of mechanical fastenings and mechanical saws or cutting wheels is recommended.

Appendix B Example Determining Protection Criteria for Plastic and Rubber Commodities

This Appendix is not a part of the requirements of this NFPA document but is included for

informational purposes only.

Appendix B explains and provides an example of the method and procedure to follow in using this standard to determine proper protection for Group A plastics. (*See Chapter 7*.)

Metric Conversion Factors for Examples

To convert from	to	Multiply by
feet (ft)	meter (m)	0.3048
square feet (ft^2)	meter/square (m^2)	0.0920
gal/min (gpm)	liter/second (L/s)	0.0631
gal per min/ft^2 (gpm/ft^2)	liter per second/m^2 [(L/s)/m^2]	0.679

Example

Building ceiling height — 23 ft

Maximum storage height — 18 ft

Wet or dry sprinkler system — Dry

Commodity. Nonexpanded, unexposed thermoplastic polyethylene and polypropylene toys in cardboard boxes stacked so as to exclude air voids within the load (forming solid unit loads). This meets the Group A plastic definition of Chapter 2.

Protection Requirements. The decision tree (*see Figure 7-1.1*) directs the user to column A of Table 7-2.2 for nonexpanded, stable, solid unit load.

To determine the proper density for 18-ft high storage, the densities given for 15-ft high and 20-ft high storage corresponding to the ceiling height of 25 ft are interpolated.

NOTE: There is no interpolation between ceiling heights. The exact height should be chosen, or, if the height is higher, it should be rounded up.

Using Table 7-2.2:

15-ft storage height and 25-ft ceiling = 0.4 gpm/ft^2 over 2500 ft^2

20-ft storage height and 25-ft ceiling = 0.3 gpm/ft^2 over 2500 ft^2

NOTE: The reason for the lower density at a 20-ft storage height is due to the favorable factor of less clearance between the top of storage and the ceiling (not the sprinkler deflector).

From interpolation, the design/area demand equals 0.34 gpm/ft^2 over 2500 ft^2 for a wet system.

Final demand for a dry system:

Adjustment to area of demand = 2500 ft^2 $\times$ 1.30 = 3250 ft^2, or

Final sprinkler density and area = 0.34 gpm/ft^2 over 3250 ft^2.

Appendix C Protection of Outdoor Storage

C-1 General.

C-1.1

The hazards of exposure to outdoor storage from ignition sources and exposing fires and the infinite variety of conditions under which such exposures can occur render impossible the formulation of any single table, formulae, or set of rules that can cover all conditions adequately.

C-1.2

Recommendations contained in this appendix are for the protection of outdoor storage of commodities covered by the standard. *(See Section 1-1.)*

C-1.3

In general, the provision of automatic fire protection is impractical for outdoor storage. As a result, emphasis must be placed upon the following:

(a) Control of potential ignition sources, such as from exposing buildings, transformers, yard equipment, refuse burners, overhead power lines, and vandals;

(b) Elimination of adverse factors such as trash accumulations, weeds, and brush;

(c) Provision of favorable physical conditions, such as limited pile sizes, low storage heights, wide aisles, and possible use of fire retardant covers (e.g., tarpaulins);

(d) The rapid and effective application of manual fire-fighting efforts by the provision of fire alarms, strategically located hydrants, and adequate hose houses or hose reels.

C-1.4

Outdoor storage should be avoided in most cases but is recognized as a necessity in many industries.

C-1.4.1 Outdoor storage is acceptable for materials that are:

(a) Of low fire hazard, not requiring protection even if located indoors.

(b) Of sufficiently low value that a potential loss would not justify the utilization of building space.

(c) Of such severe fire hazard that indoor protection is impractical when balanced against potential loss.

(d) Of large volume and bulk, making it impractical to construct and protect a building to house the storage.

C-1.4.2 Where materials that normally would be stored in buildings are stored outdoors in temporary emergencies, it is recommended that special precaution be taken for their safeguard and that they be moved to a storage warehouse as soon as possible.

C-1.5

Standards that address outdoor storage of specific commodities are found in Chapter 11.

C-2 Responsibility of Management.

C-2.1

It is the responsibility of management to properly consider the hazards of the various materials handled. Protection requirements and storage arrangements vary with the combustibility of the materials. Management should determine any special precautions that should be followed for the types of material stored. The care, cleanliness, and maintenance exercised by management determine to a large extent the relative fire safety in the storage area.

C-2.2

Consideration should be given by management to proper storage of materials in order to prevent the undue concentration of quantities of such materials in a single location, subject to one catastrophe. The criteria used to determine the amount of such material that should be stored in a single location are not only dependent upon the dollar value of the commodity but also upon the total supply and availability of the material. The impact of the loss of the storage upon the ability to continue production should be considered.

C-3 Site.

C-3.1

In selecting a site for outdoor storage, preference should be given to a location that can provide the following:

(a) Adequate municipal fire and police protection;

(b) An adequate public water system with hydrants suitably located for protection of the storage;

(c) Adequate all-weather roads for fire department apparatus response;

(d) Sufficient clear space from buildings or from other combustible storage that constitutes an exposure hazard;

(e) Absence of flood hazard;

(f) Adequate clearance space between storage piles and any highways, bridges, railroads, and woodlands;

(g) Topography as level as possible to provide storage stability.

C-3.2

The entire site should be surrounded by a fence or other suitable means to prevent access of unauthorized persons. An adequate number of gates should be provided in the surrounding fence or other barriers to permit ready access of fire apparatus.

C-4 Material Piling.

C-4.1

Materials should be stored in unit piles as low in height and small in area as is consistent with good practice for the materials stored. The maximum height should be determined by the stability of pile, effective reach of hose streams, combustibility of the commodity, and ease of pile breakdown under fire or mop-up conditions. Long narrow piles are preferred over large square piles to facilitate manual fire fighting. (The short dimension increases the effectiveness of hose streams and eases pile breakdown.)

C-4.2

Aisles should be maintained between individual piles, between piles and buildings, and between piles and the boundary line of the storage site. Sufficient driveways having the width of at least 15 ft (4.6 m) should be provided to allow the travel of fire equipment to all portions of the storage area. Aisles should be at least twice the pile height to reduce the spread of fire from pile to pile and to allow ready access for fire fighting, emergency removal of material, or salvage purposes.

C-4.3

As the commodity class increases in combustibility or where storage could be ignited easily from radiation, wider aisles should be provided. Smaller unit piles might be an alternative to wider aisles if yard space is limited.

C-4.4

For outdoor idle pallet storage, see Section 4-4 and A-4-4.1.1 of this standard. Separation between piles of idle pallets and other yard storage should be as specified in Table C-4.4.

Table C-4.4 Pile Separation

Pile Size	Minimum Distance ft (m)	
Fewer than 50 pallets	20	(6)
50-200 pallets	30	(9.1)
More than 200 pallets	50	(15.2)

C-4.5

Boundary posts with signs designating piling limits should be provided to indicate yard area, roadway, and aisle limits.

C-5 Buildings and Other Structures.

C-5.1

Yard storage, particularly storage of commodities in the higher heat release category, should have as much separation as is practical from important buildings and structures, but not less than that offered by NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures.*

C-5.1.1 As guidance in using NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures,* to establish clear spaces, the following Classification of Severity with Commodity Classes of this standard should be used on the basis of 100 percent openings representing yard storage:

(a) *Light Severity.* Commodity Class I

(b) *Moderate Severity*. Commodity Class II

(c) Interpolate between moderate and severe severity for Commodity Class III

(d) *Severe Severity*. Commodity Class IV and Class A plastics.

NOTE: The guidelines of C-5.1.1 apply to the equivalent commodity classes of this standard. The severity of the exposing building or structure also should be a consideration where establishing a clear space.

C-6 Yard Maintenance and Operations.

C-6.1

The entire storage site should be kept free from accumulation of unnecessary combustible materials. Vegetation should be kept cut low. Procedures should be provided for weed control and the periodic cleanup of the yard area.

C-6.2

Adequate lighting should be provided to allow supervision of all parts of the storage area at night.

C-6.3

All electrical equipment and installations should conform to the provisions of NFPA 70, *National Electrical Code*.

C-6.4

No heating equipment should be located or used within the storage area. Salamanders, braziers, portable heaters, and other open fires should not be used.

C-6.5

Smoking should be prohibited, except in locations prominently designated as smoking areas. “No Smoking” signs should be posted in prohibited areas.

C-6.6

Welding and cutting operations should be pro- hibited in the storage area, unless in compliance with NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*.

C-6.7

Tarpaulins used for protection of storage against the weather should be of fire retardant fabric.

C-6.8

Locomotives from which glowing particles could be emitted from exhaust stacks should not be permitted in the yard.

C-6.9

Motorized vehicles using gasoline, diesel fuel, or liquefied petroleum gas as fuel should be garaged in a separate, detached building.

C-6.9.1 Storage and handling of fuel should conform with NFPA 30, *Flammable and Combustible Liquids Code*, and NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*.

C-6.9.2 Repair operations should be conducted outside the yard unless a separate masonry wall building is provided. Vehicles should not be greased, repaired, painted, or otherwise serviced in the yard. Such work should be conducted in conformity with NFPA 88B, *Standard for Repair Garages*.

C-7 Fire Protection.

C-7.1

Provisions should be made for promptly notifying the public fire department and private fire brigade (if available) in case of fire or other emergency.

C-7.2

Hydrants should be spaced to provide a sufficient number of hose streams. (*See NFPA 24, Standard for the Installation of Private Fire Service Mains and Their Appurtenances*.)

C-7.2.1

Provisions should be made to permit the direction of an adequate number of hose streams on any pile or portion of the storage area that could be involved in fire. It is recommended that, unless adequate protection is provided by the municipal fire department, sufficient hose and other equipment should be kept on hand at the storage property, suitably housed, and provision should be made for trained personnel available to put it into operation.

C-7.2.2

Hydrants and all fire-fighting equipment should be accessible for use at all times. No temporary storage should be allowed to obstruct access to fire-fighting equipment, and any accumulation of snow or obstructing material should be removed promptly.

C-7.3

Monitor nozzles should be provided at strategic points where large quantities of highly combustible materials are stored or where average amounts of combustible materials are stored in inaccessible locations.

C-7.4

Fire extinguishers of an appropriate type should be placed at well-marked, strategic points throughout the storage area so that one or more portable fire extinguisher units can be made available quickly for use at any point. Where the climate is such that there is a danger of freezing, suitable extinguishers for freezing temperatures should be used. For guidance in the type and use of extinguishers refer to NFPA 10, *Standard for Portable Fire Extinguishers*.

C-8 Guard Service.

C-8.1

Guard service should be provided and continuously maintained throughout the yard and storage area at all times while the yard is otherwise unoccupied. The responsibilities and the training of guards should be as specified in NFPA 601, *Standard on Guard Service in Fire Loss Prevention*. It is recommended that there be some suitable means of supervising guard activities to ensure that required rounds are made at regular intervals.

C-8.2

The value of strategically placed watchtowers in large yards where a guard stationed at a point of advantage can keep the entire property under observation should be considered. It is recommended that such watchtowers be connected to the alarm system for prompt notification of fire.

Appendix D Referenced Publications

D-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.

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 Extinguishers*, 1994 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1994 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*, 1994 edition.

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, 1995 edition.

NFPA 70, *National Electrical Code*, 1993 edition.

NFPA 72, *National Fire Alarm Code*, 1993 edition.

NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*, 1993 edition.

NFPA 88B, *Standard for Repair Garages*, 1991 edition.

NFPA 204M, *Guide for Smoke and Heat Venting*, 1991 edition.

NFPA 600, *Standard on Industrial Fire Brigades*, 1992 edition.

NFPA 601, *Standard on Guard Service in Fire Loss Prevention*, 1992 edition.

NFPA 1420, *Recommended Practice for Pre-Incident Planning for Warehouse Occupancies*, 1993 edition.

NFPA *Industrial Fire Brigade Training Manual*.

Formal Interpretation

NFPA 231

General Storage

1995 Edition

Reference: 1-1
F.I. 95-1 (NFPA 231)

Question: Are offices in a mixed occupancy, Storage/Business, within the scope of 231 if they are separated by a one-hour fire rated wall?

Answer: No.

Issue Edition: 1995
Reference: 1-1
Issue Date: October 5, 1995
Effective Date: October 25, 1995

General Storage

1995 Edition

Reference: 2-1.5
F.I. 85-1

Background: Paragraph 2-1.5 treats highly plasticized polyvinyl chloride as a Group A plastic and lightly plasticized polyvinyl chloride as a Group C plastic.

Plastic industry sources consider the addition of 50% plasticizers to be highly plasticized.

Question 1: Does the addition of 50% plasticizers result in a highly plasticized product?

Answer: Yes.

Question 2: Does the addition of 25% plasticizers result in a highly plasticized product?

Answer: Yes.

Question 3: Does the addition of 10% plasticizers result in a highly plasticized product?

Answer: No.

Issue Edition: 1985
Reference:– 2-1.5
Date: April 1986

General Storage

1995 Edition

Reference: 5-1.6
F.I. 95-2 (NFPA 231)

Question No. 1: Is it the intent of 5-1.6 to carry the ceiling density 15’ beyond the storage area past a one-hour fire rated wall separating the storage area from the office area?

Answer: No.

Question No. 2: If the answer to Question No. 1 is yes, are these sprinklers required to be at the roof level in the interstitial space above the ceiling of the offices?

Answer: N/A

Issue Edition: 1995
Reference: 5-1.6
Issue Date: October 5, 1995
Effective Date: October 25, 1995

NFPA 231C

1995 Edition

Standard for Rack Storage of Materials

1995 Edition

This edition of NFPA 231C, *Standard for Rack Storage of Materials*, was prepared by the Technical Committee on Rack Storage 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.

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 231C

In August 1967, representatives for rack manufacturers, fire protection equipment manufacturers, the insurance community, and industrial users met and organized the Rack Storage Fire Protection Committee. This committee developed and financially sponsored a program of full-scale fire tests for the storage of combustible materials in racks.

In 1968, the NFPA Committee on Rack Storage of Materials was organized. All of the data developed by the Rack Storage Fire Protection Committee was subsequently turned over to the NFPA committee. Thus, it was possible for the NFPA committee to write a standard supported entirely by actual fire test data. NFPA 231C was first adopted at the Annual Meeting in May 1971.

In 1972, revisions included changing certain recommendations to requirements, and new material was added to the appendix. In 1973, it was revised further to include storage for heights above 25 ft (7.6 m) and to relocate advisory material to Appendix A. In 1974, the entire format was revised, editorial changes were made, and new material was added.

In 1975, new test data resulted in the introduction of additional material. The 1980 edition was a partial revision to the standard, including changes to the tables and figures in Chapter 6. Revisions made in 1986 included expanded protection criteria for plastic commodities.

The 1991 edition incorporated a variety of changes that included editorial improvements as well as numerous substantive changes. Technically important changes in the 1991 edition included permission to utilize intermediate- and high-temperature sprinklers for plastic commodities. In addition, a series of figures were included that show the relative positions of in-rack sprinklers for rack storage of Group A plastics. The previously issued TIA on ESFR sprinklers was incorporated as a new chapter.

The 1995 edition incorporates criteria for miscellaneous storage, extra-large orifice sprinklers, quick response and large orifice sprinklers for in-rack applications, and new large drop and ESFR sprinkler applications. In addition, new definitions were introduced and some chapters were reworded to improve the user friendliness of the document.

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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.

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 prevention and fire protection considerations for the rack storage of materials, including automatic systems. This Committee also shall have primary responsibility for emergency operations, including fire-fighting operations in facilities used for the rack storage of materials.

NFPA 231C
Standard for
Rack Storage of Materials

1995 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph or section in the text indicates explanatory material on that paragraph or section in Appendix A.
A dagger (†) following the number or letter designating a paragraph or section in the text indicates explanatory test data and procedures with regard to that paragraph or section in Appendix B.
Information on referenced publications can be found in Chapter 13 and Appendix C.

Chapter 1 Introduction

1-1 Application and Scope.

This standard shall apply to storage of materials representing the broad range of commodities stored in racks.

Exception: Miscellaneous storage shall be permitted to be protected in accordance with NFPA 13, Standard for the Installation of Sprinkler Systems.

Storage on plastic pallets or plastic shelves is outside the scope of this standard.

Storage of high hazard materials such as tires, roll paper stored on end, and flammable liquids is outside the scope of this standard. Storage of such commodities shall be protected in accordance with the provisions of NFPA 30, *Flammable and Combustible Liquids Code*; NFPA 40, *Standard for the Storage and Handling of Cellulose Nitrate Motion Picture Film*; NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*; NFPA 81, *Standard for Fur Storage, Fumigation and Cleaning*; NFPA 231, *Standard for General Storage*; NFPA 231D, *Standard for Storage of Rubber Tires*; NFPA 231F, *Standard for the Storage of Roll Paper*; NFPA 232, *Standard for the Protection of Records*, and NFPA 490, *Code for the Storage of Ammonium Nitrate*, as applicable.

NOTE: See also NFPA 231E, *Recommended Practice for the Storage of Baled Cotton*.

Bin storage and shelf storage are outside the scope of this standard.

1-1.1

Nothing in this standard is intended to restrict new technologies or alternate arrangements, provided the level of safety prescribed by the standard is not reduced.

1-2 Retroactivity Clause.

The provisions of this document shall be 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.

1-3 Definitions.

Unless specifically stated elsewhere, for the purpose of this standard, the terms in this section shall be defined as follows.

Aisle Width. The horizontal dimension between the face of the loads in racks under consideration. [*See Figure 1-3(a).*]

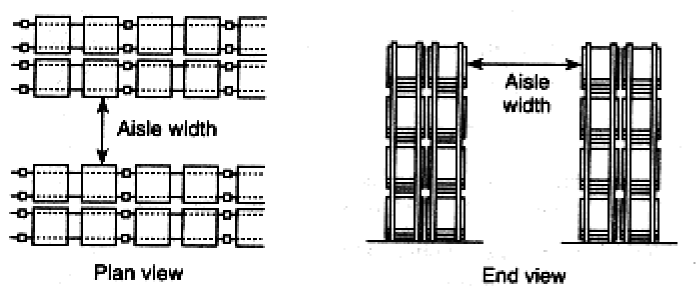


Figure 1-3(a) Illustration of aisle width.

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.

Bulkhead. A vertical barrier across the rack.

Ceiling Height. The distance between the floor and the underside of the ceiling above (or roof deck) within the storage area.

Commodity. The combinations of product, packing material, and container upon which commodity classification is based.

Conventional Pallets. A material-handling aid designed to support a unit load with openings to provide access for material-handling devices. [*See Figure 1-3(b).*]

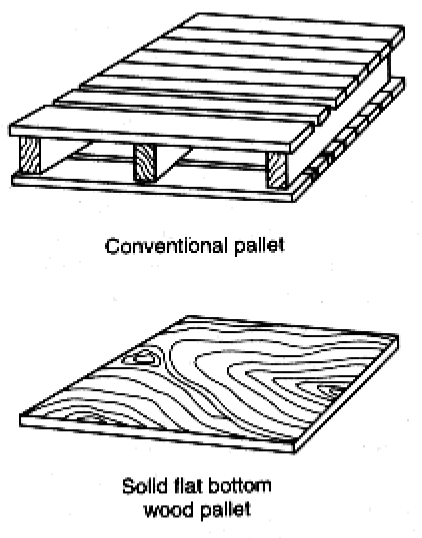


Figure 1-3(b) Typical pallets.

Early Suppression Fast Response Sprinklers (ESFR). See NFPA 13, *Standard for the Installation of Sprinkler Systems*.

Encapsulated. A method of packaging consisting of a plastic sheet completely enclosing the sides and top of a pallet load containing a combustible commodity or a combustible package or a group of combustible commodities or combustible packages. Combustible commodities individually wrapped in plastic sheeting and stored exposed in a pallet load also are to be considered encapsulated.

Totally noncombustible commodities on wood pallets enclosed only by a plastic sheet as described are not covered under this definition. Banding, i.e., stretch-wrapping around the sides only of a pallet load, is not considered to be encapsulation. Where there are holes or voids in the plastic or waterproof cover on the top of the carton that exceed more than half of the area of the cover, the term “encapsulated” shall not apply. The term encapsulated does not apply to plastic-enclosed product or packages inside a large, nonplastic, enclosed container.

Face Sprinklers. Standard sprinklers located in transverse flue spaces along the aisle or in the rack, within 18 in. (0.46 m) of the aisle face of storage and used to oppose vertical development of fire on the external face of storage.

Free-Flowing Plastic Materials. Those plastics that fall out of their containers during a fire, fill flue spaces, and create a smothering effect on the fire. Examples: powder, pellets, flakes, or random-packed small objects [razor blade dispensers, 1-oz to 2-oz (28-g to 57-g) bottles, etc.].

Horizontal Barrier. A solid barrier in the horizontal position covering the entire rack, including all flue spaces at certain height increments, to prevent vertical fire spread.

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.

Longitudinal Flue Space. The space between rows of storage perpendicular to the direction of loading. [*See Figure 1-3(c)*.]

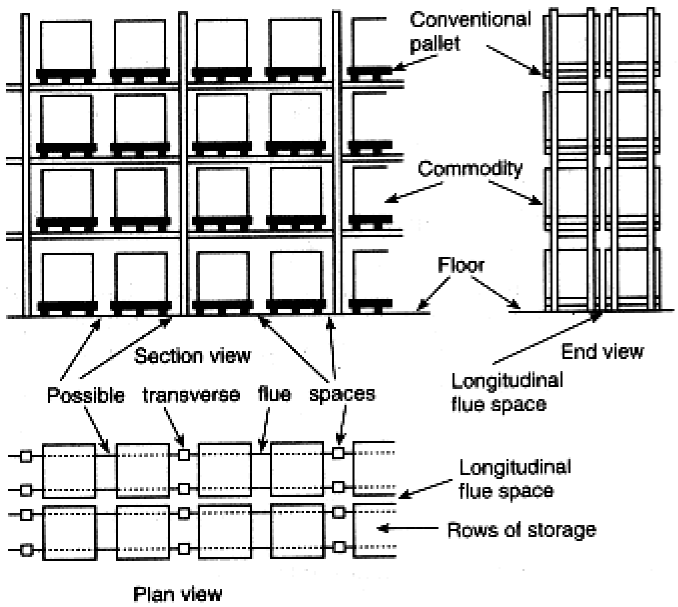


Figure 1-3(c) Typical double-row (back-to-back) rack arrangement.

Miscellaneous Storage. Storage that does not exceed 12 ft (3.7 m) in height and is incidental to another occupancy use group as defined in NFPA 13, *Standard for the Installation of Sprinkler Systems*. Such storage shall not constitute more than 10 percent of the building area or 4000 ft^2 (372 m^2) of the sprinklered area, whichever is greater. Such storage shall not exceed 1000 ft^2 (93 m^2) in one pile or area, and each such pile or area shall be separated from other storage areas by at least 25 ft (7.6 m).

Rack. Any combination of vertical, horizontal, and diagonal members that supports stored materials. Some rack structures use solid shelves. Racks shall be permitted to be fixed, portable, or movable [*see Figures A-4-1(a) through (k)*]. Loading shall be permitted to be either manual, using lift trucks, stacker cranes, or hand placement; or automatic, using machine controlled storage and retrieval systems.

Double-Row Racks. Double-row racks are two single-row racks placed back-to-back having a combined width up to 12 ft (3.7 m) with aisles at least 3.5 ft (1.1 m) on each side.

Movable Racks. Movable racks are racks on fixed rails or guides. They can be moved back and forth only in a horizontal, two-dimensional plane. A moving aisle is created as abutting racks are either loaded or unloaded, then moved across the aisle to abut other racks. Rack arrangements generally result in the same protection requirements as those for multiple-row racks.

Multiple-Row Racks. Multiple-row racks are racks greater than 12 ft (3.7 m) wide or single- or double-row racks separated by aisles less than 3.5 ft (1.1 m) wide having an overall width greater than 12 ft (3.7 m).

Portable Racks. Portable racks are racks that are not fixed in place. They can be arranged in any number of configurations.

Single-Row Racks. Single-row racks are racks with no longitudinal flue space and having a width up to 6 ft (1.8 m) with aisles at least 3.5 ft (1.1 m) from other storage.

Roof Height. The distance between the floor and the underside of the roof deck within the storage area.

Shall. Indicates a mandatory requirement.

Shelf Storage. Storage on structures less than 30 in. (7.62 cm) deep, with shelves usually 2 ft (0.6 m) apart vertically and separated by approximately 30-in. (76.2-cm) aisles.

Should. Indicates a recommendation or that which is advised but not required.

Slave Pallet. A special pallet captive to a material-handling system. [*See Figure 1-3(b).*]

Solid Shelving. Solid shelving is solid, slatted, and other types of shelving located within racks that obstruct sprinkler water penetration down through the racks.

Transverse Flue Space. The space between rows of storage parallel to the direction of loading. [*See Figure 1-3(c).*]

Chapter 2 Classification of Storage

2-1 Commodity Classifications.

2-1.1

Class I commodities are defined as essentially noncombustible products on wood pallets, or in ordinary corrugated cartons with or without single-thickness dividers, or in ordinary paper wrappings, all on wood pallets. Such products shall be permitted to have a negligible amount of plastic trim, such as knobs or handles.

Examples of Class I products include:

Foods. Foods in noncombustible containers; frozen foods; meats; fresh fruits and vegetables in nonplastic trays or containers; dairy products in nonwax-coated paper containers; beer and wine, up to 20 percent alcohol, in metal, glass, or ceramic containers.

Glass Products. Glass bottles, empty or filled with noncombustible liquids; mirrors.

Metal Products. Metal desks with plastic tops and trim; electrical coils; electrical devices in their metal enclosures; pots and pans; electrical motors; dry cell batteries; metal parts; empty cans; stoves; washers; dryers; metal cabinets.

Others. Oil-filled and other types of distribution transformers; cement in bags; electrical insulators; gypsum board; inert pigments; dry insecticides.

2-1.2

Class II commodities are defined as Class I products in slatted wooden crates, solid wooden boxes, multi-wall corrugated cartons, or equivalent combustible packaging material on wood pallets.

Examples of Class II products include:

Thinly coated fine wire such as radio coil wire on reels or in cartons; incandescent or fluorescent light bulbs; beer or wine, up to 20 percent alcohol in wood containers; Class I products, if in small cartons or small packages placed in ordinary paperboard cartons.

2-1.3

Class III commodities are defined as wood, paper, natural fiber cloth, and Group C plastics or products thereof on wood pallets. Products shall be permitted to contain a limited amount of Group A or B plastics. Wood dressers with plastic drawer glides, handles, and trim are examples of a commodity containing a limited amount of plastic.

Examples of Class III products include:

Leather Products. Shoes; jackets; gloves; luggage.

Paper Products. Books; magazines; newspapers; stationery; plastic-coated paper food containers; paper or cardboard games; tissue products; rolled paper on side or steel banded on end; regenerated cellulosics (cellophane).

Textiles. Natural fiber upholstered nonplastic furniture; wood or metal furniture with plastic padded and covered armrests; mattresses without expanded plastic or rubber; absorbent cotton in cartons; natural fiber and viscose yarns, thread, and products; natural fiber clothing or textile products.

Wood Products. Doors; windows; door and window frames; combustible fiberboard; wood cabinets; furniture; other wood products.

Others. Tobacco products in paperboard cartons; nonflammable liquids such as soaps, detergents and bleaches, and nonflammable pharmaceuticals in plastic containers; combustible foods and cereal products; non-negative-producing film packs in sealed metal foil wrappers in paperboard packages.

2-1.4

Class IV commodities are defined as Class I, II, and III products containing an appreciable amount of Group A plastics in paperboard cartons or Class I, II, and III products with Group A plastic packing in paperboard cartons on wood pallets. Group B plastics and free-flowing Group A plastics also are included in this class. (*See Section 1-1.*)

Examples of Class IV products include:

Small appliances, typewriters, and cameras with plastic parts; plastic-backed tapes; and synthetic fabrics or clothing. An example of packing material is a metal product in a foamed plastic cocoon in a corrugated carton.

Class IV commodities also include:

Textiles. Synthetic thread and yarn, except viscose; nonviscose synthetic fabrics or clothing.

Others. Vinyl floor tile; wood or metal frame upholstered furniture or mattresses with plastic covering or padding, or both; plastic-padded metal dashboards or metal bumpers.

2-1.5 Classification of Plastics, Elastomers, and Rubber.

NOTE: The following categories are based on unmodified plastic materials. The use of fire- or flame-retarding modifiers or the physical form of the material can change the classification.

2-1.5.1 Group A.

ABS (acrylonitrile-butadiene-styrene copolymer)

Acetal (polyformaldehyde)
Acrylic (polymethyl methacrylate)
Butyl rubber
EPDM (ethylene-propylene rubber)
FRP (fiberglass reinforced polyester)
Natural rubber (if expanded)
Nitrile rubber (acrylonitrile-butadiene rubber)
PET (thermoplastic polyester)
Polybutadiene
Polycarbonate
Polyester elastomer
Polyethylene
Polypropylene
Polystyrene
Polyurethane
PVC (polyvinyl chloride — highly plasticized, e.g., coated fabric, unsupported film)
SAN (styrene acrylonitrile)
SBR (styrene-butadiene rubber)

2-1.5.2 Group B.

Cellulosics (cellulose acetate, cellulose acetate butyrate, ethyl cellulose)
Chloroprene rubber
Fluoroplastics (ECTFE - ethylene-chlorotrifluoro-ethylene copolymer; ETFE - ethylene-tetrafluoro-ethylene copolymer; FEP - fluorinated ethylene-propylene copolymer)
Natural rubber (not expanded)
Nylon (nylon 6, nylon 6/6)
Silicone rubber

2-1.5.3 Group C.

Fluoroplastics (PCTFE - polychlorotrifluoroethylene; PTFE - polytetrafluoroethylene)
Melamine (melamine formaldehyde)
Phenolic
PVC (polyvinyl chloride — rigid or lightly plasticized, e.g., pipe, pipe fittings)
PVDC (polyvinylidene chloride)
PVDF (polyvinylidene fluoride)
PVF (polyvinyl fluoride)
Urea (urea formaldehyde)

Chapter 3 Building Construction

3-1 Construction.

Buildings used for the rack storage of materials that are protected in accordance with this standard shall be of any of the types described in NFPA 220, *Standard on Types of Building Construction*.

3-2 Fire Protection of Steel.

3-2.1

With sprinkler systems installed in accordance with Chapters 6 through 10, fire protection of roof steel shall not be required.

3-2.2

Where ceiling sprinklers and sprinklers in racks are installed in accordance with Chapters 5 through 8, fire protection of steel building columns shall not be required.

3-2.3

Where storage height exceeds 15 ft (4.6 m) and ceiling sprinklers only are installed, fire protection by one of the following methods shall be required for all types of steel building columns located within the racks or for vertical rack members that support the building:

(a) One-hour fire proofing.

(b) Sidewall sprinklers at the 15-ft (4.6-m) elevation, pointed toward one side of the steel column.

(c) Provision of ceiling sprinkler density for a minimum of 2000 ft^2 (185.9 m^2) with 165°F (74°C) or 286°F (141°C) rated sprinklers as shown in Table 3-2.3(c) for storage heights above 15 ft (4.6 m), up to and including 20 ft (6.1 m).

(d) Provision of large drop or early suppression fast response (ESFR) ceiling sprinkler protection in accordance with Chapters 9 and 10, respectively.

Table 3-2.3(c) Ceiling Sprinkler Densities for Protection of Steel Building Columns

	Aisle Width	
Commodity Class	4 ft (1.22 m)	8 ft (2.44 m)
	gpm/ft^2	[(L/s)/m^2]
I	0.37	0.33
II	0.44	0.37
III	0.49	0.42
IV and Plastics	0.68	0.57

NOTE: For aisle widths of 4 ft to 8 ft (1.22 m to 2.44 m), a direct linear interpolation between densities may be made.

3-3 Vents and Draft Curtains.

Design curves are based on the assumption that roof vents and draft curtains are not being used.

Chapter 4 Storage Arrangement

4-1* Rack Structure.

Rack configurations shall be of a generally accepted arrangement.

4-2* Rack Loading.

Racks shall not be loaded beyond their design capacity.

4-3 Flue Space.

4-3.1*†

In double-row racks with height of storage up to and including 25 ft (7.6 m), and without solid shelves, a longitudinal flue space (back-to-back clearance) is not necessary. Nominal 6-in. (152.4-mm) transverse flue space between loads or at rack uprights shall be maintained. Random variations in the width of the flue spaces or in their vertical alignment shall be permitted. (*See Figure 4-3.1.*)

Exception: A longitudinal flue shall be required where ESFR sprinkler protection is provided.

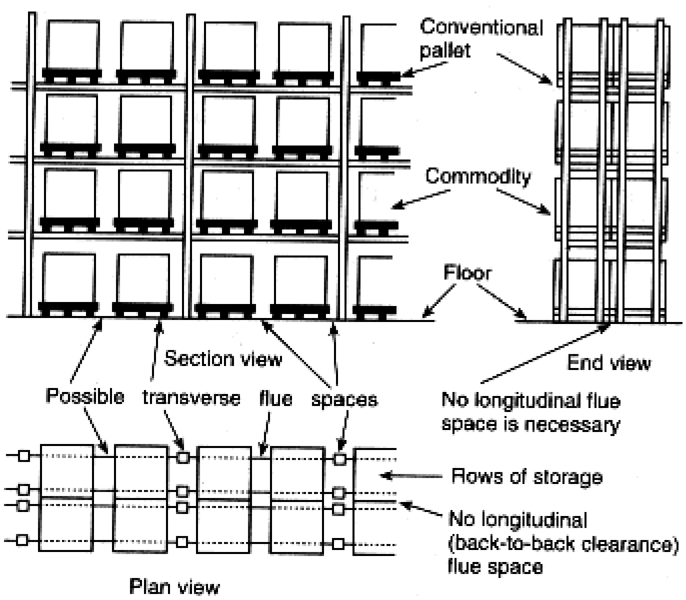


Figure 4-3.1 Typical double-row rack with back-to-back loads.

4-3.2

In double-row racks with height of storage over 25 ft (7.6 m), a minimum longitudinal flue space of (nominal) 6 in. (152.4 mm) shall be provided.

4-4* Aisle Widths.

4-4.1

Aisle widths and depth of racks are determined by material-handling methods. The width of aisles shall be considered in the design of the protection system. (*See Chapters 5 through 7*.)

4-4.2

This standard contemplates aisle widths maintained either by fixed rack structures or control in placing of portable racks. Any decrease in aisle width shall require a review of the adequacy of the protective system.

4-5*† Storage Heights.

The distance from the top of storage to the ceiling sprinkler deflectors shall be not less than 18 in. (0.46 m).

Exception: Where large-drop or ESFR sprinkler protection is used, the distance from the top of storage to the ceiling sprinkler deflectors shall be not less than 36 in. (0.91 m).

4-6 Commodity Clearances.

4-6.1*

Commodity clearances shall be maintained in accordance with NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*.

4-6.2* Incandescent Light Fixtures.

4-7*† Storage of Idle Combustible Pallets.

Bulk storage of idle combustible pallets shall be in accordance with NFPA 231, *Standard for General Storage*.

Chapter 5 Fire Protection — General

5-1 Protection Systems.

5-1.1

Protection systems that are provided for rack storage facilities shall be in accordance with the provisions of this chapter.

5-1.2

The densities and areas provided in the tables and curves in Chapters 6 through 8 are based on fire tests using standard response standard orifice [$^{1}/_{2}$ in. (12.7 mm)] and large orifice [$^{17}/_{32}$ in. (13.5 mm)] sprinklers. For the use of large drop and ESFR sprinklers, see Chapters 9 and 10, respectively.

Exception: The use of extra-large orifice (ELO) sprinklers [$^{5}/_{8}$ in. (15.9 mm)] shall be permitted where listed for such use and where installed at a minimum design pressure of 10 psi (69 kPa).

5-2 Ceiling Sprinklers.

5-2.1*

Where automatic sprinkler systems are installed, they shall be in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

Exception: Where modified by this standard.

5-2.2*

In buildings that are occupied in part for rack storage of commodities, the ceiling sprinkler system design within 15 ft (4.6 m) of the racks shall be the same as that provided for the rack storage area.

5-3 Ceiling Sprinkler Spacing.

For the purpose of selecting sprinkler spacing in hydraulically designed sprinkler systems to achieve a stipulated density, 60 psi (413.7 kPa) shall be the maximum discharge pressure used at the calculation starting point.

5-4 In-Rack Sprinkler System Size.

The area protected by a single system of sprinklers in racks (in-rack sprinklers) shall not exceed 40,000 ft^2 (3716 m^2) of floor area occupied by the racks, including aisles, regardless of the number of intermediate sprinkler levels.

5-5* In-Rack Sprinkler System Control Valves.

5-5.1*

Where sprinklers are installed in racks, separate indicating control valves and drains shall be provided and arranged so that ceiling and in-rack sprinklers can be controlled independently.

Exception No. 1: Installation of twenty or fewer in-rack sprinklers supplied by any one ceiling sprinkler system.

Exception No. 2: The separate indicating valves shall be permitted to be arranged as sectional control valves where the racks occupy only a portion of the area protected by ceiling sprinklers. (See 5-2.2.)

5-6 In-Rack Sprinkler Water Demand.

The water demand for sprinklers installed in racks shall be added to the ceiling sprinkler water demand at the point of connection. The demand shall be balanced to the higher pressure.

5-7*† Sprinkler Waterflow Alarm.

5-8 Hose Connections.

For first aid fire fighting and for mop-up operations, small [$1^1/_2$ in. (38.1 mm)] hose lines shall be available to cover all areas of the rack structure. Such small hose shall be supplied from the following:

(a) Outside hydrants

(b) A separate piping system for small hose stations

(c) Valved hose connections on sprinkler risers where such connections are made upstream of all sprinkler control valves

(d) Adjacent sprinkler systems.

Exception: Where separately controlled in-rack sprinklers are provided, the ceiling sprinkler system in the same area shall be permitted to be used.

5-9 Hose Demand.

5-9.1

For inside hose streams, an allowance of at least 100 gpm (378 L/min) shall be added to the sprinkler water demand for Class I, II, III, IV, and plastic commodities.

5-9.2

For combined inside and outside hose streams, an allowance of at least 500 gpm (1893 L/min) shall be added to the sprinkler water demand for Class I, II, III, IV, and plastic commodities.

5-10 Duration of Water Supplies.

For double-row racks, the water supply duration shall be at least $1^1/_2$ hours for Class I, II, and III commodities and at least 2 hours for Class IV and Group A plastic commodities. For multiple-row racks, the water supply duration shall be at least 2 hours for all classifications of commodities.

5-11 High-Expansion Foam.

5-11.1*

Where high-expansion foam systems are installed, they shall be in accordance with NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*, and they shall be automatic in operation.

Exception: Where modified by this standard.

5-11.2

Where high-expansion foam systems are used in combination with ceiling sprinklers, in-rack sprinklers shall not be required.

5-12 Detectors for High-Expansion Foam Systems.

Detectors shall be listed and shall be installed as follows:

(a) At the ceiling only where installed at one-half listed linear spacing [e.g., 15 ft × 15 ft (4.6 m × 4.6 m) rather than at 30 ft × 30 ft (9.1 m × 9.1 m)];

Exception: Ceiling detectors alone shall not be used where clearance from the top of storage exceeds 10 ft (3.1 m) or the height of storage exceeds 25 ft (7.6 m); or

(b) At the ceiling at listed spacing and in racks at alternate levels; or

(c) Where listed for rack storage installation and installed in accordance with their listing to provide response within one minute after ignition using an ignition source equivalent to that used in a rack storage testing program.

5-13 Solid and Slatted Shelves.

5-13.1*

Slatted shelves shall be considered to be equivalent to solid shelves.

5-13.2

Sprinklers shall be installed at the ceiling and beneath each shelf in double- or multiple-row racks with solid shelves that obstruct both longitudinal and transverse flue spaces. Design curves for combined ceiling and in-rack sprinklers shall be used with this storage configuration.

5-14 Open-Top Combustible Containers.

5-15 Movable Racks.

Rack storage in movable racks shall be protected in the same manner as multiple-row racks.

Chapter 6 Fire Protection — Storage up to and Including 25 ft (7.6 m) in Height

Part A General

(*See also Chapter 5*.)

6-1 General.

For the storage of Class I through Class IV commodities stored 12 ft (3.7 m) or less in height, the sprinkler design criteria for miscellaneous storage specified in NFPA 13, *Standard for the Installation of Sprinkler Systems*, shall apply.

6-2 In-Rack Sprinkler Type.

Sprinklers in racks shall be ordinary temperature standard response classification with nominal $^{1}/_{2}$-in. (12.7-mm) orifice size, pendent or upright. Sprinklers with 212°F (100°C) and 286°F (141°C) temperature ratings shall be used near heat sources as required by NFPA 13, *Standard for the Installation of Sprinkler Systems*.

Exception: Quick-response sprinklers shall be permitted to be installed in racks.

6-3 In-Rack Sprinkler Pipe Size.

The number of sprinklers and the pipe sizing on a line of sprinklers in racks is restricted only by hydraulic calculations and not by any piping schedule.

6-4 In-Rack Sprinkler Water Shields.

Water shields shall be provided directly above in-rack sprinklers, or listed sprinklers equipped with water shields shall be used where there is more than one level, if not shielded by horizontal barriers.

6-5 In-Rack Sprinkler Location.

6-5.1*†

The elevation of in-rack sprinkler deflectors with respect to storage shall not be a consideration in single- or double-row rack storage up to and including 20 ft (6.1 m) high.

6-5.2*

In single- or double-row racks without solid shelves with storage over 20 ft (6.1 m) high, or in multiple-row racks, or in single- or double-row racks with solid shelves and storage height up to and including 25 ft (7.6 m), a minimum of 6 in. (152.4 mm) vertical clear space shall be maintained between the sprinkler deflectors and the top of a tier of storage. Sprinkler discharge shall not be obstructed by horizontal rack members.

6-5.3

In-rack sprinklers at one level only for storage up to and including 25 ft (7.6 m) high in single- or double-row racks shall be located at the first tier level at or above one-half of the storage height.

6-5.4

In-rack sprinklers at two levels only for storage up to and including 25 ft (7.6 m) high shall be located at the first tier level at or above one-third and two-thirds of the storage height.

6-6 In-Rack Sprinkler Spacing.

6-6.1*

Maximum horizontal spacing of sprinklers in single- or double-row racks with nonencapsulated storage up to and including 25 ft (7.6 m) in height shall be in accordance with Table 6-6.1:

Table 6-6.1 In-Rack Sprinkler Spacing

	Commodity Class		
Aisle Widths	**I and II**	**III**	**IV**
8 ft	12 ft	12 ft	8 ft
4 ft	12 ft	8 ft	8 ft

For SI units: 1 ft = 0.3048 m

For encapsulated storage, maximum horizontal spacing shall be 8 ft (2.44 m).

6-6.2

Sprinklers installed in racks shall be spaced without regard to rack uprights.

6-7 In-Rack Sprinkler Discharge Pressure.

Sprinklers in racks shall discharge at not less than 15 psi (103.4 kPa) for all classes of commodities.

6-8 In-Rack Sprinkler Water Demand.

The water demand for sprinklers installed in racks shall be based on simultaneous operation of the most hydraulically remote sprinklers as follows:

(a) Six sprinklers where only one level is installed in racks with Class I, II, or III commodities;

(b) Eight sprinklers where only one level is installed in racks with Class IV commodities;

(c) Ten sprinklers (five on each two top levels) where more than one level is installed in racks with Class I, II, or III commodities;

(d) Fourteen sprinklers (seven on each two top levels) where more than one level is installed in racks with Class IV commodities.

6-9*† Ceiling Sprinkler Water Demand.

The design curves in Figures 6-12(a) through (g) shall apply to nominal 20-ft (6.1-m) height of storage.

6-9.1

The design curves indicate water demands for nominal 165°F (74°C) and nominal 286°F (141°C) rated sprinklers at the ceiling. The 165°F (74°C) design curves shall be used for sprinklers with ordinary and intermediate temperature classification but not less than 160°F (71°C) rating. The 286°F (141°C) rating design curve shall be used for sprinklers with high temperature classification.

6-9.2

For storage height up to and including 25 ft (7.6 m) protected with ceiling sprinklers only, and for storage height up to and including 20 ft (6.1 m) protected with ceiling sprinklers and minimum required in-rack sprinklers, densities obtained from design curves shall be adjusted in accordance with Figure 6-9.2.

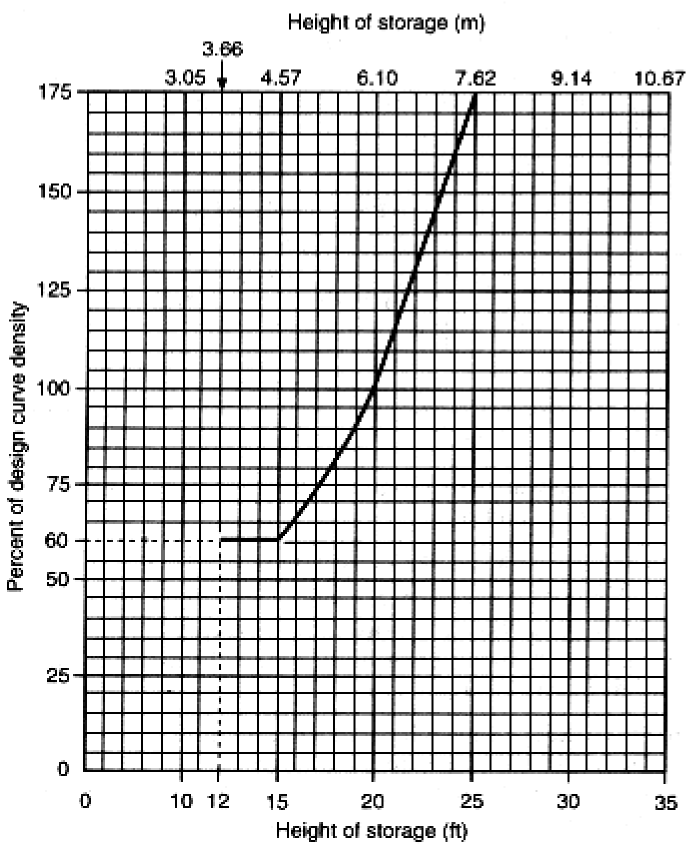


Figure 6-9.2 Ceiling sprinkler density vs storage height.

Table 6-9.2 Adjustment to Ceiling Sprinkler Density for Storage Height and In-Rack Sprinklers

Permitted

Storage Height (ft)	In-Rack Sprinklers	Apply Fig. 6-9.2	Ceiling Sprinklers Density Adjustments
Over 12 ft (3.7 m) through 25 ft (7.6 m)	None	Yes	None
	Minimum required	Yes	None
Over 12 ft (3.7 m) through 20 ft (6.1 m)	More than minimum but not in every tier	Yes	Reduce density 20% from that of minimum in-rack sprinklers
	In every tier	Yes	Reduce density 40% from that of minimum in-rack sprinklers
	Minimum required	No	None
Over 20 ft (6.1 m) through 25 ft (7.6 m)	More than minimum but not in every tier	No	Reduce density 20% from that of minimum in-rack sprinklers
	In every tier	No	Reduce density 40% from that of minimum in-rack sprinklers

6-9.3

For storage height over 20 ft (6.1 m) up to and including 25 ft (7.6) protected with ceiling sprinklers and minimum required in-rack sprinklers, densities obtained from design curves shall be used. Densities shall not be adjusted in accordance with Figure 6-9.2.

6-9.4

For storage height up to and including 20 ft (6.1 m) protected with ceiling sprinklers and with more than one level of in-rack sprinklers, but not in every tier, densities obtained from design curves and adjusted in accordance with Figure 6-9.2 shall be permitted to be reduced an additional 20 percent.

6-9.5

For storage height over 20 ft (6.1 m) up to and including 25 ft (7.6 m) protected with ceiling sprinklers, and with more than the minimum required level of in-rack sprinklers, but not in every tier, densities obtained from design curves shall be permitted to be reduced 20 percent. Densities shall not be adjusted in accordance with Figure 6-9.2.

6-9.6

For storage height up to and including 20 ft (6.1 m) protected with ceiling sprinklers and in-rack sprinklers at each tier, densities obtained from design curves and adjusted in accordance with Figure 6-9.2 shall be permitted to be reduced an additional 40 percent.

6-9.7

For storage height over 20 ft (6.1 m) up to and including 25 ft (7.6 m) protected with ceiling sprinklers and in-rack sprinklers at each tier, densities obtained from design curves shall be permitted to be reduced 40 percent. Densities shall not be adjusted in accordance with Figure

6-9.2.

6-9.8

Where clearance from ceiling to top of storage is less than 4$^1/_2$ ft (1.37 m) (*see Section 4-5*), the sprinkler operating area indicated in curves E, F, G, and H in Figures 6-12(a) through (e) shall be permitted to be reduced as indicated in Figure 6-9.8 but to not less than 2000 ft^2 (185.8 m^2). (*See 6-9.9.*)

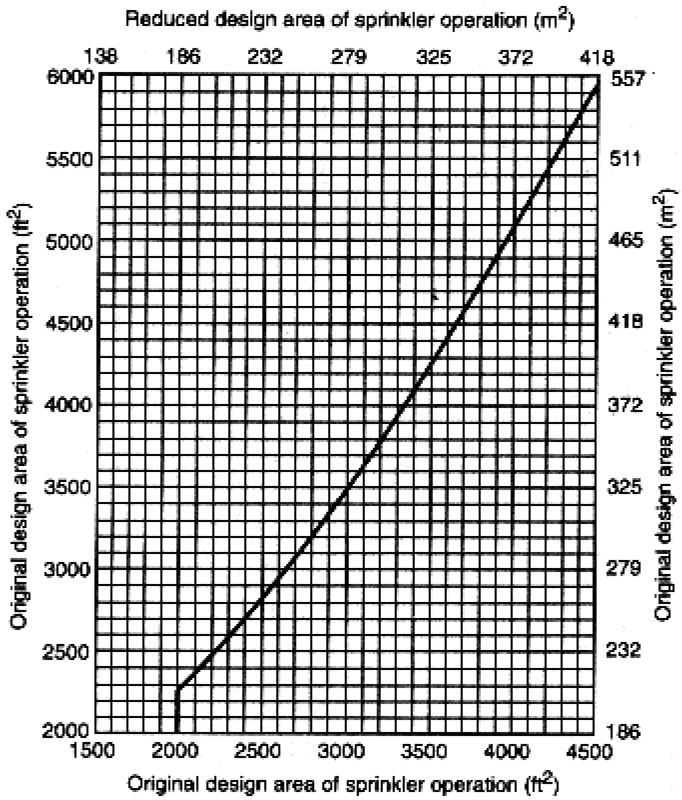


Figure 6-9.8 Adjustment of design area of sprinkler operation for clearance from top of storage to ceiling.

6-9.9

Where clearance from ceiling to top of Class I or II encapsulated storage is 1$^1/_2$ ft to 3 ft (0.46 m to 0.91 m), the sprinkler operating area indicated in curve F only of Figure 6-12(e) shall be permitted to be reduced by 50 percent but to not less than 2000 sq ft^2 (185.8 m^2).

6-9.10

Where solid, flat-bottom wood pallets are used, with storage height up to and including 25 ft (7.6 m), the densities indicated in the design curves, based on conventional pallets, shall be increased 20 percent for the given area. This percentage shall be applied to the density determined in accordance with Figure 6-9.2. This increase shall not apply where in-rack sprinklers are installed.

6-10 High-Expansion Foam Submergence.

6-10.1*

Where high-expansion foam systems are used without sprinklers, the maximum submergence time shall be 5 minutes for Class I, II, or III commodities and 4 minutes for Class IV commodities.

6-10.2

Where high-expansion foam systems are used in combination with ceiling sprinklers, the maximum submergence time shall be 7 minutes for Class I, II, or III commodities and 5 minutes for Class IV commodities.

6-11 High-Expansion Foam Ceiling Sprinkler Density.

Where high-expansion foam systems are used in combination with ceiling sprinklers, the minimum ceiling sprinkler design density shall be 0.2 gpm/ft^2 [(8.15 L/min)/m^2] for Class I, II, or III commodities or 0.25 gpm/ft^2 [(10.2 L/min)/m^2] for Class IV commodities for the most hydraulically remote 2000-ft^2 (185.8-m^2) operating area.

Part B Double- and Single-Row Racks

(*See also Chapter 5*.)

6-12* Ceiling Sprinkler Water Demand.

For Class I, II, III, or IV commodities encapsulated or nonencapsulated in single- or double-row racks, ceiling sprinkler water demand in terms of density (gpm/ft^2) [(L/min)/m^2] and area of sprinkler operation [ft^2 (m^2) of ceiling or roof] shall be selected from the curves in Figures 6-12(a) through (g). The curves in Figures 6-12(a) through (g) also shall apply to portable racks arranged in the same manner as single- or double-row racks or multiple-row racks. The design shall be sufficient to satisfy a single point on the appropriate curve related to the storage configuration and commodity class. It shall not be required to meet all points on the selected curve. Figure 6-9.2 shall be used to adjust the density for storage height unless otherwise specified.

For SI units: 1 ft = 0.3048 m

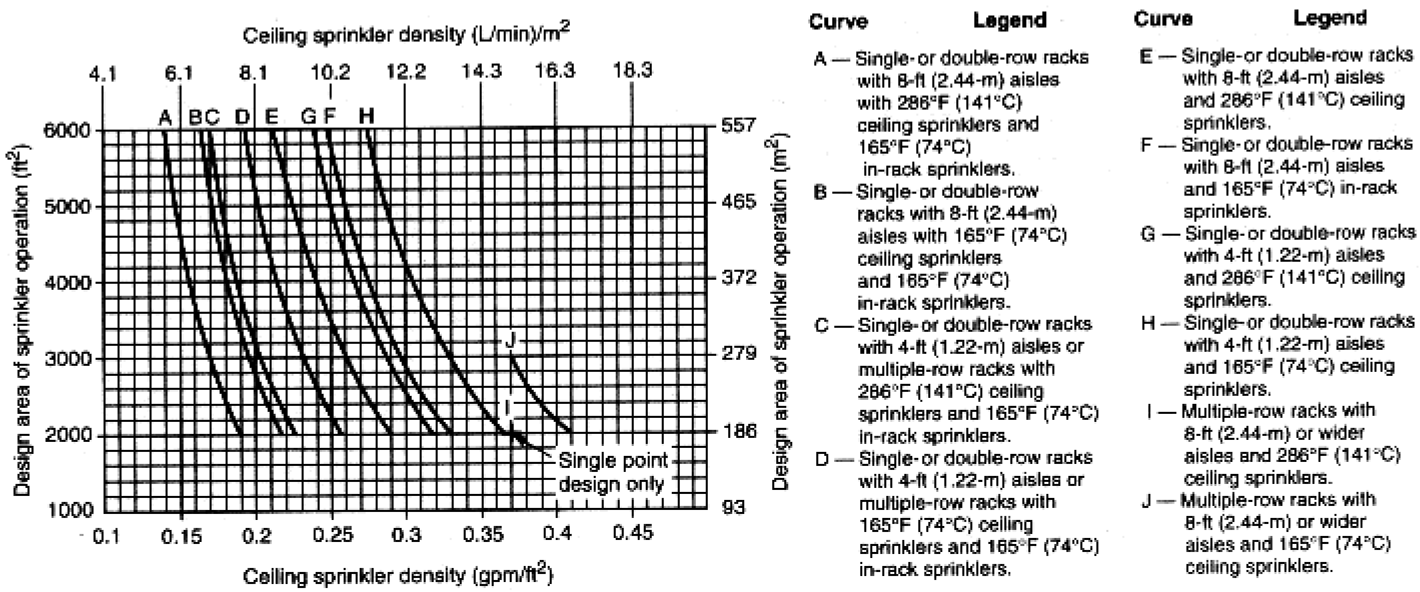


Figure 6-12(a) Sprinkler system design curves — 20-ft (6.1-m) high rack storage — Class I nonencapsulated commodities — conventional pallets.

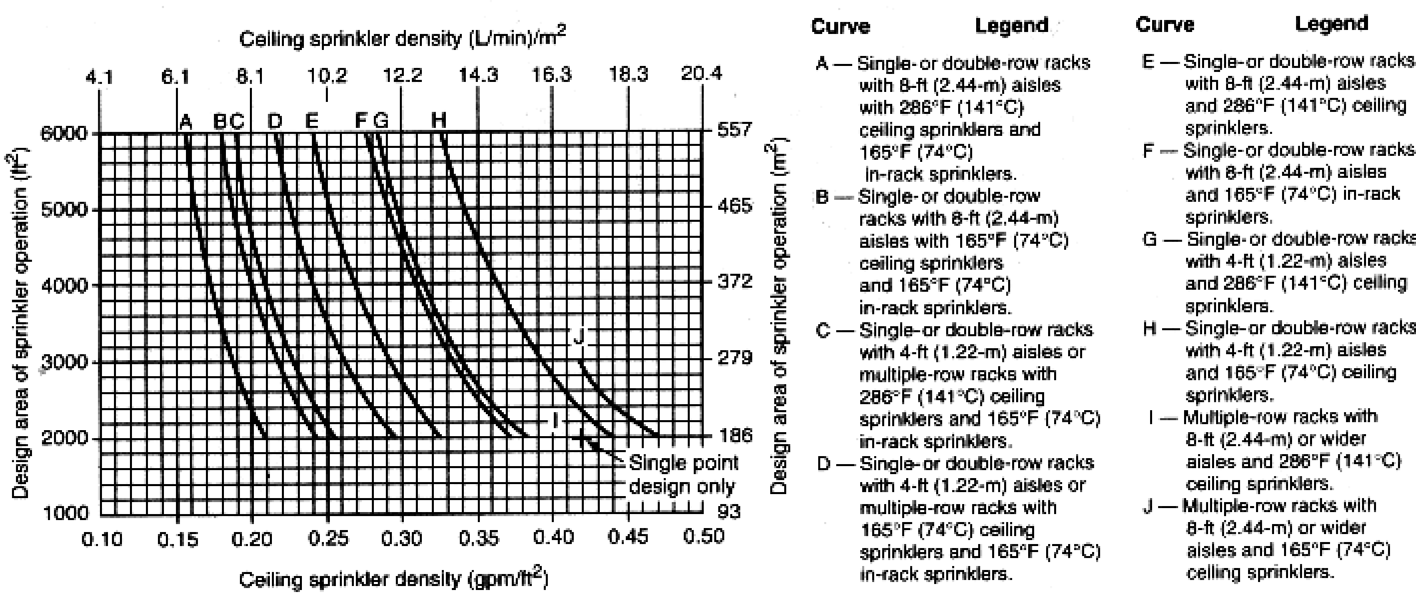


Figure 6-12(b) Sprinkler system design curves — 20-ft (6.1-m) high rack storage — Class II nonencapsulated commodities — conventional pallets.

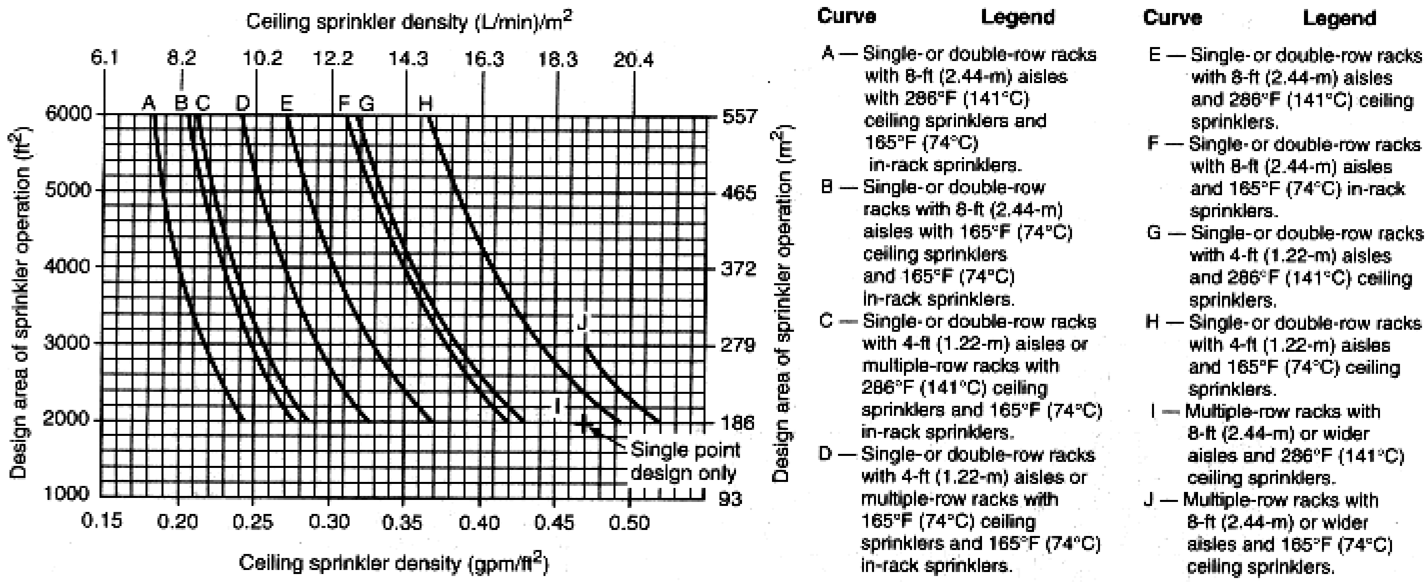


Figure 6-12(c) Sprinkler system design curves — 20-ft (6.1-m) high rack storage — Class III nonencapsulated commodities — conventional pallets.

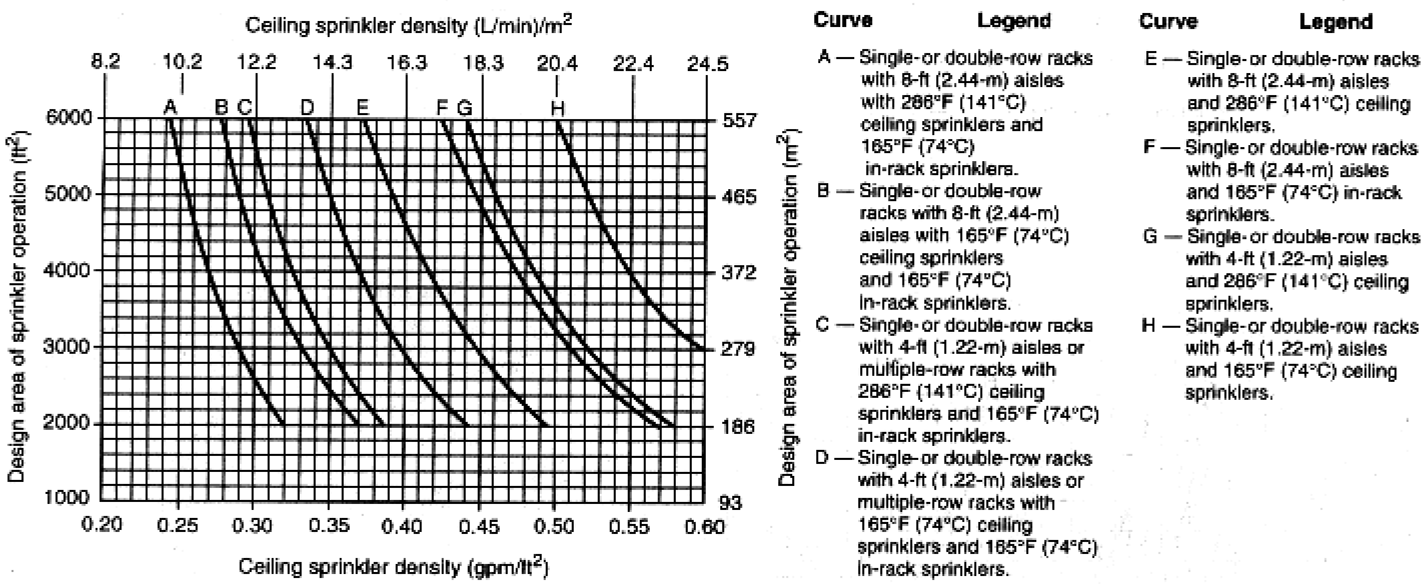


Figure 6-12(d) Sprinkler system design curves — 20-ft (6.1-m) high rack storage — Class IV nonencapsulated commodities — conventional pallets.

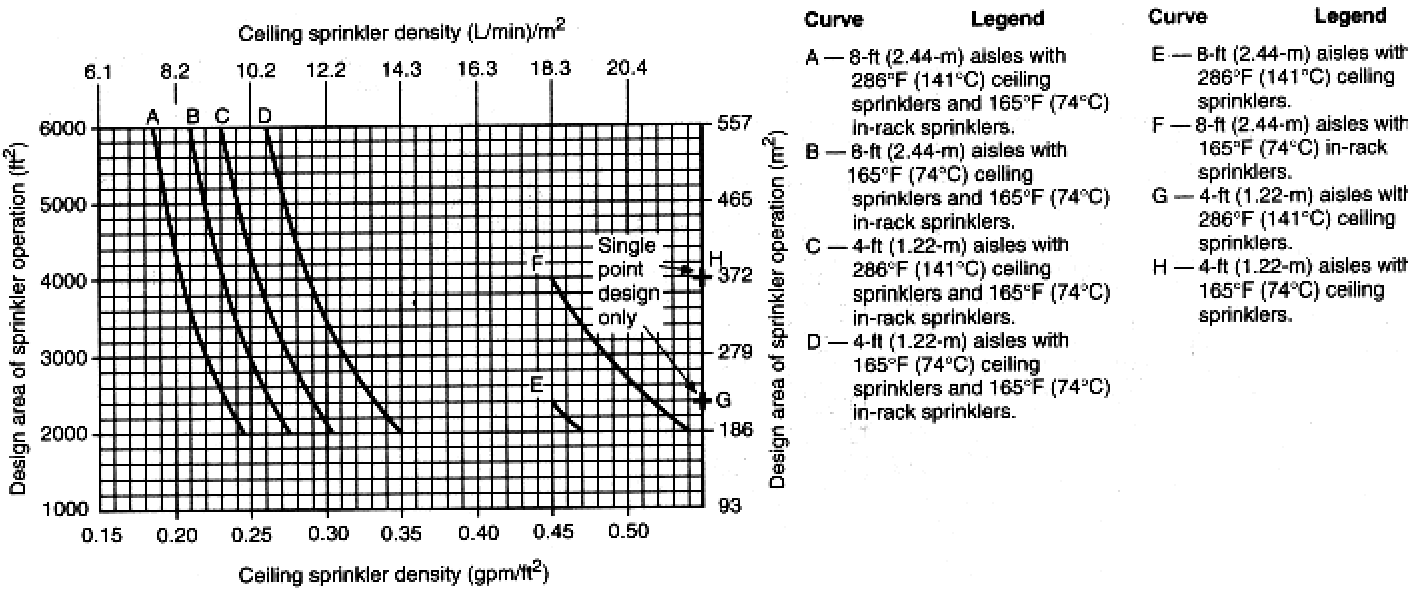


Figure 6-12(e) Single- or double-row racks — 20-ft (6.1-m) high rack storage — sprinkler system design curves — Class I and II encapsulated commodities — conventional pallets.

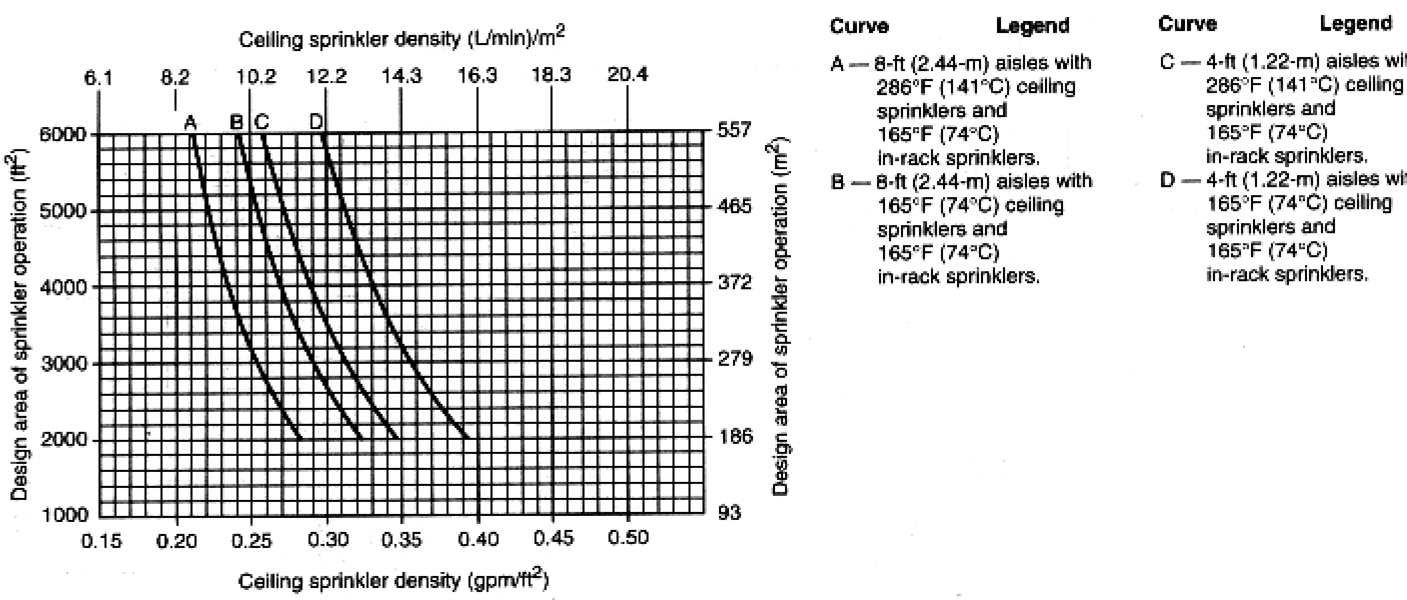


Figure 6-12(f) Single- or double-row racks — 20-ft (6.1-m) high rack storage — sprinkler system design curves — Class III encapsulated commodities — conventional pallets.

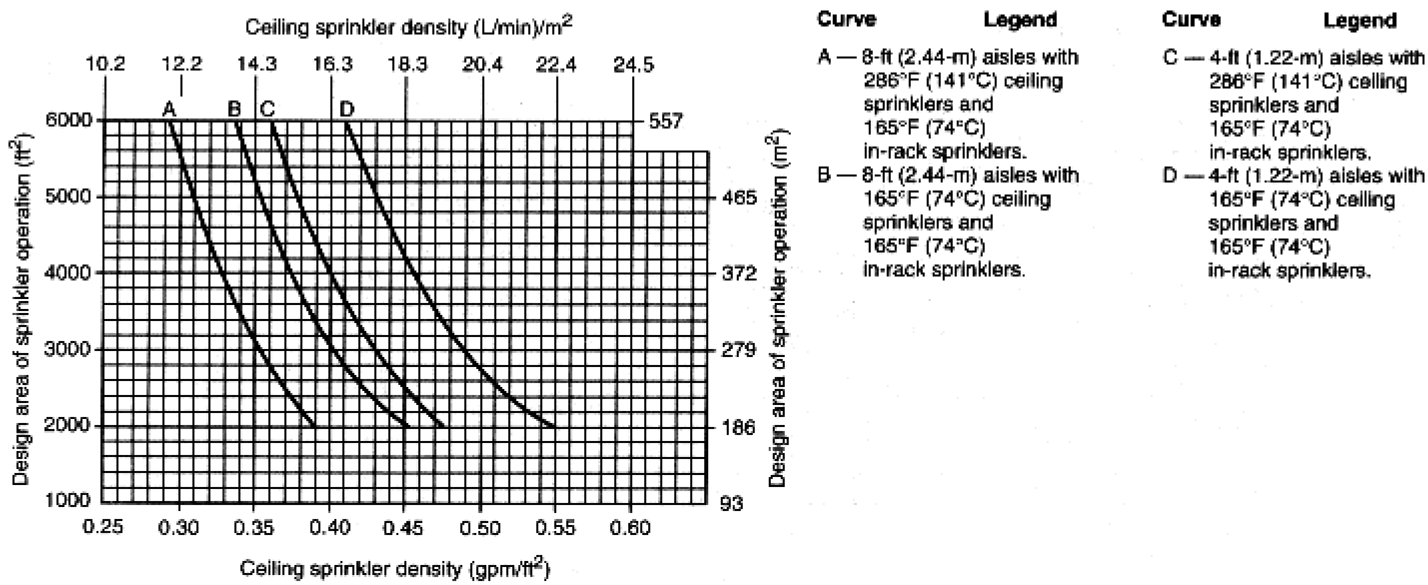


Figure 6-12(g) Single- or double-row racks — 20-ft (6.1-m) high rack storage — sprinkler system design curves — Class IV encapsulated commodities — conventional pallets.

6-12.1

Design curves for single- and double-row racks shall be selected to correspond to aisle width. For aisle widths between 4 ft (1.22 m) and 8 ft (2.44 m), a direct linear interpolation between curves shall be made. The density given for 8-ft (2.44-m) wide aisles shall be applied to aisles wider than 8 ft (2.44 m). The density given for 4-ft (1.22-m) wide aisles shall be applied to aisles narrower than 4 ft (1.22 m) down to $3^1/_2$ ft (1.07 m). Where aisles are narrower than $3^1/_2$ ft (1.07 m), racks shall be considered to be multiple-row racks.

6-13 In-Rack Sprinkler Location.

In single- or double-row racks without solid shelves, in-rack sprinklers shall be installed in accordance with Table 6-12.

Table 6-12 Single- or Double-Row Racks. Storage Height up to and Including 25 ft, Aisles Wider than 4 ft, without Solid Shelves.

Height	Commodity Class	Encap-sulated	Aisles (ft) (4-4.1) (B-6-11.2)	Sprinklers Mandatory In-Rack	Ceiling Sprinkler Water Demand					
					With In-Rack Sprinklers			Without In-Rack Sprinklers		
					Fig.	Curves	Apply Fig. 6-9.2	Fig.	Curves	Apply Fig. 6-9.2
Over 12 ft, Up to and including 20 ft	I	No	4 8	No	6-12(a)	C&D A&B	Yes	6-12(a)	G&H E&F	Yes
		Yes	4 8	No	6-12(e)	C&D A&B		6-12(e)	G&H E&F	Yes
	II	No	4 8	No	6-12(b)	C&D A&B		6-12(b)	G&H E&F	Yes
		Yes	4 8	No	6-12(e)	C&D A&B		6-12(e)	G&H E&F	Yes
	III	No	4 8	No	6-12(c)	C&D A&B		6-12(c)	G&H E&F	Yes
		Yes	4 8	1 Level	6-12(f)	C&D A&B				
	IV	No	4 8	No	6-12(d)	C&D A&B		6-12(d)	G&H E&F	Yes
		Yes	4 8	1 Level	6-12(g)	C&D A&B				
Over 20 ft, Up to and including 22 ft	I	No	4 8	No	6-12(a)	C&D A&B	No	6-12(a)	G&H E&F	Yes
		Yes	4 8	1 Level	6-12(e)	C&D A&B				
	II	No	4 8	No	6-12(b)	C&D A&B		6-12(b)	G&H E&F	Yes
		Yes	4 8	1 Level	6-12(e)	C&D A&B				
	III	No	4 8	No	6-12(c)	C&D A&B		6-12(c)	G&H E&F	Yes
		Yes	4 8	1 Level	6-12(f)	C&D A&B				
	IV	No	4 8	No	6-12(d)	C&D A&B		6-12(d)	G&H E&F	Yes
		Yes	4 8	1 Level	6-12(g)	C&D A&B				
Over 22 ft, Up to and including 25 ft	I	No	4 8	No	6-12(a)	C&D A&B	No	6-12(a)	G&H E&F	Yes
		Yes	4 8	1 Level	6-12(e)	C&D A&B				
	II	No	4 8	No	6-12(b)	C&D A&B		6-12(b)	G&H E&F	Yes
		Yes	4 8	1 Level	6-12(e)	C&D A&B				
	III	No	4 8	No	6-12(c)	C&D A&B		6-12(c)	G&H E&F	Yes
		Yes	4 8	1 Level	6-12(f)	C&D A&B				
		No	4		6-12(d)	C&D				

For SI units: 1 ft = 0.3048 m

Part C Multiple-Row Racks

(*See also Chapter 5*.)

6-14 In-Rack Sprinkler Location.

For encapsulated or nonencapsulated storage in multiple-row racks no deeper than 16 ft (4.88 m) with aisles no narrower than 8 ft (2.44 m), in-rack sprinklers shall be installed in accordance with Table 6-14.

Table 6-14 Multiple-Row Racks. Rack Depth up to and Including 16 ft, Aisles Wider than 8 ft, Storage Height up to 25 ft.

Height	Commodity Class	Encapsulated	Sprinklers Mandatory In-Racks	Ceiling Sprinkler Water Demand							
				With In-Rack Sprinklers				Without In-Rack Sprinklers			
				Fig. No.	Curves	Apply Fig. 6-9.2	1.25 x Density	Fig. No.	Curves	Apply Fig. 6-9.2	1.25 x Density
Over 12 ft up to and including 15 ft	I	No	No	6-12(a)	C&D	Yes	No	6-12(a)	I&J	Yes	No
		Yes		6-12(a)			Yes	6-12(a)	I&J		Yes
	II	No		6-12(b)			No	6-12(b)	I&J	Yes	No
		Yes		6-12(b)			Yes	6-12(b)	I&J		Yes
	III	No	No	6-12(c)			No	6-12(c)	I&J	Yes	No
		Yes	1 level	6-12(c)			Yes				
	IV	No	No	6-12(d)			No	6-12(d)	C&D	No	No
		Yes	1 level	6-12(d)	A&B		1.50 x density				
Over 15 ft up to and including 20 ft	I	No	No	6-12(a)	C&D	Yes	No	6.12(a)	I&J	Yes	No
		Yes		6-12(a)			Yes	6-12(a)	I&J		Yes
	II	No		6-12(b)			No	6-12(b)	I&J	Yes	No
		Yes		6-12(b)			Yes	6-12(b)	I&J		Yes
	III	No	No	6-12(c)			No	6-12(c)	I&J	Yes	No
		Yes	1 level	6-12(c)			Yes				
	IV	No	1 Level	6-12(d)			No				
		Yes		6-12(d)	A&B		1.50 x density				
Over 20 ft up to and including 25 ft	I	No	No	6-12(a)	C&D	No	No	6-12(a)	I&J	Yes	No
		Yes	1 level	6-12(a)			Yes				
	II	No	1 level	6-12(b)			No				
		Yes		6-12(b)			Yes				
	III	No		6-12(c)			No				
		Yes		6-12(c)			Yes				
	IV	No	2 levels	6-12(d)			No				
		Yes		6-12(d)	A&B		1.50 x density				

For SI units: 1 ft = 0.3048 m

6-14.1

For encapsulated or nonencapsulated storage in multiple-row racks deeper than 16 ft (4.88 m), or with aisles less than 8 ft (2.44 m) wide, in-rack sprinklers shall be installed in accordance with Table 6-14.1.

Table 6-14.1 Multiple-Row Racks; Rack Depth Over 16 ft or Aisles Narrower than 8 ft, Storage Height up to and Including 25 ft.

				Ceiling Sprinkler Water Demand							
				With In-Rack Sprinklers				Without In-Rack Sprinklers			
Height	Commodity Class	Encap-sulated	Sprinklers Mandatory In-Racks	Fig. No.	Curves	Apply Fig. 6-9.2	1.25 x Density	Fig. No.	Curves	Apply Fig. 6-9.2	1.25 x Density
Over 12 ft up to and including 15 ft	I	No	No	6-12(a)	C&D	Yes	No	6-12(a)	I&J	Yes	No
		Yes		6-12(a)			Yes	6-12(a)	I&J		Yes
	II	No		6-12(b)			No	6-12(b)	I&J	Yes	No
		Yes		6-12(b)			Yes	6-12(b)	I&J		Yes
	III	No		6-12(c)			No	6-12(c)	I&J	Yes	No
		Yes	1 level	6-12(c)			Yes				
	IV	No	No	6-12(d)			No	6-12(d)	C&D	No	No
		Yes	1 level	6-12(d)			1.50 x density				
Over 15 ft up to and including 20 ft	I	No	1 level	6-12(a)	C&D	Yes	No				
		Yes		6-12(a)			Yes				
	II	No		6-12(b)			No				
		Yes		6-12(b)			Yes				
	III	No		6-12(c)			No				
		Yes		6-12(c)			Yes				
	IV	No		6-12(d)			No				
		Yes		6-12(d)			1.50 x density				
Over 20 ft up to and including 25 ft	I	No	1 level	6-12(a)	C&D	No	No				
		Yes		6-12(a)			Yes				
	II	No		6-12(b)			No				
		Yes		6-12(b)			Yes				
	III	No		6-12(c)			No				
		Yes		6-12(c)			Yes				
	IV	No	2 levels	6-12(d)			No				
		Yes		6-12(d)			1.50 x density				

For SI units: 1 ft = 0.3048 m

6-14.2*

Maximum horizontal spacing of sprinklers on branch lines, in multiple-row racks with encapsulated or nonencapsulated storage up to and including 25 ft (7.6 m) in height, shall not exceed 12 ft (3.7 m) for Class I, II, or III commodities and 8 ft (2.44 m) for Class IV commodities, with area limitations of 100 ft^2 (9.29 m^2) per sprinkler for Class I, II, or III commodities and 80 ft^2 (7.43 m^2) per sprinkler for Class IV commodities. The rack plan view shall be considered in determining the area covered by each sprinkler. The aisles shall not be included in area calculations.

6-14.3

A minimum of 6 in. (152.4 mm) shall be maintained between the sprinkler deflector and the top of a tier of storage.

6-15 Ceiling Sprinkler Water Demand.

6-15.1

For nonencapsulated Class I, II, III, or IV commodities, ceiling sprinkler water demand in terms of density (gpm/ft^2) [(L/min)/m^2] and area of sprinkler operation [ft^2 (m^2) of ceiling or roof] shall be selected from the curves in Figures 6-12(a) through (d). The curves in Figures 6-12(a) through (d) also shall apply to portable racks arranged in the same manner as single-, double-, or multiple-row racks. The design shall be sufficient to satisfy a single point on the appropriate curve related to the storage configuration and commodity class. It shall not be required to meet all points on the selected curve. Figure 6-9.2 shall be used to adjust density for storage height unless otherwise specified. (*See A-6-6.1 and A-6-12.*)

6-15.2

For encapsulated Class I, II, or III commodities with storage height up to and including 25 ft (7.6 m) on multiple-row racks, ceiling sprinkler density shall be 25 percent greater than for nonencapsulated commodities on multiple-row racks.

6-15.3

For encapsulated Class IV commodities with storage height up to and including 25 ft (7.6 m) on multiple-row racks, ceiling sprinkler density shall be 50 percent greater than for nonencapsulated commodities on double-row racks.

Chapter 7 Fire Protection — Storage over 25 ft (7.6 m) in Height

Part A General

7-1 In-Rack Sprinkler Type.

Sprinklers in racks shall be ordinary temperature standard response classification with nominal $^1/_2$-in. (12.7-mm) or $^{17}/_{32}$-in. (13.5-mm) orifice size, pendent or upright. Sprinklers with 212°F (100°C) and 286°F (141°C) temperature ratings shall be used near heat sources as required in NFPA 13, *Standard for the Installation of Sprinkler Systems*.

Exception: Quick-response sprinklers shall be permitted to be installed in racks.

7-2 In-Rack Sprinkler Spacing.

In-rack sprinklers shall be staggered horizontally and vertically where installed in accordance with Table 7-10.1, Figures 7-10.1(a) through (j), and Figures 7-10.3(a) through (e).

7-3 In-Rack Sprinkler Pipe Size.

The number of sprinklers and the pipe sizing on a line of sprinklers in racks shall be restricted only by hydraulic calculations and not by any piping schedule.

7-4 In-Rack Sprinkler Water Shields.

Water shields shall be provided directly above in-rack sprinklers, or listed sprinklers equipped with water shields shall be provided where there is more than one level, if not shielded by horizontal barriers. (*See B-6-4.*)

7-5 In-Rack Sprinkler Location.

In single-row, double-row, or multiple-row racks, a minimum 6-in. (152.4-mm) vertical clear space shall be maintained between the sprinkler deflectors and the top of a tier of storage. Face sprinklers in such racks shall be located a minimum of 3 in. (76.2 mm) from rack uprights and no more than 18 in. (0.46 m) from the aisle face of storage. Other sprinklers in racks shall be located a minimum of 2 ft (0.61 m) from rack uprights.

Exception: Where the distance between uprights is less than 4 ft (1.22 m), sprinklers shall be centered between uprights.

7-6 In-Rack Sprinkler Discharge.

Sprinklers in racks shall discharge at not less than 30 gpm (113.6 L/min) for all classes of commodities. (*See B-6-8*.)

7-7 In-Rack Sprinkler Water Demand.

7-7.1

The water demand for sprinklers installed in racks shall be based on simultaneous operation of the most hydraulically remote sprinklers as follows:

(a) Six sprinklers where only one level is installed in racks with Class I, II, or III commodities;

(b) Eight sprinklers where only one level is installed in racks with Class IV commodities;

(c) Ten sprinklers (five on each two top levels) where more than one level is installed in racks with Class I, II, or III commodities;

(d) Fourteen sprinklers (seven on each two top levels) where more than one level is installed in racks with Class IV commodities.

7-8 High-Expansion Foam Submergence.

Where high-expansion foam systems are used for storage over 25 ft (7.6 m) high up to and including 35 ft (10.67 m) high, they shall be used in combination with ceiling sprinklers. The maximum submergence time for the high-expansion foam shall be 5 minutes for Class I, II, or III commodities and 4 minutes for Class IV commodities.

7-9 High-Expansion Foam—Ceiling Sprinkler Water Demand.

Where high-expansion foam is used in combination with ceiling sprinklers, the minimum ceiling sprinkler design density shall be 0.2 gpm/ft^2 [(8.15 L/min)/m^2] for Class I, II, or III commodities and 0.25 gpm/ft^2 [(10.2 L/min)/m^2] for Class IV commodities for the most hydraulically remote 2000-ft^2 (185.8-m^2) area.

Part B Double- and Single-Row Racks

7-10 In-Rack Sprinkler Location.

7-10.1

In double-row racks without solid shelves and with a maximum of 10 ft (3.1 m) between the top of storage and the ceiling, in-rack sprinklers shall be installed in accordance with Table 7-10.1 and Figures 7-10.1(a) through (j). The highest level of in-rack sprinklers shall be not more than 10 ft (3.1 m) below the top of storage. (*See Section 7-11*.)

7-10.2

In-rack sprinklers for storage higher than 25 ft (7.6 m) in double-row racks shall be spaced horizontally and located in the horizontal space nearest the vertical intervals specified in Table 7-10.1 and Figures 7-10.1(a) through (j).

7-10.3*

In single-row racks without solid shelves with storage height over 25 ft (7.6 m) and a maximum of 10 ft (3.1 m) between the top of storage and the ceiling, sprinklers shall be installed in accordance with Figures 7-10.3(a) through (e).

7-11* In-Rack Sprinkler Horizontal Barriers.

Horizontal barriers used in conjunction with in-rack sprinklers to impede vertical fire development shall be constructed of sheet metal, wood, or similar material and shall extend the full length and width of the rack. Barriers shall be fitted within 2 in. (50.8 mm) horizontally around rack uprights. [*See Table 7-10.1, Figures 7-10.1(a), (g), and (j), and Figures 7-10.3(c) and (e)*.]

7-12 Ceiling Sprinkler Water Demand.

7-12.1*†

The water demand for nonencapsulated storage on racks without solid shelves separated by aisles at least 4 ft (1.22 m) wide and with not more than 10 ft (3.1 m) between the top of storage and the sprinklers shall be based on sprinklers in a 2000-ft^2 (185.8-m^2) operating area, discharging a minimum of 0.25 gpm/ft^2 [(10.18 L/min)/m^2] for Class I commodities, 0.3 gpm/ft^2 [(12.2 L/min)/m^2] for Class II and III commodities, and 0.35 gpm/ft^2 [(14.26 L/min)/m^2] for Class IV commodities, for 165°F (74°C) rated sprinklers; or a minimum of 0.35 gpm/ft^2 [(14.26 L/min)/m^2] for Class I commodities, 0.40 gpm/ft^2 [(16.3 L/min)/m^2] for Class II and III commodities, and 0.45 gpm/ft^2 [(18.3 L/min)/m^2] for Class IV commodities, for 286°F (141°C) rated sprinklers. (*See Table 7-10.1*.)

7-12.2

Where storage as described in 7-12.1 is encapsulated, ceiling sprinkler density shall be 25 percent greater than for nonencapsulated storage.

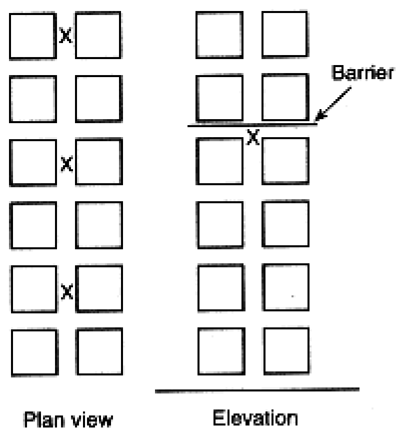
Table 7-10.1 Double-Row Racks without Solid Shelves, Storage Higher than 25 ft, Aisles Wider than 4 ft

Commodity Class	In-rack sprinklers — approximate vertical spacing at tier nearest the vertical distance and maximum horizontal spacing [1,2] Longitudinal Flue[3]	Face [4,8]	Fig. No.	Maximum Storage Height	Stagger	Ceiling Sprinkler Operating	Ceiling Sprinkler Density (gpm/sq ft)[6] Clearance[5] up to 10 ft[7] 165°	286°
I	Vertical 20 ft Horizontal 10 ft under horizontal barriers	None	7-10.1(a)	30 ft	No	2000 ft²	0.25	0.35
	Vertical 20 ft Horizontal 10 ft	Vertical 20 ft Horizontal 10 ft	7-10.1(b)	Higher than 25 ft	Yes		0.25	0.35
I, II, & III	Vertical 10 ft or at 15 ft & 25 ft Horizontal 10 ft	None	7-10.1(c)	30 ft	Yes	2000 ft²	0.30	0.40
	Vertical 10 ft Horizontal 10 ft	Vertical 30 ft Horizontal 10 ft	7-10.1(d)	Higher than 25 ft	Yes		0.30	0.40
	Vertical 20 ft Horizontal 10 ft	Vertical 20 ft Horizontal 5 ft	7-10.1(e)		Yes		0.30	0.40
	Vertical 25 ft Horizontal 5 ft	Vertical 25 ft Horizontal 5 ft	7-10.1(f)		No		0.30	0.40
	Horizontal barriers at 20 ft. Vertical intervals—2 lines of sprinklers under barriers—maximum horizontal spacing 10 ft staggered.		7-10.1(g)		Yes		0.30	0.40
I, II, III, & IV	Vertical 15 ft Horizontal 10 ft	Vertical 20 ft Horizontal 10 ft	7-10.1(h)	Higher than 25 ft	Yes	2000 ft²	0.35	0.45
	Vertical 20 ft Horizontal 5 ft	Vertical 20 ft Horizontal 5 ft	7-10.1(i)		No		0.35	0.45
	Horizontal barriers at 15 ft. Vertical intervals—2 lines of sprinkler under barriers—maximum horizontal spacing 10 ft staggered		7-10.1(j)		Yes		0.35	0.45

For SI Units: 1 ft = 0.3048 m

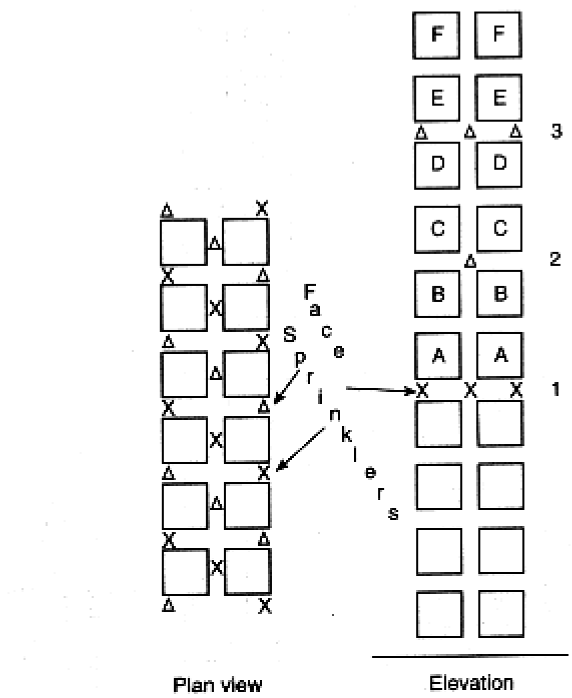
Footnotes to Table 7-10.1

[1]Minimum in-rack sprinkler pressure, 30 psi (2.1 bar) (Section 7-6).
[2]Water shields required (Section 6-4 and Section 7-4).
[3]Install sprinklers at least 2 ft (0.61 m) from uprights (A-6-5.1).
[4]Install sprinklers at least 3 in. (76.2 mm) from uprights (Section 7-5).
[5]Clearance is distance between top of storage and ceiling.
[6]For encapsulated commodity, increase density 25 percent (7-12.1).
[7]See A-7-10.3, A-7-11, and A-7-12.1 for protection recommendations where clearance is greater than 10 ft (3.05 m).
[8]Face sprinklers shall not be required for a Class I commodity consisting of noncombustible products on wood pallets (without combustible containers) except for arrays shown in Figure 7-10.1(g) and Figure 7-10.1(j).



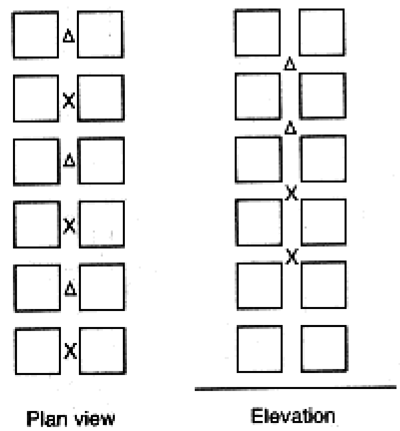
NOTES:
1. Symbol X indicates in-rack sprinklers.
2. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-10.1(a) In-rack sprinkler arrangement, Class I commodities, maximum storage height 25 ft to 30 ft (7.6 m to 9.1 m).



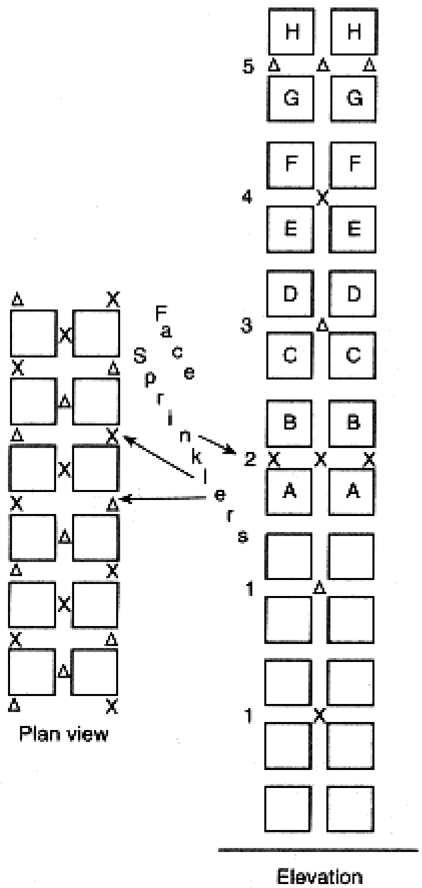
NOTES:
1. Sprinklers labeled 1 (the selected array from Table 7-10.1) shall be required where loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled C or D represent top of storage.
3. Sprinklers labeled 1 and 3 shall be required where loads labeled E or F represent top of storage.
4. For storage higher than represented by loads labeled F, the cycle defined by Notes 2 and 3 is repeated, with stagger as indicated.
5. Symbol Δ or X indicates sprinklers on vertical or horizontal stagger.
6. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-10.1(b) In-rack sprinkler arrangement, Class I commodities, storage height over 25 ft (7.6 m).



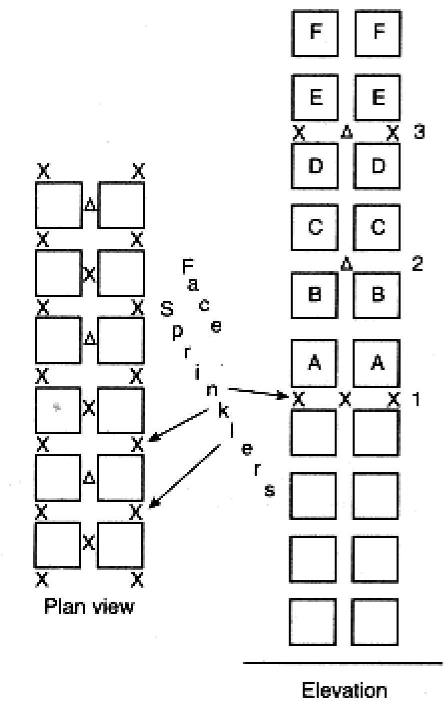
NOTES:
1. Alternate location of in-rack sprinklers. Sprinklers may be installed at the second and fourth or the third and fifth tiers.
2. Symbol Δ or X indicates sprinklers on vertical or horizontal stagger.
3. Each square in the figure represents a storage cube measuring 4 ft or 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-10.1(c) In-rack sprinkler arrangement, Class I, II, or III commodities, maximum storage height 25 ft to 30 ft (7.6 m to 9.1 m).



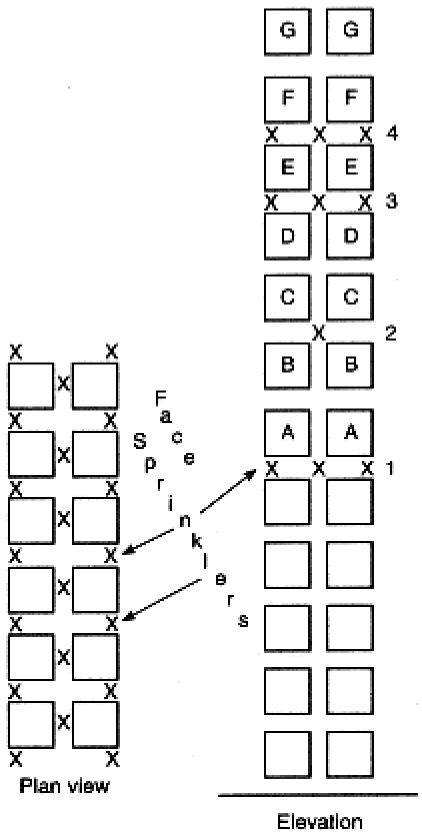
NOTES:
1. Sprinklers labeled 1 shall be required where loads labeled A represent the top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled B or C represent top of storage.
3. Sprinklers labeled 1, 2, and 3 shall be required where loads labeled D or E represent top of storage.
4. Sprinklers labeled 1, 2, 3, and 4 shall be required where loads labeled F or G represent top of storage.
5. Sprinklers labeled 1, 2, 3, 4, and 5 shall be required where loads labeled H represent top of storage.
6. For storage higher than represented by loads labeled H, the cycle defined by Notes 3, 4, and 5 is repeated with stagger as indicated.
7. The indicated face sprinklers shall be permitted to be omitted where commodity consists of unwrapped or unpackaged metal parts on wood pallets.
8. Symbol Δ or X indicates sprinklers on vertical or horizontal stagger.
9. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-10.1(d) In-rack sprinkler arrangement, Class I, II, or III commodities, storage height over 25 ft (7.6 m).



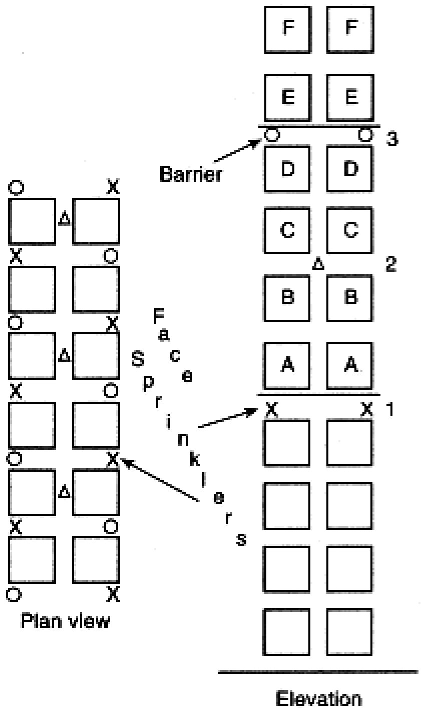
NOTES:
1. Sprinklers labeled 1 (the selected array from Table 7-10.1) shall be required where loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled C or D represent top of storage.
3. Sprinklers labeled 1 and 3 shall be required where loads labeled E or F represent top of storage.
4. For storage higher than represented by loads labeled F, the cycle defined by Notes 2 and 3 is repeated, with stagger as indicated.
5. Symbol Δ or X indicates sprinklers on vertical or horizontal stagger.
6. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-10.1(e) In-rack sprinkler arrangement, Class I, II, or III commodities, storage height over 25 ft (7.6 m).



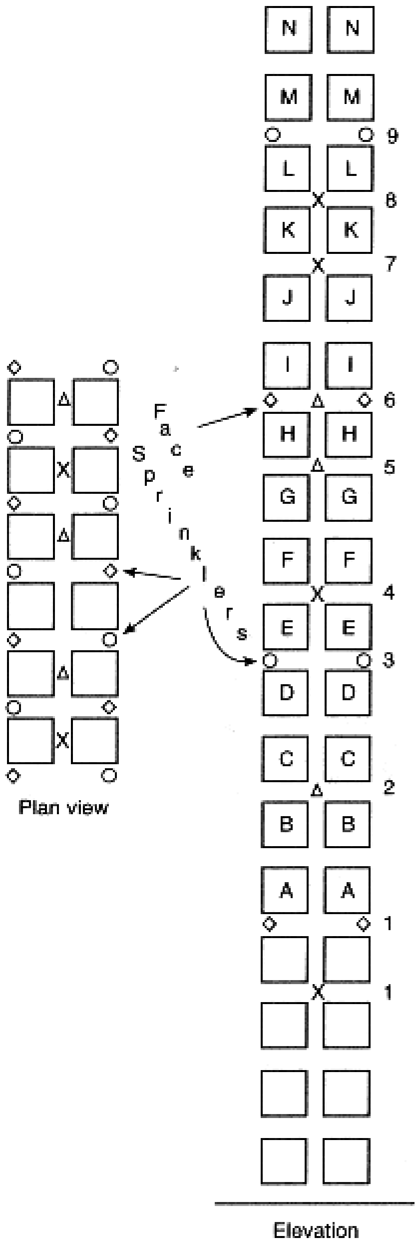
NOTES:
1. Sprinklers labeled 1 (the selected array from Table 7-10.1) shall be required where loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled C or D represent top of storage.
3. Sprinklers labeled 1 and 3 shall be required where loads labeled E represent top of storage.
4. Sprinklers labeled 1 and 4 shall be required where loads labeled F or G represent top of storage.
5. For storage higher than represented by loads labeled G, the cycle defined by Notes 2, 3, and 4 is repeated.
6. Symbol X indicates face and in-rack sprinklers.
7. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-10.1(f) In-rack sprinkler arrangement, Class I, II, or III commodities, storage height over 25 ft (7.6 m).



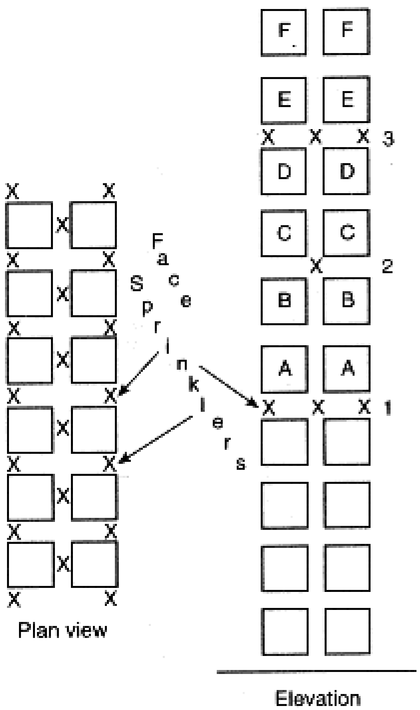
NOTES:
1. Sprinklers labeled 1 (the selected array from Table 7-10.1) shall be required where loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled C or D represent top of storage.
3. Sprinklers labeled 1 and 3 shall be required where loads labeled E or F represent top of storage.
4. For storage higher than represented by loads labeled F, the cycle defined by Notes 2 and 3 is repeated.
5. Symbols O, Δ, and X indicate sprinklers on vertical or horizontal stagger.
6. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-10.1(g) In-rack sprinkler arrangement, Class I, II, or III commodities, storage height over 25 ft (7.6 m).



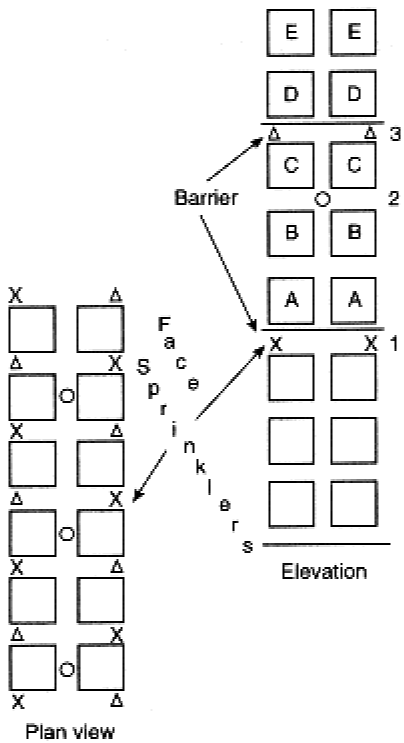
NOTES:
1. Sprinklers labeled 1 (the selected array from Table 7-10.1) shall be required where loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled C or D represent top of storage.
3. Sprinklers labeled 1 and 3 shall be required where loads labeled E or F represent top of storage.
4. Sprinklers labeled 1, 2, 3, and 4 shall be required where loads labeled G represent top of storage.
5. Sprinklers labeled 1, 2, 3, 4, and 5 shall be required where loads labeled H represent top of storage.
6. Sprinklers labeled 1, 2, 3, 4, and 6 (not 5) shall be required where loads labeld I or J represent top of storage.
7. Sprinklers labeled 1, 2, 3, 4, 6, and 7 shall be required where loads labeled K represent top of storage.
8. Sprinklers labeled 1, 2, 3, 4, 6, and 8 shall be required where loads labeled L represent top of storage.
9. Sprinklers labeled 1, 2, 3, 4, 6, 8, and 9 shall be required where loads labeled M or N represent top of storage.
10. For storage higher than represented by loads labeled N, the cycle defined by Notes 1 through 9 is repeated, with stagger as indicated. In the cycle, loads labeled M are equivalent to loads labeled A.
11. Symbols O, X, and Δ indicate sprinklers on vertical or horizontal stagger.
12. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-10.1(h) In-rack sprinkler arrangement, Class I, II, III, or IV commodities, storage height over 25 ft (7.6 m).



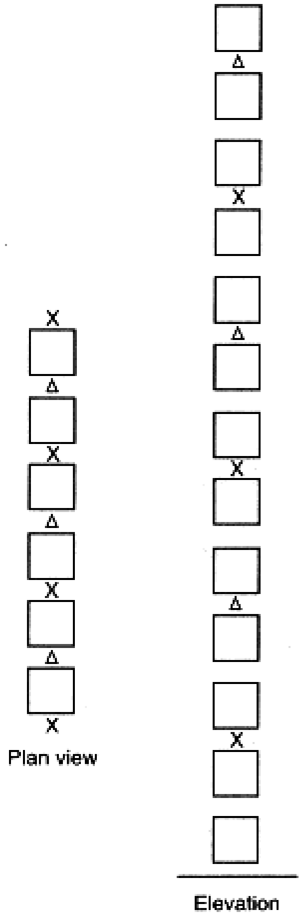
NOTES:
1. Sprinklers labeled 1 (the selected array from Table 7-10.1) shall be required where loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled C or D represent top of storage.
3. Sprinklers labeled 1 and 3 shall be required where loads labeled E or F represent top of storage.
4. For storage higher than represented by loads labeled F, the cycle defined by Notes 2 and 3 is repeated.
5. Symbol X indicates face and in-rack sprinklers.
6. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-10.1(i) In-rack sprinkler arrangement, Class I, II, III, or IV commodities, storage height over 25 ft (7.6 m).



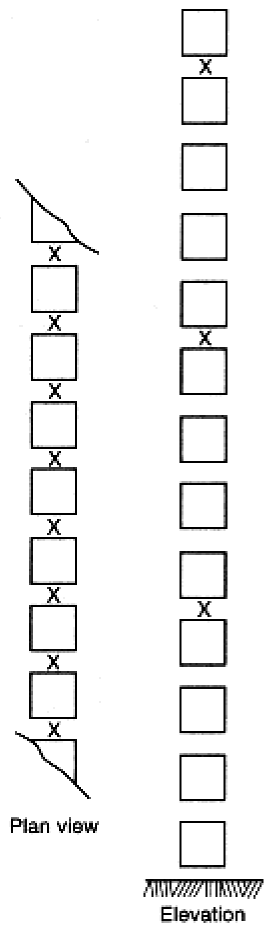
NOTES:
1. Sprinklers labeled 1 (the selected array from Table 7-10.1) shall be required where loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 and barrier labeled 1 shall be required where loads labeled C represent top of storage.
3. Sprinklers and barriers labeled 1 and 3, shall be required where loads labeled D or E represent top of storage.
4. For storage higher than represented by loads labeled E, the cycle defined by Notes 2 and 3 is repeated.
5. Symbol Δ or X indicates sprinklers on vertical or horizontal stagger.
6. Symbol O indicates longitudinal flue space sprinklers.
7. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-10.1(j) In-rack sprinkler arrangement, Class I, II, III, or IV commodities, storage height over 25 ft (7.6 m).



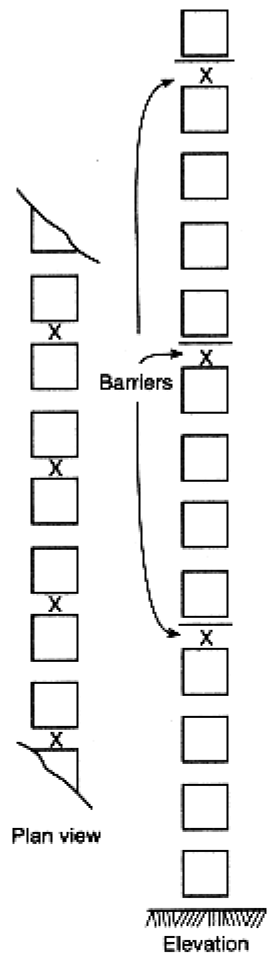
NOTES:
1. For all storage heights, sprinklers shall be installed in every other tier and staggered as indicated.
2. Symbol Δ or X indicates sprinklers on vertical or horizontal stagger.
3. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-10.3(a) Class I, II, III, or IV commodities. In-rack sprinkler arrangement, single-row racks, storage height over 25 ft (7.6 m).



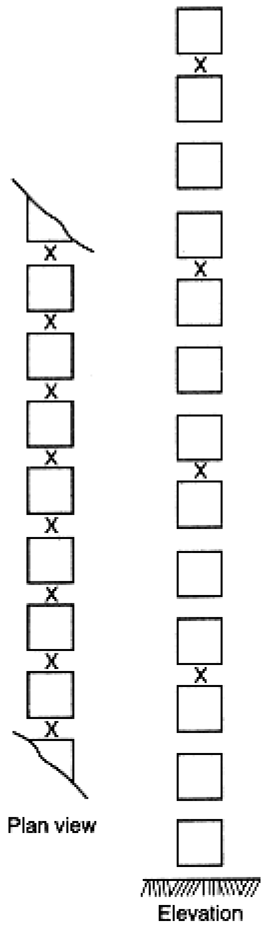
NOTE:
1. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-10.3(b) Class I, II, or III commodities.



NOTE:
1. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-10.3(c) Class I, II, or III commodities.



NOTE:
1. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-10.3(d) Class I, II, III, or IV commodities.

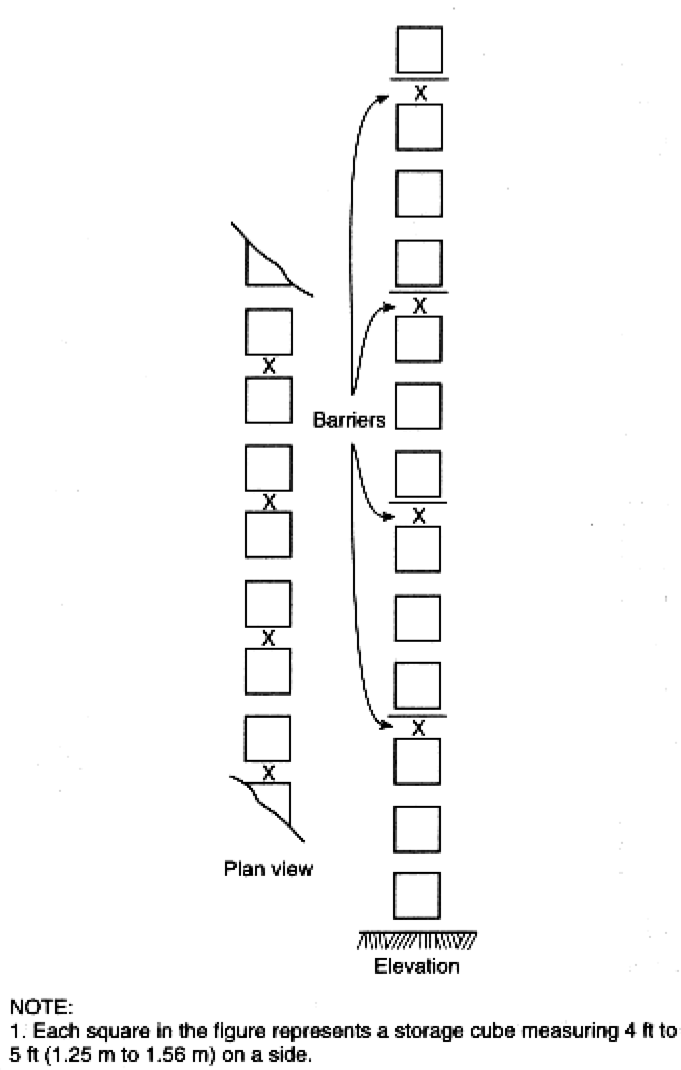


Figure 7-10.3(e) Class I, II, III, or IV commodities.

Part C Multiple-Row Racks

7-13* In-Rack Sprinkler Location.

In multiple-row racks with a maximum of 10 ft (3.1 m) between the top of storage and the ceiling, in-rack sprinklers shall be installed as indicated in Figures 7-13(a), (b), and (c). The highest level of in-rack sprinklers shall be not more than 10 ft (3.1 m) below maximum storage height for Class I, II, or III commodities or 5 ft (1.52 m) below the top of storage for Class IV commodities. (*See Table 7-13.*)

7-14 In-Rack Sprinkler Spacing.

Maximum horizontal spacing of sprinklers in multiple-row racks with storage higher than 25 ft

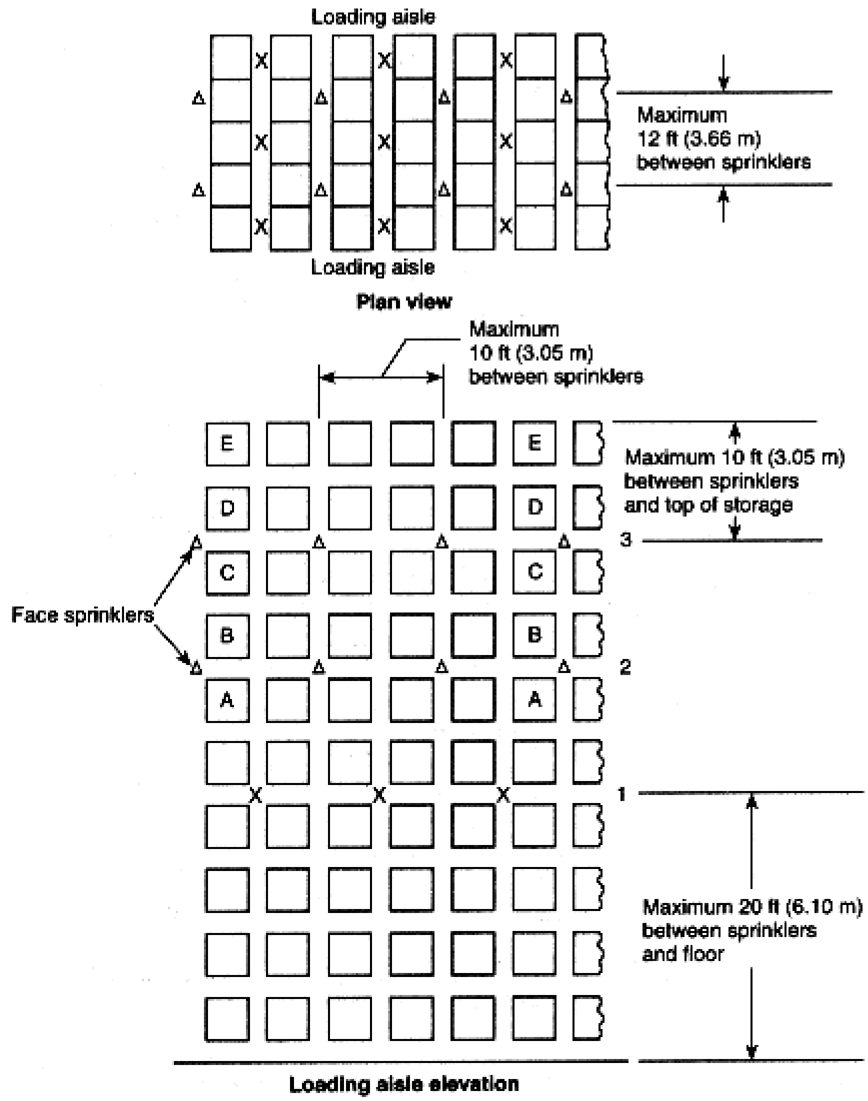
(7.6 m) shall be in accordance with Figures 7-13(a), (b), and (c).

Table 7-13 Multiple-Row Racks. Storage Heights over 25 ft.

Commodity Class	Encapsulated	In-Rack Sprinklers[1] Approximate Vertical Spacing (ft)	In-Rack Sprinklers[1] Maximum Horizontal Spacing In a Flue (ft)	In-Rack Sprinklers[1] Maximum Horizontal Spacing Across Flue (ft)	Height Limit (ft)	Stagger	Fig. No.	Maximum Spacing from Top of Storage to Highest In-Rack Sprinklers (ft)	Ceiling Sprinkler Operating Area (ft^2)	Ceiling Sprinklers Density (gpm/ft^2) 165° Rating	Ceiling Sprinklers Density (gpm/ft^2) 286° Rating
I	No	20	12	10	None	Between adjacent flues	7.13(a)	10	2000	0.25	0.35
	Yes									0.31	0.44
I, II, & III	No	15	10	10			7-13(b)	10		0.30	0.40
	Yes									0.37	0.50
I, II, III, & IV	No	10	10	10			7.13(c)	5		0.35	0.45
	Yes									0.44	0.56

[1]All four rack faces shall be protected by sprinklers located within 18 in. of the faces, as indicated in Figures 7-13(a), (b), and (c). It shall not be required for each sprinkler level to protect all faces. (*See A-7-13.*)

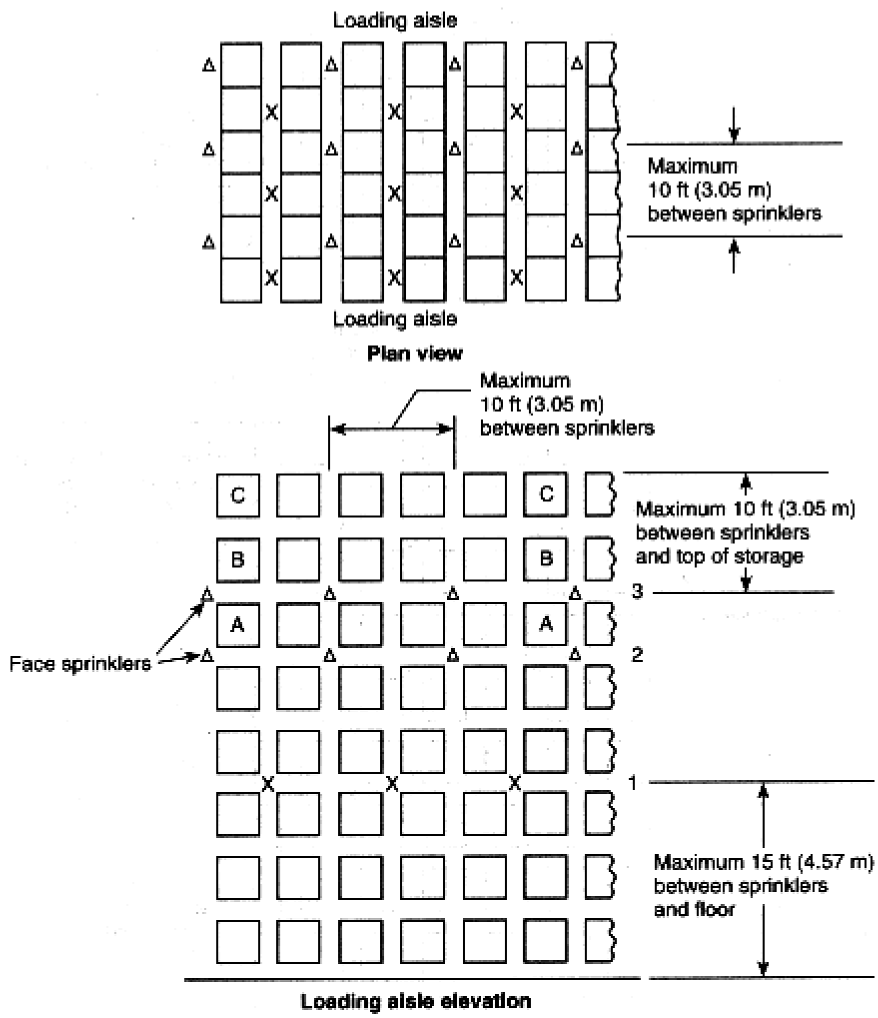
For SI units: 1 ft = 0.3048 m; C = 5/9 (F−32); 1 gpm/ft^2 = 40.746 (L/min)/m^2



NOTES:

1. Sprinklers labeled 1 shall be required if loads labeled A represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required if loads labeled B or C represent top of storage.
3. Sprinklers labeled 1 and 3 shall be required if loads labeled D or E represent top of storage.
4. For storage higher than represented by loads labeled E, the cycle defined by Notes 2 and 3 is repeated, with stagger as indicated.
5. Symbol Δ or X indicates sprinklers on vertical or horizontal stagger.
6. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-13(a) In-rack sprinkler arrangement — multiple-row racks, Class I commodities, storage height over 25 ft (7.6 m).



NOTES:
1. Sprinklers labeled 1 and 2 shall be required if loads labeled A represent top of storage.
2. Sprinklers labeled 1 and 3 shall be required if loads labeled B or C represent top of storage.
3. For storage higher than represented by loads labeled C, the cycle defined by Notes 2 and 3 is repeated, with stagger as indicated.
4. Symbol Δ or X indicates sprinklers on vertical or horizontal stagger.
5. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-13(b) In-rack sprinkler arrangement — multiple-row racks, Class I, II, or III commodities, storage height over 25 ft (7.6 m).

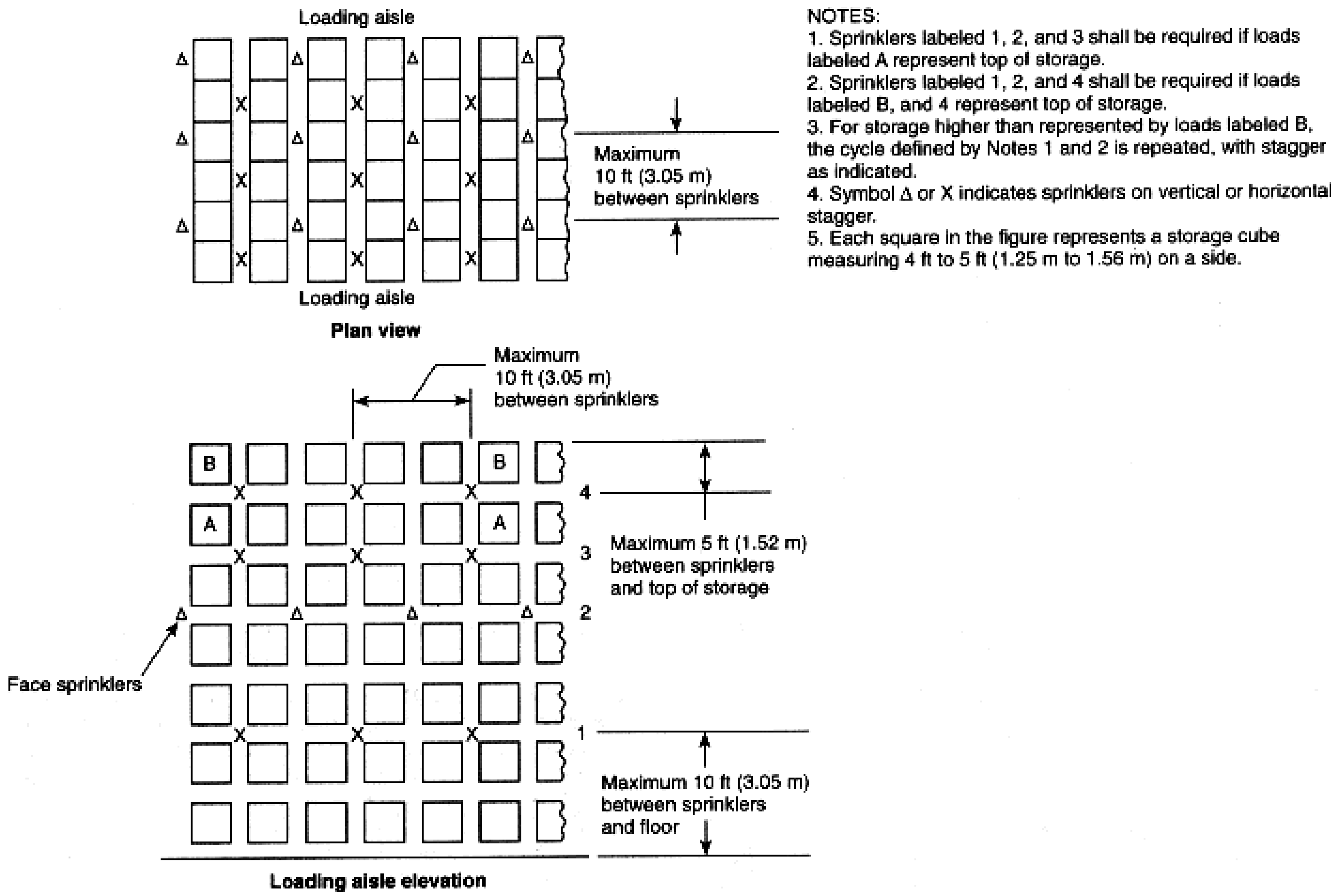


Figure 7-13(c) In-rack sprinkler arrangement, Class I, II, III, or IV commodities — multiple-row racks, storage height over 25 ft (7.6 m).

7-15 Ceiling Sprinkler Water Demand.

7-15.1

The water demand for nonencapsulated storage on racks without solid shelves separated by aisles at least 4 ft (1.22 m) wide and with not more than 10 ft (3.1 m) between the top of storage and the sprinklers shall be based on sprinklers in a 2000-ft^2 (185.8-m^2) operating area for multiple-row racks, discharging a minimum of 0.25 gpm/ft^2 [(10.19 L/min)/m^2] for Class I commodities, 0.3 gpm/ft^2 [(12.2 L/min)/m^2] for Class II and III commodities, and 0.35 gpm/ft^2 [(14.26 L/min)/m^2] for Class IV commodities, for 165°F (74°C) rated sprinklers; or a minimum of 0.35 gpm/ft^2 [(14.26 L/min)/m^2] for Class I commodities, 0.40 gpm/ft^2 [(16.8 L/min)/m^2] for Class II and III commodities, and 0.45 gpm/ft^2 [(18.3 L/min)/m^2] for Class IV commodities, for 286°F (141°C) rated sprinklers. (*See Table 7-13.*)

7-15.2

Where such storage is encapsulated, ceiling sprinkler density shall be 25 percent greater than for nonencapsulated storage.

Chapter 8* Plastics

8-1 General.

For the storage of Group A plastics stored 5 ft (1.5 m) or less in height, the sprinkler design criteria for miscellaneous storage specified in NFPA 13, *Standard for the Installation of Sprinkler Systems*, shall be used.

8-1.1

Plastics in corrugated cartons shall be protected in accordance with Figure 8-1.1. This decision tree also shall be used to determine protection for commodities that are not entirely Group A plastics but contain such quantities and arrangement of Group A plastics that they are deemed more hazardous than Class IV commodities.

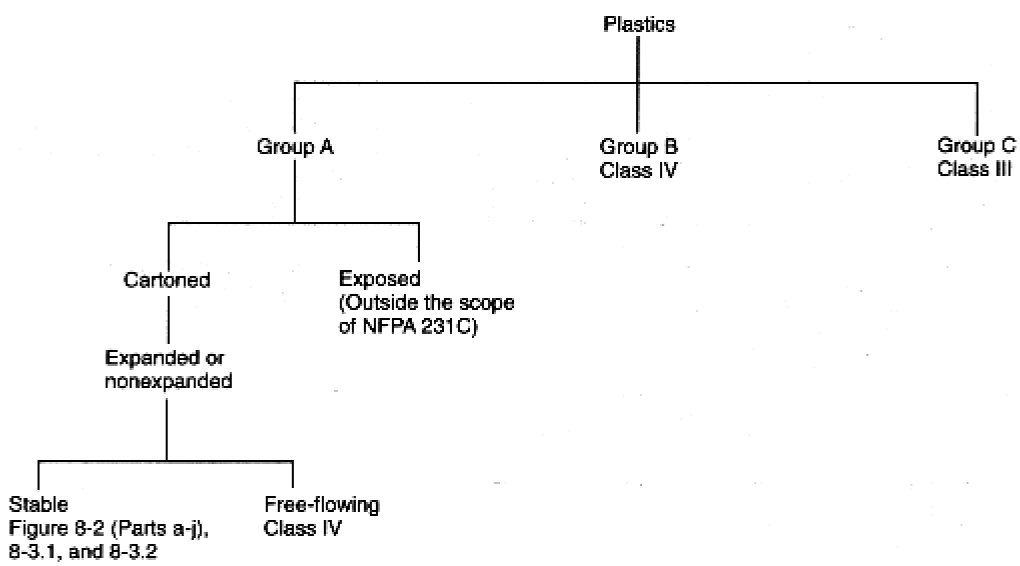


Figure 8-1.1 Decision tree.

8-1.2

Group B plastics and free-flowing Group A plastics shall be protected the same as Class IV commodities.

8-1.3

Group C plastics shall be protected the same as Class III commodities.

8-1.4

Ceiling sprinklers shall be large orifice [$^{17}/_{32}$ in. (13.5 mm)] and rated ordinary to high temperature.

Exception No. 1: Large drop sprinklers in accordance with Chapter 9.

Exception No. 2: ESFR sprinklers in accordance with Chapter 10.

Exception No. 3: For densities of 0.30 gpm/ft^2 [(12.2 L/min)/m^2] or less, $^1/_2$-in. (12.7-mm) orifice sprinklers shall be permitted.

Exception No. 4: High-temperature sprinklers shall be used where required by NFPA 13, Standard for the Installation of Sprinkler Systems.

8-1.5 In-Rack Sprinklers.

8-1.5.1 In-Rack Sprinkler Classification. Sprinklers in racks shall be ordinary-temperature standard response classification.

Exception No. 1: High-temperature sprinklers shall be used as specified in NFPA 13, Standard for the Installation of Sprinkler Systems.

Exception No. 2: Quick-response sprinklers shall be permitted to be installed in racks.

8-1.5.2 In-Rack Sprinkler Pipe Size. The number of sprinklers and the pipe sizing on a line of sprinklers in racks shall be restricted only by the hydraulic calculations and not by any piping schedule.

8-1.5.3 In-Rack Sprinkler Water Shields. Where in-rack sprinklers are not shielded by horizontal barriers, water shields shall be provided above the sprinklers, or listed sprinklers equipped with water shields shall be used.

8-1.5.4 In-Rack Sprinkler Clearance. The minimum of 6 in. (152.4 mm) vertical clear space shall be maintained between the sprinkler deflectors and the top of a tier of storage.

8-1.5.5 In-Rack Sprinkler Water Demand. The water demand for sprinklers installed in racks shall be based on simultaneous operation of the most hydraulically remote sprinklers as follows:

(a) Eight sprinklers where only one level is installed in racks;

(b) Fourteen sprinklers (seven on each top two levels) where more than one level is installed in racks.

8-1.5.6 Chapters 1 through 5 apply to plastics storage.

8-2 Single-, Double-, and Multiple-Row Racks — Storage up to and Including 25 ft (7.6 m) Clearances up to and Including 10 ft (3.1 m).

8-2.1 Ceiling Sprinkler Water Demand.

For Group A plastic commodities in cartons, encapsulated or nonencapsulated in single-, double-, and multiple-row racks, ceiling sprinkler water demand in terms of density (gpm/ft^2) [(L/min)/m^2] and area of operation [ft^2 (m^2)] shall be selected from Figure 8-2 Parts (a) through (g). Linear interpolation of design densities and areas of application shall be permitted between storage heights with the same clearances. No interpolation between clearances shall be permitted.

8-2.1.1 Single-, Double-, and Multiple-Row Racks — 5-ft to 10-ft (1.25-m to 3.1-m) Storage with $1^1/_2$-ft to 10-ft (0.5-m to 3.1-m) Clearance. The protection strategies utilizing ceiling sprinklers only, as shown in Figure 8-2 Part (a), shall be acceptable for single- and double-row rack storge with 4-ft (1.22-m) or greater aisles and for multiple-row storage.

8-2.1.2 Single- and Double-Row Racks — 15-ft (4.6-m) Storage with Less than 5-ft (1.25-m) Clearance. The protection strategy utilizing ceiling sprinklers only as shown in Figure 8-2 Part (b) shall be acceptable only for single- and double-row rack storage with 8-ft (2.4-m) aisles. For 3 1/2-ft (1-m) aisles, a density of 0.60 gpm/ft^2 [(24.5 L/min)/m^2] and an area of application of 1500 ft^2 (139.5 m^2) shall be used. For aisle widths of 3 1/2 ft to 8 ft (1 m to 2.4 m), a direct linear interpolation shall be permitted between densities and areas of application.

8-2.1.3 Single- and Double-Row Racks — 15-ft (4.6-m) Storage with 10-ft (3.1-m) Clearance; 20-ft (6-m) Storage with Less than 5-ft (1.25-m) Clearance. The protection strategies utilizing ceiling sprinklers only as shown in Figures 8-2 Parts (c) and (d) shall be acceptable only for single- and double-row rack storage with 8-ft (2.4-m) aisles. In-rack sprinkler protection shall be required for aisles less than 8 ft (2.4 m) in width.

Where utilizing the strategies for ceiling sprinklers only, as shown in Figure 8-2 Parts (c) and (d), column steel shall be protected in accordance with 3-2.3(a) or (b). Roof structural steel shall be protected in such a manner as to provide a minimum of 15 minutes fire resistance.

8-2.1.4 Multiple-Row Racks — 15-ft (4.6-m) Storage with Less than 5-ft (1.25-m) Clearance. The protection strategy utilizing ceiling sprinklers only, as shown in Figure 8-2 Part (b), shall not be permitted for multiple-row rack storage. The density to be used shall be 0.60 gpm/ft^2 [(24.5 L/min)/m^2] over 2000 ft^2 (186 m^2). The combination of ceiling and in-rack sprinklers specified in Figure 8-2 Part (b) shall be permitted as an alternative.

8-2.1.5 Multiple-Row Racks — 15-ft (4.6-m) Storage with 10-ft (3.1-m) Clearance; 20-ft (6-m) Storage with Less than 5-ft (1.25-m) Clearance. The protection strategies utilizing ceiling sprinklers only as shown in Figure 8-2 Parts (c) and (d) shall not be permitted for multiple-row rack storage. Only the specified combinations of ceiling and in-rack sprinklers shall be used.

Strategies for Protection of Rack Storage of Plastics—Single-Row, Double-Row, and Multiple-Row Rack Configurations, Unexposed (Expanded and Unexpanded) Group A Plastics

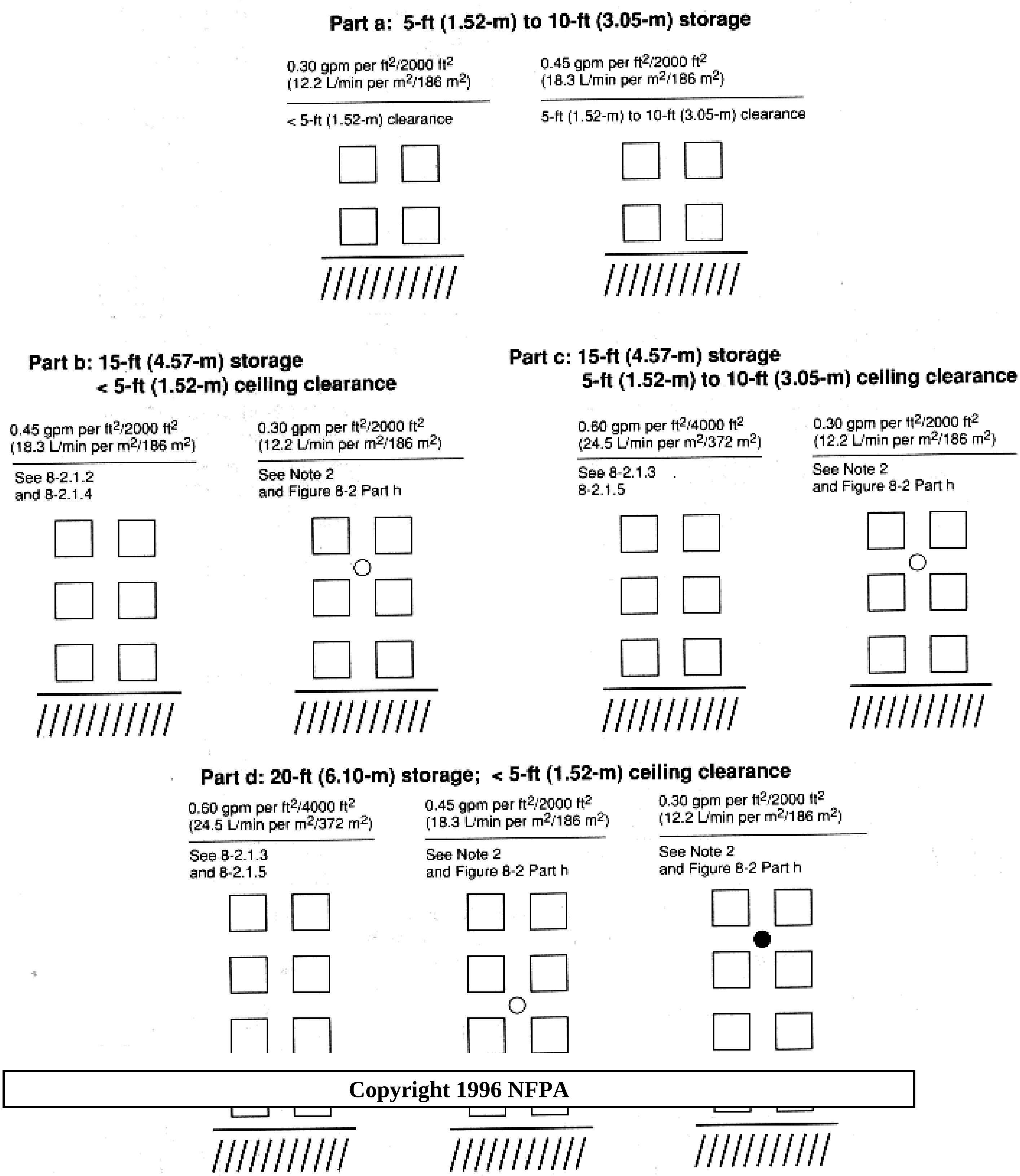


Figure 8-2. (cont'd)

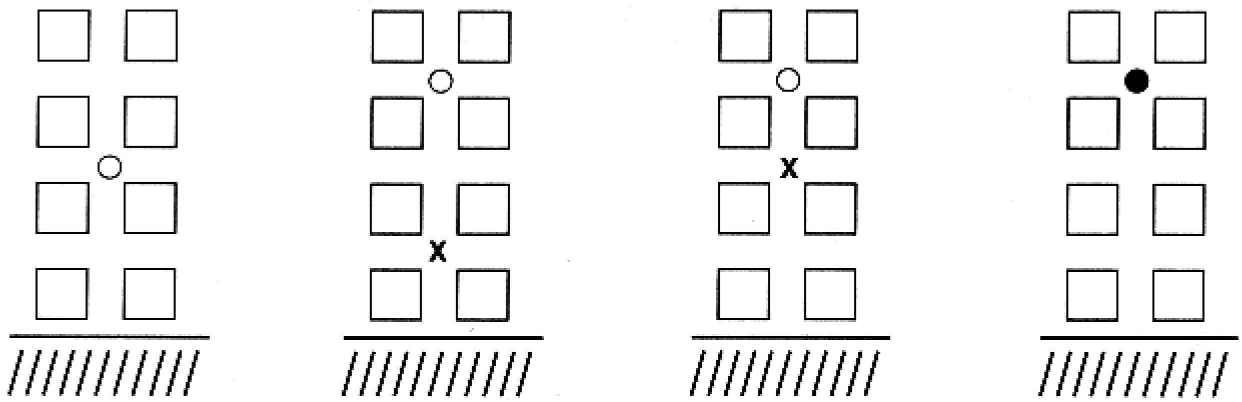
**Part e: 20-ft (6.10-m) storage
5-ft (1.52-m) to 10-ft (3.05-m) ceiling clearance (See Note 5)**

0.45 gpm per ft^2/2000 ft^2 (18.3 L/min per m^2/186 m^2)
See Note 2 and Figure 8-2 Part h

0.30 gpm per ft^2/2000 ft^2 (12.2 L/min per m^2/186 m^2)
See Note 4 and Figure 8-2 Part j

0.30 gpm per ft^2/2000 ft^2 (12.2 L/min per m^2/186 m^2)
See Note 4 and Figure 8-2 Part j

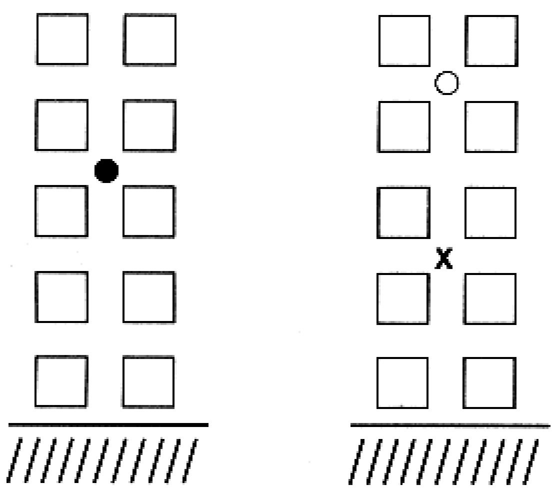
0.30 gpm per ft^2/2000 ft^2 (12.2 L/min per m^2/186 m^2)
See Note 3 and Figure 8-2 Part i



**Part f: 25-ft (7.62-m) storage
< 5-ft (1.52-m) ceiling clearance
(See Note 5)**

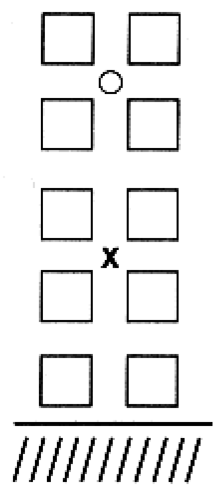
0.45 gpm per ft^2/2000 ft^2 (18.3 L/min per m^2/186 m^2)
See Note 3 and Figure 8-2 Part i

0.30 gpm per ft^2/2000 ft^2 (12.2 L/min per m^2/186 m^2)
See Note 4 and Figure 8-2 Part j



**Part g: 25-ft (7.62-m) storage
5-ft (1.52-m) to 10-ft (3.05-m)
ceiling clearance (See Note 5)**

0.30 gpm per ft^2/2000 ft^2 (12.2 L/min per m^2/186 m^2)
See Note 4 and Figure 8-2 Part j



**Part h: One level of in-rack sprinklers – plan view
ordinary spacing (See Note 2)**

Single-row rack storage

Multiple-row rack storage

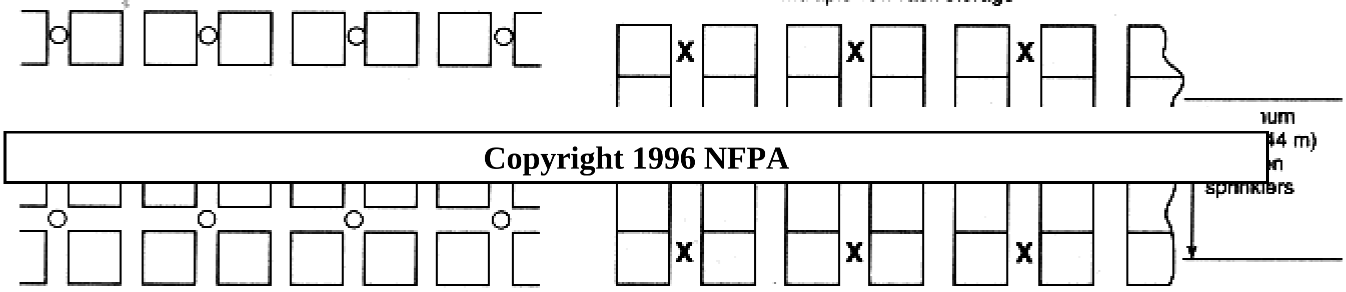
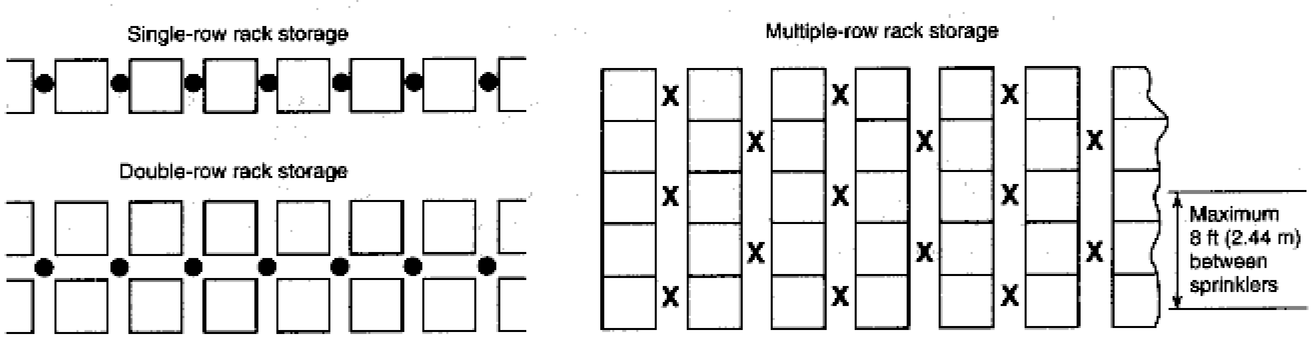
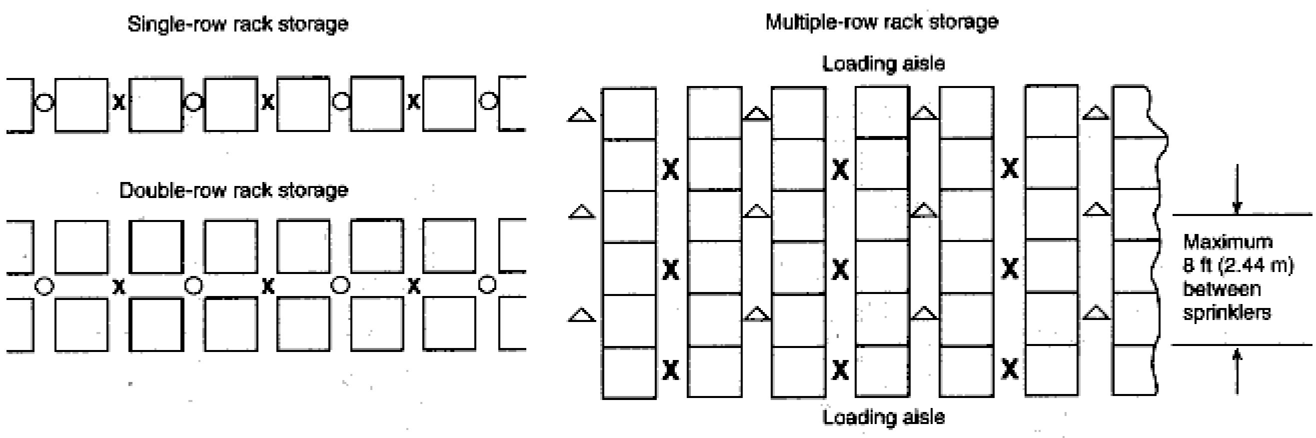


Figure 8-2. (cont'd)

Part i: One level of in-rack sprinklers – plan view close spacing (See Note 3)



Part j: Two levels of in-rack sprinklers – plan view ordinary spacing (See Note 4)



Notes to parts a through j:

1. Each square in the figures represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.
2. Single level of in-rack sprinklers (½ in. or 17/32 in. operating at 15 psi [1.03 bar] minimum) installed on 8 ft to 10 ft (2.5 m to 3.12 m) spacings located, as indicated, in the transverse flue spaces.
3. Single level of in-rack sprinklers (17/32 in. operating at 15 psi [1.03 bar] minimum or ½ in. operating at 30 psi [2.07 bar] minimum) installed on 4 ft to 5 ft (1.25 m to 1.56 m) spacings located, as indicated, in the longitudinal flue space at the intersection of every transverse flue space.
4. Two levels of in-rack sprinklers (½ in. or 17/32 in. operating at 15 psi [1.03 bar] minimum) installed on 8 ft to 10 ft (2.5 m to 3.12 m) spacings located as indicated and staggered in the transverse flue spaces.
5. Ceiling only protection shall not be permitted for this storage configuration.

Figure 8-2. (cont'd)

8-2.2 In-Rack Sprinklers.

In-rack sprinklers shall be installed in accordance with Figure 8-2 Parts (b) through (j).

8-3 Single- and Double-Row Racks — Storage over 25 ft (7.6 m) in Height.

8-3.1 Ceiling Sprinkler Water Demand.

For Group A plastic commodities in cartons, encapsulated or nonencapsulated in single- and double-row racks, ceiling sprinkler water demand in terms of density (gpm/ft^2) [(L/min)/m^2] and area of operation [ft^2 (m^2)] shall be selected from Table 8-3.1.

Table 8-3.1 Single- and Double-Row Racks.Storage Height over 25 ft.

Storage Height above Top Level In-Rack Sprinklers	Ceiling Sprinklers Density (gpm/ft^2)/Area of Application (ft^2)
5 ft or less	0.30/2000
Over 5 ft up to 10 ft	0.45/2000

For SI units: 1 ft = 0.3048 m; 1 gpm = 3.785 L/min; 1 gpm/ft^2 = 40.74 (L/min)/m^2

NOTE: Provide in-rack sprinkler protection per Figures 8-3.2.1(a) and (b) and Figures 8-3.2.3(a) through (c).

8-3.2 In-Rack Sprinkler Location.

8-3.2.1 In double-row racks without solid shelves and with a maximum of 10 ft (3.1 m) between the top of storage and the ceiling, in-rack sprinklers shall be installed in accordance with Figures 8-3.2.1(a) or (b). The highest level of in-rack sprinklers shall be not more than 10 ft (3.1 m) below the top of storage.

8-3.2.2 In-rack sprinklers for storage higher than 25 ft (7.6 m) in double-row racks shall be spaced horizontally and located in the horizontal space nearest the vertical intervals specified in Figures 8-3.2.1(a) or (b).

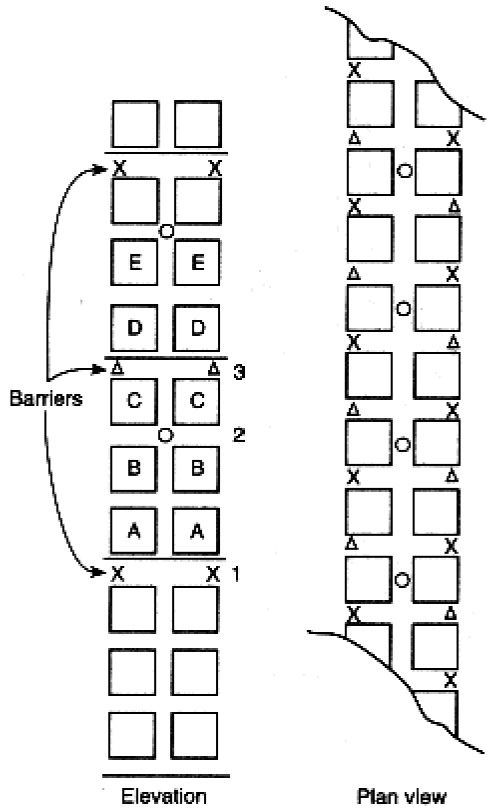
8-3.2.3 In single-row racks without solid shelves with storage height over 25 ft (7.6 m) and a maximum of 10 ft (3.1 m) between the top of storage and the ceiling, sprinklers shall be installed as indicated in Figures 8-3.2.3(a), (b), or (c).

8-3.3 In-Rack Sprinkler Size.

Sprinklers in racks shall be $^{1}/_{2}$-in. (12.7-mm) or $^{17}/_{32}$-in. (13.5-mm) orifice size, pendent or upright.

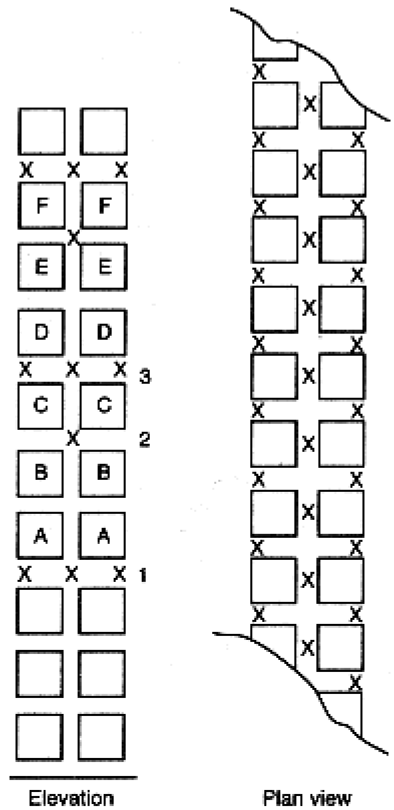
8-3.4 In-Rack Sprinkler Discharge Pressure.

Sprinklers in racks shall discharge at not less than 30 gpm (113.6 L/min).



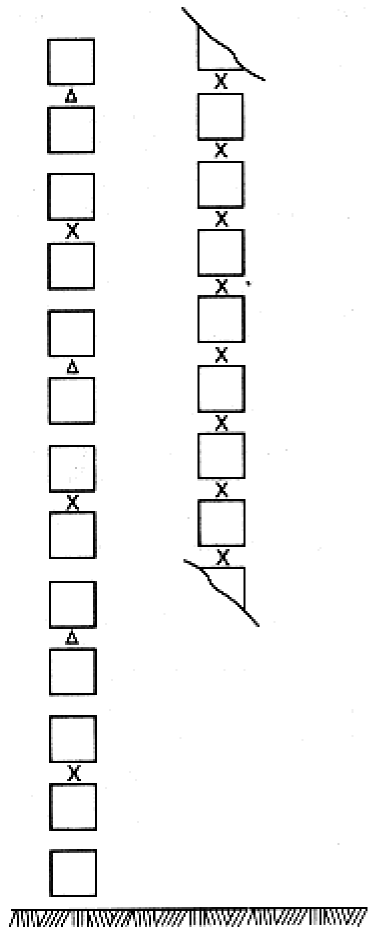
NOTES:
1. Sprinklers and barriers labeled 1 shall be required where loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 and barriers labeled 1 shall be required where loads labeled C represent top of storage.
3. Sprinklers and barriers labeled 1 and 3 shall be required where loads labeled D or E represent top of storage.
4. For storage higher than represented by loads labeled, E the cycle defined by Notes 2 and 3 is repeated.
5. Symbol Δ or X indicates face sprinklers on vertical or horizontal stagger.
6. Symbol O indicates longitudinal flue space sprinklers.
7. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 8-3.2.1(a) In-rack sprinkler arrangement, Group A plastic commodities, storage height over 25 ft (7.6 m).



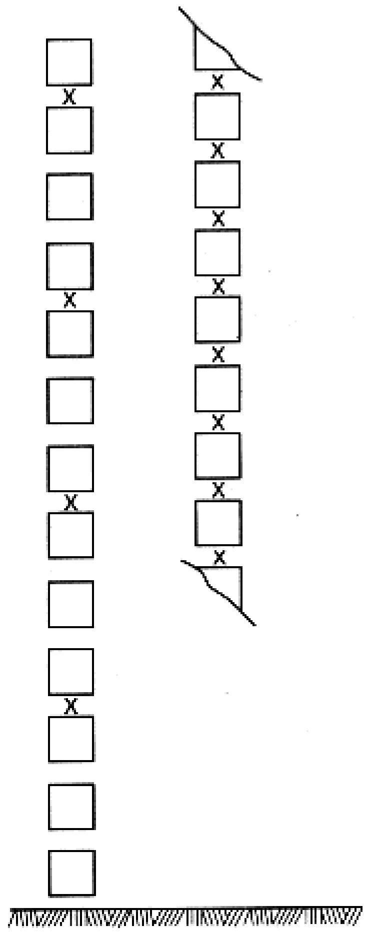
NOTES:
1. Sprinklers labeled 1 shall be required where loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled C represent top of storage.
3. sprinklers labeled 1 and 3 shall be required where loads labeled D or E represent top of storage.
4. For storage higher than loads labeled F, the cycle defined by Notes 2 and 3 is repeated.
5. Symbol X indicates face and in-rack sprinklers.
6. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 8-3.2.1(b) In-rack sprinkler arrangement, Group A plastic commodities, storage height over 25 ft (7.6 m).



NOTE:
1. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 8-3.2.3(a) In-rack sprinkler arrangement, Group A plastic commodities, single-row racks, storage height over 25 ft (7.6 m).



NOTE:
1. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 8-3.2.3(b) In-rack sprinkler arrangement, Group A plastic commodities, single-row racks, storage height over 25 ft (7.6 m).

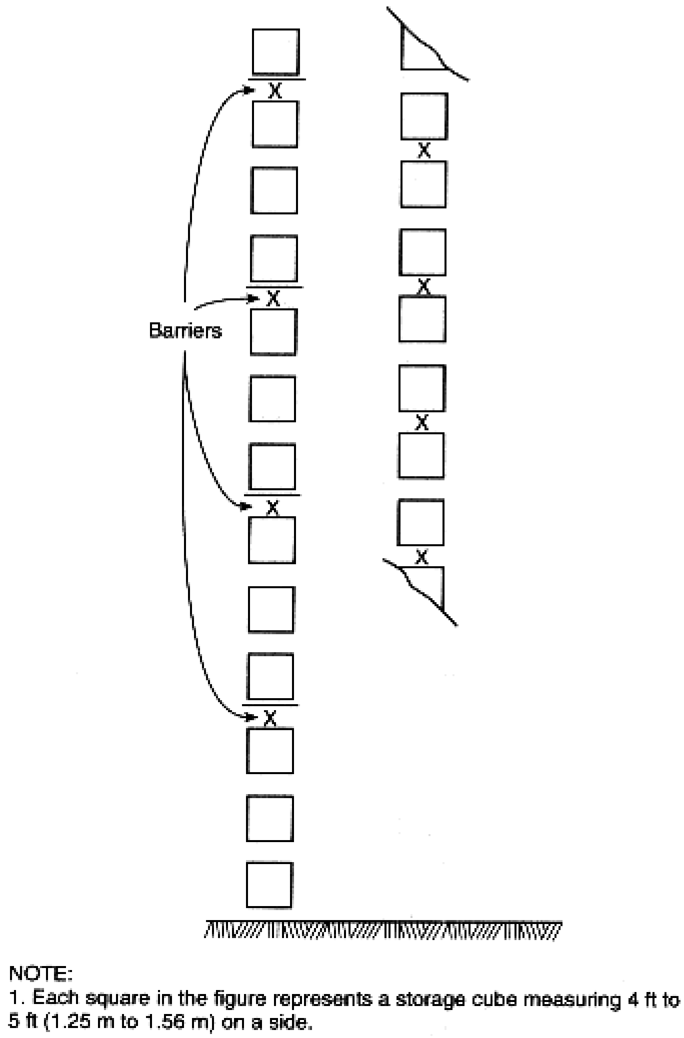


Figure 8-3.2.3(c) In-rack sprinkler arrangement, Group A plastic commodities, single-row racks, storage height over 25 ft (7.6 m).

Chapter 9 Large Drop Sprinklers

9-1 General.

9-1.1

Large drop sprinklers shall be suitable for use with the hazards specified in Table 9-1.1.

Table 9-1.1 Large Drop Sprinkler Data Pressure and Number of Design Sprinklers Required for Various Hazards for Large Drop Sprinklers

Hazard	Type of System	Minimum Operating Pressure, psi (bar) 25 (1.7)	50 (3.4)	75 (5.2)	Hose Stream Demand gal/min (dm^3/min)	Water Supply Duration (hr)
			Number of Design Sprinklers			
Double-Row Storage with Minimum 5.5-ft (1.7-m) Aisle Width and Multiple-Row Rack Storage with Minimum 8.0-ft (2.5-m) Aisle Width (Note 1)						
Class I and II commodities up to 25 ft (7.6 m) with maximum 5-ft (1.5-m) clearance to ceiling	Wet Dry	20 30	Note 2 Note 2	Note 2 Note 2	500 (1900)	1½
Class I and II commodities up to 30 ft (9.1 m) with maximum 5-ft (1.5-m) clearance to ceiling	Wet Dry	20 plus one level of in-rack sprinklers 30 plus one level of in-rack sprinklers	Note 2 Note 2	Note 2 Note 2	500 (1900)	1½
Class I, II, and III commodities up to 20 ft (6.1 m) with maximum 10-ft (3.1-m) clearance to ceiling	Wet Dry	15 25	Note 2 Note 2	Note 2 Note 2	500 (1900)	1½
Class I, II, and III commodities up to 25 ft (7.6 m) with maximum 10-ft (3.1-m) clearance to ceiling	Wet Dry	15 plus one level of in-rack sprinklers 25 plus one level of in-rack sprinklers	Note 2 Note 2	Note 2 Note 2	500 (1900)	1½
Class IV commodities up to 20 ft (6.1 m) with maximum 10-ft (3.1-m) clearance to ceiling	Wet Dry	NA NA	20 NA	15 NA	500 (1900)	2
Class IV commodities up to 25 ft (7.6 m) with maximum 10-ft (3.1-m) clearance to ceiling	Wet Dry	NA NA	20 plus one level of in-rack sprinklers NA	15 plus one level of in-rack sprinklers NA	500 (1900)	2
Unexpanded plastics up to 20 ft (6.1 m) with maximum 10-ft (3.1-m) clearance to ceiling	Wet Dry	NA NA	30 NA	20 NA	500 (1900)	2
Unexpanded plastics up to 25 ft (7.6 m) with maximum 10-ft (3.1-m) clearance to ceiling	Wet Dry	NA NA	30 plus one level of in-rack sprinklers NA	20 plus one level of in-rack sprinklers NA	500 (1900)	2
Class IV commodities and unexpanded plastics up to 20 ft (6.1 m) with maximum 5-ft (1.5-m) clearance to ceiling	Wet Dry	NA NA	15 NA	Note 2 NA	500 (1900)	2
Class IV commodities and unexpanded plastics up to 25 ft (7.6 m) with maximum 5-ft (1.5-m) clearance to ceiling	Wet Dry	NA NA	15 plus one level of in-rack sprinklers NA	Note 2 NA	500 (1900)	2

NOTE 1: Conventional wood pallets only shall be used; no slave pallets shall be permitted to be used.
NOTE 2: The high pressure shall be permitted to be used, but the required number of design sprinklers shall not be reduced from that required for the lower pressure.
N/A: Not applicable.

9-1.2

Each joist channel of open, wood joist construction shall be fully firestopped to its full depth at intervals not exceeding 20 ft (6 m).

Exception: Unfirestopped, open, wood joist construction or firestops at intervals exceeding 20 ft (6 m) shall be permitted where the minimum operating pressure is increased by 40 percent.

9-1.3

Building steel shall not require special protection where Table 9-1.1 is applied.

9-1.4

Protection requirements are based on rack storage having no solid shelves or slave pallets.

9-1.5

A minimum of 6 in. (152.4 mm) longitudinal flue spaces shall be maintained in addition to transverse flue spaces.

9-1.6

For dry-pipe systems, high-temperature sprinklers shall be used; for wet-pipe systems, ordinary- or high-temperature sprinklers shall be permitted.

9-1.7

Sprinkler spacing shall be not less than 80 ft^2 (7.4 m^2) or more than 100 ft^2 (9.3 m^2).

9-1.8

All requirements contained in NFPA 13, *Standard for the Installation of Sprinkler Systems*, shall apply.

Exception: Where modified by this standard.

Chapter 10 Early Suppression Fast Response (ESFR) Sprinklers

10-1* General.

Early suppression fast response (ESFR) sprinklers shall be permitted for the protection of rack storage in accordance with Table 10-1 and shall be used only in buildings equal to, or less than, the height of the building for which they have been listed.

Exception: ESFR protection as defined shall not apply to:

1. Rack storage involving solid shelves

2. Rack storage involving combustible, open-top cartons or containers.

Table 10-1 Early Suppression Fast Response (ESFR) Sprinkler Data

Type of Storage	Commodity	Maximum Height of Storage ft (m)	Maximum Height of Building (ft) (m) (Note 1)	Nominal K Factor	Sprinkler Design Pressure psi (bars)	Commodity Limitation
Single-, double-, and multiple-row rack storage (No open-top containers or solid shelves)	Cartoned unexpanded plastic; cartoned expanded plastic; uncartoned unexpanded plastic; and Class I, II, III, or IV commodities, encapsulated or unencapsulated	25 (7.6)	30 (9.1)	13.5–14.5	50 (3.4)	—
	Cartoned unexpanded plastic; and class I, II, III, or IV commodities, encapsulated or unencapsulated	35 (10.7)	40 (12.2)	13.5–14.5	75 (5.2)	Note 2
		20 (6.1)	25 (7.6)	11.0–11.5	50 (3.4)	

NOTE 1: Maximum building height shall be measured to the underside of the roof deck or ceiling.
NOTE 2: Only ESFR sprinklers specifically listed for 40-ft (12.2-m) high buildings shall be used in buildings higher than 30 ft (9.1 m) up to 40 ft (12.2 m).

10-2 Sprinkler System Design.

10-2.1*

ESFR sprinkler systems shall be designed to provide the minimum operating pressure, in accordance with Table 10-1 for the commodity, storage height, and building height involved, to the twelve most hydraulically remote sprinklers based on flowing four sprinklers on each of three branch lines.

10-2.2

The distance between branch lines and sprinklers on branch lines shall not be more than 10 ft (3.1 m) nor less than 8 ft (2.4 m) for buildings higher than 30 ft (9.1 m) up to 40 ft (12.2 m), and not more than 12 ft (3.7 m) nor less than 8 ft (2.4 m) for buildings up to 30 ft (9.1 m) high.

10-2.3

Only wet-pipe systems are acceptable for use with ESFR sprinklers.

10-2.4

All requirements contained in NFPA 13, *Standard for the Installation of Sprinkler Systems*, shall apply.

Exception: Where modified by this standard.

10-2.5

ESFR sprinklers shall be ordinary-temperature rated sprinklers.

Exception No. 1: ESFR sprinklers located in proximity to heat sources.

Exception No. 2: ESFR sprinklers located under skylights.

10-3 Water Demand.

10-3.1

A minimum of 250 gpm (16 L/s) shall be added to the sprinkler demand for combined large and small hose streams.

10-3.2

Water supply duration shall be at least 1 hour.

Chapter 11 Equipment

11-1 Mechanical Handling Equipment—Industrial Trucks.

11-1.1

Power-operated industrial trucks shall be of the type designated in NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance, and Operation*, and their maintenance and operation shall be in accordance with Chapters 2 and 3 of that standard.

11-1.2

Industrial trucks using LP-Gas or liquid fuel shall be refueled outside of the storage building at a location designated for that purpose.

Chapter 12 Building Maintenance and Operation

12-1* Building Operations Other than Storage.

Welding, soldering, brazing, and cutting shall be permitted to be performed on rack or building components that cannot be removed, provided no storage is located below and within 25 ft (7.6 m) of the working area and flameproof tarpaulins enclose this section. During any of these operations, the sprinkler system shall be in service. Water-type extinguishers with a capacity of $2^1/_2$ gal (9.45 L) and charged inside hose lines shall be located in the working area. A fire watch shall be maintained during these operations and for at least 30 additional minutes.

12-2* Waste Disposal.

Approved containers for rubbish and other trash materials shall be provided.

12-3 Smoking.

Smoking shall be strictly prohibited. “No Smoking” signs shall be posted in prohibited areas.

Exception: Smoking shall be permitted in locations prominently designated as smoking areas.

12-4* Maintenance.

Fire walls, fire doors, and floors shall be maintained in good repair at all times.

12-5* Plant Emergency Organization.

A fire watch shall be maintained when the sprinkler system is not in service.

12-6* General Fire Protection.

The sprinkler system and the water supplies shall be inspected, tested, and maintained in accordance with NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection 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 11A, *Standard for Medium- and High-Expansion Foam Systems*, 1994 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1994 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 40, *Standard for the Storage and Handling of Cellulose Nitrate Motion Picture Film*, 1994 edition.

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, 1995 edition.

NFPA 81, *Standard for Fur Storage, Fumigation and Cleaning*, 1986 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*, 1995 edition.

NFPA 220, *Standard on Types of Building Construction*, 1992 edition.

NFPA 231, *Standard for General Storage*, 1995 edition.

NFPA 231D, *Standard for Storage of Rubber Tires*, 1994 edition.

NFPA 231F, *Standard for the Storage of Roll Paper*, 1987 edition.

NFPA 232, *Standard for the Protection of Records*, 1991 edition.

NFPA 490, *Code for the Storage of Ammonium Nitrate*, 1993 edition.

NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance, and Operation*, 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-4-1

Rack storage as referred to in this standard contemplates commodities in a rack structure, usually steel. Many variations of dimensions are found. Racks can be single-row, double-row, or multiple-row, with or without solid shelves. The standard commodity used in most of the tests was 42 in. (1.07 m) on a side. The types of racks covered in this standard are as follows:

Double-Row Racks. Pallets rest on two beams parallel to the aisle. Any number of pallets can be supported by one pair of beams. [*See Figures A-4-1(a) through (d).*]

Automatic Storage-Type Rack. The pallet is supported by two rails running perpendicular to the aisle. [*See Figure A-4-1(e).*]

Multiple-Row Racks More than Two Pallets Deep, Measured Aisle to Aisle. These include drive-in racks, drive-through racks, flow-through racks, portable racks arranged in the same manner, and conventional or automatic racks with aisles less than 42 in. (1.07 m) wide. [*See Figures A-4-1(f) through (i).*]

Movable Racks. Movable racks are racks on fixed rails or guides. They can be moved back and forth only in a horizontal two-dimensional plane. A moving aisle is created as abutting racks are either loaded or unloaded, then moved across the aisle to abut other racks. [*See Figure A-4-1(k).*]

Solid Shelving. Conventional pallet racks with plywood shelves on the shelf beams [*see Figures A-4-1(c) and (d)*]. These are used in special cases. (*See Chapter 5.*)

Cantilever Rack. The load is supported on arms that extend horizontally from columns. The load can rest on the arms or on shelves supported by the arms. [*See Figure A-4-1(j).*]

Load depth in conventional or automatic racks should be considered a nominal 4 ft (1.22 m). [*See Figure A-4-1(b).*]

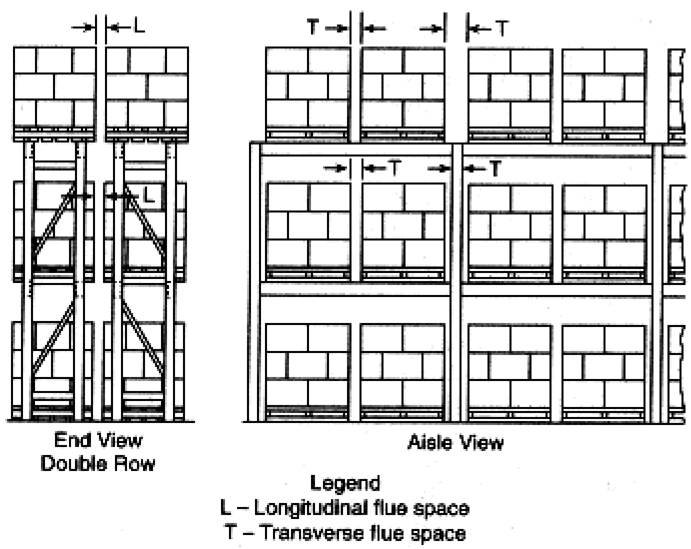


Figure A-4-1(a) Conventional pallet rack.

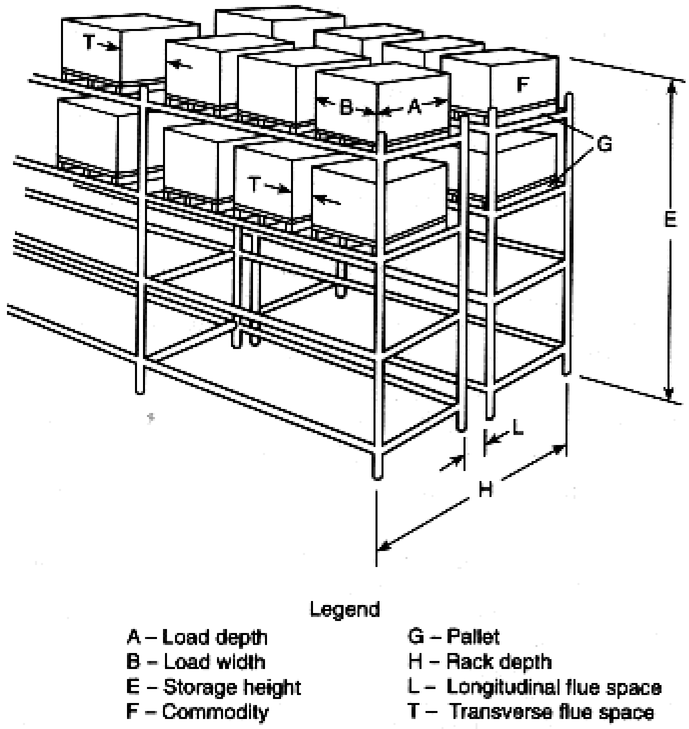


Figure A-4-1(b) Double-row racks without solid or slatted shelves.

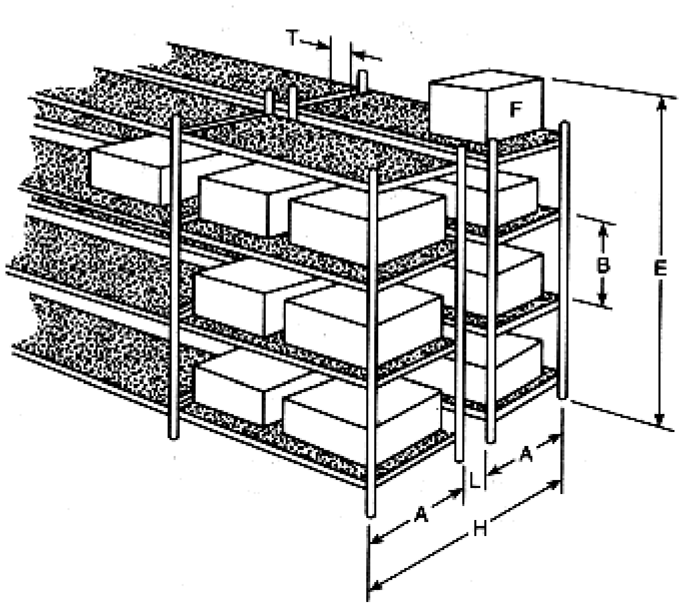


Figure A-4-1(c) Double-row racks with solid shelves.

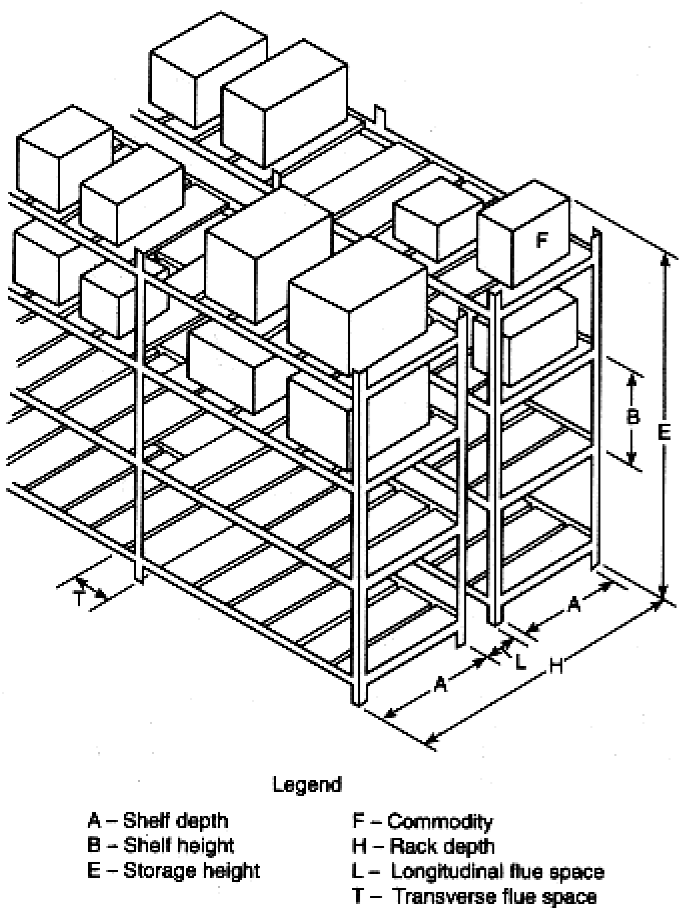


Figure A-4-1(d) Double-row racks with slatted shelves.

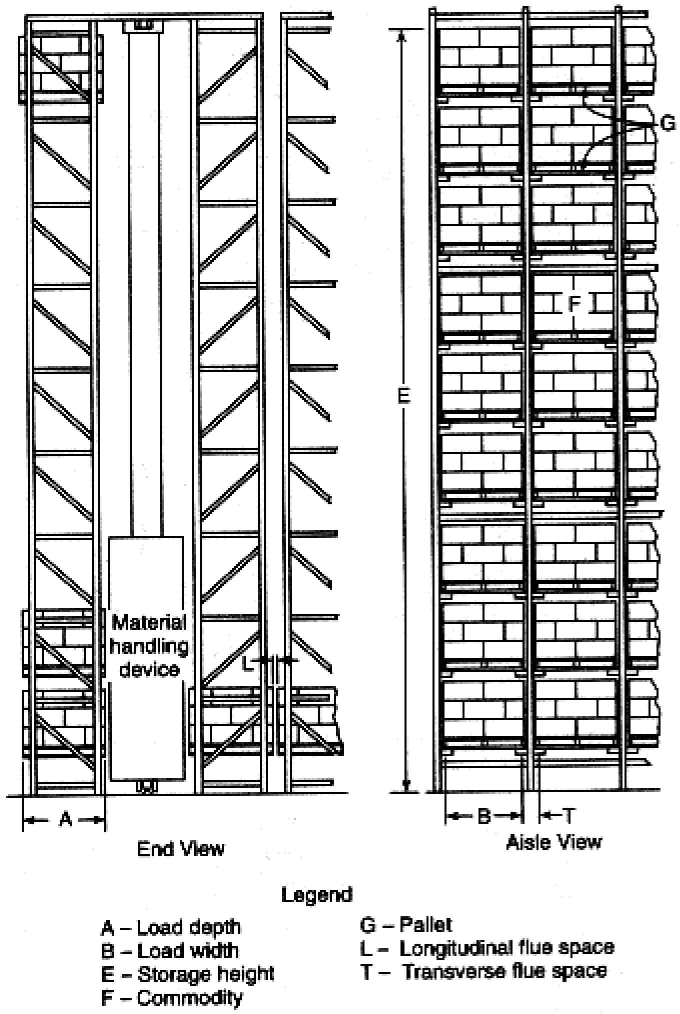


Figure A-4-1(e) Automatic storage-type rack.

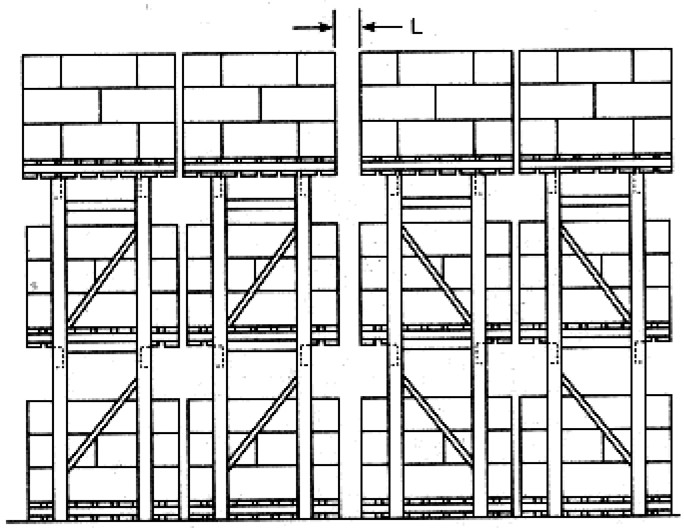


Figure A-4-1(f) Multiple-row rack to be served by a reach truck.

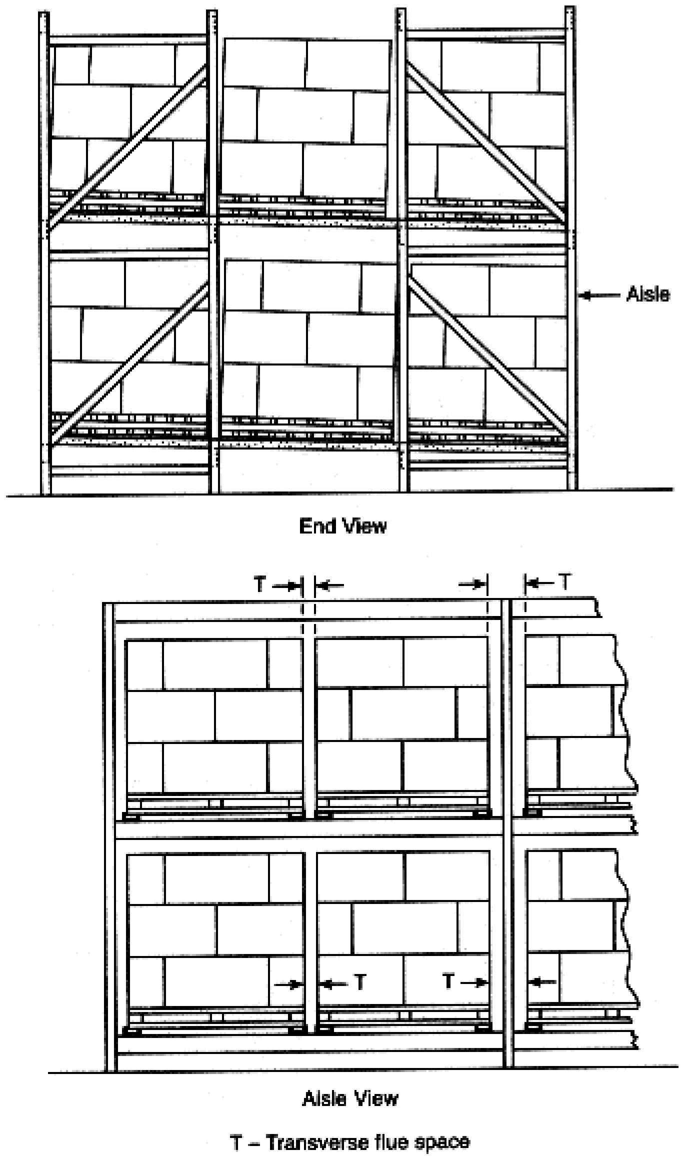


Figure A-4-1(g) Flow-through pallet rack.

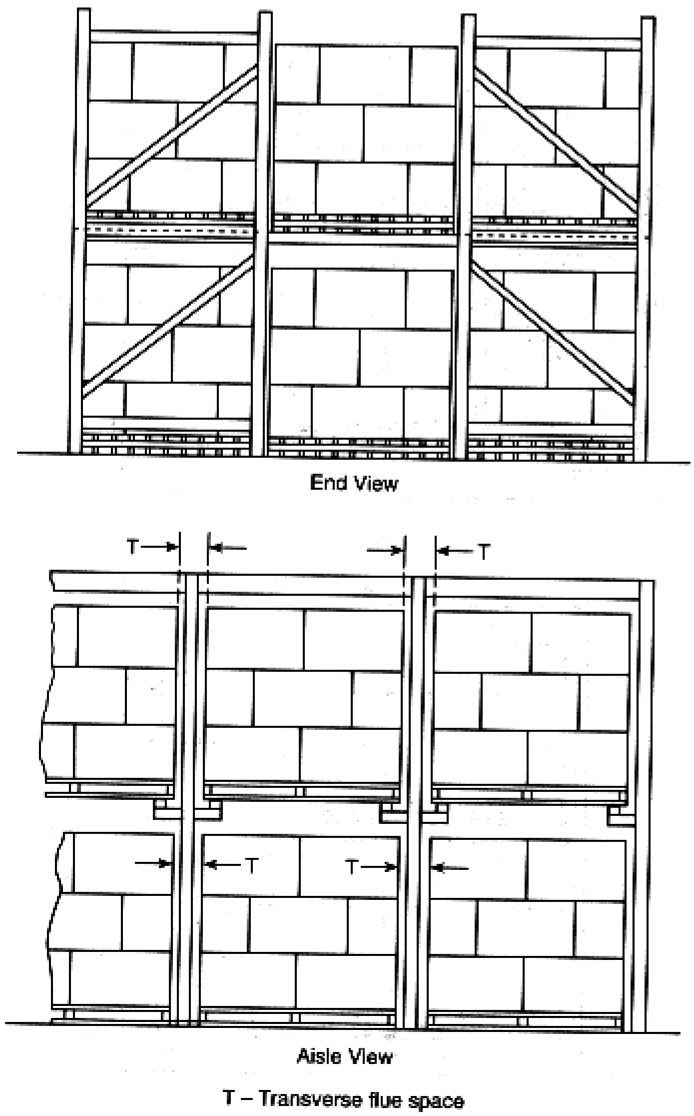


Figure A-4-1(h) Drive-in rack — two or more pallets deep (fork truck drives into the rack to deposit and withdraw loads in the depth of the rack).

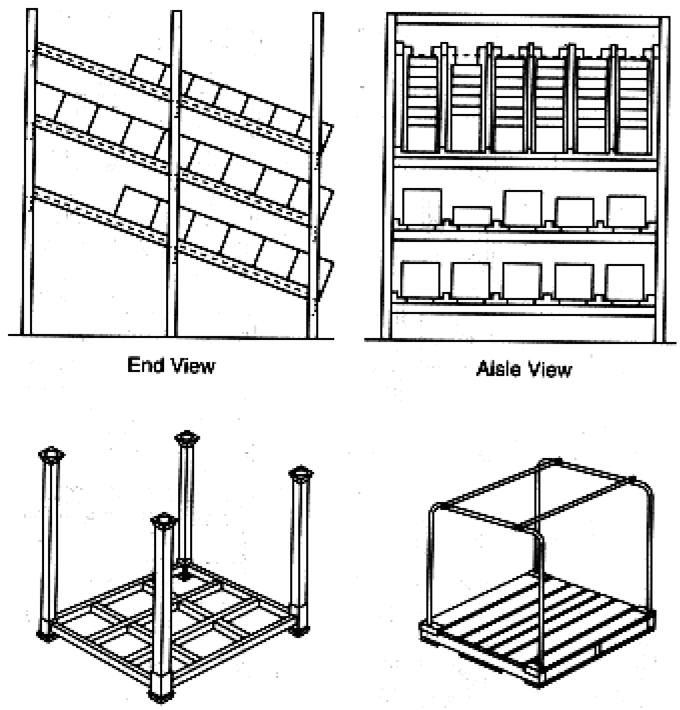


Figure A-4-1(i) Flow-through racks (top) and portable racks (bottom).

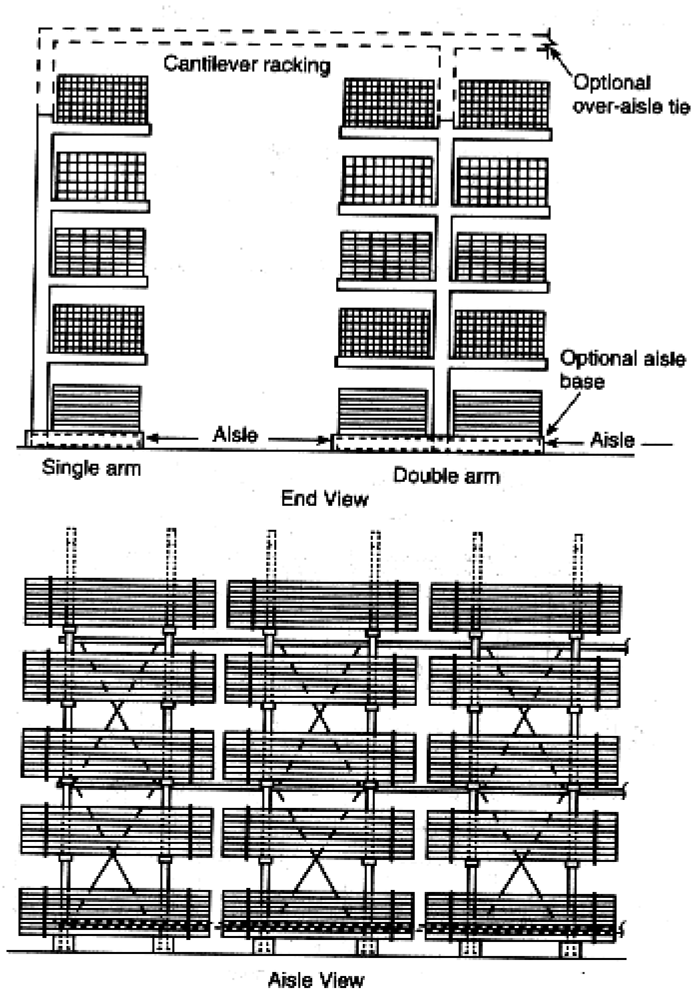


Figure A-4-1(j) Cantilever rack.

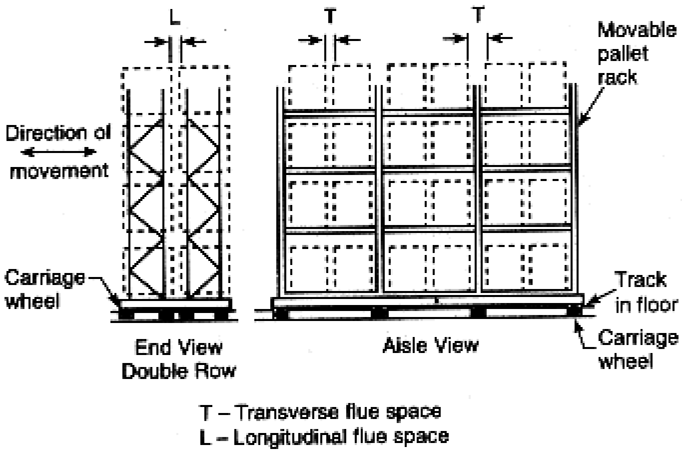


Figure A-4-1(k) Movable rack.

A-4-2

Fixed rack structures should be designed to facilitate removal or repair of damaged sections without resorting to flame cutting or welding in the storage area. Where sprinklers are to be installed in racks, rack design should anticipate the additional clearances necessary to facilitate installation of sprinklers. The rack structure should be anchored to prevent damage to sprinkler lines and supply piping in racks.

Rack structures should be designed for seismic conditions in areas where seismic resistance of building structure is required.

A-4-3.1

Nominal 6-in. (152.4-mm) transverse flues should be provided in multiple-row racks.

A-4-4

Storage in aisles can render protection ineffective and should be discouraged.

A-4-5

The fire protection system design should contemplate the maximum storage height. For new sprinkler installations, maximum storage height is the usable height at which commodities can be stored above the floor when the minimum required unobstructed space below sprinklers is maintained. For the evaluation of existing situations, maximum storage height is the maximum existing if space between the sprinklers and storage is equal to or greater than that required.

A-4-6.1

A horizontal clearance of at least 1 ft (0.30 m) should be maintained between storage and major unprotected roof structural members where storage is stored above the bottom of such members.

A-4-6.2

Incandescent light fixtures should have shades or guards to prevent ignition of commodities from hot bulbs where possibility of contact with storage exists.

A-4-7

Idle combustible pallets should not be stored in racks.

A-5-2.1 Ceiling Sprinklers.

Wet systems are recommended for rack storage occupancies.

Dry systems may be permitted only where it is impractical to provide heat.

Preaction systems should be considered for rack storage occupancies that are unheated, particularly where in-rack sprinklers are installed or for those occupancies that are highly susceptible to water damage.

A-5-2.2

Where 286°F (141°C) rated sprinklers are installed at the ceiling, 286°F (141°C) rated sprinklers also should extend beyond storage in accordance with Table A-5-2.2.

Table A-5-2.2

Design Area for 286°F (141°C) Sprinklers		Distance Beyond Perimeter of High-Hazard Occupancy for High-Temp. Sprinklers	
(ft^2)	(m^2)	(ft)	(m)
2000	185.8	30	9.14
3000	278.7	40	12.2
4000	371.6	45	13.72
5000	464.5	50	15.24
6000	557.4	55	16.76

A-5-5

In-rack sprinklers and ceiling sprinklers selected for protection should be controlled by at least two separate indicating valves and drains.

A-5-5.1

In higher rack arrangements, consideration should be given to providing more than one in-rack control valve in order to limit the extent of any single impairment.

A-5-7

Approved supervisory alarm service should be provided for all fire detection and extinguishing systems.

A central station, auxiliary, remote station, or proprietary sprinkler waterflow alarm should be provided, except that local waterflow alarm may be permitted where approved guard service is provided. (*See NFPA 72, National Fire Alarm Code*.)

A-5-11.1

Detection systems, concentrate pumps, generators, and other system components essential to the operation of the system should have an approved standby power source.

A-5-13.1

In NFPA 13, *Standard for the Installation of Sprinkler Systems*, A-4-4.1.3.2.1 states: “Slatting of decks or walkways or the use of open grating as a substitute for automatic sprinkler thereunder is not acceptable.”

In addition, where shelving of any type is employed, it is for the basic purpose of providing an intermediate support between the structural members of the rack. As a result, it becomes almost impossible to define and maintain transverse flue spaces across the rack as required in 4-3.1 and illustrated in Figure 4-3.1.

A-6-5.1

Where possible, it is preferable to locate in-rack sprinkler deflectors at least 6 in. (152.4 mm) above pallet loads.

A-6-5.2

Where possible, it is preferable to locate in-rack sprinklers away from rack uprights.

A-6-6.1

Spacing of sprinklers on branch lines in racks in the various tests demonstrates that maximum spacing as specified is proper.

A-6-9

Bulkheads are not a substitute for sprinklers in racks. Their installation does not justify reduction in sprinkler densities or design operating areas as specified in the design curves.

A-6-10.1

Where high-expansion foam is contemplated as the protection media, consideration should be given to possible damage to the commodity from soaking and corrosion. Consideration also should be given to the problems associated with removal of foam after discharge.

A-6-12

Where dry-pipe systems are used, the areas of operation specified in the design curves should be increased by 30 percent. Densities should be selected so that areas of operation, after the 30 percent increase, do not exceed 6000 ft^2 (557.4 m^2).

A-6-14.2

In-rack sprinklers at one level only for storage up to and including 25 ft (7.6 m) in multiple-row racks should be located at the tier level nearest one-half to two-thirds of the storage height.

A-7-10.3

In single-row racks with more than 10 ft (3.1 m) between the top of storage and the ceiling, a horizontal barrier should be installed above storage with one line of sprinklers under the barrier.

A-7-11

Where the ceiling is more than 10 ft (3.1 m) above the maximum height of storage, a horizontal barrier should be installed above storage with one line of sprinklers under the barrier for Class I, II, and III commodities and two lines of sprinklers under the barrier for Class IV commodities. In-rack sprinkler arrays should be installed as indicated in Table 7-10.1 and

Figures 7-10.1(a) through (j).

Barriers should be of sufficient strength to avoid sagging that interferes with loading and unloading operations.

Horizontal barriers are not required to be provided above a Class I or Class II commodity with in-rack sprinkler arrays in accordance with Figures 7-10.1(a) and (b), provided one line of in-rack sprinklers is installed above the top tier of storage.

A-7-12.1

Water demand for storage height over 25 ft (7.6 m) on racks without solid shelves separated by aisles at least 4 ft (1.22 m) wide and with more than 10 ft (3.1 m) between the top of storage and the sprinklers should be based on sprinklers in a 2000-ft^2 (185.8-m^2) operating area for double-row racks and a 3000-ft^2 (278.7-m^2) operating area for multiple-row racks discharging a minimum of 0.18 gpm/ft^2 [(7.33 L/min)/m^2] for Class I commodities, 0.21 gpm/ft^2 [(8.56 L/min)/m^2] for Class II and III commodities, and 0.25 gpm/ft^2 [(10.19 L/min)/m^2] for Class IV commodities, for 165°F (74°C) rated sprinklers; or a minimum of 0.25 gpm/ft^2 [(10.19 L/min)/m^2] for Class I commodities, 0.28 gpm/ft^2 [(11.41 L/min)/m^2] for Class II and III commodities, and 0.32 gpm/ft^2 [(13.04 L/min)/m^2] for Class IV commodities, for 286°F (141°C) rated sprinklers. (*See A-7-11 and A-7-13.*)

Where such storage is encapsulated, ceiling sprinkler density should be 25 percent greater than for nonencapsulated storage.

A-7-13

In multiple-row racks with more than 10 ft (3.1 m) between the maximum height of storage and ceiling, a horizontal barrier should be installed above storage with a level of sprinklers, spaced as stipulated for in-rack sprinklers, installed directly beneath the barrier. In-rack sprinklers should be installed as indicated in Figures 7-13(a) through (c).

A-8

All rack fire tests of plastics were run with an approximate 10-ft (3.1-m) maximum clearance between the top of storage and the ceiling sprinklers. Within 30-ft (9.1-m) high buildings, greater clearances above storage configurations should be compensated for by the addition of more in-rack sprinklers or the provision of greater areas of application, or both.

A-10-1

ESFR sprinklers were designed to respond quickly to growing fires and deliver heavy discharge to suppress fires rather than to control them. ESFR sprinklers should not be relied upon to provide suppression if they are used outside these design parameters.

A-10-2.1

Design parameters were determined from a series of full-scale fire tests conducted as a joint effort between Factory Mutual Research Corporation and the National Fire Protection Research Foundation. (Copies of the test reports are available from the National Fire Protection Research Foundation.)

A-12-1

The use of welding, cutting, soldering, or brazing torches in the storage areas introduces a severe fire hazard. The use of mechanical fastenings and mechanical saws or cutting wheels is recommended. Where welding or cutting operations are absolutely necessary, the requirements of NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, should apply.

Locomotives should not be allowed to enter the storage area.

A-12-2

Containers should be emptied and their contents removed from the premises at frequent intervals. (*See NFPA 82, Standard on Incinerators and Waste and Linen Handling Systems and Equipment*.)

A-12-4

Periodic inspections of all fire protection equipment should be made in conjunction with regular inspections of the premises. Unsatisfactory conditions should be reported immediately and necessary corrective measures taken promptly.

The sprinkler system and the water supplies should be checked and maintained in accordance with NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*.

A-12-5 Plant Emergency Organization.

Arrangements should be made, in case of fire or other emergency, to permit rapid entry into the premises of the municipal fire department, police department, or other personnel that could be summoned to deal with any emergency. A well-trained plant emergency organization should be provided to control emergency conditions that arise.

The plant emergency organization should be instructed and trained in the following procedures:

(a) Maintenance of the security of the premises

(b) Means of summoning outside aid immediately in an emergency

(c) Use of hand extinguishers and hose lines on small fires and mop-up operations

(d) Operation of the sprinkler system and water supply equipment

(e) Use of material-handling equipment while sprinklers are operating to effect final extinguishment

(f) Supervision of sprinkler valves after system is turned off so that system can be reactivated if rekindling occurs

(g) Need for breathing apparatus.

Attention should be given to advance planning and training with respect to fire department response, access, and fire fighting.

A-12-6 General Fire Protection.

All fire-fighting and safety personnel should realize the great danger in shutting off sprinklers once opened by heat from fire. Shutting off sprinklers to locate fire could cause a disaster. Ventilation, use of smoke masks, smoke removal equipment, and removal of material are safer. (*See NFPA 1420, Recommended Practice for Pre-Incident Planning for Warehouse Occupancies, for additional information*.)

Sprinkler water should be shut off only after the fire is extinguished or completely under the control of hose streams. Even then, rekindling is a possibility. To be ready for prompt valve reopening if fire rekindles, a person stationed at the valve, a fire watch, and dependable communications between them are needed until automatic sprinkler protection is restored.

(a) **Pre-Fire Emergency Planning.** It is important that such planning be done by management and fire protection personnel and the action to be taken discussed and correlated with the local fire department personnel.

The critical time during any fire is in the incipient stage, and the action taken by fire protection personnel upon notification of fire can allow the fire to be contained in its early stages.

Pre-emergency planning should contemplate the following:

1. Availability of hand fire-fighting equipment for the height and type of commodity involved;

2. Availability of fire-fighting equipment and personnel properly trained for the type of storage arrangement involved;

3. Assurance that all automatic fire protection equipment, such as sprinkler systems, water supplies, fire pumps and hand hose, is in service at all times.

(b) **Fire Department Operations.** Sprinkler protection installed as required in this standard is expected to protect the building occupancy without supplemental fire department activity. Fires that occur in rack storage occupancies protected in accordance with this standard are likely to be controlled within the limits outlined in B-1-1, since no significant building damage is expected. Fire department activity can, however, minimize the extent of loss. The first fire department pumper arriving at a rack storage-type fire should connect immediately to the sprinkler siamese fire department connection and start pumping operations.

In the test series for storage up to 25 ft (7.6 m), the average time from ignition to smoke obscuration in the test building was about 13 minutes. The first sprinkler operating time in these same fires averaged about 3 minutes. Considering response time for the waterflow device to transmit a waterflow signal, approximately 9 minutes remains between the time of receipt of a waterflow alarm signal at fire department headquarters and the time of smoke obscuration within the building as an overall average.

In the test series for storage over 25 ft (7.6 m), the visibility time was extended. If the fire department or plant protection department arrives at the building in time to have sufficient visibility to locate the fire, suppression activities with small hose lines should be started. (Self-contained breathing apparatus is recommended.) If, on the other hand, the fire is not readily visible, hose should be laid to exterior doors or exterior openings in the building and charged lines provided to these points, ready for ultimate mop-up operations. Manual fire-fighting operations in such a warehouse should not be considered a substitute for sprinkler protection.

IMPORTANT: The sprinkler system should be kept in operation during manual fire-fighting and mop-up operations.

During the testing program, the installed automatic extinguishing system was capable of controlling the fire and reducing all temperatures to ambient within 30 minutes of ignition. Ventilation operations and mop-up were not started until this point. The use of smoke removal equipment is important.

Smoke removal capability should be provided. Examples of smoke removal equipment include:

(a) Mechanical air-handling systems

(b) Powered exhaust fans

(c) Roof-mounted gravity vents

(d) Perimeter gravity vents.

Whichever system is selected, it should be designed for manual actuation by the fire department, thus allowing personnel to coordinate the smoke removal (ventilation) with mop-up operations.

Appendix B Explanation of Test Data and Procedures

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

Appendix B provides and explanation of the test data and procedures that led to the development of this standard. The paragraphs are identified by the same number as the text in this standard to which they apply.

B-1-1 Application and Scope.

This standard uses as a basis the large-scale fire test series conducted at the Factory Mutual Research Center, West Glocester, Rhode Island.

The test building is approximately 200 ft × 250 ft (61 m × 76 m) [50,000 ft^2 (4.65 km^2) in area], of fire-resistive construction, and contains a volume of approximately 2.25 million ft^3 (63 761.86 m^3), the equivalent of a 100,000-ft^2 (9.29-km^2) building 22.5 ft (6.86 m) high. The test building has two primary heights beneath a single large ceiling. The east section is 30 ft (9.1 m) high, and the west section is 60 ft (18.29 m) high.

The test series for storage height of 20 ft (6.1 m) was conducted in the 30-ft (9.1-m) section with clearances from the top of storage to the ceiling nominally 10 ft (3.1 m).

Doors at the lower and intermediate levels and ventilation louvers at the tops of walls were kept closed during the majority of the fire tests. This minimized the effect of exterior conditions.

The entire test series was fully instrumented with thermocouples attached to rack members, simulated building columns, bar joists, and the ceiling.

Racks were constructed of steel vertical and horizontal members designed for 4000-lb (1814-kg) loads. Vertical members were 8 ft (2.44 m) O.C. for conventional racks and 4 ft (1.22 m) O.C. for simulated automated racks. Racks were $3^1/_2$ ft (1.07 m) wide with 6-in. (152.4-mm) longitudinal flue space for an overall width of $7^1/_2$ ft (2.29 m). Simulated automated racks and slave pallets were used in the main central rack in the 4-ft (1.22-m) aisle tests. Conventional racks and conventional pallets were used in the main central rack in the 8-ft (2.44-mm) aisle tests. The majority of the tests were conducted with 100-ft^2 (9.29-m^2) sprinkler spacing.

The test configuration for storage heights of 15 ft (4.6 m), 20 ft (6.1 m), and 25 ft (7.6 m) covered an 1800-ft^2 (167.2-m^2) floor area, including aisles between racks. Tests that were used in producing this standard limited fire damage to this area. The maximum water damage area anticipated in the standard is 6000 ft^2 (557.4 m^2), the upper limit of the design curves.

The test data shows that, as density is increased, both the extent of fire damage and sprinkler operation are reduced. The data also indicates that, with sprinklers installed in the racks, a reduction is gained in the area of fire damage and sprinkler operations (i.e., water damage).

Table B-1-1 illustrates these points. The information shown is taken from the test series for storage height of 20 ft (6.1 m) using the standard commodity.

Table B-1-1

Density gpm/ft2		Fire Damage in Test Array		Sprinkler Operation (165°F) Area
		(%)	(ft^2)	(ft^2)
0.30	(Ceiling only)	22	395	4500-4800
0.375	(Ceiling only)	17	306	1800
0.45	(Ceiling only)	9	162	700
0.20	(Ceiling only)	28-36	504-648	13,100-14,000
0.20	(Sprinklers at ceiling and in racks)	8	144	4100
0.30	(Sprinklers at ceiling and in racks)	7	126	700

For SI units: 1 ft = 0.3048 m; °C = $^5/_9$ (°F-32);1 gpm/ft^2 = 40.746 (L/min)/m^2

The fact that there is a reduction in both fire damage and area of water application as sprinkler densities are increased or where sprinklers are installed in racks should be considered carefully by those responsible for applying this standard to the rack storage situation.

In the test for storage height of 25 ft (7.6 m), a density of 0.55 gpm/ft^2 [(22.4 L/min)/m^2] produced 42 percent, or 756 ft^2 (70.26 m^2), fire damage in the test array and a sprinkler-wetted area of 1400 ft^2 (130.1 m^2). Lesser densities would not be expected to achieve the same limited degree of control. Therefore, if the goal of smaller areas of fire damage is to be achieved, sprinklers in racks should be considered.

The test series for storage height over 25 ft (7.6 m) was conducted in the 60-ft (18.29-m) section of the test building with nominal clearances from the top of storage to the ceiling of either 30 ft (9.1 m) or 10 ft (3.1 m).

Doors at the lower and intermediate levels and ventilation louvers at the top of walls were kept closed during the fire tests. This minimized the effect of exterior wind conditions.

The purpose of the over-25-ft (7.6-m) series was to:

(a) Determine the arrangement of in-rack sprinklers that can be repeated as pile height increases and that provide control of the fire.

(b) Determine other protective arrangements, such as high-expansion foam, that provide control of the fire.

Control was considered to have been accomplished if the fire was unlikely to spread from the rack of origin to adjacent racks or spread beyond the length of the 25-ft (7.6-m) test rack. To aid in this judgment, control was considered to have been achieved if the fire did not:

(a) Jump the 4-ft (1.22-m) aisles to adjoining racks.

(b) Reach the end face of the end stacks (north or south ends) of the main rack.

Control is defined as holding the fire in check through the extinguishing system until the commodities initially involved are consumed or until the fire is extinguished by the extinguishing system or manual aid.

The standard commodity as selected in the 20-ft (6.1-m) test series was used in the majority of over-25-ft (7.6-m) tests. Hallmark products and 3-M products described in the 20-ft (6.1-m) test series report also were used as representative of Class III or IV commodities, or both, in several tests. The results of privately sponsored tests on Hallmark products and plastic encapsulated standard commodities also were made available to the committee.

A 25-ft (7.6-m) long test array was used for the majority of the over-25-ft (7.6-m) high test series. The decision to use such an array was made because it was believed that a fire in racks over 25 ft (7.6 m) high that extended the full length of a 50-ft (15.24-m) long rack could not be considered controlled, particularly as storage heights increased.

One of the purposes of the tests was to determine arrangements of in-rack sprinklers that can be repeated as pile height increases and that provide control of the fire. The tests for storage height of 30 ft (9.1 m) explored the effect of such arrays. Many of these tests, however, produced appreciable fire spread in storage in tiers above the top level of protection within the racks. (In some cases, a total burnout of the top tiers of both the main rack and the target rack occurred.) In the case of the 30-ft (9.1-m) Hallmark Test 134 on the 60-ft (18.3-m) site, the material in the top tiers of storage burned vigorously, and the fire jumped the aisle above the fourth tier. The fire then burned downward into the south end of the fourth tier. In the test on the floor, a nominal 30-ft (9.1-m) clearance occurred between the top of storage and the ceiling sprinklers, whereas on the platform this clearance was reduced to nominal 10 ft (3.1 m). In most cases, the in-rack sprinklers were effective in controlling fire below the top level of protection within the racks. It has been assumed by the Test Planning Committee that, in an actual case with a clearance of 10 ft (3.1 m) or less above storage, ceiling sprinklers would be expected to control damage above the top level of protection within the racks. Tests have been planned to investigate lesser clearances.

Tests 114 and 128 explore the effect of changing the ignition point from the in-rack standard ignition point to a face ignition location. It should be noted, however, that both of these tests were conducted with 30-ft (9.1-m) clearance from the ceiling sprinklers to the top of storage and, as such, ceiling sprinklers had little effect on the fire in the top two tiers of storage. Fire spread in the three lower tiers is essentially the same. A similar change in the fire spread where the ignition point is changed was noted in Tests 126 and 127. Once again, 30-ft (9.1-m) clearance occurred between the top of storage and the ceiling sprinklers, and, as such, the ceiling sprinklers had little effect on the face fire. Comparisons of Tests 129, 130, and 131 in the test series for storage height of 50 ft (15.24 m) indicate little effect of point of ignition in the particular configuration tested.

Test 125, when compared with Test 133, indicates no significant difference in result between approved low profile sprinklers and standard sprinklers in the racks.

B-2-1

A review of full-scale fire tests run on the standard commodity (double tri-wall carton with metal liner); of Hallmark products and 3-M products (e.g., abrasives, pressure-sensitive tapes of plastic fiber, and paper); and of the considerable number of commodity tests conducted provides a guide for commodity classifications. This guide is not related to any other method of classification of materials; therefore, sound engineering judgment and analysis of the commodity and the packaging should be used when selecting a commodity classification.

B-3-2.1

None of the tests that were conducted with densities in accordance with the design curves produced critical temperatures in bar joists $12^1/_2$ ft (3.81 m) from the ignition source. Therefore, with sprinkler systems designed in accordance with the curves, fireproofing of roof steel should not be necessary.

B-3-2.2

Temperatures in the test column were maintained below 1000°F (538°C) in all tests where sprinklers in racks were used.

B-3-2.3

Temperatures in the test column were maintained below 1000°F (538°C) with densities, of roof ceiling sprinklers only, of 0.375 gpm/ft^2 [(15.3 L/min)/m^2] with 8-ft (2.44-m) aisles and 0.45 gpm/ft^2 [(18.34 L/min)/m^2] with 4-ft (1.22-m) aisles using the standard commodity.

B-3-3

Tests were conducted as a part of this program with eave line windows or louvers open to simulate smoke and heat venting. These tests opened 87.5 percent and 91 percent more sprinklers than did comparative tests without windows or louvers open. Venting tests that have been conducted in other programs were without the benefit of sprinkler protection and, as such, are not considered in this report, which covers only buildings protected by sprinklers. The design curves are based upon the absence of roof vents or draft curtains in the building. During mop-up operations, ventilating systems, where installed, should be capable of manual exhaust operations.

B-4-3.1

Test 80 was conducted to determine the effect of closing back-to-back longitudinal 6-in. (152.4-mm) flue spaces in conventional pallet racks. Test results indicated fewer sprinklers operating than with the flue space open, and, as such, no minimum back-to-back clearance is necessary if the transverse flue space is kept open.

Tests 145 and 146 were conducted to investigate the influence of longitudinal and transverse flue dimensions in double-row racks without solid shelves. Results were compared with Tests 65 and 66. Flue dimensions in Tests 65, 66, 145, and 146 were 6 in. (152.4 mm), 6 in. (152.4 mm), 3 in. (76.2 mm), and 12 in. (0.30 m), respectively. All other conditions were the same.

In Tests 65 and 66, 45 and 48 sprinklers operated compared with 59 and 58 for Tests 145 and

146, respectively. Fire damage in Tests 145 and 146 was somewhat less than in Tests 65 and 66: 2100 ft^3 (59.51 m^3) and 1800 ft^3 (51 m^3) in Tests 145 and 146, respectively, versus 2300 ft^3 (65.13 m^3) and 2300 ft^3 (65.13 m^3) in Tests 65 and 66, respectively, of combustible material were consumed.

Test results indicate narrow flue spaces of about 3 in. (76.2 mm) allow reasonable passage of sprinkler water down through the racks.

Tests 96 and 107, on multiple-row racks, used 6-in. (152.4-mm) transverse flue spaces. The water demand recommended in the standard is limited to those cases with nominal 6-in. (152.4-mm) transverse flues in vertical alignment.

B-4-5

Most tests in the 25-ft (7.6-m) and under test series were conducted with a clearance of 10 ft (3.1 m) from the top of storage to the sprinkler deflectors, and the basic design curves in Figures 6-12(a) through (g) reflect this condition.

Tests 140 and 141 were conducted with a 3-ft (0.91-m) clearance between the top of storage and the ceiling sprinkler deflectors. In Test 140, using a density of 0.30, 36 sprinklers operated compared with 45 and 48 sprinklers in Tests 65 and 66 with a 10-ft (3.1-m) clearance. In Test 141, 89 sprinklers operated compared with 140 sprinklers in Test 70 with a 10-ft (3.1-m) clearance. Fire spread in Tests 140 and 141 was somewhat less than in Tests 65, 66, and 70.

Test 143 was conducted with an 18-in. (0.46-m) clearance between the top of storage and the ceiling sprinkler deflectors, and with 0.30 density. Thirty-seven sprinklers operated compared with 36 sprinklers in Test 140 with a 3-ft (0.91-m) clearance and 45 and 48 sprinklers in Tests 65 and 76 with a 10-ft (3.1-m) clearance. Fire spread in Test 143 with an 18-in. (0.46-m) clearance was somewhat less than in Tests 65 and 66 with a 10-ft (3.1-m) clearance and Test 140 with a 3-ft (0.91-m) clearance.

Privately sponsored tests, using a 0.45 ceiling sprinkler density and an encapsulated commodity, indicated 40 sprinklers operating with a 10-ft (3.1-m) clearance, 11 sprinklers operating with a 3-ft (0.91-m) clearance, and 10 sprinklers operating with an 18-in. (0.46-m) clearance. Fire spread was less in the test with the 18-in. (0.46-m) clearance than the 3-ft (0.91-m) clearance and also was less with the 3-ft (0.46-m) clearance than with the 10-ft (3.1-m) clearance.

B-4-7

No tests were conducted with idle pallets in racks. Such storage conceivably would introduce fire severity in excess of that contemplated by protection criteria for an individual commodity classification.

B-5-3

The highest operating pressure at any sprinkler in the test program was 62.5 psi (430.93 kPa).

Tests in the 20-ft (6.10-m) high test series were conducted using wood and metal bulkheads to determine whether bulkheads could be a substitute for either higher ceiling sprinkler densities or for intermediate sprinklers. Bulkheads of either type had no appreciable beneficial effect on the overall sprinkler performance in double-row rack tests.

Tests 125 and 134 were conducted to compare the effect of a different commodity in the 30-ft (9.1-m) high test array. If the degree of damage above the top level of protection (fifth and sixth tiers) is ignored, the Class III commodity represented by Hallmark cards would appear to be protected to the same degree as a Class II commodity.

Tests 132 and 135 were conducted to determine the effect of a different commodity in the test series for storage height of 50 ft (15.24 m). The degree of control achieved with the 3-M products in Test 135 closely approximates that achieved with the standard commodity in Test 132. The results of the Hallmark Test 134 and the private Hallmark test with geometric, in-rack sprinkler array, and in-rack sprinkler flow rate that differs from other tests, conducted as a separate program, suggests that in storage height over 25 ft (7.6 m), Class III commodities can be protected in the same fashion as Class II commodities.

Tests 112 and 115 compare a 10-ft (3.1-m) clearance above storage to sprinklers with a 30-ft (9.1-m) clearance.

B-5-7

The time of operation of the first sprinkler varied from 52 seconds to 3 minutes and 55 seconds, with most tests under 3 minutes, except in Test 64 (Class III), where the first sprinkler operated in 7 minutes and 44 seconds. Fire detection more sensitive than waterflow is, therefore, considered necessary only in exceptional cases.

B-5-8

In most tests conducted, it was necessary to use small hose for mop-up operations. Small hoses were not used in the high-expansion foam test.

Test 97 was conducted to evaluate the effect of dry-pipe sprinkler operation. Test results were approximately the same as the base test with a wet-pipe system. A study of NFPA records, however, indicates an increase in area of operation of 30 percent to be in order for dry-pipe systems as compared with wet-pipe systems.

B-5-10

In all valid tests, with double-row racks, sprinkler water supplies were shut off at approximately 60 minutes. In only one test did the last sprinkler operate in excess of 30 minutes after ignition; the last sprinkler operated in excess of 25 minutes in three tests, with the majority of tests involving the last sprinkler operating within 20 minutes.

B-5-13.2

Test 98 with solid shelves 24 ft (7.3 m) long and $7^1/_2$ ft (2.3 m) deep at each level produced total destruction of the commodity in the main rack and jumped the aisle. Density was 0.3 gpm/ft^2 [(12.22 L/min)/m^2] from the ceiling sprinklers only. Test 108 with shelves 24 ft (7.3 m) long and $3^1/_2$ ft (1.07 m) deep and with a 6-in. (152.4-mm) longitudinal flue space and one level of sprinklers in the rack resulted in damage to most of the commodity in the main rack, but did not jump the aisle. Density from ceiling sprinklers was 0.375 gpm/ft^2 [(15.28 L/min)/m^2], and rack sprinklers discharged at 15 psi (103.41 kPa).

These tests did not yield sufficient information to develop a comprehensive protection standard for solid shelf racks. Items such as increased ceiling density, use of bulkheads, other configurations of sprinklers in racks, and limitation of shelf length and width should be considered.

Where such rack installations exist or are contemplated, the damage potential should be considered, and sound engineering judgment should be used in designing the protection system.

Test 98, with solid shelving obstructing both the longitudinal and transverse flue space, produced unsatisfactory results and indicates a need for sprinklers at each level in such a rack structure.

Test 147 was conducted with ceiling sprinklers only. Density was 0.45 gpm/ft^2 [(18.34 L/min)/m^2] with a sprinkler spacing of 100 ft^2 (9.29 m^2). A total of 47 sprinklers opened, and 83 percent of the commodity was consumed. The fire jumped both aisles and spread to both ends of the main and target racks. The test was considered unsuccessful.

Test 148 was conducted with ceiling sprinklers and in-rack sprinklers. In-rack sprinklers were provided at each level (top of first, second, and third tiers) and were located in the longitudinal flue. They were directly above each other and 24 ft (7.32 m) on center or 22 ft (6.71 m) on each side of the ignition flue. Ceiling sprinkler discharge density was 0.375 gpm/ft^2 [(15.3 L/min)/m^2]. In-rack sprinkler discharge pressure was 30 psi (206.8 kPa). A total of 46 ceiling sprinklers and 3 in-rack sprinklers opened, and 34 percent of the commodity was consumed. The fire consumed most of the material between the in-rack sprinklers and jumped both aisles.

B-5-14

Fire tests with open-top containers in the upper tier of storage and a portion of the third tier of storage produced an increase in sprinkler operation from 36 to 41 sprinklers and a more pronounced aisle jump and increase in fire spread in the main array. The smooth underside of the containers closely approximates fire behavior of slave pallets.

Installation of in-rack sprinklers or an increase in ceiling sprinkler density should be considered.

B-6-4

Tests 71, 73, 81, 83, 91, 92, 95, and 100 in the 20-ft (6.1-m) high array involving a single level of in-rack sprinklers were conducted without heat or water shields. Results were satisfactory.

Test 115 was conducted with two levels of sprinklers in racks with shields. Test 116, identical to Test 115 but without water shields, produced a lack of control. Visual observation of lower level in-rack sprinklers that did not operate although they were in the fire area indicated a need for water shields.

Tests 115 and 116 were conducted to investigate the necessity for water shields where multiple levels of in-rack sprinklers are installed. Where water shields were not installed in Test 116, the fire jumped the aisle, and approximately 76 boxes were damaged. In Test 115 with water shields, the fire did not jump the aisle, and only 32 boxes were damaged. Water shields are, therefore, suggested wherever multiple levels of in-rack sprinklers are installed, except for installations with horizontal barriers or shelves that serve as water shields.

B-6-5.1

In one 20-ft (6.1-m) high test, sprinklers were buried in the flue space 1 ft (0.30 m) above the bottom of the pallet load; results were satisfactory. Coverage of aisles by in-rack sprinklers is, therefore, not necessary, and distribution across the tops of pallet loads at any level is not necessary for the occupancy classes tested.

B-6-6.2

In all tests with in-rack sprinklers, obstructions measuring 3 in. × 3 ft (7.62 mm × 0.30 m) were introduced on each side of the sprinkler approximately 3 in. (76.2 mm) from the sprinkler to simulate rack structure member obstruction. This obstruction had no effect on sprinkler performance in the 20-ft (6.1-m) high tests.

Tests 103, 104, 105, and 109 in the 30-ft (9.1-m) high test with in-rack sprinklers obstructed by rack uprights produced unsatisfactory results. Tests 113, 114, 115, 117, 118, and 120 in the 30-ft (9.1-m) high test series with in-rack sprinklers located a minimum of 2 ft (0.61 m) from rack uprights produced improved results.

B-6-7

Operating pressures were 15 psi (103.4 kPa) on all tests of sprinklers in racks with storage 20 ft (6.1 m) high and 30 psi (206.8 kPa) for storage 30 ft (9.1 m) and 50 ft (15.24 m) high.

Tests 112 and 124 were conducted to compare the effect of increasing sprinkler discharge pressure at in-rack sprinklers from 30 psi to 75 psi (206.8 kPa to 517.1 kPa). With the higher discharge pressure, the fire did not jump the aisle, and damage below the top level of protection within the racks was somewhat better controlled by the higher discharge pressure of the in-rack sprinklers. A pressure of 15 psi (103.4 kPa) was maintained on in-rack sprinklers in the first 30-ft (9.1-m) high tests (Tests 103 and 104). Pressure on in-rack sprinklers in subsequent tests was 30 psi (206.8 kPa), except in Test 124, where it was 75 psi (517.1 kPa).

B-6-8

In all except one case, using the standard commodity with one line of sprinklers installed in racks, only two sprinklers opened. In the one exception, two sprinklers opened in the main rack, and two sprinklers opened in the target rack.

B-6-9

Tests 65 and 66, compared with Test 69, and Test 93, compared with Test 94, indicated a reduction in areas of application of 44.5 percent and 45.5 percent, respectively, with 286°F (141°C) rated sprinklers as compared with 165°F (74°C) rated sprinklers. Other extensive Factory Mutual tests produced an average reduction of 40 percent. Design curves are based on this area reduction. In constructing the design curves, the 286°F (141°C) curves above 3600 ft^2 (334.6 m^2) of application therefore represent 40 percent reductions in area of application of the 165°F (74°C) curves in the 6000 ft^2 to 10,000 ft^2 (557.6 m^2 to 929.41 m^2) range.

Test 84 indicated the number of 212°F (100°C) rated sprinklers operating is essentially the same as 165°F (74°C) rated sprinklers.

B-6-9.8

Tests 77 and 95 were conducted to investigate protection needed on encapsulated commodities. The standard commodity [38 in. × 38 in. × 36 in. high (0.97 m × 0.97 m × 0.91 m high) sheet metal container inside a 42 in. × 42 in. × 42 in. (1.07 m × 1.07 m × 1.07 m) double tri-walled carton] was covered with a sheet of 4-mil to 6-mil thick polyethylene film stapled in place at the bottom. Test 77 at 0.30 density with ceiling sprinklers only went beyond the parameters for validity. Subsequent privately sponsored tests indicated control at 0.45 density. Test 95 indicated sprinklers at the ceiling and in racks adequately control this hazard. These test results were compared with Tests 65, 66, and 82 with comparable test configurations but without the plastic film covering.

A privately sponsored test was made with ceiling sprinklers only. At a density of 0.45 gpm/ft^2

[(18.30 L/min)/m^2], 40 sprinklers operated. Fire spread was slightly greater than in Test 65 with 0.3 gpm/ft^2 [(12.22 L/min)/m^2] discharging from 45 sprinklers. Where the distance from the top of storage to the ceiling was reduced from 10 ft to 3 ft (3.1 m to 0.91 m) with 0.45 gpm/ft^2 [(18.33 L/min)/m^2] density, 11 sprinklers operated. Fire spread was less than in Test 65 or the previous privately sponsored test.

In order to evaluate the effect on plastic wrapping or encapsulation of pallet loads, Tests 77 and 95 were conducted as a part of the 20-ft (6.1-m) test series within the rack storage testing program, and Tests 1 and 2 were conducted as a part of privately sponsored Society of the Plastics Industry, Inc. tests. Both SPI Tests 1 and 2 are considered valid and indicate that Class I and II commodities can be protected by ceiling sprinklers only, using densities as indicated in design curves. These two tests also compare the results of a 3-ft (0.91-m) clearance from the top of storage to the sprinkler head deflectors with a 10-ft (3.1-m) clearance from the top of storage to the sprinkler head deflectors. A significant reduction in the number of sprinklers opening is indicated with the 3-ft (0.91-m) deflector clearance to the top of storage.

Subsequently, Tests 140 and 141 were made using the standard commodity. The distance from the top of storage to the sprinkler deflector was reduced to 3 ft (0.91 m). With 0.30 gpm/ft^2 [(12.22 L/min)/m^2] density, 36 sprinklers operated; and with 0.20 gpm/ft^2 [(8.15 L/min)/m^2] density, 89 sprinklers operated. Fire spread was somewhat less than in Tests 65 and 70 with a 10-ft (3.1-m) space between the top of storage and the ceiling.

B-6-12.1

Tests were not conducted with aisles wider than 8 ft (2.44 m) or narrower than 4 ft (1.22 m). It is, therefore, not possible to determine whether lower ceiling densities should be used for aisle widths greater than 8 ft (2.44 m) or if higher densities should be used for aisle widths less than 4 ft (1.22 m).

B-6-14

Test 107, a multiple-row rack test conducted with pallet loads butted against each other, was twelve rows long. Each row was four boxes deep. With 0.45 gpm/ft^2 [(18.3 L/min/m^2] density from ceiling sprinklers only, fire spread to a depth of three rows on both sides of the ignition point. Fire damage, number of sprinklers open, and time rack steel temperature above 1000°F (538°C) were considerably greater than in comparable double-row rack Test 68. Temperatures at the ceiling did not reach dangerous limits. Fire intensity at the ends of rows was sufficiently intense to conclude that racks with deeper rows need additional protection.

B-7-12.1

The recommended use of 165°F (74°C) rated sprinklers at ceiling for storage higher than 25 ft (7.6 m) was determined by the results of fire test data. A test with 286°F (141°C) rated sprinklers and 0.45 gpm/ft^2 [(18.30 L/min)/m^2] density resulted in fire damage in the two top tiers just within acceptable limits, with three ceiling sprinklers operating. A test with 0.45 gpm/ft^2 [(18.30 L/min)/m^2] density and 165°F (74°C) rated sprinklers produced a dramatic reduction in fire damage with four ceiling sprinklers operating.

The four 165°F (74°C) rated ceiling sprinklers operated before the first of the three 286°F (141°C) rated ceiling sprinklers. In both tests, two in-rack sprinklers at two levels operated at approximately the same time. The 286°F (141°C) rated sprinklers were at all times fighting a larger fire with less water than the 165°F (74°C) rated ceiling sprinklers.

Tests 115 and 119 compare ceiling sprinkler density of 0.30 gpm/ft^2 [(12.22 L/min)/m^2] with 0.45 gpm/ft^2 [(18.3 L/min)/m^2]. Damage patterns coupled with the number of boxes damaged in the main rack suggest that the increase in density produces improved control, particularly in the area above the top tier of in-rack sprinklers.

Tests 119 and 122 compare 286°F (141°C) with 165°F (74°C) ceiling sprinkler temperature rating. A review of the number of boxes damaged and the fire spread patterns indicates that the use of 165°F (74°C) rated ceiling sprinklers on a rack configuration that incorporates in-rack sprinklers dramatically reduces the amount of fire spread. Considering that in-rack sprinklers in the over-25-ft (7.6-m) test series operated prior to ceiling sprinklers, it would seem that the installation of in-rack sprinklers converts an otherwise rapidly developing fire, from the standpoint of ceiling sprinklers, to a slower developing fire with a lower rate of heat release.

In the 20-ft (6.1-m) high test series, ceiling sprinklers operated before in-rack sprinklers. In the 30-ft (9.1-m) high series, ceiling sprinklers operated after in-rack sprinklers. The 50-ft (15.24-m) high test did not operate ceiling sprinklers. Ceiling sprinklers would, however, be needed if fire occurred in upper levels.

These results indicate the effect of in-rack sprinklers on storage higher than 25 ft (7.6 m). From the ceiling sprinkler operation standpoint, a fire with an expected high heat release rate was converted to a fire with a much lower heat release rate.

Since the fires developed slowly and opened sprinklers at two levels in the racks, only a few ceiling sprinklers were needed to establish control. Thus, the sprinkler operating area does not vary with height for storage over 25 ft (7.6 m) or for changes in sprinkler temperature rating and density.

All tests with sprinklers in racks were conducted using nominal $^1/_2$-in. (12.7-mm) orifice size sprinklers of ordinary temperature.

B-8-1.1

In the RSP Rack Storage test series as well as the Stored Plastics Program Palletized test series, compartmented 16-oz (0.47-L) polystyrene jars were found to produce significantly higher protection requirements than the same commodity in a nested configuration. Polystyrene glasses and expanded polystyrene plates were comparable to the nested jars.

Different storage configurations within cartons or different products of the same basic plastic might, therefore, require reduced protection requirements.

In Test RSP-7, with nominal 15-ft (4.6-m) high storage with compartmented jars, a 0.60 gpm/ft^2 [(24.4 L/min)/m^2] density, 8-ft (2.44-m) aisles, and a 10-ft (3.1-m) ceiling clearance, 29 sprinklers opened. In Tests RSP-4 with polystryrene glasses, RSP-5 with expanded polystyrene plates, and RSP-16 with nested polystyrene jars all stored at nominal 15-ft (4.6-m) height, 10-ft (3.1-m) ceiling clearance, 8-ft (2.44-m) aisles, and 0.60 gpm/ft^2 [(24.4 L/min)/m^2] density, only 4 sprinklers opened.

However, Test RSP-11, with expanded polystyrene plates and 6-ft (1.83-m) aisles, demonstrated an increase in the number of operating sprinklers to 29. Test RSP-10 with expanded polystyrene plates, nominally 15 ft (4.6 m) high with a 10-ft (3.1-m) clearance and 8-ft (2.44-m) aisles, but protected only by 0.45 gpm/ft^2 [(18.3 L/min)/m^2] density, opened 46 sprinklers and burned 100 percent of the plastic commodity.

At a nominal 20-ft (6.1-m) storage height with 8-ft (2.44-m) aisles and a 3-ft (0.91-m) ceiling clearance, 0.60 gpm/ft^2 [(24.4 L/min)/m^2] density opened 4 sprinklers with polystyrene glasses in Test RSP-2 and 11 sprinklers with expanded polystyrene plates in Test RSP-6. In Test RSP-8, however, with the ceiling clearance increased to 10 ft (3.1 m) and other variables held constant, 51 sprinklers opened, and 100 percent of the plastic commodity burned.

Test RSP-3 with polystyrene glasses at a nominal height of 25 ft (7.6 m) with a 3-ft (0.91-m) ceiling clearance, 8-ft (2.44-m) aisles, and 0.60 gpm/ft^2 [(24.4 L/min)/m^2] ceiling sprinkler density in combination with one level of in-rack sprinklers, resulted in 4 ceiling sprinklers and 2 in-rack sprinklers operating. Test RSP-9, with the same configuration but with polystyrene plates, opened 12 ceiling sprinklers and 3 in-rack sprinklers.

No tests were conducted with compartmented polystyrene jars at storage heights in excess of a nominal 15 ft (4.6 m) as a part of this program.

B-8-1.4

All tests in the RSP series were conducted utilizing 165°F (74°C) rated sprinklers. However, after close review of all test data, the Technical Committee on Rack Storage believes that using intermediate-or high-temperature rated sprinklers does not cause the demand areas to be any larger than those designated in Chapter 8; therefore, their use should be permitted.

B-11-1.2

Test 85 was conducted to evaluate the results of a liquid spill fire. Test results indicate it is not practical from an economic standpoint to install sprinkler systems with densities capable of controlling such a fire, and, therefore, industrial trucks should be fueled outside of buildings only.

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*, 1994 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, 1995 edition.

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1994 edition.

NFPA 72, *National Fire Alarm Code*, 1993 edition.

NFPA 82, *Standard on Incinerators and Waste and Linen Handling Systems and Equipment*, 1994 edition.

NFPA 231E, *Recommended Practice for the Storage of Baled Cotton*, 1989 edition.

NFPA 1420, *Recommended Practice for Pre-Incident Planning for Warehouse Occupancies*, 1993 edition.

C-1.2 Other References.

Factory Mutual Research Corporation, 1151 Boston-Providence Turnpike, Norwood, MA 02061-9102.

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

Society of the Plastics Industry, Inc., 1275 K Street, NW, Suite 400, Washington, DC 20005.

Formal Interpretation

NFPA 231C

Rack Storage of Materials

1995 Edition

Reference: 1-1
F.I. 95-1 (NFPA 231C)

Question: Are offices in a mixed occupancy, Storage/Business, within the scope of 231C if they are separated by a one-hour fire rated wall?

Answer: No.

Issue Edition: 1995
Reference: 1-1
Issue Date: October 5, 1995
Effective Date: October 25, 1995

Rack Storage of Materials

1995 Edition

Reference: 3-2.3(b)

F.I. 75-4

Question: Does 3-2.3(b) apply when columns occur adjacent to single row racks (whether at building wall or otherwise)?

Answer: No.

Issue Edition: 1975
Reference:– 3-2.3(b)
Date: November 1979
Reprinted to correct error: January 1989

Rack Storage of Materials

1995 Edition

Reference: 5-2.2
F.I. 95-2 (NFPA 231C)

Question No. 1: Is it the intent of 5-2.2 to carry the ceiling density 15' beyond the storage area past a one-hour fire rated wall separating the storage area from the office area?

Answer: No.

Question No. 2: If the answer to Question No. 1 is yes, are these sprinklers required to be at the roof level in the interstitial space above the ceiling of the offices?

Answer: N/A

Issue Edition: 1995
Reference: 5-2.2
Issue Date: October 5, 1995
Effective Date: October 25, 1995

Rack Storage of Materials

1995 Edition

Reference: 6-5.2
F.I. 86-1 (NFPA 231C)

Question 1: Is it the intent of 6-5.2 to require the placement of in-rack sprinklers within rack flue spaces so that the discharge from the sprinklers will wet the storage when storage consists of double row racks without solid shelves with height of storage over 20 feet?

Answer: Yes.

Question 2: If the answer to Question 1 is "yes," is it the intent of 6-5.2 to prevent sprinklers from being located behind horizontal rack structural members that would obstruct the sprinkler spray onto the storage when the storage consists of double row racks without solid shelves with height of storage over 20 feet?

Answer: Yes.

Issue Edition: 1986
Reference: 6-4.2
Issue Date: October 1987
Reissued to correct error: August 1995

Rack Storage of Materials

1995 Edition

Reference: Tables 6-12**,** 7-10.1
F.I. 75-5 (NFPA 231C)

Question 1: If Figure A-4-1.1(c) is an example of double row racks with solid shelves, are Tables 6-12 and 7-10.1 applicable?

Answer: Yes.

Question 2: If so, then is the definition of a solid shelf one that obstructs both transverse and longitudinal flue spaces, making Figure A-4-1.1(c) inaccurate?

Answer: Paragraph 5-13.2 deals with one type of solid shelf arrangement in which both the longitudinal and transverse flue spaces are blocked. There are other applications of solid shelves in which some degree of transverse and/or longitudinal flue spaces are maintained. This is what is illustrated in Figure A-4-1.1(c). The amount of in-rack protection required in these variations is a judgment based upon the information provided in B-5-13.2.

Question 3: If Tables 6-12 and Tables 7-10.1 are not applicable to rack storage with this type of shelf, how is the ceiling sprinkler density demand determined?

Answer: Tables 6-12 and 7-10.1 are applicable.

Issue Edition: 1975
Reference: Tables 6-11.1, 7-10.1
Issue Date: November 1979
Reissued to correct error: August 1995

Rack Storage of Materials

1995 Edition

Reference: 6-7
F.I. 80-6

Question 1: When an individual rack contains fewer in-rack sprinklers than the number specified in Section 6-7, may the hydraulic calculations be based on the sprinklers in that one rack?

Answer: No.

Question 2: If the answer to Question 1 is "no," must sprinklers in adjacent racks be used to bring the total number up to that required by Section 6-7?

Answer: Yes.

Issue Edition: 1980
Reference:– 6-7
Date: November 1984

NFPA 231D

1994 Edition

Standard for Storage of Rubber Tires

1994 Edition

This edition of NFPA 231D, *Standard for Storage of Rubber Tires*, was prepared by the Technical Committee on Rubber Tires 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 231D

A tentative standard on the storage of rubber tires was developed by a subcommittee of the Committee on General Storage and adopted by the National Fire Protection Association, Inc. at its 1974 Annual Meeting in Miami Beach, FL.

The first official edition of NFPA 231D was prepared by the Committee on General Storage. It included revisions made to the tentative standard and was adopted by the Association at its 1975 Fall Meeting in Pittsburgh, PA. The 1980 edition was a partial revision of the 1975 edition, and the 1986 edition was a partial revision of the 1980 edition. The 1989 edition contained guidelines for outdoor storage of scrap tires in Appendix C.

The 1994 edition of the standard incorporates findings from recent full-scale fire tests. The concept of miscellaneous storage was introduced, and the suggestions for fighting rubber tire fires in sprinklered buildings were revised. Additional changes were incorporated to further enhance the document's user friendliness.

Technical Committee on Rubber Tires

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Robert C. Everson, Calabash, NC

James M. Ingalls, Industrial Risk Insurers, CT

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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.

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 for the indoor storage of rubber tires.

NFPA 231D

Standard for

Storage of Rubber Tires

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 D.

Chapter 1 Introduction

1-1 Scope.

1-1.1

This standard shall apply to the indoor storage of rubber tires.

1-1.2

The provisions contained in this standard shall apply to new facilities for tire storage and the conversion of existing buildings to tire storage occupancy. This standard can be used as a basis for evaluating existing storage facilities.

1-1.3

Miscellaneous storage, as defined in this standard, shall be permitted to be protected in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

1-2 Definitions.

Unless expressly stated otherwise, for the purposes of this standard, the following definitions shall apply:

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.

Available Height for Storage. The maximum height at which tires can be stored above the floor while maintaining adequate clearance from structural members and the required clearance below sprinklers.

Bundled Tires. A storage method in which a number of tires are strapped together.

Conventional Pallet. A material handling aid designed to support a unit of load with stringers to provide support for material handling devices.

Encapsulated. A method of packing consisting of plastic sheet completely enclosing the sides and top of a combustible commodity or combustible package.

NOTE: Stretch-wrapping around the sides only shall not be considered to be encapsulated.

Horizontal Channel. Any uninterrupted space in excess of 5 ft (1.5 m) in length between horizontal layers of stored tires. Such channels may be formed by pallets, shelving, racks, or other storage arrangements.

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.

Laced Storage. Tires stored where the sides of the tires overlap, creating a woven or laced appearance. *[See Figure 1-3(g).]*

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.

Miscellaneous Storage.* The storage of rubber tires that is incidental to the main use of the building. Storage areas shall not exceed 2000 ft^2 (186 m^2). (*See Section 3-3.*)

On-side Storage. Tires stored horizontally or flat.

On-tread Storage. Tires stored vertically or on their treads.

Palletized. Storage on portable racks of various types utilizing a conventional pallet as a base.

Pyramid Storage. On-floor storage in which tires are formed into a pyramid to provide pile stability.

Rack. Any combination of vertical, horizontal, and diagonal members that supports stored materials. Racks may be fixed or portable. A fixed rack is a supporting framework that remains in a fixed position within the warehouse during normal usage and into which the placement and retrieval of storage is by means of handling tires individually or in pallet loads.

NOTE: See NFPA 231C, *Standard for Rack Storage of Materials for Rack Arrangements.*

Rubber Tires. Pneumatic tires for passenger automobiles, aircraft, light and heavy trucks, trailers, farm equipment, construction equipment (off-the-road), and buses.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Sprinkler Temperature Rating. Ordinary temperature-rated sprinklers include temperature ratings between 135°F and 175°F (57°C and 80°C), and high temperature-rated sprinklers include temperature ratings between 250°F and 300°F (121°C and 149°C).

Storage Aids. Commodity storage devices such as shelves, pallets, dunnage, separators, and skids.

1-3 Illustrations.

The following illustrations do not necessarily cover all possible storage configurations.

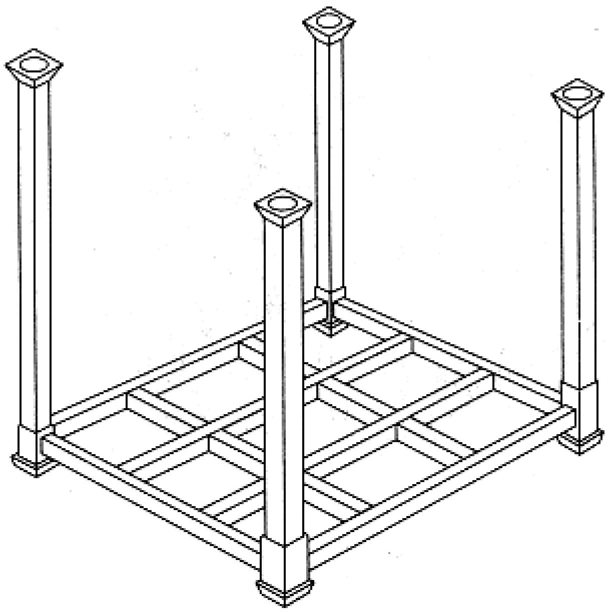


Figure 1-3(a) Typical open portable rack unit.

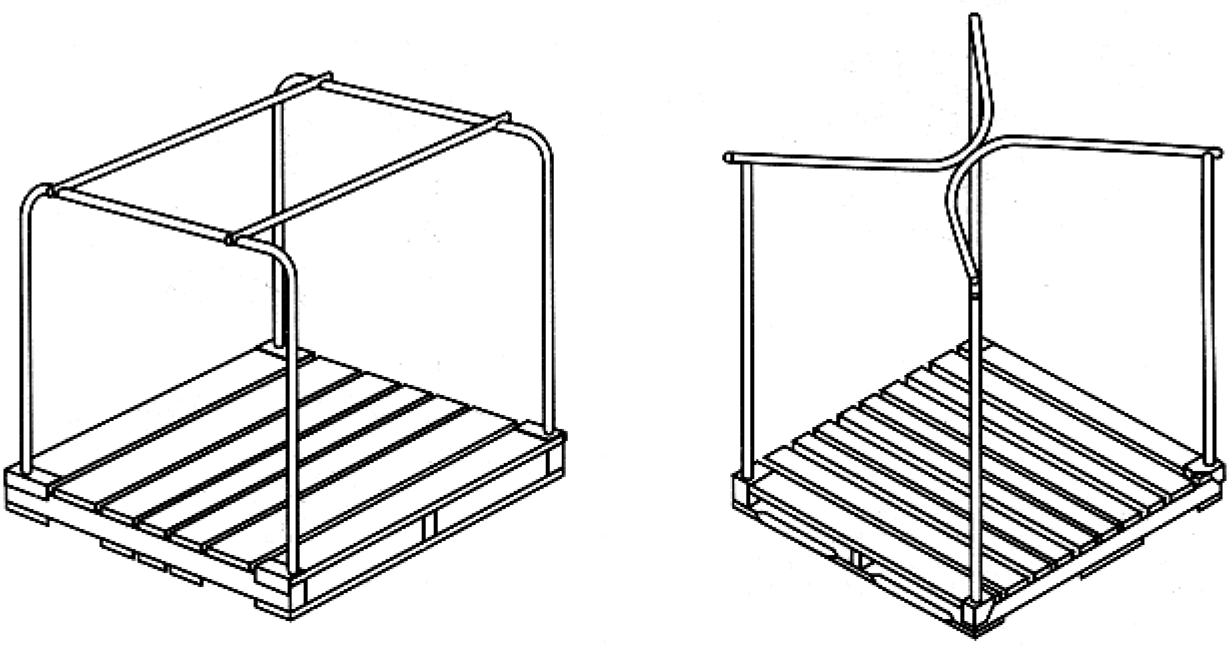


Figure 1-3(b) Typical palletized portable rack units.

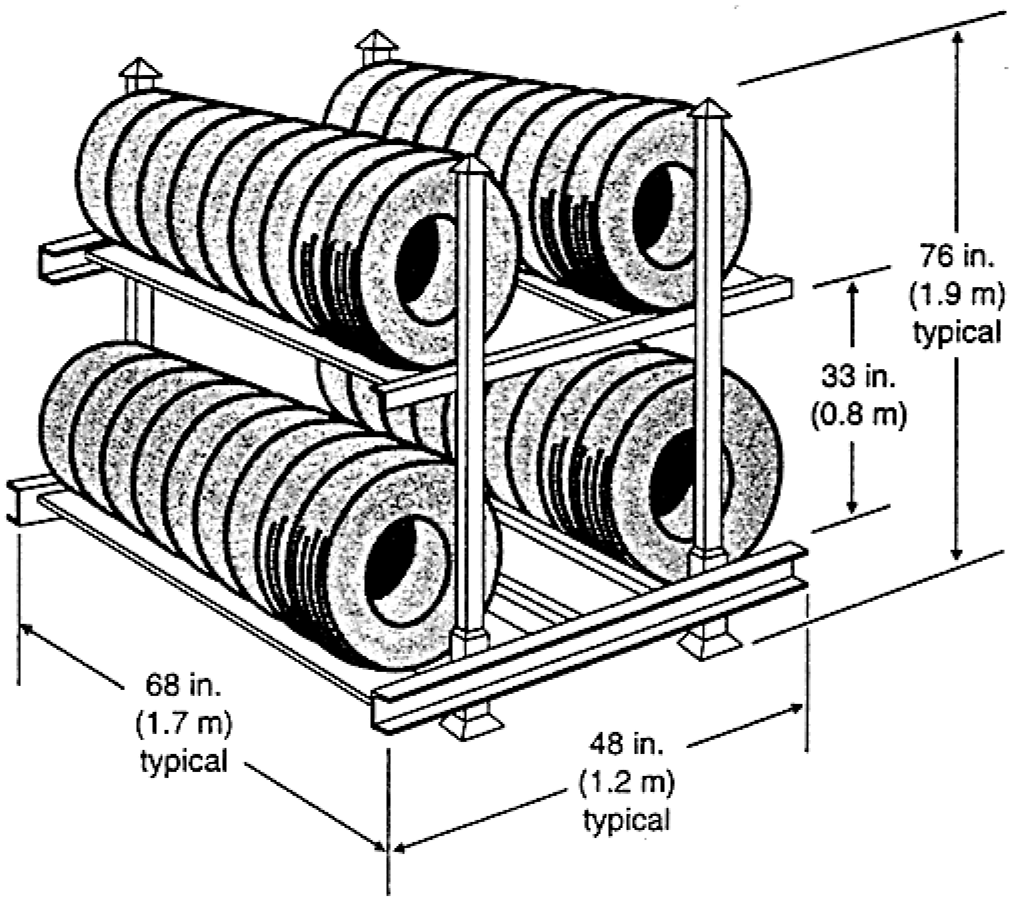
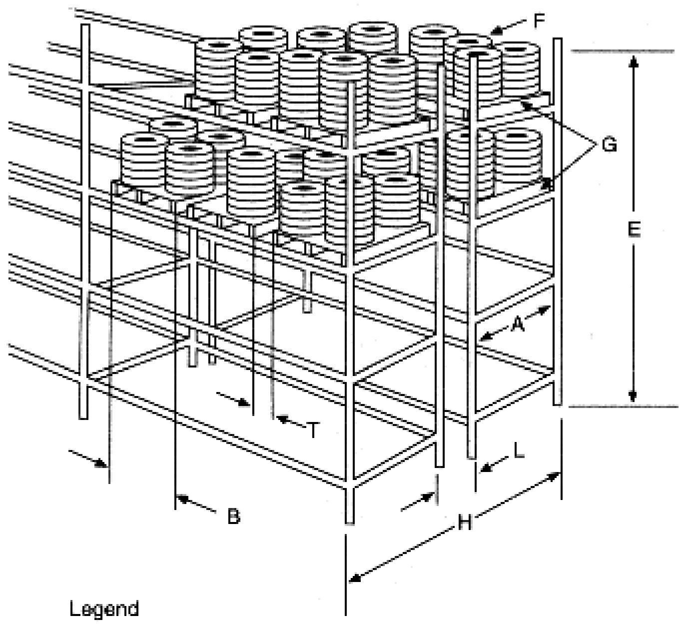


Figure 1-3(c) Open portable rack.



Legend

A—Load depth
B—Load width
E—Storage height
F—Commodity
G—Pallet
H—Rack depth
L—Longitudinal flue space
T—Transverse flue space

Figure 1-3(d) Double-row fixed rack storage.

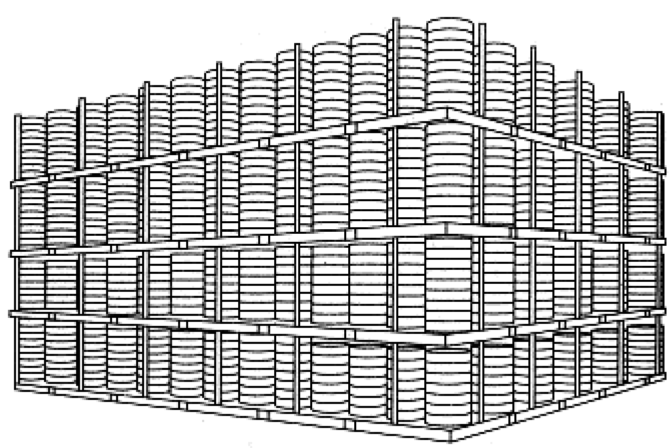


Figure 1-3(e) Palletized portable rack on-side storage arrangement (bundled or unbundled).

Figure 1-3(f) On-floor storage; on-tread, normally bundled; distance along tire hole not to exceed 25 ft (7.7 m).

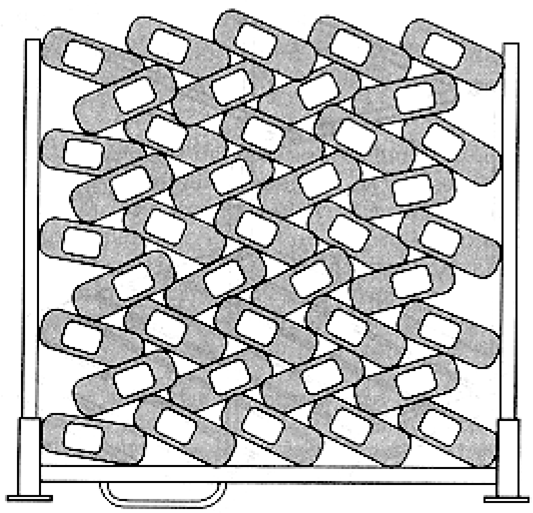


Figure 1-3(g) Typical laced storage.

Chapter 2 Building Arrangement

2-1* Construction.

2-1.1*

Buildings used for the storage of tires that are protected in accordance with this standard shall be permitted to be of any of the types described in NFPA 220, *Standard on Types of Building Construction*.

2-1.2

Steel columns shall be protected as follows:

(a) Storage exceeding 15 ft through 20 ft (4.6 m through 6 m) in height.

One-hour fireproofing or one sidewall sprinkler directed to one side of the column at a 15-ft (4.6-m) level.

(b) Storage exceeding 20 ft (6 m) in height.

Two-hour fireproofing for the entire length of the column, including connections with other structural members; or two sidewall sprinklers, one at the top of the column and the other at a 15-ft (4.6-m) level, both directed to the side of the column.

Exception: The above protection shall not be required where storage in fixed racks is protected by in-rack sprinklers.

2-2 Fire Walls.

2-2.1

Where protection in accordance with Section 4-1 is provided, stored tires shall be segregated from other combustible storage by aisles at least 8 ft (2.4 m) wide. Where not so protected, stored tires shall be separated by fire walls.

2-2.2

Where tires are stored up to 15 ft (4.6 m) high, walls between adjacent warehouse areas and between manufacturing and warehouse areas shall have not less than a 4-hour fire rating. Where tires are stored over 15 ft (4.6 m) high, walls between manufacturing and warehouse areas shall have a fire rating of not less than 6 hours.

Chapter 3 Storage Arrangement

3-1* Piling Procedures.

3-1.1

Piles shall not be more than 50 ft (15 m) in width.

Exception No. 1: Where tires are stored on-tread, the dimension of the pile in the direction of the wheel hole shall be not more than 50 ft (15 m).

Exception No. 2: Tires stored adjacent to or along one wall shall not extend more than 25 ft (7.6 m) from that wall.

3-1.2

The width of the main aisles between piles shall not be less than 8 ft (2.4 m).

3-2 Clearances.

3-2.1

The clearance from the top of storage to sprinkler deflectors shall be not less than 3 ft (0.9 m).

3-2.2

Storage clearance in all directions from roof structures shall be not less than 3 ft (0.9 m).

3-2.3

Storage clearance from ducts shall be maintained in accordance with NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*.

3-2.4

Storage clearance from unit heaters, radiant space heaters, duct furnaces, and flues shall be not less than 3 ft (0.9 m) in all directions or shall be in accordance with the clearance shown on the approval agency label.

3-2.5*

Clearance shall be maintained to lights or light fixtures to prevent possible ignition.

3-2.6

Not less than 24 in. (0.6 m) clearance shall be maintained around the path of fire door travel unless a barricade is provided.

3-3 Miscellaneous Storage.

3-3.1

On-tread storage piles, regardless of storage method, shall not exceed 25 ft (7.6 m) in the direction of the wheel holes.

3-3.2

Acceptable storage arrangements shall include:

(a) On-floor, on-side storage up to 12 ft (3.7 m) high;

(b) On-floor, on-tread storage up to 5 ft (1.5 m) high;

(c) Double-row or multi-row fixed or portable rack storage up to 5 ft (1.5 m) high;

(d) Single-row fixed or portable rack storage up to 12 ft (3.7 m) high; or

(e) Laced tires in racks up to 5 ft (1.5 m) in height.

Chapter 4 Fire Protection

4-1 Automatic Sprinkler Systems.

4-1.1

Automatic sprinklers, where provided, shall be installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

4-1.2*

Sprinkler discharge densities and areas of application shall be in accordance with Table 4-1.2.

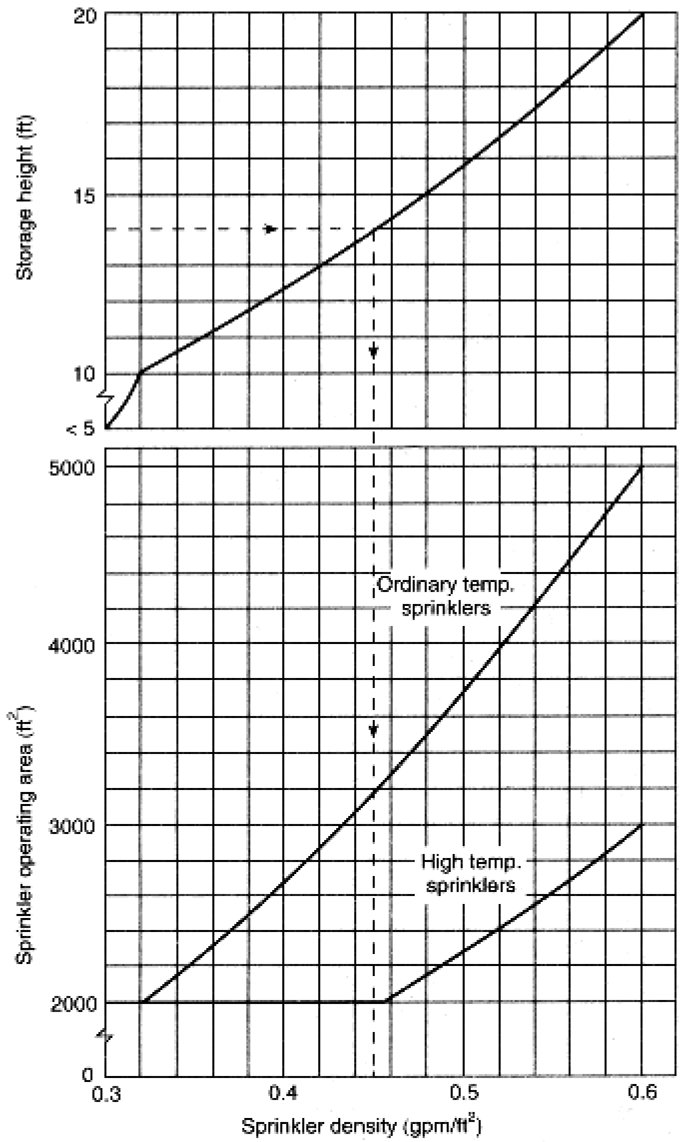


Figure 4-1.2 Sprinkler system design curves for palletized portable rack storage and fixed rack storage with pallets over 5 ft to 20 ft (1.5 m to 6 m) in height.

To use the graph in Figure 4-1.2, note the example indicated by the broken line. Read across the graph at a storage height of 14 ft (4.3 m) until the storage height intersects the storage height curve at a sprinkler density of 0.45 gpm/ft^2 [18.3 (L/min)/m^2]. Then read down until the sprinkler density intersects the sprinkler operating area curves at 3,200 ft^2 (297 m^2) for ordinary sprinklers and 2,000 ft^2 (186 m^2) for high temperature sprinklers.

Table 4-1.2

Piling Method	Piling Height (ft)	Sprinkler Discharge Density (gpm/ft^2) (*See Notes 1 and 2*)	Areas of Application (ft^2) (*See Note 1.*)	
			Ordinary Temp.	High Temp.
(1) On-floor storage	Up to 5	0.19	2,000	2,000
(a) Pyramid piles on-side	Over 5 to 12	0.30	2,500	2,500
(b) Other arrangements such that no horizontal channels are formed (*See Note 3.*)	Over 12 to 18	0.60	N/A	2,500
(c) Tires on-tread (*See Note 4.*)	Up to 5	0.19	2,000	2,000
	Over 5 to 12	0.30	2,500	2,500
(2) Palletized portable rack storage	Up to 5	0.19	2,000	2,000
(a) On-side or on-tread	Over 5 to 20	See Figure 4-1.2		
	Over 20 to 30	0.30 plus high-expansion foam	3,000	3,000
(b) On-side	20 to 25	0.60 and 0.90 (*see Note 5*); or	N/A N/A	5,000 3,000
		0.60 with 1-hr fireproofing of roof and ceiling assembly; or	N/A	4,000
		0.75	N/A	4,000
(3) Open portable rack storage, on-side or on-tread	Up to 5	0.19	2,000	2,000
	Over 5 to 12	0.60	5,000	3,000
	Over 12 to 20	0.60 and 0.90 (*see Note 5*); or	N/A N/A	5,000 3,000
		0.30 plus high-expansion foam	3,000	3,000
(4) Single-, double-, and multi-row fixed rack storage on pallets, on-side or on-tread	Up to 5	0.19	2,000	2,000
	Over 5 to 20	See Figure 4-1.2; or		
		0.40 plus one level in-rack sprinklers; or	3,000	3,000
		0.30 plus high-expansion foam	3,000	3,000
	Over 20 to 30	0.30 plus high-expansion foam	N/A	3,000
(5) Single-, double-, and multi-row fixed rack storage without pallets or shelves, on-side or on-tread	Up to 5	0.19	2,000	2,000
	Over 5 to 12	0.60	5,000	3,000
	Over 12 to 20	0.60 and 0.90 (*see Note 5*); or	N/A N/A	5,000 3,000
		0.40 plus one level in-rack sprinklers; or	3,000	3,000
		0.30 plus high-expansion foam	3,000	3,000
	Over 20 to 30	0.30 plus high-expansion foam	N/A	3,000
(6) Laced tires in racks	See A-4-1.2.			

NOTE 1: Sprinkler discharge densities and areas of application are based on a maximum clearance of 10 ft (3.1 m) between sprinkler deflectors and the maximum available height of storage. The maximum clearance is noted from actual testing and should not be viewed as a definitive measurement. The authority having jurisdiction should use the appropriate judgement where this distance is modified.
NOTE 2: The densities and areas provided in the table are based on fire tests using standard response, standard orifice [½ in. (12.7 mm)], and large orifice [17/32 in. (13.5 mm)] sprinklers. The use of extra large orifice (ELO) (⅝ in.) sprinklers shall be permitted where listed for such use, and where installed at a minimum operating pressure of 10 psi (69 kPa). In buildings where "old style" sprinklers exist, discharge densities shall be increased by 25 percent. For use

NOTE 5: Water supply shall fulfill both requirements.
NOTE 6: N/A = Not applicable.
For SI units: 1 sq ft = 0.0929 m^2; 1 gpm/sq ft = 40.746 (L/min)/m^2.

4-1.3 System Requirements.

4-1.3.1 For the purpose of selecting sprinkler spacings in hydraulically designed sprinkler systems, to obtain a stipulated density, 60 lb (4 atmospheres) /in.^{2} (414 kPa) shall be the maximum discharge pressure used at the calculation starting point.

4-1.3.2 In buildings used in part for tire storage, for the purposes of this standard, the required sprinkler protection shall extend 15 ft (4.6 m) beyond the perimeter of the tire storage area.

4-1.4 In-rack Sprinkler System Requirements.

4-1.4.1 In-rack sprinklers, where provided, shall be installed in accordance with NFPA 231C, *Standard for Rack Storage of Materials*, except as modified by 4-1.4 through 4-1.4.5.

4-1.4.2 In-rack sprinkler deflectors shall be located at the same level as the bottom of the pallet support to maintain an unobstructed clear space of at least 4 in. (102 mm). In-rack sprinklers shall be located at least 2 ft (0.6 m) from rack uprights.

4-1.4.3 The maximum horizontal spacing of sprinklers in racks shall be 8 ft (2.4 m).

4-1.4.4 Sprinklers in racks shall discharge at not less than 30 psi (207 kPa).

4-1.4.5 Water demand for sprinklers installed in racks shall be based on simultaneous operation of the most hydraulically remote 12 sprinklers where only one level is installed in racks.

4-2 High-expansion Foam Systems.

4-2.1*

High-expansion foam systems installed in accordance with NFPA 11A, *Standard for Medium-and High-Expansion Foam Systems*, as modified herein, shall be permitted to be installed in addition to automatic sprinklers. Where so installed, a reduction in sprinkler discharge density to one-half the density specified in Table 4-1.2 or 0.24 gpm/ft^2 [(9.78 L/min)/m^2], whichever is higher, shall be allowed.

4-2.2

High-expansion foam systems shall be automatic in operation.

4-2.3

Detectors shall be listed and shall be installed at the ceiling at one-half listed spacing in accordance with NFPA 72, *National Fire Alarm Code*.

4-2.4

Detection systems, concentrate pumps, generators, and other system components essential to the operation of the system shall have an approved standby power source.

4-3 Water Supplies.

4-3.1

The rate of water supply shall be sufficient to provide the required sprinkler discharge density over the required area of application plus provision for generation of high-expansion foam and in-rack sprinklers where used.

4-3.2

Total water supplies shall include provision for not less than 750 gpm (2,835 L/min) for hose streams, in addition to that required for automatic sprinklers and foam systems. Water supplies shall be capable of supplying the demand for sprinkler systems and hose streams for not less than 3 hours.

Exception: For on-floor storage up to and including 5 ft (1.5 m) in height, hose stream requirements shall be permitted to be 250 gpm (946 L/min), with a water supply duration of not less than 2 hours.

4-3.3*

Where dry pipe systems are used, the area of sprinkler application shall be increased by not less than 30 percent.

4-4 Manual Inside Protection.

4-4.1

Where automatic sprinkler protection is provided, small hose [$1^1/_2$ in. (38 mm)] shall be provided to reach any portion of the storage area. Small hose shall be supplied from one of the following:

(a) Hydrants;

(b) A separate piping system for small hose stations;

(c) Valved hose connections on sprinkler risers where such connections are made upstream of sprinkler control valves;

(d) Adjacent sprinkler systems.

4-4.2 Portable Fire Extinguishers.

Portable fire extinguishers shall be provided in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*. Up to one-half of the requirement complement of portable fire extinguishers for Class A fires shall be permitted to be omitted in storage areas where fixed, small hose lines [$1^1/_2$ in. (38 mm)] are available to reach all portions of the storage area.

4-5 Hydrants.

At locations without public hydrants, or where hydrants are not within 250 ft (76 m), private hydrants shall be installed in accordance with NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*.

4-6 Alarm Service.

4-6.1

Automatic sprinkler systems and foam systems, where provided, shall have approved central station, auxiliary, remote station, or proprietary waterflow alarm service.

Exception: Local waterflow alarm service shall be permitted to be provided where recorded guard service also is provided.

NOTE: See NFPA 601, *Standard on Guard Service in Fire Loss Prevention.*

4-6.2

Alarm service shall comply with NFPA 72, *National Fire Alarm Code.*

4-7* Fire Emergency Organization.

(*Also see Appendix B.*)

4-7.1

Arrangements shall be made to permit rapid entry into the premises by the municipal fire department, police department, or other authorized personnel in case of fire or other emergency.

4-7.2

Plant emergency organizations, where provided, shall be instructed and trained in the following procedures:

(a) Maintenance of the security of the premises;

(b) Means of summoning outside aid immediately in an emergency;

(c) Use of portable extinguishers and small hose lines or small fires and mop-up operations;

(d) Operation of the sprinkler system and water supply equipment;

(e) Use of material handling equipment while sprinklers are still operating to effect final extinguishment;

(f) Supervision of sprinkler valves after the system is turned off so that the system can be reactivated if rekindling occurs.

4-7.3

A fire watch shall be maintained when the sprinkler system is not in service.

Chapter 5 Building Equipment, Maintenance, and Operations

5-1 Mechanical Handling Equipment.

5-1.1 Industrial Trucks.

Power-operated industrial trucks shall comply with NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance, and Operation*.

5-2 Storage of Empty Wood Pallets.

Wood pallets shall be stored in accordance with the requirements of NFPA 231, *Standard for General Storage*, Section 4-4.

5-3 Cutting and Welding Operations.

5-3.1

Where welding or cutting operations are necessary, the requirements of NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, shall be followed. Where possible, work shall be removed to a safe area.

5-3.2

Welding, soldering, brazing, and cutting shall be permitted to be performed on rack or building components that cannot be removed, provided no storage is located below and within 25 ft (7.6 m) of the working area and provided flameproof tarpaulins enclose this area. During any of these operations, the sprinkler system shall be in service. Extinguishers suitable for Class A fires with a minimum rating of 2A and charged inside hose lines, where provided, shall be located in the working area. A fire watch shall be maintained during these operations and for not less than 30 minutes following completion of open-flame operation.

5-4 Waste Disposal.

Rubbish, trash, and other waste material shall be disposed of at regular intervals.

NOTE: See NFPA 82, *Standard on Incinerators and Waste and Linen Handling Systems and Equipment*.

5-5 Smoking.

Smoking shall be strictly prohibited. “No Smoking” signs shall be posted in prohibited areas.

Exception: Locations prominently designated as smoking areas.

5-6 Maintenance and Inspection.

5-6.1

Fire walls, fire doors, and floors shall be maintained in good repair at all times.

5-6.2

The sprinkler system and the water supplies shall be inspected, tested, and maintained in accordance with NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*.

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 11A, *Standard for Medium- and High-Expansion Foam Systems*, 1994 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1994 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 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1994 edition.

NFPA 72, *National Fire Alarm Code*, 1993 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*, 1992 edition.

NFPA 220, *Standard on Types of Building Construction*, 1992 edition.

NFPA 231, *Standard for General Storage*, 1990 edition.

NFPA 231C, *Standard for Rack Storage of Materials*, 1991 edition.

NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance, and Operation*, 1994 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 Miscellaneous Storage.

The limitations on the type and size of storage are intended to identify those situations where tire storage is present in limited quantities and incidental to the main use of the building. Occupancies such as aircraft hangars, automobile dealers, repair garages, retail storage facilities, automotive and truck assembly plants, and mobile home assembly plants are types of facilities where miscellaneous storage could be present. The fire protection sprinkler design densities specified by NFPA 13, *Standard for the Installation of Sprinkler Systems*, are adequate to provide protection for the storage heights indicated. Storage beyond these heights or areas presents hazards that are properly addressed by this standard and are outside the scope of NFPA 13.

A-2-1

Smoke removal is important to manual fire fighting and overhaul. Since most fire tests were conducted without smoke and heat venting, protection specified in Section 4-1 was developed without the use of such venting. However, venting through eaveline windows, doors, monitors, gravity, or mechanical exhaust systems is essential to smoke removal after control of the fire is achieved.

A-2-1.1

Building codes and insurance requirements affect the type of construction selected.

A-3-1

It is not the intent to limit the pile length.

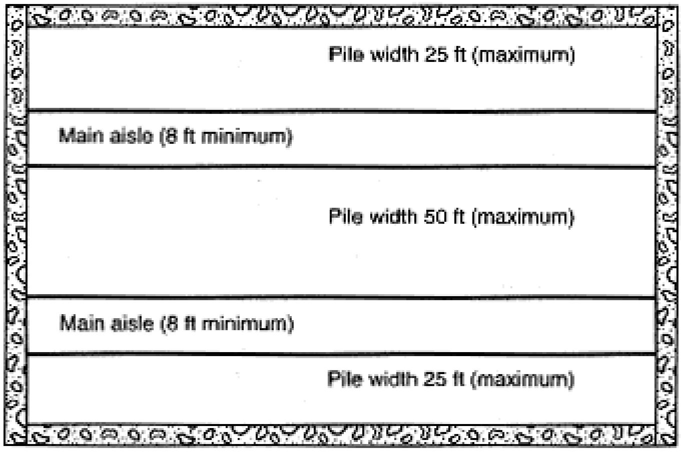


Figure A-3-1 Typical piling arrangement in accordance with Section 3-1.

A-3-2.5

Incandescent light fixtures should have shades or guards to prevent ignition of commodity from hot bulbs where possibility of contact with storage exists.

A-4-1.2

Density and areas of application in Table 4-1.2 have been developed from fire test data. Protection requirements for other storage methods are beyond the scope of this standard at the present time. From recent fire testing with densities of 0.45 gpm/ft^2 [18.3L/min)/m^2] and higher, there have been indications that large orifice sprinklers at greater than 50-ft^2 (4.6-m^2) spacing produce better results than the $^1/_2$-in. (12.7-mm) orifice sprinklers at 50-ft^2 (4.6-m^2) spacing.

Table 4-1.2 is based on operation of standard sprinklers. Use of “quick response” or other special sprinklers should be based on appropriate tests as approved by the authority having jurisdiction.

The current changes to Table 4-1.2 represent test results from rubber tire fire tests performed at the Factory Mutual Research Center.

Storage heights and configurations, or both, [e.g., laced tires, automated material handling systems above 30 ft (9.1 m), etc.] beyond those indicated in the table have not had sufficient test data developed to establish recommended criteria. Detailed engineering reviews of the protection should be conducted and approved by the authority having jurisdiction.

A-4-1.2 Note 3 to

Table 4-1.2. Laced tires are not stored to a significant height by this method due to the damage inflicted on the tire (i.e., bead).

A-4-2.1

In existing buildings used for tire storage, high-expansion foam might be used to augment an existing sprinkler system whose calculated density is below that required for the proposed storage height. For example, an existing system calculated to provide 0.25 gpm/ft^2 [(10.2

L/min)/m^2] could be used for storages requiring up to 0.50 gpm/ft^2 [(20.3 L/min)/m^2] with the addition of a high-expansion foam system. An alternative might be to reinforce or redesign the sprinkler system.

A-4-3.3

Wet systems are recommended for tire storage occupancies. Dry systems may be permitted only where it is impracticable to provide heat.

A-4-7

Information on emergency organization is provided in NFPA 600, *Standard on Industrial Fire Brigades*. (*Also see Appendix B.*)

Appendix B Recommendations for Fighting Rubber Tire Fires in Sprinklered Buildings

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

B-1 Introduction.

It is essential that the steps necessary for fighting rubber tire fires be understood by both the building occupant and the fire service to prevent unnecessary injury or loss of life and to prevent loss of fire control during overhaul. This necessitates emergency preplanning with the local fire department, building occupant, and others as deemed necessary.

Fire tests of rubber tire storage have indicated that smoke can quickly obstruct the visibility within a building and obscure the burning materials; plans for the attack and extinguishment of the fire should be prepared in advance.

Because the products of combustion are harmful, all personnel assigned to interior functions should use breathing apparatus even before obscuration occurs.

Ventilation efforts should be carefully controlled. Drafts from open doors and windows allow fresh air to reach the fire and make control of the fire difficult. Doors and windows should be closed as soon as possible to limit the air supply to the fire and to allow control by automatic systems to be established.

Fire brigades should be trained and equipped with the necessary tools and equipment to respond to a fire emergency and, if possible, attack the fire prior to the arrival of the fire department.

Review of building and fire protection system plans should be part of the ongoing training of both the on-site personnel and fire departments.

A tire fire can progress quickly through the phases described in the following paragraphs, and each phase presents different conditions to responding emergency personnel. Items for consideration in the emergency preplanning program are provided for inclusion in such plans.

Observations at tire fire tests and accounts of actual fires have indicated that, while automatic sprinklers with adequate densities in approved configurations can control a fire, extinguishment by sprinklers alone normally does not occur. The four tests used also indicate that sprinkler protection can be overcome by:

(a) Storage exceeding the heights indicated in this standard; and

(b) Storage configurations that inhibit the movement of heat to the roof, slowing sprinkler operation, and inhibit the waterflow to the seat of the fire, reducing sprinkler effectiveness.

Incipient Stage. This stage occurs within 2 to 5 minutes of ignition.

Important: Drafts from open doors increase the intensity of the fire and make control difficult. Doors should be closed as quickly as possible to isolate the fire area.

Important: Fire tests indicate that smoke obscuration occurs within 6 to 9 minutes of ignition, even when the fire is sprinkler controlled. Breathing apparatus might be needed even before obscuration occurs.

If caught in the incipient stage, control can be achieved using interior hand hose and portable extinguishers. Quick reaction is essential, as this window of opportunity no longer exists within 2 to 5 minutes of actual ignition, since the generation of heat and smoke make the area untenable. Dry chemical extinguishers have been found to be most effective but should be backed up with small hose, as the “knock-down” is only temporary.

Tires in the affected area should be removed from storage. Tires removed from storage should be taken out of doors, thoroughly soaked, and left where they cannot expose other combustibles. The area where the fire occurred should be closely watched for several hours for rekindling.

While the first sprinkler can be expected to operate within the first 2 to 5 minutes of ignition, the updraft from the fire can disrupt the sprinkler pattern to such an extent that the water might not get to the seat of the fire. After the first 4 minutes, the fire has generally progressed beyond the stage where portable extinguishers are effective and, within minutes, the smoke and carbon monoxide make the area untenable. Vision is obscured, and any personnel without breathing apparatus is at risk.

Active Stage. The active stage of the fire follows the initial stage and is generally defined as that period where the sprinkler system is establishing control over the fire.

Important: Even though the fire is sprinkler controlled, roof temperatures resulting from the tire fires can reach temperatures high enough to cause steel joists to deflect and possibly fail. In recent fire tests, gas temperatures at roof level ranged between 1,110°F and 1,450°F (593°C and 788°C) for 10 minutes. Roof steel exposed to this high gas temperature could deflect or fail if subjected to additional loading. <u>DO NOT</u> place personnel on roof to attempt ventilation.

Important: Local fire departments attempting to draft from the sprinkler supply system will decrease the sprinkler effectiveness. If possible, separate municipal hydrants should be identified for fire department use.

Important: As the sprinklers gain control of the fire, the smoke will turn from black to gray. A return to black smoke is an indication that the sprinklers are not controlling the fire. Pump and system pressure also should be monitored. Loss of system pressure is an indication of more sprinklers operating, pump failure, or loss of control.

Responding local fire departments should be arriving by this time. Building personnel should advise arriving fire personnel of the location of all occupants of the building. At this point, there is little for the fire department to do except to connect to the municipal water supply and prepare to supplement the fire protection system through the fire department connection.

Fire department personnel or maintenance personnel, or both, should respond to the fire pump room and work to maintain operation of the fire pump. System discharge pressure should be observed to determine if the pressure is stable. Unstable or decreasing discharge pressure indicates changes in the operating conditions of the fire protection system.

During this stage, the building is untenable, and obscured vision makes the use of hose streams questionable. It should be noted that, in buildings with smoke vents, longer use of fire hose might be possible, but at some risk to personnel. It is best to allow the sprinklers to take control of the fire. Most of the sprinklers will begin to operate within 15 to 20 minutes of ignition, if sprinkler control is effected. Sprinklers should be allowed to operate at least 60 to 90 minutes to gain control. Successful fire tests indicate that waterflow stabilizes within the first 20 minutes of the fire.

The building is best left unventilated at this time. As control is gained, the smoke will change from black to gray and will diminish in intensity. During this period, at least six charged $1^1/_2$-in. (38.1-mm) hose lines should be laid out prepatory to entering the building. Portable flood lights should be secured as well as turn-out gear, breathing apparatus, and forklifts for the overhaul crew.

Critical Stage. The critical stage occurs between the final extinguishment and the ventilation of the building.

Important: Ventilation should be done slowly, and the sprinklers should be left in operation. A return to black smoke is an indication that control is being lost. If this happens, ventilation should cease, the building should be closed, and the sprinkler system should be allowed to regain control. It should be understood that, during the attempt to ventilate the building, the fire intensity can increase due to the addition of outside air. Additional sprinklers can be expected to operate during the ventilation effort. If control has been gained, extra sprinklers might make no difference in overall performance. If control has not been gained or is marginal, this increase in the number of operating sprinklers could make regaining control more difficult due to the overall increase in sprinkler demand. Unless there is a system failure, the sprinklers should regain control. If there is any doubt that control of the fire has been gained, the sprinkler system should be allowed to "soak" the fire for longer than 90 minutes.

Important: The officer in charge should have a contingency plan if control is lost due to a system failure. In the event that control of the fire is lost, as evidenced by such indicators as increasing smoke generation, loss of pressure at the fire pump discharge (indicating massive sprinkler operation), or collapsing roof, efforts should be directed toward preventing the spread of the fire beyond the area bounded by the fire walls. At this point, consideration should be given to shutting off the sprinklers in the fire area to provide water for protecting the exposures.

After 60 to 90 minutes and when the smoke intensity has diminished, the building should be ventilated around the periphery of the fire area. If control has been gained, the roof temperature will usually have cooled sufficiently to allow roof vents to be opened manually if they have not already opened automatically.

Overhaul. Although visible fire is no longer present, overhaul of the area of the fire should be conducted to be certain of complete extinguishment.

Important: Care should be taken that the hose streams do not lower the pressure or water supply to the sprinkler system. Sprinkler operation should cease only when the fire chief is certain that hose can control the fire.

Important: Caution should be used, as the tire piles will be unstable.

As soon as the smoke clears to the extent that the building can be entered, entry should be made using small hose streams that should be directed into the burning tires. Sprinklers should be kept in operation during this period.

Forklifts and other means should be used to remove the tires from the fire area to outside the building. It usually is necessary to keep the sprinklers in operation during this procedure at least until there is no evidence of flame. Patrols should be made of the affected area for at least 24 hours following the fire.

Following fire extinguishment, all fire protection systems should be restored to service as quickly as possible. These systems include, but are not limited to:

(a) Sprinkler systems

(b) Alarm systems

(c) Pumps

(d) Water supplies.

Use of High-expansion Foam. If a high-expansion foam system is used in connection with automatic sprinklers, sprinklers may be permitted to be shut off 1 hour after ignition, and foam may be permitted to soak the fire for an additional 1 hour before the building is opened and overhaul is begun. Limited tests with high-expansion foam indicate that fire extinguishment is largely complete after a period of soaking in foam. As a precautionary measure, charged hose streams should be available when foam is drained away.

After the initial fill, foam generators should be operated periodically during the soaking period to maintain the foam level. This is necessary, since sprinklers and products of combustion will cause partial foam breakdown.

Appendix C Guidelines for Outdoor Storage of Scrap Tires

C-1 General.

The intent of these recommendations is to provide fire protection guidance to minimize the fire hazard in areas for outside scrap tire storage. Each individual property has its own special conditions of tire handling, exposure, and topography. For this reason, only basic fire protection principles that are intended to be applied with due consideration of the local factors involved are covered in this appendix. The authority having jurisdiction should be consulted in all cases.

Rubber has a heat combustion of about 15,000 Btus per pound, or roughly twice that of ordinary combustibles (e.g., paper and wood). Once ignited, fire development is rapid, and high temperatures can be expected due to the large exposed surface area of tires. Burning is likely to persist for hours. In cases where the fire is controlled, rekindling is a possibility.

These recommendations are not intended to apply to storage of shredded tires (chips, granules, etc.).

C-2 Definitions.

Unless expressly stated elsewhere, for the purpose of these recommendations, the following terms are defined as indicated:

Aisle. An accessible clear space between storage piles or groups of piles suitable for housekeeping operations, visual inspection of piling areas, and initial fire-fighting operations.

Clear Space. Any area free of combustible materials. This does not preclude the storage of noncombustible materials that will not transmit an exposure fire.

Fire Lane. A clear space suitable for fire-fighting access and operations by motorized fire apparatus.

Scrap Tire. A tire that is no longer suitable for vehicular use.

Units (equivalent passenger). One average size passenger tire weighing approximately 25 lb (11 kg).

Yard. The outdoor areas where scrap tires are stored.

C-3 Fire Experience.

C-3.1

Fire experience in outdoor storage of scrap tires reveals a number of concerns, including the generation of large amounts of black smoke; the fact that the storage is often too close to buildings on the same or adjacent premises, which causes fires in these exposed buildings; the generation of oil during a fire where the oil contributes to the fire or where the runoff contaminates the surrounding area; delays in reporting fires; and the lack of fire-fighting capabilities. The fire hazards inherent in scrap rubber tire storage are best controlled by a positive fire prevention program that includes the objectives that a fire be contained to the pile of origin and that the exposures to other piles or associated structures be limited.

C-3.2 Fire Prevention.

C-3.2.1 The fire hazard potential inherent in scrap rubber tire storage operations can best be controlled by a positive fire prevention program. The method of stacking should be solid piles in an orderly manner and should include:

(a) Fire lanes to separate piles and to provide access for effective fire-fighting operations.

(b) Separation of yard storage from buildings and other exposures.

(c) An effective fire prevention maintenance program including control of weeds, grass, and other combustible materials within the storage area.

(d) Consideration of topography, since oil accumulations or runoff can be expected in fire conditions. Scrap tire storage preferably should be on a level area.

C-3.2.2 Appropriate steps should be taken to limit access to the tire storage area. Acceptable access should be provided for fire-fighting equipment.

C-4 Exposure Protection.

C-4.1

For 500 units or less, the minimum separation between scrap rubber tires and structures should be 25 ft (7.6 m) or as reduced by Chapter 3, "Means of Protection," and Chapter 4, "Application of Means of Protection," of NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*.

C-4.2 For More than 500 Units.

C-4.2.1 The minimum distance between outside scrap rubber tire storage and buildings should be determined in accordance with NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*. Since the minimum distance is based on exposure from a burning building, restrictions are needed for application to an outside storage configuration.

(a) The height of exposing fire from burning tires should be considered as 1.5 times the height of the tire pile, since flames extending above the burning tires contribute to the size of the radiation surface area. In accordance with NFPA 80A, the height of the exposing fire equals the building height. The height of combustibles stored within the building is not covered; it depends on the severity of the exposure fire. A comparative building height would have to exceed the height of piling by several feet at least, and it could be substantially higher. Furthermore, the height (and width) of flames above a fire-penetrated roof would be substantially influenced by the debris of the fire-damaged or collapsed roof, whereas flame height above yard storage would have no such restriction.

(b) The width of the exposing fire should be taken as the combined width of piles facing the exposed building, disregarding the nominal separation between piles provided by narrow access aisles and roadways. In order for storage piles to be considered isolated piles, the minimum separation distance between piles should be in accordance with Table C-4.2.3. This distance can be reduced to that necessary to provide a dirt berm at least 1.5 times the height of the pile.

(c) The percent of opening in the exposing wall area should be considered to be 100 percent.

(d) The severity of the exposing fire should be considered as severe.

C-4.2.2 Means of protecting a building exposed by burning tire storage should be selected from NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*, Chapter 3, and separation adjustments should be based on building construction and protective measures as provided in NFPA 80A, Chapter 4, except that the separation should never be reduced below that necessary for fire-fighting access. (*See Section C-4.3.*)

C-4.2.3 Table C-4.2.3 provides representative separations between the exposed building and piles or between isolated piles.

Table C-4.2.3 Representative Exposure Separation Distances[1]

Tire Storage Pile Height (ft)

Exposed Face Dimensions

(ft)	8	10	12	14	16	18	20
25	56	62	67	73	77	82	85
50	75	84	93	100	107	113	118
100	100	116	128	137	146	155	164
150	117	135	149	164	178	189	198
200	130	149	167	183	198	212	226
250	140	162	181	198	216	231	245

1Separation distances are based on NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*, Chapter 2, using a factor of 1.5 in accordance with C-4.2.1(a).
For SI units: 1 ft = 0.305 m.

C-4.2.4 Because of the extensive fire expected in scrap tire storage, some form of exposure protection for adjoining properties should be considered. If the clear space as recommended in Table C-4.2.3 cannot be provided, provide a dirt berm 1.5 times the height of the tire storage.

C-4.2.5 The distance between storage and grass, weeds, and brush should be 50 ft (15 m).

C-4.3 Fire-fighting Access.

C-4.3.1 Maximum pile height should be 20 ft (6 m). Pile width and length should not exceed 250 ft (76.2 m) without a separation according to Table C-4.2.3. Dirt berms may be permitted to be used in lieu of cross aisles in accordance with C-4.2.1(b). (*See Figure C-4.3.1.*)

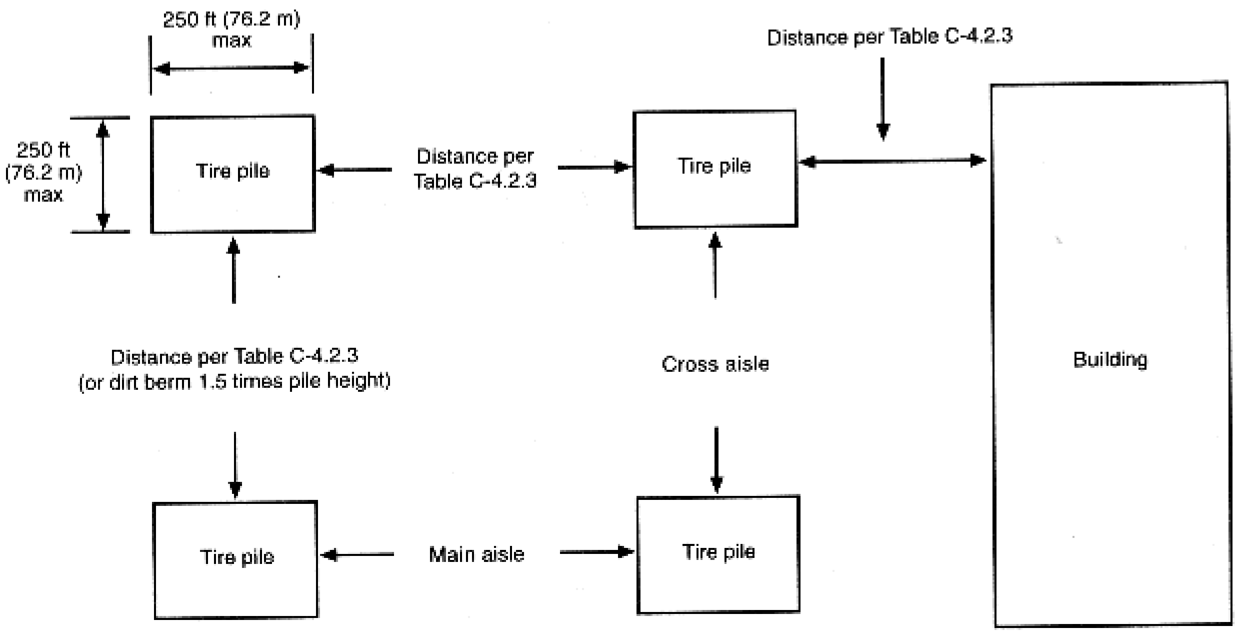


Figure C-4.3.1 Tire pile arrangement.

C-4.3.2 The fire department should be consulted for advice on provision of all-weather roadways to and within the storage area. Depending on such factors as storage area configuration and size, access obstruction (e.g., rivers, railroad yards), prevailing wind direction, and alternative tactics, fire-fighting strategy might necessitate that one or more aisles be wider than those described in C-4.3.1.

C-4.3.3 Pre-emergency planning should be made with the local fire protection agency so that fire emergencies can be properly handled in the tire storage facility.

C-5 General Fire Protection.

C-5.1 General.

C-5.1.1 Weeds, grass, and similar vegetation should be eliminated throughout the entire yard. Combustibles should be removed as they accumulate.

C-5.1.2 Smoking should be prohibited within the tire storage area. Other types of potential ignition sources such as cutting and welding, heating devices, and open fires should be prohibited.

C-5.1.3 Suitable safeguards should be provided to minimize the hazard of sparks from such equipment as refuse burners, boiler stacks, and vehicle exhaust.

C-5.2 Water Supplies.

C-5.2.1 A public or private fire main and hydrant system should be provided. A water system should be provided to supply a minimum of 1,000 gpm (3,780 L/min) for less than 10,000 units storage, or 2,000 gpm (7,560 L/min) for 10,000 units or more for a duration of 3 hours.

C-5.2.2 If there is access to a lake, stream, pond, or other body of water in the vicinity of the storage area, a fire department suction connection should be provided.

C-5.2.3 If fire hoses are not immediately available from responding public fire departments, on-site storage of 1,000 ft (304.8 m) of $2^1/_2$-in. (63-mm) hose and sufficient nozzles should be provided.

C-5.2.4 Bulldozers, front-end loaders, and similar equipment may be permitted to be used to move tires not yet involved in the fire, to create breaks in the tire pile, or to cover burning tires with soil.

Appendix D Referenced Publications

D-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.

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*, 1994 edition.

NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*, 1993 edition.

NFPA 82, *Standard on Incinerators and Waste and Linen Handling Systems and Equipment*, 1994 edition.

NFPA 231C, *Standard for Rack Storage of Materials*, 1991 edition.

NFPA 600, *Standard on Industrial Fire Brigades*, 1992 edition.

NFPA 601, *Standard on Guard Service in Fire Loss Prevention*, 1992 edition.

D-1.2 Other Publication.

FMRC J. I. OWIR3.RR, "Rubber Tires: Investigation of Common Protection for Three Types of Storage," March 1993, prepared for Rubber Manufacturers Association, 1400 K Street NW, Washington, DC 20005.

Formal Interpretation

NFPA 231D

Storage of Rubber Tires

1994 Edition

Reference: 3-1.1
F.I. 89-1

Background: The first sentence of 3-1.1 read as follows:

Where tires are stored on tread the dimension of the pile in the direction of the wheel hole shall not exceed 50 ft (15 m).

Question 1: Does the 50 ft (15 m) limitation apply to rack storage?

Answer: Yes.

Issue Edition: 1989
Reference:– 3-1.1
Issue Date: October 22, 1990
Effective Date: November 12, 1990

NFPA 231E

1996 Edition

Recommended Practice for the Storage of Baled Cotton

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This edition of NFPA 231E, *Recommended Practice for the Storage of Baled Cotton*, was prepared by the Technical Committee on General Storage 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 231E was approved as an American National Standard on February 2, 1996.

Origin and Development of NFPA 231E

In the early 1900s, a group of marine underwriters formulated regulations to reduce the frequency of excessive fire loss in baled cotton facilities. In 1916, following a joint conference with the cotton industry, guidelines were established under the title “Specifications and Standards” (also known as “Marine Standards”).

From 1947 through 1969, the sponsorship was through the Cotton Warehouse and Inspection Service (dissolved in 1969). In 1967, interested insurance rating bureaus were added as sponsors, and, in 1969, to prevent conflicts with various rating bureau schedules, the word “Standards” was replaced with “Recommended Good Practices”; however, since 1939, the booklet has been commonly referred to as the “Blue Book.”

Numerous revisions have been made over the years to keep current, the last made in 1973. Early in 1978, the committee for the “Blue Book” requested that the NFPA consider a standard on baled cotton storage and handling based on the “Blue Book” recommended practices. The NFPA Correlating Committee for Storage expanded the scope to include all fibers in baled form, which were covered in NFPA 44, *Storage of Combustible Fibers*, which was withdrawn many years ago.

Little data was found on fire experience for baled fibers, other than cotton, and that data was largely empirical in nature.

Therefore, NFPA 231E was developed by consensus of a test group formed in 1978 and made up of the cotton warehousing, cotton processing, and insurance industries, under the auspices of the Technical Committee on General Storage, and is limited to cotton fiber in baled form, with the intent to convert to a standard as field experience becomes available to further substantiate its content.

The 1989 edition was a reconfirmation of the 1984 edition.

The 1996 edition incorporates a number of editorial changes to improve the user friendliness of the document. In addition, the terminology has been updated to reflect current practices.

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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.

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 safeguarding general warehousing and commodities stored indoors or outdoors against fire. This Committee does not cover storage specifically covered by other NFPA standards.

NFPA 231E

Recommended Practice for the Storage of Baled Cotton

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 C.

Chapter 1 Introduction

1-1 Scope.

1-1.1

This recommended practice provides fire protection guidance for the storage of baled cotton in buildings and in yards.

1-1.2

None of the provisions outlined should be considered mandatory; however, it is recommended that property owners follow these recommended practices as a minimum means of limiting firespread by the application of the storage methods specified, by the separation of major storages using fire walls or clear spaces, and by the provision of an adequate means of extinguishment.

1-1.3

These guidelines may be permitted to be applied to new or existing facilities.

1-1.4

There is no intent to restrict new technologies or alternative arrangements that offer protection features superior to those outlined.

1-2 General.

1-2.1

Cotton fiber is readily ignitible and burns freely and, when stored in relatively large quantities, poses special fire control problems not generally encountered in other common commodities.

Cotton fiber is compressed to various densities into baled form for transport, storage, and handling and is largely covered by industry-accepted packaging materials and bound by steel, synthetic or wire bands, or wire. The bale surfaces normally are ragged in appearance due to the loose fibrous material not confined by the binding or wrapping. Frequently, this ragged appearance is further aggravated by sampling, which exposes additional fibrous material and can contribute to the rapid spread of fire.

Bale storage in relatively large quantities can pose severe fire control problems due to the potential flashover and the large area of involvement that could overcome even a well designed and supplied sprinkler system; therefore, this recommended practice takes into consideration limits on the number of bales per building or fire division and the size of storage blocks.

Where the bales are tiered or piled in buildings or outdoors, the loose surface fibers are easily ignited in the presence of an ignition source and the fire can spread rapidly over the entire mass or body of the material; this commonly is called “flashover.” Fire then can burrow into the bale interiors making detection and extinguishment difficult, particularly in large mass storage. A quick, hot fire then can ensue and spread beyond the control of ordinary extinguishing methods.

In properly arranged storage and with adequate automatic sprinkler protection, fire normally is confined to the pile of origin, although an aisle fire can be expected to involve more than one tier or pile. Sprinklers usually operate beyond the confines of the fire and wet down bales immediately adjacent to the burning pile.

If adequate sprinkler protection is lacking, if tiers or piles are too large or high, if aisle separation is not properly maintained, or if the bales are otherwise improperly arranged, damage to the section, building, or area of involvement will be more severe, if not totally destructive.

1-2.2

Common causes of fire in baled cotton include, but are not limited to:

(a) Fire-packed bales from the ginning or other process.

(b) Steel bands breaking and striking or rubbing (friction) against each other or other metallic objects causing sparks.

(c) Extraneous sparks from sources such as vehicle exhausts and incinerators.

(d) Miscellaneous sources such as cutting and welding, electrical and mechanical faults, and smoking.

1-3 Definitions.

Unless expressly stated elsewhere, for the purpose of this document, the following definitions apply:

Approved.* Acceptable to the authority having jurisdiction.

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

Baled Cotton.* A natural seed fiber wrapped and secured in industry-accepted materials, usually consisting of burlap, woven polypropylene or sheet polyethylene, and secured with steel, synthetic or wire bands, or wire; can also include linters (lint removed from the cottonseed) and motes (residual materials from the ginning process). (*See Table A-1-3.*)

Block Storage. The number of bales closely stacked in cubical form and enclosed by aisles or building sides, or both.

Cold Cotton. Baled cotton five or more days old after the ginning process.

Fire-packed. A bale within which a fire has been packed as a result of a process, with ginning being the most frequent cause.

Flameover. A fire that spreads rapidly over the exposed linty surface of the bales. In the cotton industry, the common term is “flashover” and has the same meaning.

Flashover. See Flameover.

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.

Naked Bale. A bale secured with wire or steel straps without wrapping.

Racks. Any combination of vertical, horizontal, and diagonal members that supports stored materials. Some rack structures use solid shelves. Racks can be fixed or portable.

Should. Indicates a recommendation or that which is advised but not required.

Tiered Storage. An arrangement in which bales are stored directly on the floor or ground, usually on dunnage where stored outdoors, and two or more bales high.

Yard Storage. An arrangement in which bales are stored outdoors in any open area. See Section 5-2 for additional definitions that apply to yard storage only.

Chapter 2 Building Construction

2-1 Construction.

2-1.1

Buildings used for the storage of baled cotton that is stored and protected in accordance with this recommended practice may be permitted to be of any of the types described in NFPA 220, *Standard on Types of Building Construction*.

2-1.2

Buildings that are equipped, or that are to be equipped, with automatic sprinkler protection also should meet the recommendations of Chapter 4.

2-2 Emergency Smoke and Heat Venting.

The protection outlined in this recommended practice applies to buildings with or without roof vents and draft curtains.

2-3 Fire Divisions or Clear Spaces between Buildings.

2-3.1

A fire division is a building, compartment, or section cut off by fire walls or separation.

2-3.1.1 Fire divisions or clear spaces between buildings should be in accordance with NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*.

2-3.1.2 Baled cotton storage generally has a fire load in excess of 15 lb/ft^2 (73 kg/m^2), which would place its classification, according to NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*, in the "severe" category.

2-3.2*

Fire walls should be of masonry and rated for at least 4 hours (based on NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*; ASTM E 119, *Standard Methods for Fire Tests of Building Construction and Materials*; and UL 263, *Standard for Safety Fire Tests of Fire Resistance of Building Construction and Materials*). Such walls should be parapeted as follows:

(a) For wood frame [Type V (111-000)] and ordinary or heavy timber masonry [Type III (211-200) and Type IV (2 HH)], construction parapets should extend at least 5 ft (1.5 m) above the highest point of any adjacent monitor or roof structure within 50 ft (15.2 m) of the fire wall. Where the monitors or the roof structure adjoins a fire wall, the parapet should extend not less than $7^1/_2$ ft (2.3 m) horizontally from the vertical side of the roof structure. If intersecting end or side walls are other than masonry, the fire wall should extend outward 10 ft (3.1 m) beyond the end or side wall or should be "teed" at the ends 10 ft (3.1 m) from each side of the wall or should be "elled" 20 ft (6.1 m) and of an equivalent fire rating.

(b) For noncombustible construction [Type II (000)] other than that outlined in 2-3.2(c), parapets should be at least $2^1/_2$ ft (0.75 m) above the roof. If intersecting side walls are other than masonry, such wall construction should conform to the specifications of 2-3.2(a).

(c) For noncombustible construction [Type II (222-111)] having masonry walls and with roofs of concrete, gypsum, or Class 1 (UL classified) metal deck, the parapet should extend at least 12 in. (0.3 m) above the roof.

(d) For walls and roofs of fire-resistive construction, [Type I (443-332)] parapets are not necessary.

2-3.3

Fire walls should be free of openings. Where openings are necessary, the number should be kept to the minimum necessary, and each side should be protected by an approved and listed 3-hour-rated fire door, installed in accordance with NFPA 80, *Standard for Fire Doors and Fire Windows*. Doors should be automatic closing with detectors or fusible links installed on both sides of the opening and interconnected so that the operation of any single detector or fusible link closes both doors simultaneously.

2-3.4

Substantial guards of a size to protect fire doors from damage or obstruction should be provided.

Chapter 3 Storage Arrangements

3-1 General.*

This chapter applies to buildings protected by a sprinkler system in accordance with Chapter 4, or to those not so protected. The tier heights, block sizes, and aisle widths outlined may be permitted but represent recommended maximum and minimum limitations. Fire experience and fire tests of high-piled commodities have shown that lower pile heights, smaller block sizes, and wider aisles result in a substantial delay in firespread and in providing for manual fire fighting. Automatic sprinkler effectiveness is also improved substantially, with a reduction in water demand and a decrease in the quantity of goods damaged.

3-2 Storage Blocks.

3-2.1

Storage blocks, tiered or untiered, or on racks, should be limited to 700 bales of compressed cotton or 350 bales of flat cotton. (*See 3-3.4 for a permitted variation and also Table A-1-3 for typical cotton bale types and approximate sizes.*)

3-2.2

The height of tiered or rack storage should be limited to a nominal 15 ft (4.6 m). Rack storage, as used in this document, contemplates baled cotton in a skeleton steel pipe or tubular frame, without shelving, and is limited to a single- or double-row configuration not in excess of two bales deep. Any variation could create a serious handicap to automatic sprinklers that is beyond the design capability and should be referred to the authority having jurisdiction.

3-2.3

Rack storage should not extend over aisles or doorways.

3-2.4

Racks should not be loaded beyond their design capacity and should be designed for seismic conditions in areas where seismic resistance for buildings is required.

3-3 Aisles.

3-3.1

Aisles should be provided and maintained to minimize the spread of fire and to allow convenient access for fire fighting, removal of storage, and salvage operations.

3-3.2

At least one main aisle, 12 ft (3.7 m) or more in width, should be provided in each fire division and arranged to subdivide the storage into two or more approximately equal areas.

3-3.3

Cross aisles separating each storage block should be at least 4 ft (1.2 m) in width. The recommended 4-ft (1.2-m) aisles allow sprinkler water to penetrate the lower areas of storage; however, it should be noted that, for aisles less than 8 ft (2.4 m) in width, a fire can be expected to communicate readily from one block to another, especially in the case of an easily ignitible commodity such as cotton fiber.

3-3.4

Where a 15-ft (4.6-m) cross aisle is provided after every fourth or fifth tiered block, each storage block may be permitted to be increased to 800 bales of compressed cotton and 400 bales of flat cotton. The purpose of this alternate method of tiered storage is to encourage wider cross aisles at least intermittently, without reducing the recommended storage capacity, as an aid in reducing the flashover fire potential. Because of the increase in block sizes, however, it is recommended that the authority having jurisdiction be consulted prior to practicing this method.

3-3.5

Cross aisles separating each single- or double-row rack storage configuration should be at least 10 ft (3.1 m) in width.

3-3.6

Aisles should be maintained free of loose cotton fibers.

3-4 Freshly Ginned Cotton Bales.

See Section 5-5.

3-5 Storage of Commodities Other than Cotton.

3-5.1

Cotton warehouses, in general, may be permitted to be used for the storage of other commodities, subject to the following:

(a) The storage of other commodities in a building may be permitted where baled cotton is not stored.

(b) High hazard commodities, such as nitrates or similar oxidizing materials, flammable liquids or gases, explosives, or materials of a highly combustible nature, should not be permitted where baled cotton is stored in the fire division.

(c) Any commodities that could be hazardous in combination with each other should be stored so that they cannot come in contact with each other.

3-5.2

Where it is necessary to store other commodities with baled cotton storage, a clear space of at least 15 ft (4.6 m) should be maintained between the baled cotton storage and other commodities.

3-5.3

Where commodities of different classifications are permitted and stored in the same building, whether on a seasonal or other basis, the protection should be adequate for the most hazardous material. (*For protection of other commodities, see the applicable NFPA storage standards.*)

3-6 Clearances.

3-6.1

Proper clearances from lights or light fixtures should be maintained to prevent possible ignition. Incandescent light fixtures should have guards to prevent ignition of a commodity from hot bulbs where the possibility of contact exists.

3-6.2

No storage should be located within 3 ft (0.9 m) of any electrical switch or panel boards and fuse boxes.

3-6.3

Baled cotton storage and other combustibles should be kept at least 4 ft (1.2 m) from fire door openings so that the transmission of fire through a door opening is minimized.

3-6.4

At least 2 ft (0.6 m) of clearance should be maintained around all doors (other than as indicated in 3-6.3), fire protection equipment (including automatic sprinkler risers, controlling valves, hose stations, and portable extinguishers), and telephones for accessibility.

3-6.5

A clearance of at least 3 ft (0.9 m) should be maintained between the top of storage and the roof or ceiling construction in order to allow sufficient space for the effective use of hose streams in buildings not equipped with automatic sprinkler protection.

Chapter 4 Fire Protection

4-1 Automatic Sprinkler Systems.

4-1.1

Automatic sprinkler protection is not part of the recommendations of this document. However, it is unfortunate that, in a fire situation, human response is, in most cases, unreliable in the first critical moments of fire development. Sprinkler protection is, therefore, the most reliable method of fire detection and suppression. Property owners are encouraged to provide sprinkler protection as the best means of minimizing a large loss. (*See Section 3-5 for sprinkler protection for other than cotton fiber storage.*)

4-1.2

Automatic sprinkler systems, where provided, should be installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

Exception: Where modified by this chapter.

4-1.3

For tiered or rack storage up to a nominal 15 ft (4.6 m) in height, sprinkler discharge densities and areas of application should be in accordance with Figure 4-1.3. The density provided for the area of operation can be taken from any point on the selected curve. It is not necessary to meet more than one point on the selected curve.

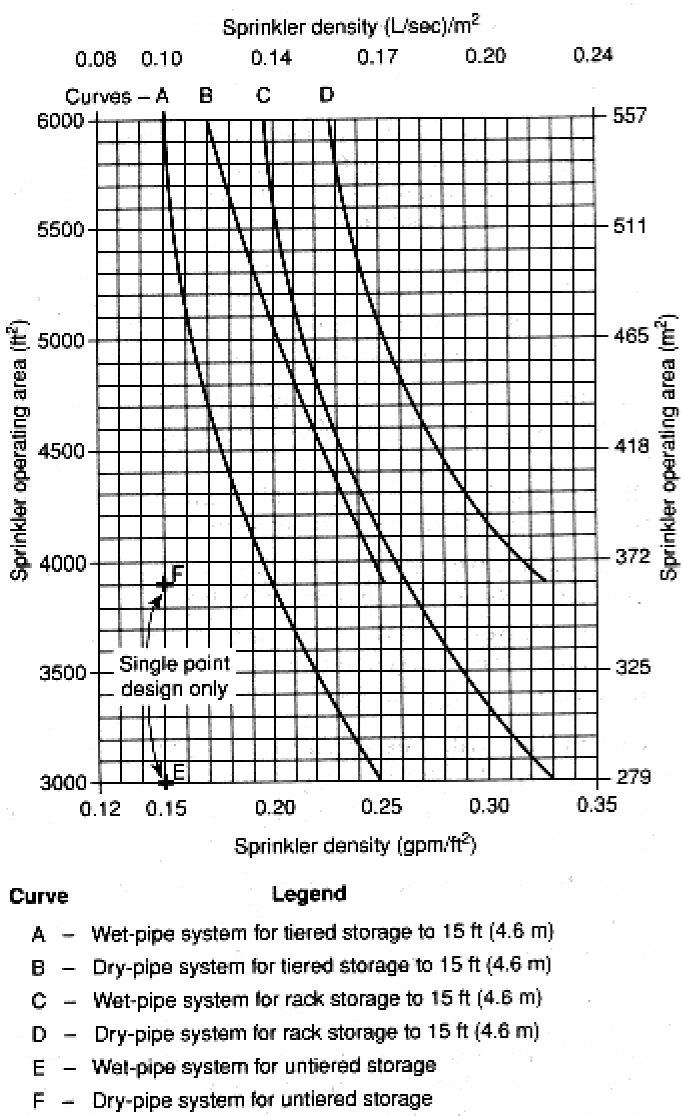

Figure 4-1.3 Sprinkler system design curves.

4-1.3.1 Where roof or ceiling heights would prohibit storage above a nominal 10 ft (3.1 m), the sprinkler discharge density may be permitted to be reduced by 20 percent of that indicated in Figure 4-1.3 but should not be reduced to less than 0.15 gpm/ft^2 [(0.10 L/sec)/m^2].

4-1.3.2 Baled storage that is not tiered can be based on the single-point design curve E for wet-pipe systems and curve F for dry-pipe systems. This untiered design density limits storage to the height of one bale, on side or on end, and would likely prohibit any future tiering without redesign of the sprinkler system.

4-1.3.3 In warehouses that have mixed rack storage, tiered or untiered storage, or a combination of these, the curve applicable to the storage configuration should apply and the highest density recommendation should extend at least 15 ft (4.6 m) beyond the recommended operating area.

4-1.3.4 Minimum sprinkler operating areas should be 3000 ft^2 (279 m^2) for wet-pipe systems and 3900 ft^2 (363 m^2) for dry-pipe systems; the maximum operating area should not exceed 6000 ft^2 (557 m^2). No area credit is recommended for the use of high temperature sprinklers.

4-1.3.5* On new installations, the use of sprinkler heads in the ordinary temperature range is recommended, subject to the maximum ceiling temperatures outlined in NFPA 13, *Standard for the Installation of Sprinkler Systems*.

4-1.4

Clearance between the top of the storage and the sprinkler deflectors should be at least 18 in. (0.45 m). Building heights should allow for proper clearance between the pile height and sprinkler deflectors. Fire tests of high-piled storage have shown that sprinklers are generally more effective if located $1^1/_2$ ft to $4^1/_2$ ft (0.45 m to 1.4 m) above the storage height.

4-2 Water Supplies.

4-2.1

The total water supply available should be sufficient to provide the recommended sprinkler discharge density over the area to be protected, plus a minimum of 500 gpm (32 L/sec) for hose streams.

4-2.2

Water supplies should be capable of supplying the total demand for sprinklers and hose streams for not less than 2 hours.

4-2.3

Recommended water supplies contemplate successful sprinkler operation when installed. However, because of the flashover fire potential and inherent unfavorable features of cotton warehousing, there should be an adequate water supply available for fire department use.

4-3 Hydrants.

At locations without public hydrants, private hydrants should be provided in accordance with NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*.

4-4 Manual Inside Protection.

4-4.1

In buildings of 15,000 ft^2 (1380 m^2) or larger, small hose [1$^1/_2$ in. (38.1 mm)], with combination water spray nozzle, should be provided to reach any portion of a storage area with due consideration to access aisle configuration with a maximum length of 100 ft (30.5 m) of hose. Such small hose should be supplied from one of the following:

(a) Outside hydrants;

(b) A separate piping system for small hose stations in accordance with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*;

(c) Valved hose connections on sprinkler risers where such connections are made upstream of the sprinkler control valves;

(d) Adjacent sprinkler systems in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

4-4.2

Portable listed fire extinguishers should be provided in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*, and as amended by this chapter. Up to $^1/_2$ of the required complement of portable fire extinguishers for Class A fires may be permitted to be omitted in storage areas where fixed small hose lines are installed in accordance with 4-4.1.

4-4.2.1 Cotton and its wrappings represent a Class A fire. Experience has shown that extinguishment using "wet water" (a chemical agent additive to lower the surface tension of water, thus increasing its penetrating and spreading qualities) is the most effective on baled cotton fires.

Plain water is effective on surface fires but lacks the penetrating power of wet water.

Dry chemical extinguishers using sodium bicarbonate, potassium bicarbonate, or potassium chloride base powders have been used to control a surface fire on baled fibers and work mainly by coating the fiber with the fire retardant powder, but such chemicals do not affect a smoldering or burrowing fire beneath the surface.

4-4.2.2 Additional listed extinguishers, suitable for Class B and C fires, or multipurpose types, should be provided at each press location and for each motorized vehicle or area of hazard other than Class A.

4-4.3 Wetting Agent Extinguishing Units.

4-4.3.1 Pressurized, wheeled, listed, wetting agent extinguishing units, as specified in NFPA 18, *Standard on Wetting Agents*, may be permitted to be used, subject to the authority having jurisdiction, in lieu of Class A conventional types or small hose lines, provided:

(a) The unit(s) has an equivalent extinguishing effectiveness of 20A for each 15,000 ft^2 (1380 m^2) of floor area or less.

(b) The unit(s) has an equivalent extinguishing effectiveness of 40A or more for each 30,000 ft^2 (2760 m^2) of floor area.

4-4.3.2 Placement of extinguishing units should be at locations readily accessible to the main aisles and properly protected from damage.

4-4.4

Extinguishers should be of the nonfreezing type or protected against freezing where necessary.

4-5 Alarm Service.

4-5.1

Automatic sprinkler systems should have approved central station, local, auxiliary, remote station, or proprietary waterflow supervised alarm service. Local waterflow alarm service may be permitted where standard guard service is provided in accordance with NFPA 601, *Standard for Security Services in Fire Loss Prevention*.

Alarm service should comply with NFPA 72, *National Fire Alarm Code*.

4-5.2

Valves should be supervised in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

4-6 Fire Emergency Planning.

4-6.1

Arrangements should be made to allow rapid entry into the premises by the municipal fire department, police department, or other authorized personnel in the case of fire or other emergency.

4-6.2

Industrial fire brigades, where provided, should be in compliance with NFPA 600, *Standard on Industrial Fire Brigades*.

4-6.3

Manual fire-fighting operations should not be considered to be a substitute for sprinkler operation. The sprinkler system should be kept in operation during manual fire-fighting operations until visibility has improved so that the fire can be clearly seen and the extent of fire has been reduced to a mop-up stage. It is essential that charged hose lines be available before venting is started because of a possible increase in fire intensity. When a sprinkler valve is closed, a designated person should remain at the valve so it can be opened promptly if necessary. The water supply for the sprinkler system should be augmented, where possible, and care should be exercised so that the water supply for the sprinkler system is not rendered ineffective by the use of excessive hose streams.

4-6.4*

Fire departments should be encouraged to make periodic inspections of the property in cooperation with management and personnel for the purposes of loss prevention and prefire planning.

4-6.5

A fire watch should be maintained when the sprinkler protection is not in service.

Chapter 5 Yard Storage

5-1 General.

5-1.1

This chapter applies to baled cotton storage yards designated for that purpose. Generally, yards are at or convenient to compression warehouses and gins but can include storage at locations remote from routine operations.

5-1.2

This chapter refers to seed cotton trailers or modules, vehicles, incinerators, and other facilities, or exposures from same, only for the purpose of establishing recommended distances to designated yard storage areas.

5-2 Definitions.

Unless expressly stated elsewhere, the following definitions are for the purpose of this chapter only:

Block. A basic yard storage unit comprising multiple row storage with clear spaces on all sides.

Designated Yard. An area marked by boundary lines intended for outside storage purposes only.

Group of Yards. Multiple yards with a maximum block and minimum clear space limitations.

Protected. See Section 5-7.

Quarantine Yard. A segregated area for the storage of known or suspect fire-packed bales.

Row. A minimum yard storage unit comprised of adjoining bales.

Unprotected. Not meeting the provisions of Section 5-7.

Yard. A storage unit consisting of multiple storage blocks subject to bale and clear space limitations.

5-3 Site.

Preference should be given to locations having adequate public fire and police protection, adequately supplied fire hydrants for protection of yard areas, good drainage, all-weather roads or driveways for emergency vehicle use, and remoteness from buildings or other combustible storages or facilities that could constitute an exposure hazard.

5-4 Storage Arrangements.

5-4.1

Tiered storage is not recommended; however, yard or outdoor storage conditions can necessitate storage methods other than those outlined. The authority having jurisdiction should be consulted for approval in such cases.

5-4.2

Storage should be arranged to provide reasonable fire breaks and ready access for fire fighting.

5-4.3

A row of storage should be limited to 100 bales.

5-4.4

Maximum storage limitations should be as follows:

(a) Protected block, 10 rows (1000 bales);

(b) Unprotected block, five rows (500 bales);

(c) Protected yard, five protected blocks (5000 bales);

(d) Unprotected yard, five unprotected blocks (2500 bales);

(e) Protected group yard, four protected yards (20,000 bales);

(f) Unprotected group yard, four unprotected yards (10,000 bales).

5-4.5

Minimum clear spaces should be as follows:

(a) 10 ft (3.1 m) between parallel rows and 25 ft (7.6 m) between rows arranged end-to-end;

(b) 50 ft (15.2 m) between protected or unprotected blocks;

(c) 200 ft (61 m) between protected or unprotected yards;

(d) 1000 ft (305 m) between protected or unprotected group yards.

5-4.6

Rows should be arranged so that prevailing winds blow in the direction of the parallel clear spaces between rows.

5-5 Quarantine Yards.

5-5.1

Freshly ginned cotton bales, commonly called "fire-packed bales," are highly subject to insidious fires originating from the ginning operation. Known or suspect fire-packed bales should be marked as such and kept segregated from other contents or buildings for a period of not less than 5 days; if no fire is detected after that period, the bales then can be handled in a normal manner. (*See Appendix B.*)

5-5.2

A clear space of at least 100 ft (30.5 m) from any yard storage and 25 ft (7.6 m) from all buildings should be established as a quarantine area for known or suspect fire-packed bales.

5-5.3

Known or suspect fire-packed bales should be separated from each other by at least a 10-ft (3.1-m) clear space.

5-6* Unobstructed Clear Space.

Unobstructed clear space to designated yard storage should be maintained as follows:

(a) 100 ft (30.5 m) to any approved sprinklered building;

(b) 200 ft (61 m) to any nonapproved sprinklered or nonsprinklered building;

(c) 200 ft (61 m) to an approved incinerator;

(d) 500 ft (152.5 m) to a nonapproved incinerator or open fires;

(e) 100 ft (30.5 m) to vehicle and seed trailer or module parking areas and trash piles;

(f) 50 ft (15.2 m) to roadways and railroad mainlines and sidings;

(g) 200 ft (61 m) upwind of any reconditioning activity;

(h) Yard storage areas should be maintained clear and clean of loose cotton, dry grass, weeds, and combustible trash for a distance of at least 50 ft (15.2 m) around the yard perimeter.

5-7 Fire Protection.

5-7.1

To qualify as a protected yard, hydrants should comply with Section 4-3.

Exception: Where amended by this chapter.

5-7.1.1 All areas of yard storage should be within 500 ft (152.5 m) of a fire hydrant. Adequate clearance should be maintained between storage and hydrants.

5-7.1.2* Hydrant equipment for each yard group (20,000 bales) should consist of:

(a) 250 ft (76.2 m) of $2^1/_2$-in. (63.5-mm) hose.

(b) 300 ft (91.5 m) of $1^1/_2$-in. (38.1-mm) hose with provisions to “Y-connect” to the $2^1/_2$-in. (63.5-mm) hose.

(c) Combination water spray nozzles.

(d) Proper wrenches for hydrant operation and hose connections.

5-7.1.3 Water available to the most remote yard hydrants should be capable of delivering at least 500 gpm (1893 L/min) at an effective pressure for at least a 2-hour period.

5-7.2

Approved extinguishing units should be provided on the basis of an equivalent 40A rating for each protected or unprotected yard area (*see Section 5-4*) or greater fraction thereof.

5-7.2.1 Subject to the authority having jurisdiction, a motorized wet water unit(s) may be permitted to be substituted for that specified in 5-7.2, provided that a unit of 250 gal (946 L) or greater capacity is provided for each group yard area storing up to 20,000 bales.

5-7.2.2 Placement of wheeled or motorized units should be at readily accessible locations within 250 ft (76.2 m) of each yard, protected from damage, and maintained in good operating condition at all times.

5-7.3

Water containers and pails, if used, should be distributed at a ratio of one 40-gal (151-L) or greater container with two pails for each 100 bales of storage. However, wheeled wet water pressure extinguishers may be permitted in lieu of containers and pails.

5-7.4

All motorized vehicles used in designated yard areas should be equipped with a listed multipurpose dry chemical extinguisher of a size appropriate for the anticipated hazard. (*See 4-4.2 for information on portable fire extinguishers.*)

5-7.5

A suitable and reliable means of communication should be available to summon the fire department or other appropriate personnel promptly, to sound a general alarm in the case of fire or other emergency, or both.

5-7.6

Reference should be made to Section 4-6 for fire emergency planning and procedures that apply to yard storage.

5-8 Yard Maintenance and Operations.

5-8.1

Smoking should be strictly prohibited within 100 ft (30.5 m) of yard storage areas, and "no smoking" signs should be posted conspicuously. (*See A-6-6.*)

5-8.2*

All internal combustion equipment used in or around yard storage areas should be equipped with a suitable spark arrester-type muffler properly maintained and otherwise approved by the authority having jurisdiction.

5-8.3 Guard Watch Service.

5-8.3.1 Guard watch service should be provided throughout all designated yard storage areas during all shutdown periods when fewer than 5 days have passed after cotton bales have been ginned, or when the total stock exceeds 1000 bales.

5-8.3.2 Hourly rounds should be made and recorded during all nonworking hours using an approved and listed portable clock and having key stations situated to ensure complete coverage of the area of responsibility. Watch service information should be obtained from NFPA 601, *Standard for Security Services in Fire Loss Prevention*.

Chapter 6 Administration, Buildings, Equipment, Maintenance, and Operations

6-1 Administration.

The administration of buildings and equipment, and the maintenance thereof, is an important consideration in the reduction of fire incidence and loss. The finest buildings and protective features can be abrogated quickly by neglect of the continuous, necessary maintenance of fire loss prevention programs and protective equipment. Thus, management, at all levels, plays a critical part in the reduction of fire loss.

In addition to the recommendations outlined in this chapter, the liaison between management and personnel should include a meaningful loss prevention program that:

(a) Encourages loss prevention habits;

(b) Teaches the prompt sounding of alarms;

(c) Minimizes panic and effects safe evacuation;

(d) Instructs key personnel in the effective utilization of fire extinguishing equipment and other protective features; and

(e) Teaches basic salvage and cleanup techniques to minimize the downtime of operations.

6-2 Mechanical Handling Equipment.

6-2.1 Industrial Trucks.

Power operated industrial trucks and mobile equipment should comply with NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance, and Operation*. Cotton storage and handling areas are defined as Class III, Division 2, hazardous areas and require vehicles designated as types DS, DY, ES, EE, EX, GS, LPS, and GS/LPS.

6-2.1.1 Gasoline and diesel fuel should be prohibited in cotton storage areas, on platforms, and in exposing yard areas. Fueling should be done outside at a well-detached location in accordance with NFPA 30, *Flammable and Combustible Liquids Code*.

Exception: Gasoline and diesel fuel contained in the vehicle tanks may be permitted.

6-2.1.2 Liquefied petroleum gas fuel containers shall be exchanged or removed only outdoors. The valve at the fuel container should be closed and the engine allowed to run until the fuel line is exhausted. Tanks should be refueled only at well-detached locations. LP-Gas fuel systems on LP-Gas dual fuel powered trucks should be in accordance with the applicable provisions of NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*.

6-2.1.3 Charging equipment for storage batteries should be in a separate area, room, or building designated for that purpose. If located in a separate room, the room should be lined with substantial noncombustible materials constructed to exclude “fly” or lint. Charging areas should be kept free of extraneous combustible materials and trash. Adequate ventilation should be provided to minimize concentrations of hydrogen gas during charging.

6-2.1.4 All mechanical equipment and refueling areas should be kept free of accumulations of fibrous lint, oil, and trash, with particular attention paid to the internal areas of vehicles.

6-2.2* Maintenance and Operations.

The following recommendations should be met prior to the entrance or use of industrial trucks in a cotton storage or handling area:

(a) All traces of fuel should be cleaned from the vehicle before it is started.

(b) Vehicles that have exhausted fuel tanks should be towed to the assigned fueling area for refueling.

(c) Repairs should be prohibited in cotton storage or handling areas.

(d) Alterations of the fire safety features should be prohibited.

(e) Maintenance procedures should comply with those outlined in NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance, and Operation*. (*See 6-2.1.*)

6-2.3 Interplant Haulage.

Tractors used for interplant hauling should be equipped with a properly maintained, suitable, spark arrester-type muffler.

6-2.4 Motorized Vehicles.

Motorized vehicles, other than those specified under 6-2.1, should not be permitted to enter any cotton storage area. A loading platform should be located so that trucks cannot fully enter inside the closing walls of a warehouse, with the truck space inclined away from the platform and lower than the platform. The loading area should be closed off from any under-floor building space.

6-2.5

Mechanical handling equipment, when not in use, should be stored outside.

6-3 Building Service and Equipment.

6-3.1 Electrical Installation.

(a) It is recommended that cotton storage and handling areas be free of electrical installations; however, installations that are necessary should comply with NFPA 70, *National Electrical Code*®, for Class III, Division 2, hazardous areas.

(b) Electrical extension cords should be prohibited in storage areas. If portable lights are necessary, battery-powered lanterns or flashlights may be permitted to be used.

6-3.2

Open flame heating devices, permanent or temporary, should be prohibited.

6-3.3 Shops and Equipment.

6-3.3.1 Repairing and reconditioning and boilers or similar equipment should be prohibited in cotton storage areas. Separate buildings should be provided for such purposes or should be separated from storage areas by a standard 2-hour fire wall.

6-3.3.2 The term "reconditioning" applies mainly to cotton and is defined as any opening, drying, cleaning, or picking of bales of loose cotton by any means whatsoever.

Exception No. 1: Air drying (not compressed air) of baled cotton at room temperature where not more than one band is removed from each bale being so dried.

Exception No. 2: The picking of baled cotton by hand where not more than five bales are in the process of being picked on the premises at any one time, and where at least two bands remain on each bale so picked. Removal of more than one band is to be considered part of the picking process.

Exception No. 3: The opening of bales in the press room for pressing or recompressing.

Exception No. 4: The cleaning of baled cotton by brushing (manual only) where the process employed does not remove an appreciable quantity of lint.

Mechanical reconditioning operations should confine lint and "fly" to the reconditioning building and should be separated from cotton storage (or compress) by a standard fire wall without openings or by unobstructed clear spaces as outlined in Chapter 2.

6-4 Cutting and Welding.

6-4.1

Where cutting and welding operations are necessary, the precautions contained in NFPA 51, *Standard for the Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes*, should be followed.

6-4.2

Welding, soldering, brazing, or cutting should be permitted only by the authorization of management. Proper precautions should be observed and should include the following:

(a) A supervisor should be assigned to the operation.

(b) The area should be made fire-safe.

(c) Work should be removed to a safe area, where possible.

(d) Where these operations are performed on equipment or building components that cannot be moved, there should be no storage below or within a 35-ft (10.7-m) radius.

(e) Floors should be swept clean and wooden floors wet down within the 35-ft (10.7-m) radius.

(f)* The cutting and welding equipment to be used should be in good operating condition and properly maintained.

(g) Openings and cracks in wood construction should be tightly covered to prevent the passage of sparks.

(h) All cotton bordering the area should be protected by flameproofed covers or otherwise shielded with metal or asbestos guards or curtains. The edges of the covers at the floor should be tight to prevent sparks from escaping. This precaution should extend to where several covers are used to protect a large storage pile.

(i) All fire protection equipment should be in service and ready for immediate use.

(j) A fire watch should be maintained and equipped with a portable extinguisher during these operations for not less than 1 hour following the completion of open flame operation.

6-5* Waste Disposal.

Rubbish, trash, and other waste material should be disposed of at regular intervals. Approved waste cans with self-closing covers should be used where needed. Open fires and incinerator operations should be prohibited within 100 ft (30.5 m) of any cotton storage building.

6-6* Smoking.

Smoking should be strictly prohibited. “No smoking” signs should be posted conspicuously in prohibited areas.

Exception: Smoking may be permitted in locations prominently designated as safe smoking areas.

6-7 Maintenance and Inspection.

6-7.1

Fire walls, fire doors, fire door guards, and floors should be maintained in good repair at all times.

6-7.2

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire*

Protection Systems, should be referenced for information on the maintenance and service of sprinkler systems and water supplies.

6-7.3

All portable and manual fire extinguishing equipment should be maintained and serviced.

6-7.4*

As an aid in maintaining fire protection features and equipment in full service at all times, Figure A-6-7.4 provides a simple self-inspection form that contains a checklist of loss prevention principles. This sample form can be used without change or as a guide in establishing a specialized form to suit individual facilities. [*See Figure A-6-7.4.*]

6-8 Grass and Weeds.

All dried grass and weeds should be kept clear of buildings for at least 50 ft (15.2 m).

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 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*, 1996 edition.

NFPA 18, *Standard on Wetting Agents*, 1995 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 51, *Standard for the Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes*, 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 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 220, *Standard on Types of Building Construction*, 1995 edition.

NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*, 1995 edition.

NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance, and Operation*, 1992 edition.

NFPA 600, *Standard on Industrial Fire Brigades*, 1996 edition.

NFPA 601, *Standard for Security Services in Fire Loss Prevention*, 1996 edition.

7-1.2 Other Publications.

7-1.2.1 ASTM Publication. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19105.

ASTM E 119, *Standard Methods for Fire Tests of Building Construction and Materials*, 1995.

7-1.2.2 UL Publication. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 263, *Standard for Safety Fire Tests of Fire Resistance of Building Construction and Materials*, 1992.

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-1-3 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.

Table A-1-3 Typical Cotton Bale Types and Approximate Sizes

Bale Type	Dimensions (in.)	Dimensions (mm)	Avg. Wt. (lb)	Avg. Wt. (kg)	Volume (ft^3)	Volume (m^3)	Density (lb/ft^3)	Density (kg/m^3)
Gin, flat	55 × 45 × 28	1397 × 1143 × 711	500	226.8	40.1	1.13	12.5	201
Modified gin, flat	55 × 45 × 24	1397 × 1143 × 610	500	226.8	34.4	0.97	14.5	234
Compressed, standard	57 × 29 × 23	1448 × 736 × 584	500	226.8	22.0	0.62	22.7	366
Gin, standard	55 × 31 × 21	1397 × 787 × 533	500	226.9	20.7	0.58	24.2	391
Compressed, universal	58 × 25 × 21	1475 × 635 × 533	500	226.8	17.6	0.50	28.4	454
Gin, universal	55 × 26 × 21	1397 × 660 × 533	500	226.8	17.4	0.49	28.7	463
Compressed, high density	58 × 22 × 21	1473 × 559 × 533	500	226.8	15.5	0.44	32.2	515

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-2-3.2

For a complete description of construction Types I, II, III, IV, and V, see NFPA 220, *Standard on Types of Building Construction*.

A-3-1

One building, compartment, or section classed as a fire division should not contain more than 10,000 bales of cotton if protected by a sprinkler system in accordance with Chapter 4, nor more than 5000 bales if not so protected. (*See Section 2-3.*)

A-4-1.3.5 Limited tests and actual fire experience indicate an initial low heat release; thus, sprinklers in the ordinary temperature range should offer some advantage by opening faster than those of intermediate or high temperature classifications under similar conditions.

A-4-6.4

For further information, see NFPA 13E, *Guide for Fire Department Operations in Properties Protected by Sprinkler and Standpipe Systems*.

A-5-6

In the case of buildings, sprinklered or unsprinklered, the clear space may be permitted to be reduced up to 50 percent if construction is fire-resistive or if fac- ing walls are masonry and parapeted with adequately protected openings. This area reduction also may be permitted to be applied to noncombustible buildings of a type limited to corrugated iron or asbestos panel walls and roof on a steel frame.

A-5-7.1.2 Where hose reels are used, they should be able to be pulled easily by two persons.

A-5-8.2

The U.S. Department of Transportation (DOT) has safety jurisdiction over a major segment of the trucking industry, specifically those vehicles used in transportation for interstate or foreign commerce. Reference also should be made to NFPA 512, *Standard for Truck Fire Protection*, which incorporates many requirements of DOT's Federal Motor Carrier Safety Regulations for the benefit of those not subject to DOT safety jurisdiction.

A-6-2.2

Lift trucks are a common cause of fires in cotton warehouses, due mainly to the lack of maintenance and cleanliness and the alteration or improper substitution of fire safety features.

A-6-4.2(f) Personnel operating arc welding or cutting equipment should be protected from possible shock.

A-6-5

For additional details, see NFPA 82, *Standard on Incinerators and Waste and Linen Handling Systems and Equipment*.

A-6-6

The cooperation of employees is more easily secured where a reasonable smoking policy is adopted, with smoking allowed in specified locations where there is little hazard, at specified times, and under suitable supervision. Complete prohibition is likely to lead to surreptitious smoking in out-of-the-way locations where the hazard is most dangerous.

WAREHOUSE NO.	COMPARTMENT NO.

General Housekeeping	YES	NO
1. Inside Buildings		
(a) Floor and dock areas clean of loose cotton and trash?	☐	☐
(b) Covered metal containers for loose cotton and trash?	☐	☐
2. Outside Buildings		
(a) Surrounding areas free of dried grass, weeds, and combustible trash?	☐	☐
Smoking		
(a) Evidence of smoking in unauthorized areas?	☐	☐
(b) Signs posted and readily visible?	☐	☐
Electrical Equipment		
(a) Extension cords prohibited?	☐	☐
(b) Storage in contact with lights or wiring?	☐	☐
(c) Wiring properly supported and undamaged?	☐	☐
(d) Circuits properly fused?	☐	☐
(e) All panels, junction, switch, and receptacle boxes covered?	☐	☐
Mechanical Equipment		
(a) Listed for fiber storage (Type DS, DY, ES, EE, EX, GS, or LPS)?	☐	☐
(b) Spark-retardant mufflers maintained?	☐	☐
(c) Refueled outside at designated area?	☐	☐
(d) Stored outside when idle?	☐	☐
(e) General condition and maintenance good?	☐	☐
Buildings		
(a) Fire walls in good repair, including around fire door openings?	☐	☐
(b) Fire doors in proper working condition and tested for ease of closing each week? (Overhead, roll-type doors should be tested at least annually.)	☐	☐
(c) Fire door guards in place and maintained?	☐	☐
(d) Floor and exterior walls in good repair?	☐	☐
(e) Exterior wall openings have doors and windows in place that close properly and lock?	☐	☐
(f) Space under grade floor, if any, closed off?	☐	☐
Storage Arrangements		
1. Storage blocks		
(a) Within prescribed height [15 ft (4.6 m)]?	☐	☐
(b) Sprinkler heads unimparied [18-in. (457-mm) clearance]?	☐	☐
(c) Block sizes limited to 700 bales pressed or 350 flat?	☐	☐
(d) Tiered storage stable and secure?	☐	☐
2. Aisles		
(a) At least one main aisle 12 ft (3.7 m) or more in width?	☐	☐
(b) Cross or work aisles at least 4 ft (1.2 m) in width?	☐	☐

Fire Department	YES	NO
(a) Phone number prominently displayed at each phone?	☐	☐
(b) Personnel instructed on procedure in case of fire?	☐	☐
Watch Service		
(a) Making regular rounds?	☐	☐
(b) All key stations punched?	☐	☐
(c) Records checked, dated, and filed?	☐	☐
Fire Alarm Service		
(a) Automatic fire alarm system in service?	☐	☐
(b) Manual pull stations clearly marked and accessible?	☐	☐
(c) Date last tested?	☐	☐
Manual Extinguishing Equipment Portable Extinguishers		
1. Hand Units		
(a) Properly placed and accessible?	☐	☐
(b) Recharged within the last year?	☐	☐
(c) All in good condition?	☐	☐
2. Containers and Buckets		
(a) Properly distributed?	☐	☐
(b) Kept full?	☐	☐
(c) Two buckets per barrel?	☐	☐
3. Mobile Equipment		
(a) Properly placed and protected from damage?	☐	☐
(b) Charged and ready for service?	☐	☐
Inside Hose		
(a) Hose and nozzle attached to each?	☐	☐
(b) Racked and in good condition?	☐	☐
(c) Easily accessible and ready for use?	☐	☐
(d) Valves operate readily?	☐	☐
Yard Hydrants and Hose Houses		
(a) Readily accessible?	☐	☐
(b) Hose racked or reeled and in good condition?	☐	☐
(c) Nozzles, spanners, hydrant wrench available?	☐	☐
(d) Hydrants operable?	☐	☐
(e) General condition: Good ☐ Poor ☐		

Note: 1 in. = 25.4 mm; 1 ft = 0.3048 m

REMARKS (Report on any unusual conditions and action taken):

Report by: **Date:**

Figure A-6-7.4 Sample loss prevention self-inspection form for baled cotton storage.

A-6-7.4

See Figure A-6-7.4.

Appendix B Guidelines for Fighting Fires in Baled Cotton

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

B-1 Introduction.

The information contained in this appendix is a summary of knowledge gained over the years by cotton warehouse personnel, fire fighters, and insurance authorities in fighting fires in the Cotton Belt.

A baled cotton fire has peculiarities that should be understood and respected if a large loss is to be avoided with minimum danger to personnel. Automatic sprinklers, if properly designed and supplied, can be expected to control a baled cotton fire where storage methods outlined in this recommended practice are followed, but extinguishment should not be expected.

The primary rule for any fire is always to call the responding fire department first. Fighting fires of any type is a profession and, even where a well-trained private fire organization is available, professional aid should be effected as soon as possible, and plant personnel should not be unduly exposed to the peril.

The myriad of small fibers that make up a cotton bale, especially a naked bale or one wrapped in burlap, and cover its surface offer a highly vulnerable source of ignition as well as the potential for a rapid flamespread, also known as “flashover.” A flashover is usually followed by a slower flamespread at the surface, then tenacious burrowing into the pile between bales and penetration of the interiors of individual bales. High density bales are less vulnerable to a burrowing fire, but the possibility of such a fire should not be ignored.

B-2 Causes.

Some of the causes of cotton fiber fires include breaking metal bands (ties) that strike other metallic objects resulting in sparks, fire-packed bales, electrical faults, mechanical equipment (defective lift trucks), friction (bale ties rubbing together, railroad boxcars), lightning, cutting and welding, and smoking. Sparks from bale ties and fire-packed bales appear to be the most prominent fire cause. Incendiarism and exposures are also a consideration.

B-3 Incipient Stage.

If caught in the incipient stage, control can often be effected, provided the proper procedures are followed. Portable extinguishing equipment, such as containers and pails, or pressurized or pump-type water units, can be used to wet down the exterior of the bale quickly.

If small extinguishers are not successful, portable, wheeled, wetting agent tanks or standpipe hose, or both, should be used. The last resort is hose streams from outside hydrants. Extreme caution should be exercised when using straight hose streams, as the force of the stream could scatter the burning wads or portions of cotton over a wide area. Spray or fog nozzles are recommended, but, if not available, it might be possible to deflect a solid stream off the walls, roof, or other solid object.

Once the exterior of the bale(s) is fully wet down and fire is suppressed, the bales involved then should be removed to an outside, safe location for final extinguishment.

> CAUTION: An obviously burning bale should never be dragged or mechanically moved down aisles, as this is likely to spread the fire to bales bordering the aisle. (*See Section B-9.*)

B-4 Active Stage in Sprinklered Buildings.

If a fire progresses well beyond the incipient stage or involves more than a few bales and further firespread is likely, the building could readily prove untenable and dense smoke could quickly obscure vision. It then is best to have all personnel vacate the building to a point of safety. As drafts, including early venting through roofs and walls, are undesirable, it is essential to leave the building unventilated and close all doors and cut off all possible drafts to the building or section involved. This reduces available oxygen to the fire, and the dense smoke suppresses fire intensity. Drafts not only provide fresh air to increase fire intensity but also can blow heat away from the fire, opening sprinklers beyond the fire area and possibly overtaxing the available water to the sprinkler system.

The sprinkler system should be given a chance to do its job. DO NOT VENTILATE! Ventilating a cotton fire can cause it to flash out of control, spread with explosive violence, and open an excessive number of sprinklers.

After the fire is under control of the sprinkler system, the compartment door should be opened only enough to use fire hose or to enter and remove the cotton. The smoldering bales should be removed to the outside as soon as possible for individual attention. Extreme caution should be exercised when entering a fire area. Entry should be on the downwind side, if possible, to avoid creating draft conditions that could cause the fire to reignite. It is important to remain alert for gas explosions. If the fire appears to flare up again, the building should be vacated immediately and the doors again should be closed tightly and the sprinkler system should be allowed to regain control.

B-5 Sprinkler Failure.

If the sprinkler system fails to maintain fire control, then hose streams should be used, preferably through door openings only large enough for the hose.

Where it is apparent that the fire is beyond the control of the sprinklers and the building is nearing the point of collapse, the control valve(s) to the sprinkler systems in the building or section involved should be shut off to conserve water for hose stream use.

B-6 Active Stage in Nonsprinklered Buildings.

Immediately on arrival at the fire, all openings to the compartment involved should be closed.

As many hose lines as possible, preferably supplied with a wetting agent, should be available.

The doors should be opened only enough to allow the use of the hose in a spray-like fashion. Caution should be exercised to open these doors slowly to minimize the chance of an explosion. The doors on the opposite sides of the compartment should not be opened, which would allow a cross-draft. Only the door on the lee side, and not the windward side, of the building should be opened.

B-7 Cotton Yard Fires.

Conditions in a cotton yard fire are not as controllable as those in a warehouse fire, since draft conditions are almost entirely dependent upon the climatic conditions at the time of the fire; and, if an adverse wind prevails, a small involvement can easily become a catastrophe. Preplanning is particularly important in this case. Upon arrival at a cotton yard fire, the following steps should be taken immediately:

(a) If available, fire department connection to the hydrants should be utilized.

(b) Hose lines should be laid out.

(c) Using divided stream nozzles, water should be applied ahead and downwind of the fire and then worked toward the fire.

(d) Bales and dunnage should be checked underneath for fire.

(e) It is important to remain alert for flying sparks.

(f) The nearby uninvolved cotton should be removed to create a fire break.

(g) Burned cotton should be removed to a segregated area.

B-8 After Watch.

Where the fire-involved cotton has been removed and leaves behind undamaged stock, a minute and unobserved spark often causes a rekindling of the previous fire with disastrous results. The involved area should be inspected and carefully cleaned. Hose lines and fire department watch should be maintained until the area is known to be safe. Before leaving the scene of the fire, responsible plant personnel should be advised that after watch should be kept for at least 24 hours. One of the most disastrous fires on record could possibly have been prevented with adequate after watch following a minor involvement.

B-9 Salvage Operations.

Salvage is important, and every precaution should be taken to protect the salvage. The usual severity of a fire in a cotton warehouse, along with the appearance of the charred bales, is misleading with respect to the amount of remaining salvage.

Water does not damage cotton, and if the charred bales are kept cool with hose streams until proper salvage operation is begun, the quantity of the loss can be reduced substantially.

After the fire is brought under control, all bales involved should be removed to a safe outside location as quickly as possible and practicable. Each bale then should be handled individually in order to effect complete extinguishment. This is best accomplished by the use of small hose lines or barrels and buckets, using a wetting agent known as wet water.

> WARNING: DO NOT REMOVE THE BANDS OR WIRES FROM THE BALES. To do so exposes more lint to the fire and threatens the loss of the entire bale.

Salvage crews should be ready to move the cotton out of the involved shed as rapidly as possible. *Extreme* caution should be exercised in preparing and watching the path along which the burned bales are removed from the involved shed. Burning fibers of cotton are easily blown from the bale, especially in the haste and excitement of moving the bales outside. It might be necessary to move the uninvolved bales away from the exit route (or from the entire compartment) or even to make a hole in the side of the compartment. The spread of fire along the exit route caused by burning bales is not uncommon! The burning bales should be wetted down and moved to a safe, segregated place as soon as possible for individual attention.

The following are steps to be taken in the salvage operation:

(a) An open area, without exposures, into which the burning bales can be moved should be selected.

(b) A salvage crew should be stationed at the yard.

(c) A good supply of wetting agent should be available.

(d) A good supply of water should be available.

(e) Containers, pails, and stirrup pump-type extinguishers should be available, filled with wet water.

(f) Burning bales should be wet down and removed from the fire area as soon as possible. They should be placed approximately 3 ft (0.9 m) apart in an open area away from other exposures.

(g) Care should be exercised in removing these bales so as not to start another fire in the process. If the side of the compartment is metal-clad or frame, it might be best to remove a portion of the side so that the cotton can be removed. Some warehouse personnel take the time to remove cotton from those compartments through which the burning bales travel before salvage operations are allowed to start. If there is any question regarding additional exposures, they should be removed, if possible, before moving the burning bales.

(h) Any outside blaze on the bale should be knocked down. The wet water should be applied to each smoldering spot on the bale. Often a handful of cotton soaked in the wet water can be applied directly on or into the smoldering spot. Cotton fires burrow into the bale, so it is necessary to apply the wet water as far into the hole as possible, soaking the area thoroughly. In order to be certain the fire is out, the burned cotton should be removed from each hot spot while applying wet water to the hole. When the area around the spot is no longer warm, it can be assumed that the fire has been extinguished.

(i) The bands from the bales should not be removed. To do so exposes more lint to the fire, and the bale will probably be a complete loss.

(j) Bales involved in a fire should be closely watched for at least 5 days after the last spark is believed to have been extinguished.

B-10 Fire-packed Bales.

During the cotton ginning operation, sparks, caused by stones, metal, or other foreign objects in the seed cotton striking metal parts of the gin, can ignite the fibers. Occasionally, a fire immediately erupts, but often the smoldering lint is carried onto the press box where it can be packed, undetected, into the bale. Usually the fire burns through to the outside of the bale within a few hours, but it can remain undetected for several days. Sometimes the odor is noticeable or the bale feels excessively warm.

These bales are known as fire-packed bales and are a major cause of fires in baled cotton.

The recommended procedure for handling and extinguishing fire-packed bales is as follows:

(a) All known or suspect fire-packed bales should be stored in the open and segregated from buildings and other storage. They should be separated about 3 ft (0.9 m) from other such bales.

(b) These bales should be under constant surveillance to detect fire as soon as it moves to the surface.

(c) A supply of an approved wetting agent and at least one stirrup pump should be available at all times.

(d) When fire is detected, the area around the hot spot should be wetted immediately to prevent the spread of the fire. The hot spot then should be saturated with wet water. The burned cotton should be removed by hand while constantly applying water to the hole. This procedure should be continued until no warm areas are detected. It is not uncommon for several fires to be packed into a single bale.

(e) DO NOT REMOVE THE BANDS FROM THE BALE, as this exposes more cotton fibers to ignition and usually results in the total loss of the bale.

(f) Fire-packed bales or bales suspected of being fire-packed should remain in quarantine and under surveillance for at least 5 days. After this time, they can be considered to be safe and handled in the regular manner.

NOTE: There is no set time after which a fire can be considered extinguished in a bale, as this depends on the thoroughness of extinguishment. However, 5 days after the fire is believed to have been extinguished is generally considered to be a rule of thumb safe period.

Appendix C Referenced Publications

C-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.

C-1.1 NFPA Publications.

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

NFPA 13E, *Guide for Fire Department Operations in Properties Protected by Sprinkler and Standpipe Systems*, 1995 edition.

NFPA 82, *Standard on Incinerators and Waste and Linen Handling Systems and Equipment*, 1994 edition.

NFPA 220, *Standard on Types of Building Construction*, 1995 edition.

NFPA 512, *Standard for Truck Fire Protection*, 1994 edition.

NFPA 231F

1996 Edition

Standard for the Storage of Roll Paper

1996 Edition

This edition of NFPA 231F, *Standard for the Storage of Roll Paper*, was prepared by the Technical Committee on General Storage 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 231F was approved as an American National Standard on February 2, 1996.

Origin and Development of NFPA 231F

The need for a standard for storage of roll paper was brought to the attention of the Association after the occurrence of several disastrous fires in warehouses containing roll paper. The lack of a national standard had made designing, building, and using a facility for the storage of roll paper an expensive undertaking, sometimes resulting in substandard fire protection. Because of the unique characteristics of roll paper, the Standards Council was petitioned and agreed to have the Technical Committee on General Storage develop NFPA 231F, *Standard for the Storage of Roll Paper*. The first edition was adopted in 1984. A subsequent edition was adopted in 1987.

The 1996 edition of NFPA 231F was revised to incorporate advances in sprinkler technology. Further revisions address miscellaneous storage, retroactivity, and changes to the scope of the document. A number of editorial changes were also incorporated to improve the user friendliness of the document.

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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.

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 safeguarding general warehousing and commodities stored indoors or outdoors against fire. This Committee does not cover storage specifically covered by other NFPA standards.

NFPA 231F

Standard for the Storage of Roll Paper

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 C.

Chapter 1 Introduction

1-1 Scope.

1-1.1

This standard shall apply to the storage of roll paper in buildings or structures.

1-1.2*

This standard shall apply to new facilities or where converting existing buildings to a roll paper storage occupancy. It can be used as a basis for evaluating existing storage facilities.

1-1.3

This standard shall not apply to:

(a) Storage in unsprinklered buildings and structures.

(b) Storage on racks, which shall be in accordance with NFPA 231C, *Standard for Rack Storage of Materials*.

(c) Miscellaneous storage, which shall be in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

(d) Storage of waxed paper, synthetic paper, and palletized roll storage other than on a single floor pallet or raised floor platform.

1-2 Purpose.

The purpose of this standard is to provide a reasonable degree of protection for the storage of roll paper where stored in buildings or structures by means of installation requirements based upon sound engineering principles, test data, and field experience. Nothing in this standard is intended to restrict new technologies or alternate arrangements, provided that the level of protection prescribed by the standard is not lowered.

1-3 Retroactivity Clause.

The provisions of this document shall be considered necessary to provide a substantial level of protection 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.

Approved.* Acceptable to the authority having jurisdiction.

Array.

Closed Array. A vertical storage arrangement in which the distances between columns in both directions are short [not more than 2 in. (50 mm) in one direction and 1 in. (25 mm) in the other].

Open Array. A vertical storage arrangement in which the distance between columns in both directions is lengthy (all vertical arrays other than closed or standard).

*Standard Array.** A vertical storage arrangement in which the distance between columns in one direction is short [1 in. (25 mm) or less], and is in excess of 2 in. (50 mm) in the other direction.

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

Banded Storage. Rolls provided with a circumferential steel strap [$^{3}/_{8}$ in. (9.5 mm) or wider] at each end of the roll.

Clearance. The distance from the top of storage to ceiling sprinkler deflectors.

Column. A single vertical stack of rolls.

Core. The central tube around which paper is wound to form a roll.

Early Suppression Fast Response (ESFR) Sprinkler. See NFPA 13, *Standard for the Installation of Sprinkler Systems.*

Encapsulated. A method of packaging consisting of a plastic sheet completely enclosing the sides and top of roll paper.

Extra Large Orifice (ELO) Sprinkler. See NFPA 13, *Standard for the Installation of Sprinkler Systems*.

Large Drop Sprinkler. See NFPA 13, *Standard for the Installation of Sprinkler Systems*.

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.

Paper (general term). The term for all kinds of felted sheets made from natural fibrous materials, usually vegetable but sometimes mineral or animal, and formed on a fine wire screen from water suspension.

Rack Storage. Any combination of vertical, horizontal, or diagonal members that can support roll paper storage. Racks can be fixed or portable.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Spray Sprinkler. See NFPA 13, *Standard for the Installation of Sprinkler Systems*.

Sprinkler Temperature Rating.

Ordinary Temperature Rated Sprinklers. Includes temperature ratings of 135°F to 170°F (57°C to 77°C).

Intermediate Temperature Rated Sprinklers. Includes temperature ratings of 170°F to 250°F (77°C to 121°C).

High Temperature Rated Sprinklers. Includes temperature ratings of 250°F to 300°F (121°C to 149°C).

Storage.

Horizontal Storage. Rolls stored with the cores in the horizontal plane (on-side storage).

Miscellaneous Storage. See NFPA 13, *Standard for the Installation of Sprinkler Systems*.

*Storage Height.** The maximum vertical distance above the floor at which roll paper is normally stored.

Vertical Storage. Rolls stored with the cores in the vertical plane (on-end storage).

*Wrapped Storage.** Rolls provided with a complete heavy kraft covering around both sides and ends.

Weight of Paper.* See A-2.

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). The liter unit, which is not part of but is recognized by SI, is commonly used in international fire protection.

1-5.1

If a value for measurement as given in this standard is followed by an equivalent value in other units, the first value shall be considered to be the requirement. The equivalent value might be approximate.

1-5.2

SI units have been converted by multiplying the quantity by the conversion factor and then rounding the result to the appropriate number of significant digits.

Chapter 2* Classification of Roll Paper

2-1 General.

For the purposes of this standard, the following classifications of paper shall apply. These classifications shall be used to determine the sprinkler system design criteria.

2-1.1 Heavyweight Class.

Includes paperboard and paper stock having a basis weight [weight per 1000 ft^2 (92.9 m^2)] of 20 lb (9.1 kg) or greater.

2-1.2 Mediumweight Class.

Includes the broad range of papers having a basis weight [weight per 1000 ft^2 (92.9 m^2)] of 10 lb to 20 lb (4.5 kg to 9.1 kg).

2-1.3 Lightweight Class.

Includes all papers having a basis weight [weight per 1000 ft^2 (92.9 m^2)] less than 10 lb (4.5 kg).

2-1.4 Tissue.

Includes the broad range of papers of characteristic gauzy texture, which in some cases are fairly transparent. For the purposes of this standard, tissue is defined as the soft, absorbent type, regardless of basis weight; specifically, crepe wadding and the sanitary class including facial tissue, paper napkins, bathroom tissue, and toweling.

Chapter 3 Building Construction

3-1 Construction.

3-1.1*

Buildings used for storage of materials that are stored and protected in accordance with this standard shall be permitted to be of any of the types described in NFPA 220, *Standard on Types of Building Construction*.

3-1.2

Adequate access shall be provided to all portions of the premises for fire-fighting purposes.

3-2* Emergency Smoke and Heat Venting.

The protection outlined in this standard shall apply to buildings with or without roof vents and draft curtains.

3-3* Structural Steel Protection.

The protection outlined in this standard shall apply to buildings with or without fireproofing or other modes of steel protection.

Exception: Where modified by 4-2.2.

Chapter 4 Storage Arrangement

4-1 Piling Procedures and Precautions.

The floor load design shall take into account the added weight of water that could be absorbed during fire-fighting operations by certain commodities such as newsprint, corrugating medium, and tissue.

4-2 Commodity Clearance.

4-2.1

The clearance between the top of storage and sprinkler deflectors shall be in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

Exception: Where modified by this standard.

4-2.2

If the commodity is stored above the lower chord of roof trusses, at least 1 ft (0.3 m) of clear space shall be maintained to allow wetting of the truss unless the truss is protected with 1-hour fireproofing.

4-2.3

Storage clearances from ducts shall be maintained in accordance with 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*.

4-2.4

The clearance between stored materials and unit heaters, radiant space heaters, duct furnaces, and flues shall not be less than 3 ft (0.9 m) in all directions or shall be in accordance with the clearance shown on the approval agency label.

4-2.5*

Clearance to lights or light fixtures shall be maintained to prevent possible ignition.

4-2.6

Sufficient clearance around the path of fire door travel and around fire extinguishing and protection equipment shall be maintained to ensure accessibility for inspection and operational use.

4-3 Aisles.

4-3.1

Wall aisles shall be at least 24 in. (600 mm) wide to minimize possible structural damage from roll paper that expands with the absorption of water.

4-3.2*

Aisles shall be maintained to retard transfer of fire from one pile to another and to allow convenient access for fire fighting, salvage, and removal of storage.

Chapter 5 Fire Protection

5-1 Automatic Sprinkler Systems.

5-1.1

Sprinkler systems installed in buildings or structures used for the storage of roll paper shall be in accordance with NFPA 13, *Standard for Installation of Sprinkler Systems*.

Exception: Where modified by this chapter.

5-1.1.1 Where buildings are occupied in part for vertical roll paper storage and only a portion of the sprinkler system is hydraulically designed, the design area shall extend not less than 20 ft (6.1 m) beyond the area occupied by the roll paper storage.

5-1.1.2 Wet-pipe systems shall be used in tissue storage areas.

5-1.1.3 Horizontal storage of heavyweight or mediumweight paper shall be protected as a closed array.

5-1.1.4 Mediumweight paper shall be permitted to be protected as heavyweight paper where wrapped completely on the sides and both ends, or where wrapped on the sides only with steel bands.

Wrapping material shall be either a single layer of heavyweight paper with a basis weight of 40 lb (18.1 kg), or two layers of heavyweight paper with a basis weight of less than 40 lb (18.1 kg).

5-1.1.5 Lightweight paper or tissue paper shall be permitted to be protected as mediumweight paper where wrapped completely on the sides and both ends, or where wrapped on the sides only with steel bands.

Wrapping material shall be either a single layer of heavyweight paper with a basis weight of 40 lb (18.1 kg), or two layers of heavyweight paper with a basis weight of less than 40 lb (18.1 kg).

5-1.1.6 For purposes of sprinkler system design criteria, lightweight class paper shall be protected as tissue.

5-1.2 Storage Less than 10 ft (3.1 m) in Height.

5-1.2.1 Storage of heavyweight or mediumweight classes of rolled paper up to 10 ft (3.1 m) in height shall be protected by sprinklers designed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, for Ordinary Hazard, Group 2 densities.

5-1.2.2 Storage of tissue and lightweight classes of paper up to 10 ft (3.1 m) in height shall be protected by sprinklers in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, for Extra Hazard, Group 1 densities.

5-1.3 Spray Sprinklers.

5-1.3.1 Sprinkler design criteria for storage of roll paper 10 ft (3.1 m) high and higher in buildings or structures with roof or ceilings up to 30 ft (9.1 m) shall be in accordance with Tables 5-1.3.1(a) and (b). For definition of storage height, see Section 1-4.

Table 5-1.3.1(a) Automatic Sprinkler System Design Criteria — Spray Sprinklers for Buildings or Structures with Roof or Ceilings up to 30 ft (gpm/ft^2)

Storage Height (ft)	Clearance (ft)	Heavyweight					Mediumweight				Tissue
		Closed Array Banded or Unbanded	Standard Array		Open Array		Closed Array Banded or Unbanded	Standard Array		Open Array Banded or Unbanded	All Storage Arrays
			Banded	Unbanded	Banded	Unbanded		Banded	Unbanded		
10	≤5	0.3/2000	0.3/2000	0.3/2000	0.3/2000	0.3/2000	0.3/2000	0.3/2000	0.3/2000	0.3/2000	0.45/2000
10	>5	0.3/2000	0.3/2000	0.3/2000	0.3/2000	0.3/2000	0.3/2000	0.3/2000	0.3/2000	0.3/2000	0.45/2500
15	≤5	0.3/2000	0.3/2000	0.3/2000	0.3/2500	0.3/3000	0.3/2000	0.3/2000	0.45/2500	0.45/2500	0.60/2000
15	>5	0.3/2000	0.3/2000	0.3/2000	0.3/3000	0.3/3500	0.3/2000	0.3/2500	0.45/3000	0.45/3000	0.60/3000
20	≤5	0.3/2000	0.3/2000	0.3/2500	0.45/3000	0.45/3500	0.3/2000	0.45/2500	0.6/2500	0.6/2500	0.75/2500
20	>5	0.3/2000	0.3/2500	0.3/3000	0.45/3500	0.45/4000	0.3/2500	0.45/3000	0.6/3000	0.6/3000	0.75/3000
25	≤5	0.45/2500	0.45/3000	0.45/3500	0.6/2500	0.6/3000	0.45/3000	0.6/3000	0.75/2500	0.75/2500	Note 1

NOTE 1: Sprinkler protection requirements for tissue stored above 20 ft have not been determined.
NOTE 2: Densities or areas, or both, shall be permitted to be interpolated between any 5-ft storage height increment.

Table 5-1.3.1(b) Automatic Sprinkler System Design Criteria — Spray Sprinklers for Buildings or Structures with Roof or Ceilings up to 9.1 m [(lpm)/m^2]

Storage Height (m)	Clearance (m)	Heavyweight					Mediumweight				Tissue
		Closed Array Banded or Unbanded	Standard Array		Open Array		Closed Array Banded or Unbanded	Standard Array		Open Array Banded or Unbanded	All Storage Arrays
			Banded	Unbanded	Banded	Unbanded		Banded	Unbanded		
3.1	≤1.5	12.2/185.8	12.2/185.8	12.2/185.8	12.2/185.8	12.2/185.8	12.2/185.8	12.2/185.8	12.2/185.8	12.2/185.8	18.3/185.8
3.1	>1.5	12.2/185.8	12.2/185.8	12.2/185.8	12.2/185.8	12.2/185.8	12.2/185.8	12.2/185.8	12.2/185.8	12.2/185.8	18.3/232.3
4.6	≤1.5	12.2/185.8	12.2/185.8	12.2/185.8	12.2/232.3	12.2/278.7	12.2/185.8	12.2/185.8	18.3/232.3	18.3/232.3	24.5/185.8
4.6	>1.5	12.2/185.8	12.2/185.8	12.2/185.8	12.2/278.7	12.2/322.2	12.2/185.8	12.2/232.3	18.3/278.7	18.3/278.7	24.5/278.7
6.1	≤1.5	12.2/185.8	12.2/185.8	12.2/232.3	18.3/278.7	18.3/325.2	12.2/185.8	18.3/232.3	24.5/232.3	24.5/232.3	30.6/232.3
6.1	>1.5	12.2/185.8	12.2/232.3	12.2/278.7	18.3/325.2	18.3/371.6	12.2/232.3	18.3/278.7	24.5/278.7	24.5/278.7	30.6/278.7
7.6	≤1.5	18.3/232.3	18.3/278.7	18.3/325.2	24.5/232.3	24.5/278.7	18.3/278.7	24.5/278.7	30.6/232.3	30.6/232.3	Note 1

NOTE 1: Sprinkler protection requirements for tissue stored above 6.1 m have not been determined.
NOTE 2: Densities or areas, or both, shall be permitted to be interpolated between any 1.5-m storage height increment.

5-1.3.2 Large orifice sprinklers shall be used for new sprinkler system installations.

Exception: The use of extra large orifice sprinklers shall be permitted where listed for asuch use and where installed at a minimum operating pressure of 10 psi (69 kPa).

5-1.3.3* Where dry-pipe systems are used in Heavyweight Class or Mediumweight Class storage areas, the areas of operation indicated by Tables 5-1.3.1(a) and (b) shall be increased by 30 percent.

5-1.3.4 The minimum discharge pressure from any sprinkler in the design area shall not be less than 15 psi (105 kPa).

5-1.3.5* High temperature sprinklers shall be used for installations protecting roll paper stored 15 ft (4.6 m) or higher.

5-1.3.6 The protection area per sprinkler shall not exceed 100 ft^2 (9.3 m^2) or be less than 70 ft^2 (6.5 m^2).

5-1.4 Large Drop Sprinklers.

Where automatic sprinkler system protection utilizes large drop sprinklers, hydraulic design criteria shall be as specified in Table 5-1.4. Design discharge pressure shall be 50 psi (350 kPa) in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*. The number of sprinklers to be calculated is indicated based on storage height, clearance, and system type.

Table 5-1.4 Automatic Sprinkler System Design Criteria — Large Drop Sprinklers (number of sprinklers to be calculated)

Storage Height		Clearance		System Type	Heavyweight					Mediumweight					Tissue
					Closed Array	Standard Array		Open Array		Closed Array	Standard Array		Open Array		All Storage Arrays
(ft)	(m)	(ft)	(m)		Banded or Unbanded	Banded	Unbanded	Banded	Unbanded	Banded or Unbanded	Banded	Unbanded	Banded	Unbanded	
20	6.1	< 10	< 3.1	W	15	15	15	15	N/A	15	15	15	N/A	N/A	See Note
20	6.1	< 10	< 3.1	D	25	25	25	N/A	N/A	25	25	25	N/A	N/A	N/A
26	7.9	< 34	< 10.4	W	15	15	15	15	N/A	N/A	N/A	N/A	N/A	N/A	N/A
26	7.9	< 34	< 10.4	D	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

W = wet; D = dry; N/A = not applicable.
For definition of storage height, see Section 1-4.
NOTE: 25 large drop sprinklers @ 75 psi (5.2 bars) for closed or standard array; other arrays N/A.

5-1.5 ESFR Sprinklers.

Where automatic sprinkler system protection utilizes ESFR sprinklers, hydraulic design criteria shall be as specified in Table 5-1.5. Design discharge pressure shall be applied to 12 operating sprinklers in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

Table 5-1.5 Automatic Sprinkler Design Criteria — ESFR Sprinklers (maximum height of storage permitted) 5-2 High-Expansion Foam.

ESFR K Factor	System Type	Pressure (psi)	Pressure (bars)	Building Height (ft)	Building Height (m)	Heavyweight Closed (ft)	Heavyweight Closed (m)	Heavyweight Standard (ft)	Heavyweight Standard (m)	Heavyweight Open (ft)	Heavyweight Open (m)	Mediumweight Closed (ft)	Mediumweight Closed (m)	Mediumweight Standard (ft)	Mediumweight Standard (m)	Mediumweight Open (ft)	Mediumweight Open (m)	Tissue All Arrays
11.0—11.5	Wet	50	3.4	25	7.6	20	6.1	20	6.1	20	6.1	20	6.1	20	6.1	20	6.1	N/A
13.5—14.5	Wet	50	3.4	30	9.1	25	7.6	25	7.6	25	7.6	25	7.6	25	7.6	25	7.6	N/A
13.5—14.5	Wet	75	5.2	40	12.2	30	9.1	30	9.1	30	9.1	N/A		N/A		N/A		N/A

For definition of storage height, see Section 1-4.
Pressure = Operating sprinkler discharge pressure.

5-2.1

Where high-expansion foam systems are installed in addition to automatic sprinklers, they shall be installed in accordance with NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*.

Exception: Where modified by this chapter.

5-2.2

Where high-expansion foam systems are installed in Heavyweight Class and Mediumweight Class storage areas, sprinkler discharge design densities can be reduced to not less than 0.24 gpm/ft^2 [(10 lpm)/m^2] with a minimum operating area of 2000 ft^2 (186 m^2).

5-2.3

Where high-expansion foam systems are installed in tissue storage areas, sprinkler discharge densities and areas of application shall not be reduced below those provided in Tables 5-1.3.1(a) and (b).

5-2.4

High-expansion foam systems shall be automatic in operation.

5-3 Water Supplies.

5-3.1

The water supply system for automatic fire protection systems shall be designed for a minimum duration of 2 hours.

Exception: For ESFR sprinklers, the water supply duration shall be 1 hour.

5-3.2

At least 500 gpm (1893 lpm) shall be added to the sprinkler demand for large and small hose stream demand.

Exception: For ESFR sprinklers, the hose stream allowance shall be for 250 gpm (947 lpm).

5-3.3

The water supply design shall include the demand of the automatic sprinkler system plus the hose stream demand plus, where provided, the high-expansion foam system.

5-3.4 Hydrants.

At locations without public hydrants, or where hydrants are not within 250 ft (75 m), private hydrants shall be installed in accordance with NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*.

5-4 Manual Inside Protection.

5-4.1 Small Hose Systems.

Small hoselines [1 $^{1}/_{2}$ in. (38.1 mm)] shall be available to reach all portions of the storage area.

5-4.2 Portable Fire Extinguishers.

Portable fire extinguishers shall be provided in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*.

Exception: In storage areas where fixed, 1 $^{1}/_{2}$-in. (38.1-mm) hoselines are available to reach all portions of the storage area, up to $^{1}/_{2}$ of the required complement of portable fire extinguishers for Class A fires shall be permitted to be omitted.

5-5 Maintenance.

The fire protection system shall be maintained in accordance with NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*.

A fire watch shall be maintained when the sprinkler system is not in service.

5-6 Fire Organization.

5-6.1

Arrangements shall be made to allow rapid entry into the premises by the municipal fire department, police department, or other authorized personnel in case of fire or other emergency.

5-6.2

Plant emergency organizations, where provided, shall be instructed and trained in the following procedures:

(a) Maintenance of the security of the premises;

(b) Means of summoning outside aid immediately in an emergency;

(c) Use of hand extinguishers and small [1 $^{1}/_{2}$-in. (38.1-mm)] hoselines on incipient fires and mop-up operations;

(d) Operation of sprinkler system and water supply equipment;

(e) Use of material-handling equipment while sprinklers are operating to effect final extinguishment;

(f) Supervision of sprinkler valves after the system is turned off so that the system can be reactivated if rekindling occurs;

(g)* Employee safety during fire-fighting and mop-up operations, including knowledge of the hazard potential of roll paper (i.e., collapse and tumbling);

(h)* Operation of foam systems and appropriate safety and evacuation procedures.

5-6.3

A fire watch shall be maintained when the sprinkler system is not in service.

5-7 Alarm Service.

An approved alarm system including sprinkler system waterflow and supervisory alarms shall be provided in accordance with NFPA 72, *National Fire Alarm Code*.

Exception: A local waterflow alarm shall be permitted where recorded guard service is provided or where the storage facilities are occupied on a 24-hour basis.

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 11A, *Standard for Medium- and High-Expansion Foam Systems*, 1994 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1994 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 72, *National Fire Alarm Code*, 1993 edition.

NFPA 90B, *Standard for the Installation of Warm Air Heating and Air Conditioning Systems*, 1993 edition.

NFPA 91, *Standard for the Exhaust Systems for Air Conveying of Materials*, 1995 edition.

NFPA 220, *Standard on Types of Building Construction*, 1995 edition.

NFPA 231C, *Standard for Rack Storage of Materials*, 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-1-1.2 Existing Storage Facilities.

Sprinkler systems protecting existing roll paper storage facilities should be evaluated in accordance with Tables A-1-1.2(a) and (b). While fire can be controlled by the protection shown in Tables A-1-1.2(a) and (b), greater damage can occur when the densities in Tables A-1-1.2(a) and (b) are used rather than those specified in Tables 5-1.3.1(a) and (b).

Table A-1-1.2(a) Automatic Sprinkler System Design Criteria — Spray Sprinklers for Existing Storage Facilities (gpm/ft2)

Storage Height (ft)	Clearance (ft)	Heavyweight					Mediumweight			
		Closed Array Banded or Unbanded	Standard Array		Open Array		Closed Array Banded or Unbanded	Standard Array		Open Array Banded or Unbanded
			Banded	Unbanded	Banded	Unbanded		Banded	Unbanded	
10	≤5	0.2/2000	0.2/2000	0.2/2000	0.25/2000	0.25/2000	0.2/2000	0.25/2000	0.3/2000	0.3/2000
10	>5	0.2/2000	0.2/2000	0.2/2000	0.25/2500	0.25/2500	0.2/2000	0.25/2000	0.3/2000	0.3/2000
15	≤5	0.25/2000	0.25/2000	0.25/2500	0.3/2500	0.3/3000	0.25/2000	0.3/2000	0.45/2500	0.45/2500
15	>5	0.25/2000	0.25/2000	0.25/2500	0.3/3000	0.3/3500	0.25/2000	0.3/2500	0.45/3000	0.45/3000
20	≤5	0.3/2000	0.3/2000	0.3/2500	0.45/3000	0.45/3500	0.3/2000	0.45/2500	0.6/2500	0.6/2500
20	>5	0.3/2000	0.3/2500	0.3/3000	0.45/3500	0.45/4000	0.3/2500	0.45/3000	0.6/3000	0.6/3000
25	≤5	0.45/2500	0.45/3000	0.45/3500	0.6/2500	0.6/3000	0.45/3000	0.6/3000	0.75/2500	0.75/2500
25	>5	0.45/3000	0.45/3500	0.45/4000	0.6/3000	0.6/3500	0.45/3500	0.6/3500	0.75/3000	0.75/3000
30	≤5	0.6/2500	0.6/3000	0.6/3000	0.75/2500	0.75/3000	0.6/4000	0.75/3000	0.75/3500	0.75/3500

NOTE: Densities or areas, or both, can be interpolated between any 5-ft storage height increment.

Table A-1-1.2(b) Automatic Sprinkler System Design Criteria — Spray Sprinklers for Existing Storage Facilities [(lpm)/m2]

Storage Height (m)	Clearance (m)	Heavyweight					Mediumweight			
		Closed Array Banded or Unbanded	Standard Array		Open Array		Closed Array Banded or Unbanded	Standard Array		Open Array Banded or Unbanded
			Banded	Unbanded	Banded	Unbanded		Banded	Unbanded	
3.1	≤1.5	0.76/185.8	0.76/185.8	0.76/185.8	0.95/185.8	0.95/185.8	0.76/185.8	0.95/185.8	12.2/185.8	12.2/185.8
3.1	>1.5	0.76/185.8	0.76/185.8	0.76/185.8	0.95/232.3	0.95/232.3	0.76/185.8	0.95/185.8	12.2/185.8	12.2/185.8
4.6	≤1.5	0.95/185.8	0.95/185.8	0.95/232.3	12.2/232.3	12.2/278.7	0.95/185.8	12.2/185.8	18.3/232.3	18.3/232.3
4.6	>1.5	0.95/185.8	0.95/185.8	0.95/232.3	12.2/278.7	12.2/325.2	0.95/185.8	12.2/232.3	18.3/278.7	18.3/278.7
6.1	≤1.5	12.2/185.8	12.2/185.8	12.2/232.3	18.3/278.7	18.3/325.2	12.2/185.8	18.3/232.3	24.5/232.3	24.5/232.3
6.1	>1.5	12.2/185.8	12.2/232.3	12.2/278.7	18.3/325.2	18.3/371.6	12.2/232.3	18.3/278.7	24.5/278.7	24.5/278.7
7.6	≤1.5	18.3/232.3	18.3/278.7	18.3/325.2	24.5/232.3	24.5/278.7	18.3/278.7	24.5/278.7	30.6/232.3	30.6/232.3
7.6	>1.5	183/278.7	18.3/325.2	18.3/371.6	24.5/278.7	24.5/325.2	18.3/325.2	24.5/325.2	30.6/278.7	30.6/278.7
9.1	≤1.5	24.5/232.3	24.5/278.7	24.5/278.7	30.6/232.3	30.6/278.7	24.5/371.6	30.6/278.7	30.6/325.2	30.6/325.2

NOTE: Densities or areas, or both, can be interpolated between any 1.5-m storage height increment.

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 Array, Standard.

The occasional presence of partially used rolls on top of columns of otherwise uniform diameter rolls does not appreciably affect the burning characteristics.

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 Storage Height.

The size of rolls and limitations of mechanical handling equipment should be considered in determining maximum storage height.

A-1-4 Storage Height, Wrapped Storage.

Rolls that are completely protected with a heavyweight kraft wrapper on both sides and ends are subject to a reduced degree of fire hazard. Standard methods for wrapping and capping rolls are outlined in Figure A-1-4.

In some cases, rolls are protected with laminated wrappers, using two sheets of heavy kraft with a high temperature wax laminate between the sheets. Where using this method, the overall weight of wax-laminated wrappers should be based on the basis weight per 1000 ft^2 (92.9 m^2) of the outer sheet only, rather than on the combined basis weight of the outer and inner laminated wrapper sheets. A properly applied wrapper can have the effect of changing the class of a given paper to essentially that of the wrapper material. The effect of applying a wrapper to tissue has not been determined by test.

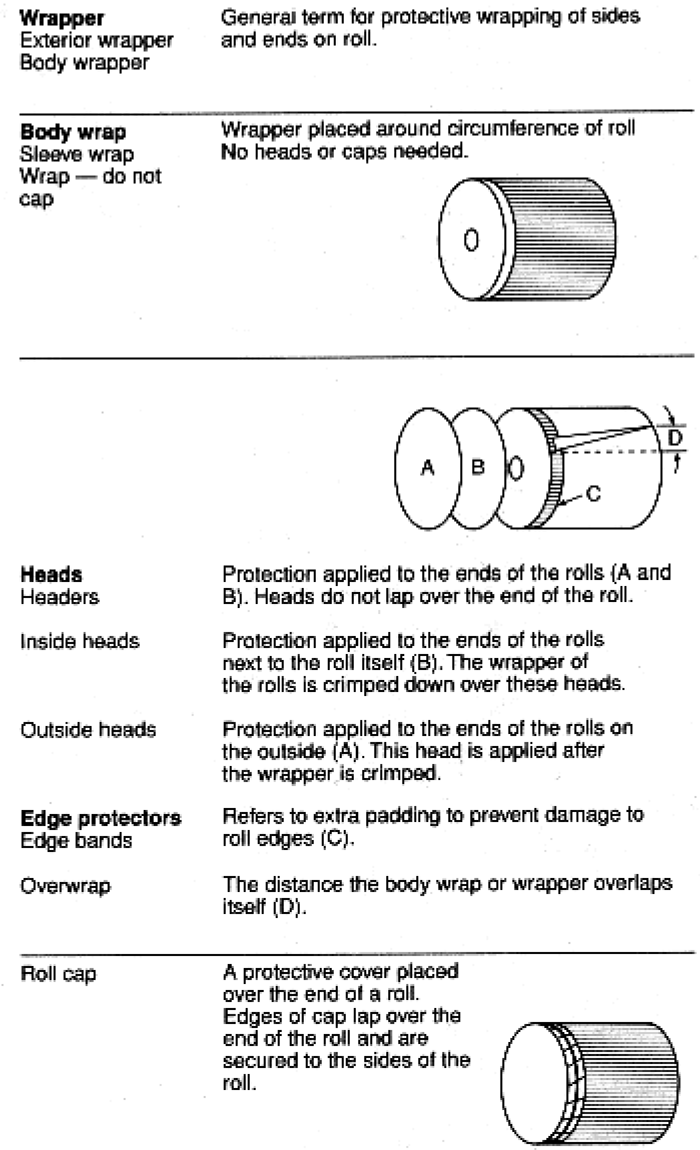

Figure A-1-4 Wrapping and capping terms and methods.

A-1-4 Weight of Paper.

See A-2.

A-1-5

For conversions and information, see ASTM E 380, *Standard Practice for Use of the International System of Units (SI).*

A-2 Paper Classification.

These classifications were derived from a series of large-scale and laboratory-type small-scale fire tests. It is recognized that not all paper in a class burns with exactly the same characteristics.

Paper can be soft or hard, thick or thin, or heavy or light and can also be coated with various materials. The broad range of papers can be classified according to various properties. One important property is basis weight, which is defined as the weight of a sheet of paper of a specified area. Two broad categories are recognized by industry: paper and paperboard. Paperboard normally has a basis weight of 20 lb (9.1 kg) or greater measured on a sheet 1000 ft^2 (92.9 m^2) in area. Stock with a basis weight less than 20 lb/1000 ft^2 (9.1 kg/92.9 m^2) is normally categorized as paper. The basis weight of paper is usually measured on a sheet 3000 ft^2 (278.7 m^2) in area. The basis weight of paper can also be measured on the total area of a ream of paper, which is normally the case for the following types of printing and writing papers:

Bond paper — 500 sheets 17 in. × 22 in. (432 mm × 559 mm) = 1300 ft^2 (120.8 m^2)/ream

Book paper — 500 sheets 25 in. × 38 in. (635 mm × 965 mm) = 3300 ft^2 (306.6 m^2)/ream

Index paper — 500 sheets 25.5 in. × 30.5 in. (648 mm × 775 mm) = 2700 ft^2 (250.8 m^2)/ream

Bristol paper — 500 sheets 22.5 in. × 35 in. (572 mm × 889 mm) = 2734 ft^2 (254 m^2)/ream

Tag paper — 500 sheets 24 in. × 36 in. (610 mm × 914 mm) = 3000 ft^2 (278.7 m^2)/ream

For the purposes of this standard, all basis weights are expressed in lb/1000 ft^2 (kg/92.9 m^2) of paper. To determine the basis weight per 1000 ft^2 (92.9 m^2) for papers measured on a sheet of different area, the following formula should be applied:

$$\text{Basis weight} / 1000\ \text{ft}^2 = \frac{\text{basis weight}}{\text{measured area}} \times 1000$$

Example: To determine the basis weight per 1000 ft^2 (92.9 m^2) of 16-lb (7.3-kg) bond paper:

$$\frac{16\ \text{lb}}{1300\ \text{ft}^2} \times 1000 = 12.3\ \text{lb}/1000\ \text{ft}^2$$

Large- and small-scale fire tests indicate that the burning rate of paper varies with the basis weight. Heavyweight paper burns more slowly than lightweight paper. Full-scale roll paper fire tests were conducted with the following types of paper:

Linerboard — 42 lb/1000 ft^2 (19.1 kg/92.9 m^2) nominal basis weight

Newsprint — 10 lb/1000 ft^2 (4.5 kg/92.9 m^2) nominal basis weight

Tissue — 5 lb/1000 ft^2 (2.3 kg/92.9 m^2) nominal basis weight

The rate of firespread over the surface of the tissue rolls was extremely rapid in the full-scale fire tests. The rate of firespread over the surface of the linerboard rolls was slower. Based on the overall results of these full-scale tests, along with additional data from small-scale testing of various paper grades, the broad range of papers has been classified into three major categories as follows:

Heavyweight — Basis weight of 20 lb /1000 ft^2 (9.1 kg/ 92.9 m^2) or greater

Mediumweight — Basis weight of 10 lb to 20 lb /1000 ft^2 (4.5 kg to 9.1 kg/92.9 m^2)

Lightweight — Basis weight of less than 10 lb /1000 ft^2 (4.5 kg/92.9 m^2) and tissues regardless of basis weight

The following SI units were used for conversion of English units:

1 lb = 0.454 kg
1 in. = 25.4 mm
1 ft = 0.3048 m
1 ft^2 = 0.0929 m^2

The various types of papers normally found in each of the three major categories are illustrated in Table A-2.

Table A-2 Paper Classification

Heavyweight	Medium-weight	Light-weight	Tissue
Linerboards	Bond & reproduction	Carbonizing tissue	Toilet tissue
Medium	Vellum	Cigarette	Towel tissue
Kraft roll wrappers	Offset	Fruit wrap	
Milk carton board	Tablet	Onion skin	
Folding carton board	Computer		
Bristol board	Envelope		
Tag	Book		
Vellum bristol board	Label		
Index	Magazine		
Cupstock	Butcher		
Pulp board	Bag		
	Newsprint (unwrapped)		

A-3-1.1

Consideration should be given to subdividing large-area warehouses in order to reduce the amount of stock that would be affected by a single fire.

It is recommended that walls or partitions be provided to separate the storage area from manufacturing or other occupancies to prevent the possibility of transmission of fire or smoke between the two occupancies.

A-3-2

Smoke removal is important to manual fire-fighting and overhaul. Since most fire tests were conducted without smoke and heat venting, the protection specified in Section 5-1 was developed without the use of such venting. However, venting through eaveline windows, doors, gravity monitors, or mechanical exhaust systems is essential to smoke removal after control of the fire is achieved. (*See NFPA 204M, Guide for Smoke and Heat Venting.*)

A-3-3

With protection installed in accordance with this standard, fire protection of overhead steel and steel columns is not necessary. However, some lightweight beams and joists can distort and necessitate replacement, particularly following fires involving plastic-wrapped rolls stored 20 ft (6.1 m) and higher.

A-4-2.5

Incandescent light fixtures should have shades or guards to prevent the ignition of commodity from hot bulbs where the possibility of contact with storage exists.

A-4-3.2

Fire tests indicate that fire does not spread between piles that are separated by aisles of 8 ft (2.4 m) or greater where sprinkler protection is provided in accordance with this standard. Main aisles and cross aisles should be located opposite window or door openings in exterior walls. This is of particular importance in buildings where there are few exterior openings.

A-5-1.3.3 In a dry-pipe system, the area increase of 30 percent should be compounded [i.e., 2000 ft^2 (185.8 m^2) (1.67 for low temperature sprinklers and 1.3 for dry-pipe systems) = 4343 ft^2 (403.5 m^2) total area]. Where dry-pipe systems are used in existing installations, the areas of operation indicated by Tables A-1-1.2(a) and (b) should be increased by 30 percent.

A-5-1.3.5 Generally, more sprinklers open in fires involving roll paper storage protected by sprinklers rated below the high temperature range. An increase of 67 percent in the design area should be considered.

A-5-6.2(g) Water absorption and pile instability caused pile collapse in all large-scale fire tests of tissue paper. This characteristic should be fully recognized where manually attacking a fire in tissue storage occupancies.

A-5-6.2(h) Information on emergency organization is provided in the following publications:

NFPA *Industrial Fire Brigade Training Manual*

NFPA 600, *Standard on Industrial Fire Brigades*.

Appendix B Summary of Test Results

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

This appendix provides a summary of the data developed from the tissue test series of full-scale roll paper tests conducted at the Factory Mutual Research Center, West Gloucester, RI.

The test building is approximately 200 ft × 250 ft [50,000 ft^2 (4.65 km^2)] in area, of fire-resistive construction, and contains a volume of approximately 2.25 million ft^3 (63,761.86 m^3), the equivalent of a 100,000-ft^2 (9.29-km^2) building 22.5 ft (6.86 m) high. The test building has two primary heights beneath a single large ceiling. The east section is 30 ft (9.1 m) high and the west section is 60 ft (18.29 m) high.

The tissue test series was conducted in the 30-ft (9.1-m) section, with clearances from the top of storage to the ceiling nominally 10 ft (3.1 m).

Figure B-1 illustrates a typical storage array used in the tissue series of tests.

The basic criteria used in judging test failure included one or more of the following:

(a) Firespread to the north end of the storage array;

(b) Gas temperatures near the ceiling maintained at high levels for a time judged to be sufficient to endanger exposed structural steel;

(c) Fire reaching the target stacks.

Table B-2 outlines the tissue test results.

Fire tests have been conducted on 20-ft (6.1-m) and 25-ft (7.6-m) high vertical storage of tissue with 10-ft (3.1-m) and 5-ft (1.5-m) clear space to ceiling in piles extending up to seven columns in one direction and six columns in the other direction. In these tests, target columns of tissue were located directly across an 8-ft (2.4-m) aisle from the main pile. Three tests were conducted using $^{17}/_{32}$-in. (13.5-mm) 286°F (141°C) high temperature sprinklers on a 100-ft^2 (9.3-m^2) spacing and at constant pressures of 14 psi, 60 psi, and 95 psi (97 kPa, 414 kPa, and 655 kPa), respectively. One test was run using 0.64-in. (16.3-mm) 286°F (141°C) high temperature sprinklers on a 100-ft^2 (9.3-m^2) spacing at a constant pressure of 50 psi (345 kPa). Two tests were conducted following a scheduled decay from an initial pressure of 138 psi (952 kPa) to a design point of 59 psi (407 kPa) if 40 sprinklers opened. The significant characteristic of these fire tests was the rapid initial firespread across the surface of the rolls. Ceiling temperatures were controlled during the decaying pressure tests and during the higher constant pressure tests. With the exception of the 20-ft (6.1-m) high decaying pressure test, the extent of firespread within the pile could not be clearly established. Aisle jump was experienced, except at the 95-psi (655-kPa) constant pressure, 20-ft (6.1-m) high decaying pressure, and large drop test. Water absorption and pile instability caused pile collapse in all tests. This characteristic should be considered where manually attacking a fire in tissue storage occupancies.

Available fire experience in roll tissue storage occupancies does not correlate well with the constant pressure full-scale fire tests with respect to the number of sprinklers operating and the extent of firespread. Better correlation is noted with the decaying pressure tests. Thirteen fires reported in storage occupancies with storage piles ranging from 10 ft to 20 ft (3.1 m to 6.1 m) high and protected by wet-pipe sprinkler systems ranging from ordinary hazard design densities to design densities of 0.6 gpm/ft^2 [(24.5 lpm)/m^2] were controlled with an average of 17 sprinkler heads. The maximum number of wet-pipe sprinkler heads that opened was 45 and the minimum number was five, versus 88 and 26, respectively, in the constant pressure tests. Seventeen sprinkler heads opened in the 20-ft (6.1-m) high decaying pressure test. One actual fire in tissue storage provided with a dry-pipe system opened 143 sprinklers but was reported as controlled.

One fire test was conducted with plastic-wrapped rolls of heavyweight kraft paper. The on-end storage was in a standard configuration, 20 ft (6.1 m) high with $9^1/_2$-ft (2.9-m) clearance to ceiling sprinklers. The prescribed 0.30-gpm/ft^2 [(12.2-lpm)/m^2] density controlled the firespread, but protection to roof steel was marginal to the point where light beams and joists might be expected to distort. A lower moisture content in the paper as a result of the protective plastic wrapping was considered to be the reason for the higher temperatures in this test as compared to a similar test where the rolls were not wrapped.

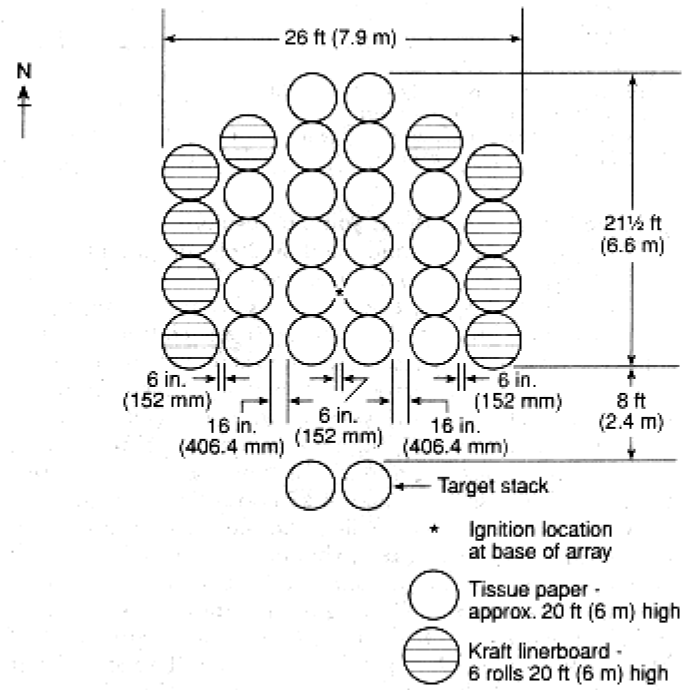

Figure B-1 Plan view of typical tissue storage array.

Table B-1 Summary of Roll Paper Tissue Tests

Test number	B1*	B2	B3	B4	B5***	B6***
Test date	10/4/79	7/23/80	7/30/80	10/15/80	7/28/82	8/5/82
Paper type	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue
Stack height [ft-in. (m)]	21-10 (6.66)	20-0 (6.1)	21-8 (21.60)	18-6 (6.64)	19-10 (6.05)	25-3 (7.69)
Paper, banded	No	No	No	No	No	No
Paper, wrapped	No	No	No	No	No	No
Fuel array	Std.	Std.	Std.	Std.	Std.	Std.
Clearance to ceiling [ft-in. (m)]	8-2 (2.49)	10-0 (3.05)	8-4 (2.54)	11-6 (3.51)	5-2 (1.58)	4-9 (1.45)
Clearance to sprinklers [ft-in. (m)]	7-7 (2.31)	9-5 (2.87)	7-9 (2.36)	10-9 (3.28)	4-7 (1.40)	4-2 (1.27)
Sprinkler orifice [in. (mm)]	17/32 (13.5)	17/32 (13.5)	17/32 (13.5)	0.64 (16.33)	17/32 (13.5)	17/32 (13.5)
Sprinkler temp. rating [°F (°C)]	280 (138)	280 (138)	280 (138)	280 (138)	280 (138)	280 (138)
Sprinkler spacing [ft × ft (m × m)]	10 × 10 (3.05 × 3.05)	10 × 10 (3.05 × 3.05)	10 × 10 (3.05 × 3.05)	10 × 10 (3.05 × 3.05)	10 × 10 (3.05 × 3.05)	10 × 10 (3.05 × 3.05)
Water pressure [psi (kPa)]	14 (0.67)**	60 (2.87)	95 (4.55)	50 (2.39)	138 (6.61) initial 102 (4.88) final	138 (6.61) initial 88 (4.21) final
Moisture content of paper (%)	9.3	9.3	10.2	6.0	8.2	9.2
First sprinkler operation (min:sec)	0:43	0:32	0:38	0:31	0:28	0:22
Total sprinklers open	88	33	26	64	17	29
Final flow [gpm (lpm)]	2575 (9746)**	1992 (7540)	1993 (7544)	4907 (18573)	1363 (5159)	2156 (8161)
Sprinkler demand area [ft² (m²)]	8800 (817.5)	3300 (306.6)	2600 (241.5)	6400 (595)	1700 (158)	2900 (269)
Avg. discharge density gpm/ft² [(lpm)/m²]	0.29 (11.8)**	0.60 (24.4)	0.77 (31.4)	—	0.92 (37.5) initial 0.80 (32.6) final	0.96 (39.1) initial 0.74 (30.2) final
Max. 1 min avg. gas temp. over ignition [°F (°C)]	1680 (916)**	1463 (795)	1634 (890)	1519 (826)	****	*****
Duration of high temp. within acceptable limits	No	Yes	Yes	Marginal	Yes	Yes
Max. 1 min avg. fire plume gas velocity over ignition [ft/sec (m/sec)]	—	40.7 (12.4)	50.2 (15.3)	47.8 (14.6)	—	—
Target ignited	Yes	Yes	No	No	No	Briefly
Extent of fire damage within acceptable limits	No	No	Marginal	Marginal	Yes	Marginal
Test duration (min)	17.4	20	20	25.5	45	45

*Phase I Test.
**Pressure increased to 50 psi (345 kPa) at 10 min.
***Phase III tests decaying pressure.
****Maximum steel temperature over ignition 341°F (172°C).
*****Maximum steel temperature over ignition 132°F (56°C).

Appendix C Referenced Publications

C-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.

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*, 1994 edition.

NFPA 204M, *Guide for Smoke and Heat Venting*, 1991 edition.

NFPA 600, *Standard on Industrial Fire Brigades*, 1996 edition.

C-1.2 Other Publications.

C-1.2.1 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)*, 1993.

C-1.2.2 Installation rules for sprinkler systems using large drop sprinklers are available from Data Sheet 2-7, Factory Mutual Research Corporation, 1151 Boston-Providence Turnpike, Norwood, MA 02062.

NFPA 232

1995 Edition

Standard for the Protection of Records

1995 Edition

This edition of NFPA 232, *Standard for the Protection of Records*, was prepared by the Technical Committee on Record 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 on July 21, 1995, with an effective date of August 11, 1995, and supersedes all previous editions.

This edition of NFPA 232 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 232

The destructive fire in the general offices of the Chicago, Burlington, and Quincy Railway in Chicago on March 25, 1922, was clear proof that valuable and often irreplaceable business records, unless properly protected, can be destroyed even in so-called “fire-resistive” buildings. Following this destructive fire, the Committee on Record Protection was organized. Reports were submitted annually from 1923 through 1936 and again in 1939. In 1947, a standard was developed from the officially adopted committee reports of 1942 to 1946. In 1960, the standard underwent major editorial revision and was revised again in 1963, 1967, and 1970. In 1975, it was reconfirmed. The 1980 edition reformatted the standard to conform to the NFPA *Manual of Style* and revised the detail specifications to performance-oriented requirements. The 1986 edition was a reconfirmation of the 1980 edition.

Changes to the 1991 edition included a reclassification of certain types of records. New provisions were added for the construction, arrangement, and protection of file rooms. These changes further increased the chance that vital documents are spared during most fire events.

The 1995 edition incorporated several editorial changes, the inclusion of a retroactivity clause, and further addressed the protection requirements for non-paper records media.

Technical Committee on Record Protection

Thomas Goonan, *Chair*
Tom Goonan Assoc., VA

Forrest V. Weir, *Secretary*
U.S. Nat’l Archives & Records Admin, MD
(Alt. to S. E. Hannestad)

Alfred R. Baker, American Nuclear Insurers, OR

Warren D. Bonisch, Schirmer Engineering Corp., VA

Alfred J. Casey, M & M Protection Consultants, MA

Jesse L. Clark, The Records Mgmt. Group, NJ

Bert M. Cohn, Bert Cohn Assoc., Inc., IL

Leon deValinger, Dover, DE
Rep. SAA

George P. Garland, Star Fire Protection Co., NY

Stephen E. Hannestad, U.S. Nat’l Archives and Records Admin, MD

Committee Scope: This Committee shall have primary responsibility for documents on the protection of books, papers, plans, and other records from loss incident to fire.

NFPA 232

Standard for the

Protection of Records

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* Introduction

1-1 Scope.

This standard provides requirements for records protection equipment, facilities, and records handling techniques that provide protection from the hazards of fire. It does not consider forcible entry.

1-1.1

Because of the volume of records, this standard does not cover large archives or records storage buildings. *See NFPA 232A, Guide for Fire Protection for Archives and Records Centers*.

1-1.2

This standard does not cover the storage and handling of cellulose nitrate film records. *See NFPA 40, Standard for the Storage and Handling of Cellulose Nitrate Motion Picture Film*.

1-2 Purpose.

This standard is prepared for the use and guidance of those charged with purchasing, designing, constructing, installing, inspecting, approving, listing, operating, or maintaining equipment and facilities that protect records against fire and its associated effects.

This standard also is intended for the use and guidance of those charged with planning, surveying, classifying, retaining, disposing, and otherwise handling records.

1-3 Retroactivity Clause.

The provisions of this document shall be 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: This standard shall apply in those cases where it is determined by the authority having jurisdiction that the existing situation involves a distinct hazard to life or property.

1-4 Planning.

It might be necessary for many of those charged with planning, inspecting, approving, operating, and maintaining records facilities, equipment, and techniques to consult with an experienced and competent fire protection engineer or records protection consultant.

1-5 Equivalency Concepts.

Nothing in this standard is intended to prevent the use of buildings, systems, methods, or devices that provide a level of fire safety for records equivalent to that prescribed herein. Any building, system, method, or device that differs from those detailed in this standard shall be permitted to be examined or tested, or both, by the authority having jurisdiction in accordance with the intent of this standard and, if found equivalent, shall be permitted to be approved.

1-6 Provisions in Excess of Requirements.

Nothing in this standard shall be construed to prohibit better or safer conditions than those required by this standard.

1-7 Definitions.

For the purpose of this standard, the following terms have the meanings specified 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.

File Processing Area. A work surface used for preparing records for filing or for retrieving records from or filing records to storage.

File Room. A fire-resistive enclosure that provides less fire protection than a vault and is used exclusively for the storage of records. An ordinary file room utilizes totally enclosed storage devices; an open-shelf file room uses open shelving and additional protection features.

File Room Door. An approved assembly that protects paper records against fire for the duration of its rated exposure.

Fire-Resistive Building.* A building of Type I or Type II-222 construction, as described in NFPA 220, *Standard on Types of Building Construction,* in which the structural members, including walls, partitions, columns, floors, and roofs, are of noncombustible or limited-combustible 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 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.

Mobile Shelving. A system of records storage in which sections or rows of shelves are moved on tracks to provide access aisles. Also called track files, compaction files, or movable files. They can be moved manually or electrically. Mobile shelving is usually a type of open-shelf file equipment.

Nonfire-Resistive Building. A building of that type of construction in which the structural members, including walls, partitions, columns, floors, and roofs, do not qualify as fire-resistive as defined herein.

Open-Shelf File Equipment. Any shelving that does not enclose file compartments on six sides.

Records Classes.*

Vital Records. Those that are irreplaceable or that contain information for which temporary unavailability could constitute a serious legal or business impairment. Examples are records for which a reproduction cannot be substituted for the original; records needed promptly to sustain business or to recover monies with which to replace buildings equipment, raw materials, finished goods, and work in process; and records needed to avoid delay in restoration of production, sales, and service.

Important Records. Those for which a reproduction, while acceptable as a substitute for the original, could be obtained only at considerable expense and labor or only after considerable delay.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Slab. A poured concrete floor-ceiling assembly.

Standard Records Vault. A completely fire-resistive enclosure used exclusively for records storage.

Ground-Supported Vault. A vault that is supported from the ground up and that is structurally independent of the building in which it is located.

Structure-Supported Vault. A vault that is supported by the framework of a fire-resistive building and that can be supported individually on any floor of such a building.

Vault Door. An approved assembly that protects paper records against fire for the duration of its rated exposure.

Vault Floor. The ground-supported slab or the slab between vaults in a tier.

Vault Roof. The ceiling or roof of a single vault and the ceiling or roof of the top vault of a tier, but not the slab between vaults in a tier, which is classified as a floor.

Chapter 2 Standard Records Vault

2-1 General.

2-1.1

The vault shall be equipped, maintained, and supervised to minimize the possibility of origin of fire within and to prevent entrance of fire from outside for a specified period of time.

2-1.2

To resist the maximum expected exposure fire, a vault shall be constructed as specified herein and in accordance with the ratings in Chapter 5.

2-2 Design.

2-2.1

In a fire-resistive building, the vault shall be of either the ground-supported or the structure-supported type.

2-2.2

In a nonfire-resistive building, the vaults shall be of the ground-supported type. The walls of a building shall not be used as walls of vault, since collapse of the building can cause damage to the vault and its contents.

2-2.3*

Plans and specifications shall be prepared and construction shall be supervised by a licensed or registered structural engineer or architect.

2-2.4

Proper design and construction of a vault shall consider its qualities as a flame barrier and as a heat-retardant, its ability to avoid settlement and consequent cracking, and its ability to maintain the integrity of the vault structure under the stresses and impacts to which it can be subjected during a fire, including impact from falling objects and stresses, strains, and erosion due to sudden cooling with fire hose streams.

2-3 Location.*

Because of the difficulty of providing resistance to severe impact, vaults in nonfire-resistive buildings shall be located where they are not exposed to the fall of a heavy object such as a safe, machine, or water tank in the event of collapse of the building as the result of a fire.

2-4 Size.

For the purpose of restricting the quantity of vital records exposed to destruction by fire in a single enclosure and to reduce the possibility of fire originating within a vault, a vault shall not exceed 5000 ft^3 (142 m^3) in volume, and the interior height shall not exceed 12 ft (3.7 m). (*For conditions requiring storage of a larger volume of vital records, see Section 2-14.*)

2-5 Foundations.

2-5.1 Ground-Supported Vaults.

Foundations for vaults shall carry the entire load of the vault or tier of vaults and contents without settlement or cracking. Unburied structural members supporting vaults shall have fire resistance at least equal to that of the vault.

2-5.2 Structure-Supported Vaults.

2-5.2.1* The supporting structures for vaults shall be of adequate strength to carry the full load, including the wet weight of the vault structure and its contents.

2-5.2.2 There shall be no combustible material in any portion of the building members that supports the vault. All building structural members that support the vault shall have fire resistance at least equal to that of the vault.

2-5.2.3 The walls of a structure-supported vault shall follow the column lines of the building wherever possible and shall extend from slab to slab in each story where a vault is located. If vaults are located on more than one floor of a building, they shall be placed, preferably one above the other, in each story.

2-6 Floor.

2-6.1

Floors shall be noncombustible and shall have floor surfacing limited to concrete sealer.

2-6.2

In structure-supported vaults, the floor of the fire-resistive building shall be permitted to serve as the floor of the vault, provided it is of noncombustible construction throughout and complies with the following:

(a) Floors above grade shall be adequate to support the full load (wet weight) and shall have unrestrained fire resistance equivalent to that required for the walls of the vault. (*See Section 2-7.*)

(b) Floors above grade shall not be pierced for any purpose.

2-7 Walls.

2-7.1

Walls shall be noncombustible and of fire-resistive construction throughout.

2-7.2

Reinforcing rods in concrete shall be located to avoid failure from fire exposure.

2-7.3

Noncombustible material shall be used for trim or partitions.

2-7.4*

The design shall provide the necessary minimum resistance to fire and fire hose streams according to structural consideration and variations in the quality of materials and workmanship. The walls shall have sufficient lateral strength to withstand impact due to collapsing structural members, toppling machinery, toppling building equipment, or combination thereof.

2-7.5 Openings in Walls.

2-7.5.1 The walls of vaults shall have no openings other than those necessary for access, electric lighting, power-limited circuits, and sprinkler piping. (*See 2-14.1*.)

2-7.5.2 Door openings shall be protected with approved vault doors. Doors shall not open into elevator, conveyor, or other shafts, and there shall be no openings from one vault into another.

2-7.5.3 The number of door openings shall not exceed two for any single vault and shall be limited in size to that necessary for convenient ingress and egress and for ventilation.

2-7.5.4 Wall penetrations for sprinkler, electric lighting, and limited-energy circuits shall be as small as possible and shall be sealed with approved or listed fire-rated material to prevent smoke, heat, flame, or water penetration. Conduit, if used, shall be sealed inside and outside.

2-7.5.5* Walls shall not be pierced for ventilation.

2-7.6 Bonding.

2-7.6.1 Vault walls of masonry units shall be laid with corners that are well-bonded for their full height.

2-7.6.2 Where the floor construction of a fire-resistive building forms the roof of the vault, the joint between the top of the vault wall and the underside of the floor arch or slab shall be finished tightly and filled thoroughly with mortar or cement grout.

2-7.6.3 If any wall of a building is of suitable construction to form part of the vault enclosure, the wall or walls of the vault that intersect with the building wall shall, where practicable, be bonded or keyed into it, or both, for the full height and width of the vault wall or walls.

2-8 Independence from Building Structure.

2-8.1

Vault construction shall not be used as a support or bearing for the structural members of the building.

2-8.2

In ground-supported vaults, the walls and supports of vaults shall be structurally independent of the building.

2-9 Roof.

2-9.1

In nonfire-resistive buildings, the roofs of vaults shall be entirely independent of the wall, floor, ceiling, columns, piers, or roof construction of the building.

2-9.2

In structure-supported vaults, the roof or the floor of the fire-resistive building shall be permitted to serve as the roof of the vault, provided it is of noncombustible construction throughout and complies with the following:

(a) The roof of the vault shall be reinforced concrete or reinforced concrete on protected steel supports.

(b) The roof of the vault shall have a fire resistance at least equivalent to that of the walls and shall have structural strength adequate to carry the design load or greater if subject to unusual impact or if exposed to fire from outside the vault.

(c) All interior supports shall have fire resistance equivalent to that of the walls.

(d) The roofs of vaults shall not be pierced for any purpose.

2-10* Vault Door.

2-10.1*

Each wall opening in the vault shall be provided with a listed or labeled vault door tested in accordance with ANSI/UL 155, *Test for Fire Resistance of Vault and File Storage Room Doors*. The vault door shall have a rating, in hours of fire resistance, equivalent to the rating of the walls of the vault, as follows:

4-hour vault - 4-hour door

6-hour vault - 6-hour door.

Figure 2-10.1(a) The 2-story vault [*see Figure 2-10.1(b)*] was in this sprinklered 4-story brick, plank-on-timber hardware factory in Syracuse, NY. The $977,000 fire was detected by the security guard. After this fire of suspicious origin was extinguished, sprinkler valves were found shut off.

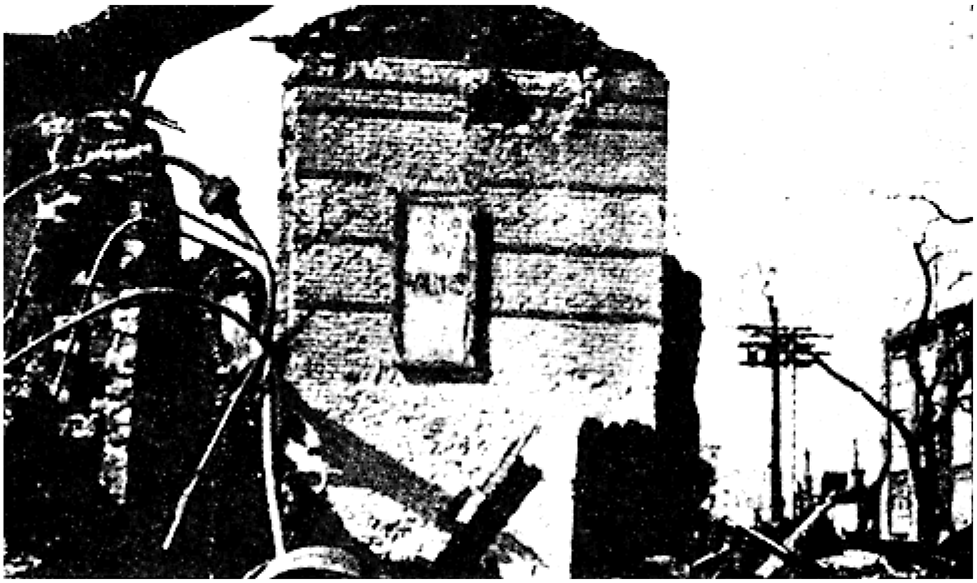

Figure 2-10.1(b) Satisfactory performance of a labeled vault door saved records in the upper story of this 2-story vault. A labeled fire door (not a vault door) on the first story was damaged, and records in the first story were destroyed. Figure 2-10.1(a) shows the fire exposure to vault.

2-10.2

Installation of the vault door unit shall be made in conformity with instructions supplied by the manufacturer and shall be entrusted only to those experienced in such installation work.

2-10.3*

The door-locking mechanism shall permit the door to be opened easily from the inside to prevent an individual from accidentally being locked in the vault.

2-10.4

Doors shall be equipped with an automatic closing device and a heat-actuated or smoke-actuated release for doors which are held in the open position.

2-11 Electrical Service.

2-11.1

All electrical service within the vault shall be enclosed in conduit and installed in accordance with NFPA 70, *National Electrical Code®*.

2-11.2

The wiring shall provide as many fixed lamps as needed for adequate illumination. No pendant lamp or extension cord shall be used within a vault. Fixed lighting shall be adequate for illumination of all portions of the vault to preclude the use of matches or other hazardous lighting.

2-11.3

Necessary lighting shall be limited to vaporproof or explosionproof lamps controlled by a two-pole switch outside the vault. No other electrical devices or appliances, shall be permitted within the vault.

Exception: Low energy devices shall be permitted within the vault.

2-12 Operating Practices.

2-12.1

Filing equipment shall be noncombustible throughout. All records shall be stored in fully enclosed noncombustible containers. (*For storage of records in open-type equipment see Chapter 3*.)

2-12.2

The records in the filing equipment shall be not less than 3 in. (76 mm) above the floor of the vault.

2-12.3

The vault shall be under responsible supervision from opening until closing time, and inspections shall be made daily, particularly before closing time, to ensure that all containers are closed, no records are left on top of the containers or are elsewhere exposed, all waste paper is removed, and the vault doors are closed and locked.

2-12.4

Vaults shall not be used as working spaces. Persons other than those authorized to handle the records shall not be permitted in the vaults.

2-12.5

General housekeeping shall be of the highest order.

2-12.6

Smoking inside vaults shall not be permitted. Matches and lighters shall not be permitted inside vaults.

2-12.7

Records containers shall be separated by at least 6 in. (152 mm) from piping and conduit that penetrates the wall. Where sprinklers are installed, records containers shall be kept 18 in. (457 mm) below sprinkler deflectors.

2-13 Fire Suppression and Signaling Equipment.

2-13.1*

Other than power-limited circuits, automatic or manual fire protection devices shall be limited to those not requiring wall penetration.

Exception: Wall penetration necessary for supplying automatic sprinklers shall be permitted. (See also Section 2-14.)

2-13.2

Portable fire extinguishers of a type suitable for Class A fires in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*, or standpipe systems with small hose suitable for use by occupants of the building in accordance with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, shall be provided at a conveniently accessible location outside the door of the vault.

2-13.3

Where automatic fire detection systems are installed for providing warning of fire inside the vault, they shall be in accordance with NFPA 72, *National Fire Alarm Code*. The systems shall be relied upon only where reliable prompt response of alarms is ensured.

2-14 Oversize Vault.

2-14.1*

Where the volume of vital records (*see definition in Section 1-7*) exceeds that which can be stored in a record vault of maximum permitted size (5000 ft^3 [142 m^3]), an oversize vault of not greater than 25,000 ft^3 (708 m^3) designed and constructed as a standard vault and equipped with automatic sprinkler protection installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, shall be permitted.

2-14.2

Filing equipment shall be noncombustible but shall not be required to be completely enclosed. Where mobile shelving is used, smoke detection in accordance with 2-13.3 shall be provided in addition to automatic sprinklers. In accordance with 2-11.3, no electrically operated mobile shelving shall be permitted.

Chapter 3 File Rooms

3-1 General.

3-1.1

All file rooms shall be provided with automatic sprinkler protection.

Exception: Sprinklers shall not be required where all storage is held in six-sided noncombustible containers.

3-1.2*

File rooms shall be used exclusively for the storage and handling of important records and shall be equipped, maintained, and operated to minimize the effects of fires of both internal and external origin. Vital records shall not be stored in a file room.

3-1.3

To minimize the effects of fires of both internal and external origin, a file room shall be constructed and operated as specified in this chapter and in accordance with the ratings in Chapter 5.

3-2 Design and Location.

3-2.1

Plans and specifications shall be prepared and construction shall be supervised by a licensed or registered structural engineer or architect in consultation with a licensed or registered fire protection engineer.

3-2.2

Fire resistance ratings prescribed for file rooms shall be of the duration that materials or assemblies have been shown to withstand a fire exposure established in accordance with the test procedures of NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*.

3-2.3*

File rooms shall not be located below ground level.

Exception: Underground storage and basement storage areas specifically designed by licensed or registered fire protection engineers to mitigate the inherent problems of subterranean storage.

3-2.4

File rooms shall be located to prevent severe impact by a falling machine, safe, water tank, or other heavy object or structure.

3-3 Size.

The volume of file rooms shall not exceed 50,000 ft^3 (1416 m^3).

3-4 Supporting Structure.

3-4.1*

The supporting structures for file rooms shall be of adequate strength to carry the full load, including the wet weight of the file room structure and its contents.

3-4.2

There shall be no combustible material in any portion of the building members that supports the file room. All building structural members that support the file room shall have fire resistance at least equal to that of the file room.

3-4.3

The walls of a structure-supported file room shall follow the column lines of the building wherever possible and shall extend from floor to floor in each story where a file room is located. If file rooms are located on more than one floor of a building, they shall be placed, preferably one above the other, in each story.

3-5 Floor.

3-5.1

In structure-supported file rooms, the floor of the fire-resistive building shall be permitted to serve as the floor of the file room, provided it is of noncombustible construction throughout and complies with the following:

(a) Floors above grade shall be adequate to support the full load (wet weight) and shall have unrestrained fire resistance equivalent to that required for the walls of the file room.

(b) Floors above grade shall not be pierced for any purpose.

3-5.2

Reinforcing rods in concrete shall be so located as to avoid failure from fire exposure.

3-6 Walls.

3-6.1

Walls shall be constructed of noncombustible or limited-combustible materials.

3-6.2

Noncombustible material shall be used for trim or partitions within the file room.

3-6.3 Openings in Walls.

3-6.3.1 The walls of file rooms shall have no openings other than those necessary for access, electric lighting, power-limited circuits, sprinkler piping, and hot water or low pressure steam piping. The sealing requirements of 2-7.5.4 shall apply.

3-6.3.2 Door openings shall be protected with approved file room doors. Doors shall not open into elevator, conveyor, or other shafts.

3-6.3.3 Walls shall not be pierced for ventilation.

3-6.4 Bonding.

If any wall of a building is of suitable construction to form part of the file room enclosure, the wall or walls of the file room that intersect with the building wall shall, where practicable, be bonded into it for the full height and width of the file room wall or walls.

3-7 Roof.

3-7.1

In nonfire-resistive buildings, the roof of the file room shall be entirely independent of the wall, floor, ceiling, columns, piers, or roof construction of the building.

3-7.2

In fire-resistive buildings, the roof or the floor shall be permitted to serve as the roof of the file room, provided it is of limited-combustible or noncombustible construction throughout and complies with the following:

(a) The roof of the file room shall be reinforced concrete or reinforced concrete on protected steel supports.

(b) The roof of the file room shall have a fire resistance at least equivalent to that of the walls and shall have structural strength adequate to carry the design load or greater if subject to unusual impact or if exposed to fire from outside the file room.

(c) All interior supports shall have fire resistance equivalent to that of the walls.

(d) The roofs of the file rooms shall not be pierced for any purpose.

3-8 File Room Door.

3-8.1

Each wall opening in the file room shall be provided with doors tested in accordance with ANSI/UL 155, *Tests for Fire Resistance of Vault and File Storage Room Doors*. The file room door shall have a rating, in hours of fire resistance, equivalent to the rating of the walls of the file room, as follows:

6-hour file room - 6-hour door

4-hour file room - 4-hour door

2-hour file room - 2-hour door

1-hour file room - 1-hour door.

3-8.2

Installation of the file room door unit shall be made in conformity with instructions supplied by the manufacturer and shall be entrusted only to those experienced in such installation work.

3-8.3*

The door-locking mechanism shall permit the door to be opened from the inside to prevent an individual from accidentally being locked in the file room.

3-8.4

Doors shall be equipped with an automatic closing device operated by a heat-actuated or smoke-actuated release.

3-9 Dampproofing.

Where the walls, floor, or roof of a file room are dampproofed, the methods and materials used shall be such that the desired fire resistance of the file room shall not be impaired.

3-10 Electrical Service.

3-10.1

All electrical service within the file room shall be enclosed in conduit and installed in accordance with NFPA 70, *National Electrical Code*.

3-10.2

The wiring shall provide as many fixed lamps as needed for adequate illumination. No pendant lamp or extension cord shall be used within a file room. Fixed lighting shall be adequate for illumination of all portions of the file room to preclude the use of temporary lighting.

3-10.3

Necessary lighting shall be limited to vaporproof or explosionproof lamps controlled by a two-pole switch equipped with a pilot light outside the file room. No other electrical devices or appliances shall be permitted within the file room.

Exception No. 1: File maintenance equipment specifically designed and approved for installation and use.

Exception No. 2: Power-limited circuits shall be permitted within the file room.

3-11 Heating and Ventilation.

3-11.1

Heating shall be by means of hot water or steam. Where steam heating is used, the coils or radiators shall be located to avoid the possibility of records coming in contact with them. Piping shall be placed overhead. Where the pipe is carried through the wall, the holes shall be made as small as practicable, the pipe shall be provided with a close-fitting noncombustible sleeve, and the space around the inside of the sleeve shall be filled completely with approved material. Floors and roofs of file rooms shall not be pierced for piping. No devices such as open-flame heaters and electrical heaters shall be used.

Exception: Slab floors on grade shall be permitted to be pierced for piping.

3-11.2*

Ventilation of the interior shall be through a door opening.

3-12 Fire Suppression and Signaling Equipment.

3-12.1

All file rooms shall be provided with an automatic sprinkler fire extinguishing system.

Exception: Where all storage is held in six-sided noncombustible containers.

3-12.1.1* If automatic sprinklers are installed, conveniently located sprinkler alarms and shutoff valves outside the file room shall be provided to allow water to be turned off promptly after the fire is extinguished.

3-12.1.2 Automatic sprinkler systems shall be designed and installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

Exception: Where modified by this section.

3-12.1.2.1 Paper Records. Where paper records are stored on open-shelf file equipment and at heights of 12 ft (3.7 m) or less, the design criteria shall be in accordance with, Ordinary Hazard Group 2.

Where paper records are stored in excess of 12 ft (3.7 m), the design criteria of NFPA 231, *Standard for General Storage* or NFPA 231C, *Standard for Rack Storage of Materials* shall apply. Storage shall be considered to be Class III commodity.

3-12.1.2.2 Other Media Records. Where records storage consists of other media with combustion characteristics that differ from paper (such as magnetic tape and audio visual materials) and is stored in open file storage equipment and at a height of 12 ft (3.7 m) or less, the requirements of NFPA 13, *Standard for the Installation of Sprinkler Systems* shall apply.

For storage in excess of 12 ft (3.7 m), the requirements of NFPA 231, *Standard for General Storage* or NFPA 231C, *Standard for Rack Storage of Materials* shall apply.

3-12.1.2.3 Where records media are mixed (e.g., paper and magnetic tape) the design shall be for the highest hazard commodity.

3-12.2

Portable fire extinguishers of a type suitable for Class A fires, in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*, or standpipe systems with small hose suitable for use by occupants of the building, in accordance with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, shall be provided at a conveniently accessible location outside the door of the file room.

3-12.3

Smoke detection systems, connected to notify the fire department when activated shall be provided for the following:

(a) File rooms having open-shelf file equipment, including mobile shelving, that has concealed spaces more than 6 ft (1.8 m) wide.

(b) File rooms having all storage held in six-sided noncombustible containers and a file processing area not exceeding 10 percent of the total file room floor area.

3-12.4

Where automatic fire detection systems are installed for providing warning of fire inside of the file room, they shall be in accordance with NFPA 72, *National Fire Alarm Code*. The systems shall be relied upon only where reliable prompt response of alarms is ensured.

3-13 Operating Practices.

3-13.1

The file room shall be under responsible supervision from opening until closing time, and inspections shall be made daily, particularly before closing time, to ensure that all containers are closed, no records are left on top of containers or are elsewhere exposed, all waste paper is removed, and file room doors are closed and locked.

3-13.2

File rooms shall not be used as working spaces. No work stations shall be permitted. Persons other than those authorized to handle records shall not be permitted in the file rooms.

Exception No. 1: Fully sprinklered file rooms.

Exception No. 2: File rooms with smoke detection and all storage held in six-sided noncombustible containers.

3-13.3

Records in the filing equipment shall be not less than 3 in. (76 mm) above the floor.

3-13.4

General housekeeping shall be of the highest order.

3-13.5

Smoking inside file rooms shall not be permitted. Matches and lighters shall not be permitted inside file rooms.

3-13.6

Records containers shall be separated by at least 6 in. (152 mm) from piping and conduit that penetrate the wall. Where sprinklers are installed, records containers shall be kept 18 in. (457 mm) below sprinkler deflectors.

Exception: Where sprinklers are located in each aisle.

Chapter 4 Records Protection Equipment

4-1* General.

Records protection equipment is movable and includes fire-resistant safes and cabinets. These devices are intended to provide protection for various types of records for various durations of fire exposure by segregating them from surrounding fire exposure.

4-2* Classification of Devices.

Only listed or labeled records protection equipment shall be used.

4-3 Selection of Equipment.

4-3.1

The selection of the class of record protection equipment shall be based on the requirements in this section and in Chapter 5.

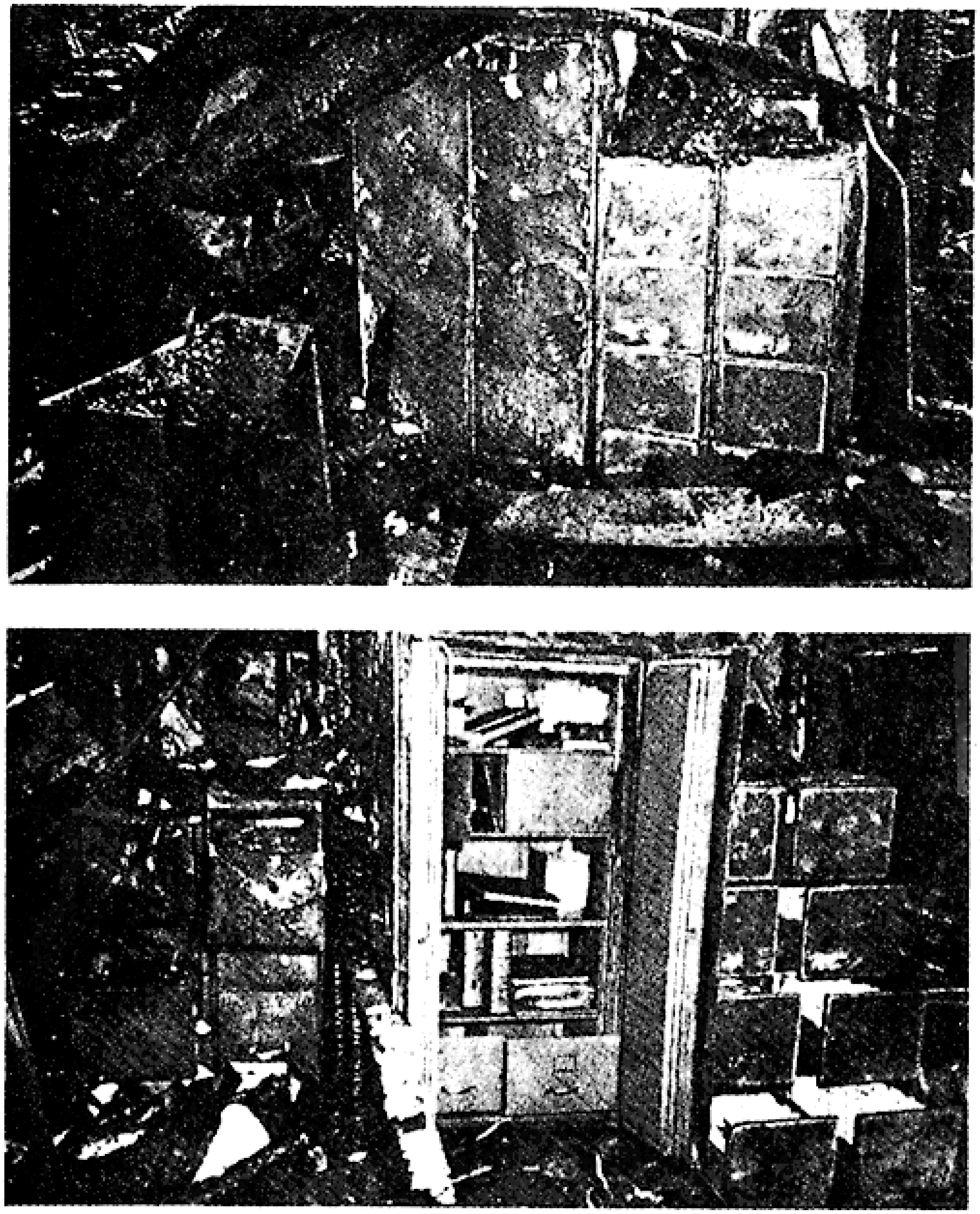

Figure 4-3.1 These two photographs of the same equipment graphically show the value of fire-rated containers for protection of records. These containers were in a 1-story brick and steel building destroyed by fire. The 1-hr rated equipment at the right and the 2-hr rated safe in the center protected their contents. Records in the nonrated equipment at left were destroyed.

4-3.2

The label on the device shall include the name of the equipment, the temperature rating, and the time rating. The label shall be applied to the equipment and shall be located to be readily visible after the equipment has been installed.

4-3.3*

Cabinets made of wood, fiberboard, or other combustible materials shall not expose containers housing vital or important records.

Chapter 5 Preservation of Records

5-1 General.

5-1.1*

The fire-resistance requirements for vaults, file rooms, and records protection devices shall be in accordance with the type of construction (e.g., fire-resistive or nonfire-resistive), the total combustibles exposing the vault, file room, or records protection device, and the records media being protected as specified in Chapters 2, 3, and 4. (*See A-5-1.1 for guidance on protection of records other than those defined as vital or important*.)

5-1.2

Some records are better protected by duplication. Where this method is used, the duplicated records shall be stored in a separate location not subject to the same fire.

5-2 Fire-Resistive Buildings.

5-2.1

The devices required to protect records adequately in a fire-resistive building shall be determined by the following:

(a) The total combustible contents per floor in the building, and

(b) The percentage of combustibles that are in an exposed position on any given floor.

The conditions of 5-2.1(a) and (b) are summarized in Table 5-2.1.

Table 5-2.1 Equipment for a Fire-Resistive Building

Total Combustible Contents per Floor, Including any Combustible Flooring, Partitions, and Trim (*See A-5-1.1A7*) [lb/ft^2 (kg/m^2) of floor area]	Noncombustible Desks, Filing Cabinets, Lockers, and Other Closed Containers. Not over 30 Percent of Combustible Exposed	Combustible Desks, Filin Shelving, Containe
Less than 5 (2.27)	1-hr device (without impact) or file room	1-hr device (without impact) or
5 to 10 (2.27 to 4.53)	1-hr device (without impact) or file room	1-hr device (with impact) or file
10 to 15 (4.53 to 6.80)	1-hr device (without impact)	2-hr device or file room
15 to 20 (6.80 to 9.07)	1-hr device (with impact) or file room	2-hr device or file room
20 to 30 (9.07 to 13.60)	1-hr device (with impact) or file room	4-hr device, file room, or vault
30 to 35 (13.60 to 15.86)	2-hr device or file room	4-hr device, file room, or vault
35 to 45 (15.86 to 20.40)	2-hr device or file room	6-hr vault or file room

45 to 50 (20.40 to 22.66)	4-hr device, file room, or vault	6-hr vault or file room
50 to 60 (22.66 to 27.20)	4-hr device, file room, or vault	6-hr device or file room with no combustibles near door

5-3 Nonfire-Resistive Buildings.

5-3.1

To adequately protect records in a nonfire-resistive building, the devices required shall be determined by the total weight of combustibles per floor, as shown in Table 5-3.1.

Table 5-3.1 Equipment for a Nonfire-Resistive Building

Total Weight of Combustibles, Including Contents and Building Members of All Floors Including Roof, but not Exterior Walls (*See A-5-1.1A7*) [lb/ft^2 (kg/m^2) of ground area]	**Record Container Rating**
Less than 25 (11.33)	2-hr device or file room, except in 1-story and basement buildings (or 2-story without basement) 1-hr device (with impact) or file room. Where impacts or blanketing of ruins by collapse of masonry wall or adjoining building is possible, a device or file room of 2-hr or higher rating shall be used.
25 to 50 (11.33 to 22.66)	2-hr device or file room.
50 to 100 (22.66 to 45.33)	4-hr device, file room, or vault. 4-hr vault for basement or ground story, 2-hr or above.
100 to 150 (45.33 to 67.99)	Vault, file room, or device: basement or ground (first) story, 6-hr; first floor, 4-hr; upper floors, 2-hr.
Over 150 (67.99)	Vault, file room, or device: shall not be located in basement or ground story without basement; first floor, 6-hr; second floor, 4-hr; upper floors, 2-hr.

NOTE: Wood weighs approximately 36 lb/ft^3 (577kg/m^3).

5-3.2

Any device located in a nonfire-resistive building shall be rated for impact resistance.

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 13, *Standard for the Installation of Sprinkler Systems*, 1994 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1993 edition.

NFPA 70, *National Electrical Code*, 1996 edition.

NFPA 72, *National Fire Alarm Code*, 1993 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 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*, 1995 edition.

6-1.2 Other Publications.

6-1.2.1 ANSI/UL Publications. American National Standards Institute, 1430 Broadway, New York, NY 10018, or Underwriters Laboratories Inc., 333 Pfingsten Rd., Northbrook, IL 60062.

ANSI/UL 72, *Standard for Tests for Fire Resistance of Record Protection Equipment*.

ANSI/UL 155, *Test for Fire Resistance of Vault and File Storage Room Doors*.

Appendix A Explanatory Material

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

A-1

Businesses have been forced to close due to the insurmountable task of replacing organizational and operational records. While accurate nationwide statistics are needed, it is known that the losses sustained in fires by such businesses has had the adverse effect of lowering their credit ratings and that some went out of business because of the destruction of their records.

Since the turn of the century, the volume of records, especially of business records, has increased rapidly. These records have to be stored. This need, stimulated by competition among manufacturers, led to the development of better records containers, especially that of lighter weight containers with greater capacity and fire resistance. The heavy, old-line safes of uncertain fire resistance could no longer meet the needs of business and have been replaced largely by modern fire-resistive containers. Newer techniques of records keeping (e.g., microfilm and electronic computers) are creating new problems and new demands.

The biggest issues facing the records protection field today are better acknowledgment and increased study of the records protection problem. Technically, the equipment needed to provide the necessary protection has been produced and rigorously tested. It is now the responsibility of records owners and custodians to learn how to estimate the protection needed and the responsibility of architects, contractors, and builders, as well as custodians, to understand how to provide this protection.

A-1-7 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-1-7 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-1-7 Fire-Resistive Building.

(*See Table A-1-7.*)

Table A-1-7 Fire Resistance Requirements 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	111	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 roofs 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 roofs 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 roofs 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	1½	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]

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-1-7 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-1-7 Records Classes.

Records of exceptionally high intrinsic value, such as those of financial securities, or records that also are rare artifacts could necessitate individualized protection measures outside the scope of this standard. Records essential to the reconstruction of other records also should be considered for special protection.

A-2-2.3

Vaults require unusually good design and construction to ensure that the structure satisfactorily withstands all of the conditions that could be imposed upon it by fire.

A-2-3

Vaults below grade are undesirable because under certain conditions sufficient burning or smoldering debris can accumulate in a basement to produce a “cooking effect” of such duration that the effects of combustion cannot be resisted by construction alone (within practical limitations). Also, vaults located below grade might be damp, causing destruction of records by the formation of mold, and can be subject to flooding under either flood or fire conditions, with consequent damage to records.

A-2-5.2.1 The wet weight of records is approximately 2.4 times the dry weight. Dry correspondence files weigh approximately 30 lb/ft^3 (480 kg/m^3).

A-2-7.4

Traditionally recognized construction that meets these requirements is as follows:

(a) Reinforced concrete with steel rods at least $^1/_2$ in. (13 mm) in diameter spaced 6 in. (152 mm) on center and running at right angles in both directions. Rods are wired securely at intersections not over 12 in. (305 mm) apart in both directions and installed centrally in the wall or panel.

(b) A structural steel frame protected with at least 4 in. (102 mm) of concrete, brickwork, or its equivalent tied with steel ties or wire mesh equivalent to No. 8 ASW gauge wire on an 8-in. (203-mm) pitch. Any brick protection used is filled solidly to the steel with concrete.

(c) Fire resistance is determined by wall thickness as follows:

1. Minimum thickness of a 4-hour vault wall is 12 in. (305 mm) for brick and 8 in. (203 mm) for reinforced concrete.

2. Minimum thickness of a 6-hour vault wall is 12 in. (305 mm) for brick and 10 in. (254 mm) for reinforced concrete.

(d) Walls of ground-supported vaults are of greater thickness than those described herein where it is necessary to account for such factors as unusual structural conditions and loads.

A-2-7.5.5 Environmental requirements such as heating, cooling, and humidity control, may be permitted to be provided by controlling the environment outside of the vault.

A-2-10

Vault doors are capable of the following:

(a) Preventing the passage into the vault chamber of flame or heat above a specified temperature for the time period indicated on the label;

(b) Withstanding the stresses and strains due to fire or the application of a fire hose stream while the unit is in a highly heated condition without materially reducing its fire resistance.

A-2-10.1

Ordinary fire doors such as hollow metal, tinclad, sheet metal, or metalclad types; steel-plate type; and file room doors may not be permitted to be used as vault doors.

A-2-10.3

Interior emergency lighting might be necessary.

A-2-13.1

Sprinklers in vaults on grade may be permitted to be supplied by pipes that rise through the floor.

A-2-14.1

Automatic sprinklers are the best fire protection devices. Records custodians, librarians, and others responsible for maintaining documents gradually are coming to accept the use of automatic sprinklers for the protection of books and records with the understanding that the sprinklers add negligible water hazards and mitigate serious fire hazards.

The following is an example of the role sprinklers play as a possible records protection medium.

The Factory Mutual engineering division ran a test on sprinklered and unsprinklered four-tier, steel, open deck library stacks. Two fires of identical nature were started in a test section containing 11,000 books. The first test used automatic sprinklers and the second did not.

In the sprinklered test, the fire burned unhampered for 3 minutes and 43 seconds when the first sprinkler opened. All fire spread halted at this point. Another sprinkler opened at 7 minutes and 53 seconds, and they both discharged for the remainder of the test (30 minutes from start). Combined, their output was 41 gal/min (26 L/sec) for a total of 978 gal (3701 L) discharged on 27 percent of the books. Wetting of the books ranged from slightly damp to soaked. Ten percent of the books were fire damaged within a range from slight charring to deep burns. No book was knocked from its shelf by the sprinklers.

In the unsprinklered test, the fire burned unhampered for 10 minutes when all four tiers were heavily involved. Hoses were applied, since the test structure was in danger. A 1-in. (25.4-mm) hose line was tried first but had little effect, and a $2^1/_2$-in. (63.5-mm) line discharging 265 gal/min (162 L/sec) had to be brought in 17 seconds later in order to save the test structure. Books were knocked onto the floor of the tiers and out of the stack. As a result, 89 percent of the books were charred deeply or destroyed, $2^1/_2$ percent were scorched, and the remaining $8^1/_2$ percent were soaked.

Sprinklers work effectively to provide protection for records. The sprinkler performance history shows premature operation of sprinklers to be a negligible problem.

The provision of sprinklers does not ensure that no records are destroyed by fire, but it can minimize the probability of a disastrous records fire.

A-3-1.2

Volumes of vital records too small to require a standard vault should not be exposed to the severe fire loading present in a file room, even where it is protected by an automatic fire suppression system. Such records could be stored in appropriate fire-rated file devices in an ordinary office environment, which poses a fire exposure that is less hazardous.

NOTE: The presence of filing personnel and processing operations within the file room, the additional hazards of lighting and heating equipment, and the greater volume of records likely to be exposed at one time add to the possibility of origin of fire and destruction of records within the enclosure.

A-3-2.3

File rooms should not be located underground because, under certain conditions, burning or smoldering debris can accumulate in a basement in sufficient quantities to produce a “cooking effect” of such duration that it cannot be resisted by construction alone (within practical limitations). Underground storage imposes risk factors such as inaccessibility, delayed or impaired access, smoke and heat ventilation, water accumulation, and availability of safe refuge.

A-3-4.1

The wet weight of records is approximately 2.4 times the dry weight. Dry correspondence files weigh approximately 30 lb/ft^3 (480 kg/m^3).

A-3-8.3

Interior emergency lighting might be necessary.

A-3-11.2

Where the natural circulation of air through the door opening does not provide sufficient ventilation, an electric fan may be permitted to be placed close to the door and directed through the door opening. Such fans may be permitted to be mounted conveniently near the top of the door. Fans should be located so that they do not obstruct the closing of the door.

A-3-12.1.1 Sprinklers in file rooms on grade may be permitted to be supplied by pipes that rise through the floor.

A-4-1

Protection of records from the effects of fire is considered to have begun about 1910 when Underwriters Laboratories Inc. conducted the first test in which both the temperatures of the furnace and of the air inside the record container under test were recorded. While the container first tested was lacking in fire-resistive properties and the test was crude compared with present-day tests of equipment, the method used set a precedent that was destined to exert an influence not only on the testing of record containers but upon fire tests in general.

To establish the fire-resistive rating of a records container, it is necessary to measure interior temperatures and set the maximum allowable temperatures. In view of the fact that the rate of temperature rise inside a safe is influenced by the temperature of the furnace fire, the new method called for closer furnace control and the use of a specific schedule of furnace fire temperatures. Gradually, as fire tests increased, practices tended toward uniformity and led eventually to the standard curve now in use.

The maximum permitted interior temperature originally was set at 350°F (177°C) in order to provide a safety factor, since the ignition temperature of most paper is somewhat higher. This limit was set before the standard time-temperature curve was adopted and helped to emphasize the desirability of a uniform rule for regulation of testing furnace temperatures. The adoption of a temperature rise limit meant that records containers were to be rated on a quantitative basis.

Recently, requirements for records containers other than paper records storage (e.g., magnetic data processing and photographic media) were developed. The requirements provide limits for interior temperature and humidity due to their affect on the integrity of such media. The limits for maximum interior temperature and humidity are 150°F (66°C) and 85 percent RH, respectively.

It has been determined that these limits provide adequate protection for most of the magnetic and photographic media available today.

A-4-2

(a) Records protection equipment is classified in terms of an interior temperature limit and a time in hours. Two temperature and humidity limits are employed: 150°F (65.6°C) with 85 percent RH, which is regarded as limiting conditions for photographic, magnetic, or similar nonpaper records, and 350°F (196°C) with 100 percent RH, which is regarded as limiting conditions for paper records. The time limits employed are 4 hours, 3 hours, 2 hours, and 1 hour.

The complete rating means that the specified interior temperature and humidity limits are not exceeded when the record protection equipment is exposed to a standard fire test for the length of time specified.

(b) Ratings are assigned to various categories as follows:

Insulated Record Containers	-	Class 150 4 hours
		Class 150 - 3 hours
		Class 150 - 2 hours
		Class 150 - 1 hour
		Class 350 - 4 hours
		Class 350 - 2 hours
		Class 350 - 1 hour
Fire-Resistant Safes	-	Class 350 - 4 hours
		Class 350 - 2 hours
		Class 350 - 1 hour
Insulated Filing Devices	-	Class 350 - 1 hour
Insulated File Drawer	-	Class 350 - 1 hour

(c) Insulated records containers and fire-resistant safes are effective in withstanding exposure to a standard test fire before and after an impact due to a fall of 30 ft (9.1 m). Insulated filing devices and file drawers are not subjected to an impact test and are not required to have the strength to endure such an impact.

(d) Insulated records containers and fire-resistant safes rated Class 350 1 hour afford more protection to records than insulated filing devices and file drawers rated Class 350 1 hour because of differences in thermocouple locations within the records protection equipment during fire tests.

(e) Insulated records containers, fire-resistant safes, and insulated filing devices can withstand a sudden exposure to 2000°F (1093°C) temperature without exploding as a result of such exposure.

(f) Noncombustible cabinets with cellular or solid insulation of less than 1-in. (25-mm) thickness have been found to have less than a 20-minute rating under standard test conditions for insulated filing devices. The exact rating depends upon the thickness and character of the insulation and other factors. Noncombustible uninsulated steel files and cabinets have been found to obtain about a 5-minute rating under standard test conditions for insulated filing devices.

NOTE: This equipment is tested in accordance with ANSI/UL 72, *Standard for Tests for Fire Resistance of Record Protection Equipment*.

A-4-3.3

In many fires, records protection equipment is subjected to severe impact. At times, in nonfire-resistive buildings, floors collapse, and the records devices fall one or more stories. The resistance of records protection equipment to impact where highly heated differs markedly from its resistance where cold. It is essential that, where these devices are intended for a location where impact is probable their classification should indicate resistance to impact.

For protection of vital or important records, it has been demonstrated that it is not good practice to rely on records protection equipment having less resistance to heat and fire than required for the fire hazard in its vicinity.

The fire records of the past 25 or 30 years show that many so-called “old line” or “iron” safes (safes of the types made prior to approximately 1917, i.e., safes made before the availability of standards and testing facilities and before the availability of present-day construction methods and materials) involved in fires in nonfire-resistive buildings did not protect their contents due to their inability to withstand stress and strain due to the following:

(a) Impact caused by falling one or more floors as a result of building collapse, or

(b) Resistance to fire exposure that was less than assumed (prior to approximately 1917, safes were usually not labeled with their fire rating; today the fire resistance of such safes is considered “uncertain”). It is obviously not good practice to rely on any safe of unknown or uncertain resistance to fire or impact for use in the protection of valuable records.

The selection of a suitable rating for a records device involves the exercise of a certain degree of judgment. When in doubt, it is obviously best to let judgment err on the side of making certain that vital and important records survive a fire that completely consumes the combustibles (fuel) in the fire area of the records enclosure.

If many and various degrees of fire hazards exist where vital and important records are or could be stored or used, it is advisable to use a standard classification or rating that preserves such records at the location of greatest hazards so that, in the event a records enclosure is shifted from a location of lightest fire hazard to a location of greatest hazard, the safety of the records is not jeopardized. Increased protection from external fires can be provided by placing the records in rated containers in a vault or a file room.

Uninsulated steel containers (closed on six sides) provide housing protection where records stored in fire-resistive vaults or file rooms where all combustible material (other than records in the containers) are completely excluded. Such installations provide less opportunity for fire to originate and have a decided retarding effect on the spread of fire, thereby reducing the possibility of a free sweep of flames or the buildup of room temperatures above the ignition point of ordinary combustible materials. Also, the files are protected from fires originating outside the vault or file room.

A-5-1.1 Protection of Nonvital Records.

A. A method of calculating fuel load is as follows:

1. Volumes in ft^3 are determined for the following:

(a) Enclosed combustibles, (e.g., volume of totally enclosed six-sided steel containers);

(b) Partially enclosed combustibles, (e.g., volume of containers enclosed on five sides with steel); and

(c) Free combustibles, (e.g., volume of combustible containers and all steel containers with less than five sides, plus the volume of paper and books placed on flat horizontal furniture tops). The volume of free combustibles on flat horizontal furniture tops is figured for furniture $6^1/_2$ ft (2 m) or less above the floor. A factor is used to convert the surface area of this furniture in ft^2 to a given volume of free combustibles that can be expected to be on the surface. Therefore, the volume of free combustibles on horizontal furniture tops is equal to the total surface area in ft^2 divided by 24.

$$\text{Volume} = \frac{\text{total surface area}}{24}$$

2. The weight of all wood or cellulose furniture as determined in lb = A;
3. The weight of all plastic furniture as determined in lb = B;
4. The weight of books and papers enclosed in six-sided steel containers is determined by multiplying the volume of the containers by 28 lb/ft^3 = C;
5. The weight of books and papers partially enclosed in five-sided steel containers is determined by multiplying the volume of the containers by 28 lb/ft^3 = D;
6. The weight of the free combustibles is determined by multiplying the volume of books and papers located on the horizontal surface $6^1/_2$ ft (2 m) or less above the floor and the volumes of both combustible containers and steel containers having less than 5 sides by 28 lb/ft^3 = E;
7. The fuel load is calculated as F = A + 2B + C + D + E;
8. The fuel load derating factor (percent is calculated as follows):

$$\frac{100 \times C}{F}$$

(a) If the derating percentage is less than 50 percent, a derating factor G of 60 percent is used;
(b) If the derating percentage is 50 percent to 80 percent, a derating factor G of 80 percent is used;
(c) If the derating percentage is more than 80 percent, a derating factor G of 90 percent is used;
(d) In all cases, the derating factor for partially enclosed combustibles equals 25 percent.

9. The total derated fuel load as calculated in lb = H = F - (C × G + 0.25D); and
10. The derated fuel load as calculated in (I) lb/ft^2:

$$I = \frac{H}{\text{gross floor area in ft}^2}$$

B. Limiting the fuel load to 6 lb/ft^2 might reduce or eliminate the need for an extinguishing system. This may be permitted to be accomplished by using any or all of the following methods.
1. Enclosed steel records handling equipment for all records and file material (e.g., regular or lateral steel filing cabinets);
2. Steel desks;

3. Noncombustible, limited-combustible, or flame-retardant partitions and space dividers;
4. Noncombustible or flame-retardant draperies or other hangings;
5. Elimination of furniture having a large combustible surface, (e.g., wooden or plastic wardrobes, supply cabinets, bookcases);
6. Elimination of lounge chairs or couches with foam cushioning;
7. Artificial plants that are either noncombustible or, if of a plastic type, fire tested to avoid any type of plastic that drips burning particles; and
8. Self-closing metallic waste baskets.

C. Complete automatic sprinkler protection might be needed in office space where the fuel load exceeds 6 lb/ft^2.

Conversion factors for SI units are as follows.

$ft^3 = 0.028\ m^3$	
$ft^2 = 0.093\ m^2$	lb = 0.45kg
$lb/ft^3 = 16kg/m^3$	ft = 0.305 m

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 40, *Standard for the Storage and Handling of Cellulose Nitrate Motion Picture Film*, 1994 edition.

NFPA 220, *Standard on Types of Building Construction*, 1995 edition.

NFPA 232A, *Guide for Fire Protection for Archives and Records Centers*, 1995 edition.

B-1.2 Other Publications.

B-1.2.1 ANSI Publication. American National Standards Institute, 1430 Broadway, New York, NY 10018.

ANSI/ACMI NQA-1, 1986 *Quality Insurance Program Requirements for Nuclear Facilities*

Custer, Richard L.P. and R.G. Bright, “Fire Detection: The State-of-the-Art.” NBS Technical Note 829, Washington, DC: National Bureau of Standards, U.S. Dept. of Commerce, June 1974, 110 pp., illus., bibliography.

Morris, John. “Managing the Library Fire Risk.” Berkeley: University of California Office of Insurance and Risk Management, 1975, 99 pp.

This is an investigation of various aspects of fire prevention and control, with emphasis on the

value of automatic fire protection systems. It contains descriptions of several library fires and a chapter on the salvage of wet books. It includes photographs, chapter bibliographies, and articles reprinted from fire journals.

Advisory Committee on the Protection of Archives and Records Centers. “Protecting Federal Records Centers and Archives from Fire.” Washington, DC: U.S. General Services Administration, April 1977, 202 pp., illus., bibliography.

Following the disastrous fire in the Military Personnel Records Center in Overland, Missouri, in July 1973, the GSA appointed a committee to review the present state of the art in records protection and to make recommendations on improved fire protection practices for federal archives and records centers. This book is the report of that committee.

Spawn, William. “After the Water Comes.” Bulletin of the Pennsylvania Library Association, Vol. 28, No. 6 (November 1973), pp. 242-251.

This is an outline of the general principles for salvaging water-damaged materials. It presents a hypothetical disaster and details recommended salvage procedures. The importance of planning for disaster recovery, the necessity for prompt action, and the value of freezing wet materials are highlighted. Photographs are included.

Waters, Peter. “Procedures of Salvage of Water-Damaged Library Materials.” Washington, DC: The Library of Congress, 1975, 30 pp.

This is the most comprehensive and up-to-date manual on the salvage of water-damaged materials. It also contains a list of individuals to contact for professional advice and sources for supplies, equipment, and services. Emphasis is placed on having a plan of action before an emergency occurs. It can be obtained at no cost from the Library of Congress.

NFPA 232A

1995 Edition

Guide for Fire Protection for Archives and Records Centers

1995 Edition

This edition of NFPA 232A, *Guide for Fire Protection for Archives and Records Centers*, was prepared by the Technical Committee on Records 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 on July 21, 1995, with an effective date of August 11, 1995, and supersedes all previous editions.

This edition of NFPA 232A 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 232A

The Committee on Record Protection prepared NFPA 232A, *Guide for Fire Protection for Archives and Record Centers*, as a source for planning fire protection for collections of records stored in large volumes. It supplements NFPA 232, *Standard for the Protection of Records*, which does not contain provisions for protecting large archives and record centers. This document is neither a standard nor a recommended practice, but a guide that is intended to provide records managers and others responsible for safeguarding large collections with the information necessary to plan intelligently for fire protection. The guide was presented originally at the 1970 NFPA Annual Meeting, where it was tentatively adopted.

The revised 1980 edition was adopted officially on May 21, 1980, at the NFPA Annual Meeting in Boston, MA. It was released by the Standards Council on June 11, 1980. The 1986 edition was a reconfirmation of the 1980 edition.

The 1991 edition was revised completely in order to make it more understandable to the user. Most changes were editorial in nature. Substantive changes were made in two new chapters that address construction features as well as building equipment and associated facilities. New appendix material on salvage procedures for damaged library materials was added.

This edition of the standard incorporates editorial changes and provides expanded information with regard to fire alarm systems, maintenance of water-based fire protection systems, and security features.

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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.

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 of books, papers, plans, and other records from loss incident to fire.

NFPA 232A
Guide for Fire Protection for Archives and Records Centers

1995 Edition

NOTICE: Information on referenced publications can be found in Chapter 8 and Appendix C.

Chapter 1 Introduction

1-1 Scope.

This guide applies to collections of records in file rooms exceeding 50,000 ft^3 (1416 m^3) and to all archives and records centers.

Since its adoption in 1947, NFPA 232, *Standard for the Protection of Records*, has been the recognized standard for the protection of records against fire. However, this document is concerned primarily with relatively small quantities of records that are kept immediately accessible to the originator or user. NFPA 232A covers facilities larger than those contemplated in NFPA 232.

1-2 Purpose.

The purpose of this guide is to provide recommendations for fire-safe storage in archives and records centers. It should be used where the size or character of the records holdings is not covered in NFPA 232, *Standard for the Protection of Records*, and to provide archivists, records managers, and others responsible for safeguarding large collections with the information necessary to plan intelligently for fire protection.

1-3 Definitions.

For the purpose of this guide, the following terms have the meanings specified 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.

Archives. Noncurrent records preserved for their historic value; also applied to the building, structure, or enclosure where such records are deposited or retained.

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.

File Room. An area used for the storage and reference of current records.

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.

Records Center. A building or enclosure used for the retention and reference of semicurrent records pending their ultimate disposition.

Should. Indicates a recommendation or that which is advised but not required.

Chapter 2 General

2-1 Types of Record Media.

This guide covers traditional paper records and records on magnetic, photographic, micrographic, and other special media. It is not possible to ensure total fire protection of records in archives and records center facilities. It is possible, however, to provide a very high level of fire protection that normally can limit the potential loss of records in such facilities. Therefore, it is important that the archivist or records manager is aware of the degree of protection available or, conversely, the degree of potential damage possible using the protection systems available for the archives or records center. The archivist or records manager should determine which, if any, of the records need the higher level of protection provided by the use of special vaults, safes, or insulated containers as specified in NFPA 232, *Standard for the Protection of Records*. It is essential that storage of cellulose nitrate film should not be permitted in archives or records centers. NFPA 40, *Standard for the Storage and Handling of Cellulose Nitrate Motion Picture Film*, should be referenced for these protection requirements.

2-2 Arrangement.

Storage devices include, but are not limited to, traditional file cabinets, records storage boxes (corrugated or solid fiberboard cartons), transfer cases, and miscellaneous containers of varying construction. The usual arrangement consists of either cartons on freestanding shelving or filing cabinets. Locations can vary from a separate area within a general office complex to specially constructed records facilities. It is not uncommon for records to be stored in basements or attics, in office spaces, in factories or warehouses, or in underground or other readily available facilities, with all such facilities of various types of construction and levels of fire safety. Keeping all records storage at least 3 in. (76 mm) above the floor minimizes the effect of flooding.

2-3 Fire Risk Evaluation Factors.

In considering the protection of records stored in mass, several basic factors should be evaluated:

(a) The exposure from the building housing the records, from nearby buildings, or from neighboring operations; (e.g., the possibility of involving the records in a fire originating outside of the records facility);

(b) The potential of fire initiation within the records facility, including the susceptibility of the records or containers to ignition;

(c) The potential of fire development posed by the stored records themselves, particularly as that potential relates to the available or proposed fire control capabilities or mechanisms;

(d) The potential impact of fire development in the stored records on the housing structure and adjacent operations;

(e) The fire control systems with the resultant extent and type of damage from fire, fire effects (e.g., heat, smoke), and fire extinguishing efforts (principally water and physical disruption of records necessary to effect manual fire fighting); and

(f) The potential threat to life to occupants and fire service personnel.

2-4 Exposure.

A maximum amount of care or the most sophisticated of protection systems within the records storage area is of little value for records stored within a structure that burns as a result of some occurrence or operation outside of the records area. Any archivist or records manager should consider the potential of the records being destroyed by a fire that initiates in an area external to the operations. The degree of additional risk imposed by neighbors varies according to the type and height of the building, the nature or hazard of the neighbors, and the type of protection used by the neighboring operations. Any reasonable degree of protection for records stored in mass quantities in any multistory building should include fire-resistive construction adequately designed to withstand the maximum fire impact of the exposing occupancy within. The same applies to single-story buildings unless a proper fire wall separates the records area from the remainder of the building. Where records need to be housed in a building that could burn around them, properly rated vaults, safes, or insulated containers capable of resisting a total burnout as specified in NFPA 232, *Standard for the Protection of Records*, should be used and are the only known means of protection that can provide reasonable assurance of records recovery. Where a separate building or a segregated floor or section of a fire-resistive building is used for records storage, however, the methods described in the chapters that follow provide a degree of protection commensurate with the type of system selected.

2-5 Facility Design.

The inherent risks in the storage of large quantities of records and the requirement for incorporation of appropriate passive and active systems to deter, detect, contain, and control records storage fires mandate that an experienced and competent fire protection engineer be consulted regarding the design of new facilities or major alterations to existing facilities.

2-6 Fire Prevention Program.

The most important factor in preventing fire loss in records facilities is the maintenance of a good fire prevention program based on good housekeeping, orderliness, maintenance of equipment, and absolute prohibition of smoking or use of open-flame devices. All of these items are fundamental precepts of good records management. Experience has shown, however, that regardless of how careful or complete the fire prevention program, the risk of fire initiation through either human error or situations beyond the control of the archivist or records manager (such as lightning striking the facility) is a distinct possibility, and any program based entirely on fire prevention activities is perpetually at risk of a major disaster.

2-7 Operations in Records Storage Areas.

Work within records storage areas normally is limited to placing records in, retrieving records from, or removing records from storage. Any additional operations could introduce ignition hazards and could be inappropriate in records storage areas. In archival facilities, records storage areas should be separated from processing areas, offices, and research rooms by a proper fire wall. Records center facilities involve considerably more staff activity in the records storage areas. Wherever records centers and archives are located within the same facility, the archival storage area should be separated from the records center storage area by a fire wall.

Other fire risks in the records storage areas can be reduced by the following means:

(a) The use of manual instead of power-operated equipment;

(b) The use of electric instead of gas-fueled fork lifts;

(c) Prohibiting the use of portable space heaters, lights on extension cords, hot plates, coffee makers, duplicating devices, battery chargers, welding or cutting torches, and other such ignition sources within storage areas;

(d) Prohibiting the storage of oils, paints, or other flammables in or contiguous to the records areas.

2-8 Fire Retardant Treatments.

Attempts have been made to develop economical methods of increasing the fire resistance of typical records storage cartons. The method tried most frequently is coating the cartons with an intumescent type of fire retardant paint. Tests of cartons protected by such paint that has been properly applied show that the coating prevents actual ignition of the cardboard. However, intumescent paint does not intumesce effectively under approximately 400°F (204°C). The temperature of even a small exposure fire (such as might occur on a library cart) could weaken the paper in the box to the point where the box breaks open under the weight of the paper it contains, exposing the ordinary combustible paper contents of the box. Similar results have occurred in tests of boxes that have been covered with aluminum foil, with the additional effect of transmission of heat through the aluminum, causing ignition of the cardboard carton beneath it. In a small-scale test conducted as a joint effort of the NFPA Technical Committee on Record Protection and the U.S. General Services Administration, the effect of a fire retardant paint coating on boxes demonstrated a very brief delay only in the ignition and development of fire up and across the face of the records storage. Therefore, as a records container still is made of paper, the inherent characteristics of easy ignition and rapid fire development associated with paper do not change.

Chapter 3 Fire Characteristics

3-1 Metal Containers.

3-1.1 Fire Initiation.

In some facilities, all records are kept in metal file equipment or equivalent metal containers (closed on six sides), and the arrangement, housekeeping, and operational methods prohibit the maintenance of any combustible materials of any type in locations outside the steel containers. Where the surrounding building and all its associated materials are noncombustible, the risk of fire or the possibility of fire development should be considered to be the burnout of one drawer and damage to the materials in the surrounding drawers above, below, behind, and beside the drawer of origin under the following conditions:

(a) All of the records are kept exclusively in metal file cabinets or equivalent metal cabinets (closed on all six sides);

(b) The arrangement, housing, and operational methods prohibit combustible materials outside the metal containers; and

(c) The surrounding buildings and all their associated materials are noncombustible.

3-1.2 Fire Development.

Where all records housed are contained within closed metal file equipment, transfer cases, or similar containers (whether or not of the insulated type) so that no fuel is exposed to flames outside the containers and there are no other combustibles in the area, no significant fire development would be expected from most initiating sources. Fire spread from a significant ignition source would be anticipated to be very slow.

3-2 Open Shelving.

3-2.1 Fire Initiation.

Records facilities use various shelf filing equipment, normally with the records either contained in file folders or stored in various styles of open or closed cartons. Typically, rows of records face each other across long service aisles about 30 in. (762 mm) in width. The exposed faces present a wall of paper. Paper has an ignition temperature of approximately 450°F (232°C). Where exposed files exist, the loose ends of the papers or the edge of the file folders can be ignited almost instantly by any source ranging from a match to a faulty fluorescent ballast or by direct contact with an exposed incandescent light bulb. Because of their mass, closed cartons resist ignition slightly longer, but there is a good probability that an ordinary match could ignite them. Ignition of a few pieces of paper, such as might occur on a service cart, could readily ignite the faces of the boxes.

3-2.2 Initial Fire Development.

Where records are stored on open-type shelving, it can be expected that fire development would occur and would approximate a typical pattern of development demonstrated in tests conducted on high-piled storage by Underwriters Laboratories Inc., Factory Mutual Research Corporation, and in tests conducted on 6-ft (1.8-m) high archive shelving arrangements by the

U.S. General Services Administration. In each instance, the initiating fire was small [2 lb (0.91 kg) of paper laid on the floor in the Underwriters Laboratories test, $^1/_2$ pt (0.24 L) of heptane on cellucotton in an open carton of records in the Factory Mutual tests, and two open cartons of records on a library cart in the U.S. General Services Administration test]. The initial fire development progressed for a brief period at a low level, producing the type of fire that could be approached and easily extinguished if promptly discovered. The period of low-level development lasted between a minimum of approximately 3 minutes to a maximum of approximately 12 minutes to 15 minutes, with an average of approximately 5 minutes. During this period, the fire was directly approachable, since heat levels were not high; however, significant quantities of smoke were produced. The temperature levels at the ceiling were sufficiently low to make it unlikely that any heat-reacting fire detection devices would have signaled the presence of fire. In view of the relatively large smoke production, smoke detectors could have detected such a fire early in its development. In tests with 14-ft (4.3-m) open shelving, smoke detectors operated within 30 seconds to 1 minute, but fire was judged to be beyond portable extinguisher control in less than 3 minutes, providing little justification for the cost of installing smoke detection systems in this case.

3-2.3 Full Fire Development.

By the end of the relatively short early development stage in each of the tests described in 3-2.2, a sufficient number of the exposed boxes had been preheated so that the fire development characteristics changed suddenly, the temperatures increased rapidly, and the flames enveloped large areas, extending almost immediately beyond human approach and the ability to attack using simple portable extinguishers. Fire development increased rapidly from this point. In each of these cases, a fire control mechanism was being tested, and the fires were not allowed to progress to their ultimate potential.

In some Factory Mutual tests, however, loose records in boxes were released by the fire and exfoliated into the aisle, providing very rapid acceleration of the fire and a condition approaching full fire development in a limited area, perhaps 60 ft^2 to 70 ft^2 (5.6 m^2 to 6.5 m^2). On the other hand, in the same test series, a fire test was conducted in which all of the papers were oriented perpendicular to the aisle and stored loose on edge in shelving 14 ft (4.3 m) high. The box fronts were removed to expose the loose paper edges. Contrary to expectations, the fire developed slowly and was never beyond the control of modest local forces employing small hose. Prevention of exfoliation of burning paper apparently served to avoid the dramatic increase in fire intensity.

3-2.4 Fire Severity Potential.

Unless fire development is stopped by either manual or automatic fire extinguishment, the entire records storage in one room or on one floor could become involved in fire quickly. The spread of a fire and the extent of damage is related directly to the total quantity of combustibles involved. The severity of a fire is approximately 1 hr for each 10 lb/ft^2 (49 kg/m^2) of gross weight of combustibles involved. The weight of paper in a typical records storage area is equivalent to approximately 10 lb/ft^2 (49 kg/m^2) for each shelf height of storage. A typical center with records stored seven shelves high contains fuel in quantities of approximately 70 lb/ft^2 (342 kg/m^2) of floor area, and in a center where records are stored 15 shelves high, the weight of the paper would approximate 150 lb/ft^2 (732 kg/m^2). In either case, there are no traditional types of fire-resistive construction capable of withstanding the total impact of burnout. This is particularly important in any situation where records are stored in a multistory building.

3-2.5 Inherent Fire Capacity.

Any archives or records centers using open-type shelving are inherently prone not only to the destruction of the records, but also to the destruction of the facility itself and its neighboring operations, unless all fires are stopped in their early stages.

3-3 Mobile Shelving.

3-3.1 Fire Initiation.

Shelving in records facilities that is mounted on rollers, usually on tracks, is used to conserve space. One aisle is provided for a series of shelving units, and, to gain access to a particular shelf, units are moved manually or by motor until the desired shelf unit is positioned to be accessible from the aisle. Ignition sources are similar to those in open-type shelving but with the added potential of an ignition source from the electric drive units. Slow-developing, burrowing fires can be expected except in the exposed aisle, where a fire would be similar in character to that in open-type shelving.

3-3.2 Initial Fire Development.

Tests conducted by Factory Mutual Research Corporation for the U.S. General Services Administration and U.S. Library of Congress indicated that fires originating in the open aisle could be expected to follow the pattern of open shelving fires in initial development and quickly involve both faces. The length and height of mobile units is determined by available space, loaded weight, access time, and other factors. A recommended limit for length is 25 ft (7.6 m). Fire spread down an open aisle with facing combustible storage is likely to be rapid. Fire spread tunneling through the shelving array is likely to be very slow, providing some opportunity for control and extinguishment by a public fire department if the fire is discovered and reported promptly.

3-3.3 Fire Severity Potential.

The potential for a total burnout of a records facility is exactly the same as for a similar quantity of records on open shelving, except that a fire that involves mobile shelving takes considerably longer to spread beyond the control of a municipal fire department.

3-3.4 Inherent Fire Capacity.

As in the case of records stored on open shelving, records stored on mobile shelving are inherently prone not only to the destruction of the records, but also to the destruction of the facility itself. The slow spread of a fire within the shelves improves the effectiveness of outside efforts to stop the fire.

Chapter 4 Fire Control

4-1 General.

The basic elements of fire control are two-fold: detection of the existence of fire plus its extinguishment. The individual efficiency and capability of both detection and extinguishment determines the degree of safety or, conversely, the extent of damage in case of fire.

4-2 Water.

Most archivists or records managers are seriously concerned about water damage. In view of the constant problems involved in the leakage of domestic water systems and steam mains, the rain intrusion from leaky roofs or windows, and the resultant damage from mildew or decomposition of paper, this concern is understandable. It is important, however, for the archivist or records manager to realize that wet records can be recovered, while burned records are lost permanently. Furthermore, unless there is a specialized fire extinguishing system to control the development and growth of a fire, responding fire-fighting forces have no choice but to attack the fire with fire department hose streams. In many records facilities, the quantity of paper fuel involved is such that the fire department has to attack a fire from a distance and under extremely adverse conditions. This normally forces the fire department to use heavy hose streams having the characteristics of a hydraulic ram. Wide and forceful disruption of the records storage arrangement is a routine consequence of efforts to prevent total destruction.

4-3 Salvage.

Recovering wet records is a problem whether the source of water is a result of fire-fighting efforts, a fire, or another source, such as a flood, a hurricane, a heavy rainstorm, roof leakage, spillage from operations located above, or a breakdown of any of the numerous water or steam systems in a building. Virtually any wet paper records can be recovered, provided prompt and proper action is taken. Effective salvage necessitates prompt action, special techniques, facilities, and expert advice. Preplanning is essential.

NOTE: Archivists and records managers interested in salvage should reference NFPA 910, *Recommended Practice for the Protection of Libraries and Library Collections*, Appendix O "Salvage of Wet Books," and the Federal Fire Council Recommended Practice No. 2, *Salvaging and Restoring Records Damaged by Fire and Water*, which is available from the Clearinghouse, U.S. Department of Commerce, Springfield, VA 22151. Salvage of wet records from the 1973 fire at the Military Personnel Records Center, St. Louis, MO, is treated in considerable detail in the July 1974 NFPA *Fire Journal* and the October 1974 *American Archivist*. Also useful as background material is the publication *Conservation of Library Materials*, a manual and bibliography on the care, repair, and restoration of library materials by George M. and Dorothy G. Cunha (Metuchen, NJ: The Scarecrow Press, Inc., 1971; two volumes; LC # 77-163871). Volume I is the manual, and Volume II is the bibliography.

4-4 Fire Extinguishers.

Regardless of the other types of fire extinguishment systems provided, it is essential that every records storage facility be provided with an adequate supply of well-distributed Class A portable fire extinguishers suitable for extinguishing fires in paper and plastic records. The extinguishers should be of the trigger action type in which the flow can be started and stopped by the operator. NFPA 10, *Standard for Portable Fire Extinguishers*, should be referenced for specific information regarding portable fire extinguishers. Gaseous extinguishers are not effective for extinguishing deep-seated fires in paper materials. The presence of proper extinguishers enables the working or guard force, on discovery of a fire or on response to an alarm from an early warning detection system, to attack and extinguish the fire while it is small with minimum damage to the records. It is important that local forces are instructed properly in the use of small extinguishing appliances.

4-5 Fire Departments.

The fire department is an essential part of any fire protection plan. The role of the fire department depends on the type and capabilities of an automatic extinguishing system, if provided. Where no extinguishing system is provided and total dependence is placed on the fire department for control of any fire that exceeds the capabilities of persons using hand extinguishers, it is reasonable to expect that the fire department will be forced to make a massive attack because of the size and position of the fire at the time of arrival. Fire fighters are limited by their tolerance to heat and smoke. To reach the actual seat of the fire, the fire department could undertake actions that are disruptive or damaging to records that are not actually burning. Rows of records might block access to the seat of the fire. High density smoke might conceal the seat of the fire. To save the structure and to prevent propagation of the fire to other areas, it might be necessary for the fire fighters to disrupt the storage arrangement in unignited areas to obtain access to the ignited area or to use high-pressure hose streams in a general sweeping action in an effort to provide a general cooling/quenching effect. In any sizable records facility, the total amount of fuel necessitates the use of heavy hose streams. In some communities, fire departments have the capability and are likely to use monitor- or snorkel-type hose streams. Properly constructed fire walls, confining the fire to a single fire area, assist a fire department in limiting the size of a fire. All records within the fire area are likely to be affected seriously by either fire or by water from the high pressure streams, or by both.

4-6 Role of Fire Department and Extinguishing Systems.

Where an automatic extinguishing system of proper design is provided, the role of the fire department changes from the implementation of direct fire attack to assisting and supplementing the automatic extinguishing system.

4-6.1

If the system is an automatic sprinkler system, the primary responsibilities of the fire department are to supplement the water supply, determine the proper time to discontinue the flow of water, extinguish fire in any small, shielded areas that the sprinkler system could not reach, and overhaul the actual burned areas to prevent rekindling or reignition. For further information, NFPA 13E, *Guide for Fire Department Operations in Properties Protected by Sprinkler and Standpipe Systems*, should be referenced.

4-6.2

Where a total flooding carbon dioxide or Halon 1301 system is provided and has been successful in its operation, the primary responsibility of the fire department is to vent the gas and to prevent the possibility of rekindling by wetting and removing the materials that were ignited. The period during which carbon dioxide gas is phased out is critical, and, unless the smothering action has been totally effective, rekindling of a serious fire can occur. This procedure is potentially hazardous and should be executed only with the full capabilities of the fire department in readiness.

4-6.3

If high-expansion foam is used, the primary responsibility of the fire department is to assist in removal of the foam and to extinguish any small glows (deep-seated fires) or flames that are found while the foam is removed. Depending on the situation, it could be desirable to continue the application of the high-expansion foam for a soaking period. However, the length of time that the foam is kept in place affects the degree of wetting. Therefore, overhaul procedures should be carried out rapidly but cautiously, with extinguishing equipment standing by in readiness.

4-7 Fire Department Preplanning.

Fire department preplanning for attack in specific locations is essential in all systems of fire control. It is important that the archivist or records manager contact the appropriate chief officer of the responding fire department to establish prefire planning arrangements. The best extinguishing system can be overcome if a fire officer, due to lack of knowledge, makes improper use of the system or prematurely removes an automatic system from operation. Conversely, lack of knowledge and a sense of caution can result in a fire officer maintaining the operation of an extinguishing system for an excessive length of time, increasing damage to the records from the extinguishing agent.

Chapter 5 Fire Control Systems

5-1 Detection.

5-1.1 General.

In any fire control system, the first step should be the detection of the presence of fire with immediate notification of emergency response forces, including the fire department (*see Section 5-5*). A number of different methods of detection are available, ranging from highly sophisticated devices for almost immediate detection of products of combustion to dependence on passersby. Detection of fire, while vitally important, does not in itself prevent fire damage. Detection needs to be followed by extinguishment, which includes the use of fire extinguishers or other first aid fire appliances by facility personnel or guards, attack by the fire department using the various manually directed appliances at its disposal, or control by automatic suppression systems, such as sprinklers, carbon dioxide, or halon. The capabilities and efficiency of each of these systems vary significantly and also can affect the extent of fire damage.

5-1.2 Human Detection Capabilities.

An evaluation of the various methods of fire detection demonstrates that any detection system that relies only on casual observation by those persons whose activities take place outside the records storage area is undependable, and a facility that depends upon detection by passersby is at risk of total burnout. Some records centers assign responsibility for fire detection to watchpersons or guards around the clock or a combination of employee responsibility during the workday and watchpersons or guards after business hours. While this approach is superior to dependence on casual observation, it should be considered very limited. (The major fire at the Military Records Center in St. Louis was first reported by a passerby, although the building had guard patrols.) As previously described, the period during which such observation can result in the detection and response to a small fire situation is quite limited if, for instance, a fire initiates within the service aisles of the stack area. Since this usually is the most critical and damaging type of fire, it is considered to be the type that most necessitates early detection. Normally, guard rounds are regulated at intervals of 1 hour or more. A major fire catastrophe could develop between periods of observation of the most alert and conscientious guard. The presence of guards can be effective in peripheral situations, such as a small office fire. They also can function in fire prevention programs. Guards are, however, of limited value in controlling a fire in record shelving, except in notifying the fire department.

5-1.3 Heat Detection.

Fixed temperature or rate-of-rise heat detection equipment sometimes is used in records facilities. As described in Chapter 3, these devices are not likely to respond to a fire until it has developed into its major stage. At this point, unless there is an installed automatic extinguishing system, the fire is likely to be beyond the capabilities of local forces. The heat detection system alone cannot control the fire. It is likely that, when the municipal fire department arrives at the scene and sets up operations, they will be severely challenged by the fire. This complicates fire-fighting efforts and increases the resultant records damage. On the other hand, if the heat-actuated detection equipment is used to operate an automatic fire control system, it could provide a very effective function.

5-1.4 Automatic Sprinkler Detection.

In considering detection systems that initiate the operation of an extinguishing system, it is necessary to consider briefly the detection aspects of automatic water sprinkler systems. Each automatic sprinkler is a fixed temperature device that opens (fuses) when heated to a preset temperature. Where the automatic sprinkler system is equipped with a waterflow detection device, the sprinkler system virtually becomes a fixed temperature fire detection system as well as an automatic water extinguishing system. For this reason, the detection of waterflow in the sprinkler system is important, and it is considered axiomatic that every sprinkler system installed in a records storage facility should be equipped with waterflow detection that activates the building fire alarm system and thus transmits the alarm.

5-1.5 Early Warning Detection.

These devices, known generically as smoke detectors, respond to either the visible (smoke) or invisible (molecular size) products of combustion, or both, produced from the moment of ignition. In a properly engineered installation, these devices can detect a smoldering fire in its low energy stage. Where ignition from a smoldering fire is likely, smoke detectors can provide warning very early in the development of fire.

5-1.5.1 Listed or approved smoke detectors include ionization type, photoelectric beam or spot type, infrared type, and others. It is possible, if necessary, for these early warning systems to activate associated fire extinguishing systems. Such smoke detectors may be permitted to be considered part of the overall system in any important records collection where a smoldering fire is possible.

5-1.5.2 Total dependence on a combination of smoke detection and hand fire extinguisher attack still leaves the facility subject to a major disaster. Dependence solely on an early warning detection system exposes the facility to full fire development before effective efforts can be undertaken.

5-1.6 Locating Smoke Detectors.

It is important that the system be individually engineered by competent personnel. Where the devices are used, they are installed because of the desire detect fire as early in its development as possible. The various types of air movement, including stratification caused by heating or other air-handling systems, as well as those caused by the records storage arrangement, are important considerations. The system should be capable of detecting and locating the presence of fire in any portion of the records storage area within a brief time in order to obtain maximum protection. While the time element specified directly affects the cost of the system, it also affects the extent of the damage. Generally, the shorter the time for detection, the higher the cost of the system. NFPA 72, *National Fire Alarm Code*, should be referenced for further information on the spacing of smoke detectors.

5-1.7 Fire Alarm Systems.

Fire alarm systems can perform numerous functions, such as detecting incipient fire, notifying on-premises first-response teams, notifying the fire department, sounding evacuation signals, shutting fire doors, starting smoke control systems, monitoring system status, and printing a permanent record of all events. They also can be used to activate certain types of fire suppression systems.

5-1.7.1 NFPA 72, *National Fire Alarm Code,* should be referenced for minimum standards for system components and their installation.

5-1.7.2 Three categories of input signals normally are provided: alarm, supervisory, and trouble signals. Alarm signals take priority over supervisory and trouble signals and include activation of manual fire alarm boxes, signals from automatic smoke and heat detectors, waterflow indications from sprinkler systems, and agent-release signals from special hazard suppression systems. Supervisory signals take priority over trouble signals and include activation by off-normal sprinkler functions (such as temperature, pressure, and valve position). Monitoring functions include status of control and circuit conditions in fire alarm systems, status of certain fire suppression systems, status of watchperson tours, and other functions. The status of critical non-fire systems also can be monitored.

5-1.7.3 System output functions can include some or all of the following, depending on the size of the building, local codes, availability of trained emergency response teams, and other factors:

(a) General evacuation signals (bells, horns, and strobes);

(b) Presignal alarm devices for initially alerting only selected staff;

(c) Selective evacuation signals (voice/tone signals, zoned);

(d) Lamp or LED text displays identifying the type and source of the alarm or monitoring signal;

(e) Logs (electronically recorded or printed) of all “change of status” events;

(f) Remote indications of alarm and monitoring signals at locations such as central stations and fire departments;

(g) Activation of fire suppression systems;

(h) Activation of smoke control systems, including HVAC shutdown and damper and door releases;

(i) Transmission of signals to building energy man- agement systems, security monitoring systems, and other systems.

5-1.7.4 Fire and security functions can be integrated into a single system, but, generally, these functions should not be controlled from the building energy management system.

5-2 Automatic Sprinkler Systems.

5-2.1 General.

The most effective fire protection element and the most economical automatic fire control system for protection of archives and records centers is the automatic wet-pipe sprinkler system. Such systems are also the most frequently opposed by records managers because of concern with water damage. Three factors serve to alleviate this concern:

(a) Sprinklers actually constitute a method of fire control involving a minimum rather than a maximum of water.

(b) Each sprinkler operates individually and, the operation of any single sprinkler does not cause the operation of any other sprinkler; therefore, only those sprinklers in the heat of the fire operate and discharge water.

(c) Wet records are recoverable; burned records are not recoverable.

5-2.1.1 The probability of sprinkler operation when no fire exists is insignificant.

5-2.1.2 Because of the rapid heat development in records storage areas, high temperature-rated sprinklers [250°F to 300°F (121°C to 149°C)] are used commonly in lieu of ordinary-rated sprinklers [135°F to 170°F (57°C to 77°C)] to limit the number of sprinklers that operate in a fire to those that act directly in extinguishment. NFPA 13, *Standard for the Installation of Sprinkler Systems*, should be referenced for additional information on the use of sprinklers. In archival storage areas, consideration should be given to using ordinary ratings [135°F to 170°F (57°C to 77°C)] where the risks of fire development exceed the risks of water damage.

5-2.2 Waterflow Alarms.

Where a records center is protected by an automatic sprinkler system, provision of a waterflow alarm that transmits a signal to the fire department on the fusing (opening) of one or more sprinklers eliminates the possibility of a sprinkler operating undetected and discharging water for a long period, excessively wetting the records underneath, after the fire has been successfully extinguished. The waterflow alarm feature, in addition to signaling the existence of a fire, also detects the flow of water in the rare instance of accidental or malicious damage to the system.

5-2.3 Sprinkler Operation Characteristics.

The sprinkler system operates only when the fire has reached the point of rapid heat rise and has passed the phase of development where hand fire extinguishment is effective. Both tests and fire experience have shown that sprinklers can confine the fire to a relatively small portion of the row of shelving where the fire started. The sprinkler discharge does not necessarily extinguish fire concealed under the shelves or inside mobile shelving. It definitely does slow down or prevent further fire propagation, removes the heat, and prevents further damage or collapse of the stack equipment. Thus, fire fighters entering the building can approach the seat of the fire and use small hose streams to quench the glowing or flaming areas.

5-2.4 Sprinklers—Expected Results.

Under normal conditions in a facility protected by sprinklers, it is probable that fire would be confined to an area of 100 ft^2 to 500 ft^2 (9.3 m^2 to 46.4 m^2). Water damage would consist primarily of superficial wetting of cartons in those areas where cartons were involved or wetting of the edge and bottom of open file records. These areas of water damage probably would extend approximately 10 ft to 20 ft (3.0 m to 6.1 m) to each side of the area of fire damage. The records on top of the top shelves would be the wettest; those on lower shelves would be shielded from the direct impact of water and would be considerably drier. Total extinguishment and shutdown likely would take place before failure of the corrugated or pressboard cartons. In this respect, cartons with wire-stapled lap-joints (rather than those that are glued) are less likely to fail. Containers that are die cut for assembly without the use of glue or staples are also suitable as protection against water damage and for avoiding possible injury and the problems associated with wire staples. Boxes with handholes are more susceptible to water damage. Water discharge from the sprinklers is in the form of a fine spray and, therefore, would not disturb the position of the records storage. Fire department operations in a sprinklered facility likely would cause only minimal physical disruption. It is probable that smoke and soot damage would be minimal. Solid fiberboard (archival) boxes resist water damage to a much greater extent than corrugated cartons.

5-2.5 Sprinklers—Special Systems.

There are four sprinkler types and systems that are considered to be suitable for records protection. NFPA 13, *Standard for the Installation of Sprinkler Systems,* should be referenced for installation details.

(a) *Pre-action System.* A pre-action system is a system in which the sprinkler piping normally is dry and in which the control valve opens only when the heat detection devices sense the development of a fire. As in the wet-pipe system, individual sprinklers are fused so that only those located directly over the fire operate. Although more costly than the ordinary system, it has the advantage of eliminating the discharge of water if a sprinkler or a line is broken accidentally or deliberately. It is more expensive than a wet-pipe system, since a complete detection system is needed in addition to the sprinkler system. It is less reliable than a wet-pipe system, since it cannot operate if the detection system is inoperative.

(b) *Recycling System.* A recycling system is an adaption of a pre-action sprinkler system with a recycling feature. When the sprinkler or sprinklers have extinguished the fire and the heat drops below a preset temperature [e.g., 140°F (60°C)], the detectors initiate a timing cycle that automatically discontinues the waterflow by closing a special valve in about 5 minutes. The system remains in readiness, and, if the fire rekindles, it recycles to start the waterflow. The system has the advantages of automatically determining when the temperature has decreased and of shutting the system off, making it almost impossible for maintenance personnel or others to close the valve accidentally.

As in the pre-action system, the recycling system needs a separate detection system. Since the system is designed to recycle, the detection system needs to be fire resistant and, therefore, is somewhat more expensive. An advantage of the recycling system over other sprinkler systems is that, if the system shuts off prematurely and fire continues or rekindles, it is reactivated automatically when the ceiling temperature increases.

(c) *On-Off Sprinklers.* Sprinklers with a recycling feature are available. Installed on wet-pipe sprinkler systems, each sprinkler operates individually at a predetermined temperature, but when the temperature drops below the predetermined temperature, the sprinkler shuts off. Each sprinkler operates independently, cycling on and off depending on the fire situation in its immediate area. No separate detection system is necessary.

(d) *Dry-Pipe Sprinkler Systems.* A dry-pipe system also is useful for the protection of records storage. The sprinkler piping is filled with compressed air. The release of air pressure through a fused sprinkler allows the water valve to open and supply water to the sprinkler piping. Each sprinkler operates independently, as do all other types described in this section. Releasing air pressure through a fused sprinkler takes appreciable time, during which the fire could grow and open additional sprinklers. Dry-pipe sprinkler systems are used primarily for protection of unheated areas where freezing temperatures are likely to occur.

5-3 High-Expansion Foam.

5-3.1 General.

High-expansion foam is a total flooding extinguishing agent that inundates the protected space. The foam surrounds all materials within the protected area with an aggregate of bubbles, each of which carries a small quantity of water. NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*, should be referenced for more extensive coverage of the characteristics of this extinguishing agent.

In tests conducted by the U.S. Atomic Energy Commission involving records media, high-expansion foam extinguished test fires quickly and easily by filling the entire volume of the storage space. The degree of wetting was low; generally, the foam did not penetrate normal corrugated fiberboard cartons. Cartons with stapled or interlocking edges tend to hold up quite well, while cartons with glued edges tend to come apart and expose the records contents to foam. Identification labels tend to slip off.

However, after exposure to the foam, it was necessary to take corrective drying action on all the materials within the area contacted by the foam.

NOTE: Data on these tests are published in an Atomic Energy Commission report, “High Expansion Foam Fire Control for Records Storage Centers,” IDO-12050, March 1966, available from the Clearinghouse, U.S. Department of Commerce, Springfield, VA 22157. Also see Beers, R. J., “High Expansion Foam Fire Control for Records Storage,” *Fire Technology*, Vol. 2, No. 2, May 1966, pp. 108-117.

5-3.2 Design of High-Expansion Foam Systems.

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*, should be referenced for the minimum requirements and design for systems that provide adequate protection. There are three types of high-expansion foam systems available:

(a) Total flooding systems

(b) Local application systems

(c) Portable foam application devices.

For the purposes of this guide, total flooding systems are most applicable. Total flooding involves filling the storage space with foam to a level above the combustible material.

Total flooding systems need to maintain sufficient foam to submerge the hazard, sufficient time to cover the hazard, and a minimum rate of discharge to compensate for the breakdown of the foam by sprinkler discharge, shrinkage, fire, and other factors. High-expansion foam systems require venting, closure of openings through which foam can escape, and maintenance of sufficient foam to cover the hazard to ensure control and extinguishment of fires. The rate of application of high-expansion foam is rapid, and a large vent area is needed for the displaced air. Automatic activation of the system is by means of a heat detection system similar to that described for other systems.

5-4 Gaseous Extinguishment.

5-4.1 General.

Extinguishment by total flooding with gas is favored by many archivists and records managers since no water damage can occur and salvage problems are simplified. Two principal gases used for this application are Halon 1301 and carbon dioxide. Total flooding involves filling the entire protected volume with a specific concentration of gas.

5-4.2 Halon 1301 Gas Systems.

While water-based agents depend on cooling and quenching and carbon dioxide depends primarily on oxygen-exclusion, Halon 1301 inhibits burning by chemically interacting with the flame radical. Halon 1301 (bromotrifluoromethane) is a liquefied gas under pressure, which is an effective flame inhibitor that also exhibits low toxic and corrosive properties. The design of Halon 1301 systems is covered by NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*. The use of this agent for total flooding applications in records storage facilities has been limited, and installation should be attempted only with expert guidance.

Because it is a flame inhibitor, Halon 1301 is not effective against smoldering fires at normal concentrations. In a records storage facility, it is important that application be undertaken as early in the fire as possible, before it becomes deep-seated. To be effective, it also is important that the system be automatic and total flooding and that it employ a properly responsive detection system. It is essential that means be provided to contain the gas without significant leakage for an extended period. Halon 1301 systems are relatively expensive, and most installations have been limited to the protection of high value collections in moderate-size spaces [less than 50,000 ft^3 (1416 m^3)]. Total extinguishment by Halon 1301 of a fire in Class A (paper) storage is not likely due to smoldering. Prevention of flaming fire pending the arrival of the municipal fire department might be adequate. Rapid fire growth would be inhibited in the interim. The fire department would be likely to use water to complete the extinguishment, possibly under conditions of low visibility. Many installations sound an evacuation alarm prior to gas discharge to prevent occupants from breathing halon or halon decomposition products. Use of Halon 1301 is not recommended for ordinary records centers or archive facilities but might be appropriate for the protection of isolated smaller collections and records of high intrinsic value.

5-4.3 Carbon Dioxide Systems.

Fire extinguishment can be accomplished by a total flooding carbon dioxide system with a soaking period. The design and proper installation of such a system are critical. NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*, should be referenced for further information.

5-4.3.1 Systems for records storage protection are designed to provide a carbon dioxide concentration of 65 percent in the protected space to control stratification and to maintain soaking for 30 minutes Openings that are not necessary for pressure venting are to be closed at the time of discharge to avoid loss of carbon dioxide during the soaking period. Underdesigned carbon dioxide systems are subject to failure at the time of fire. Proper performance can be ensured only by actual testing to make certain that the design concentration is achieved and maintained for the full soaking period.

5-4.3.2 Since atmospheres containing fire extinguishing concentrations of carbon dioxide cannot sustain life, it could be fatal to be trapped in the flooded space. Ample warning and time delay are to be given prior to discharge to allow occupants to escape from the area to be flooded. A person cannot leave the area safely after the discharge starts. Provision should be made for exhausting the atmosphere after the soaking period without creating a hazardous atmosphere in another location.

5-4.3.3 For effective fire control, the activation of the carbon dioxide system should be automatic in response to fire and triggered by a properly designed and installed heat detection system.

5-4.3.4 Discharge of carbon dioxide can cause condensation of humidity (fogging), which can obstruct vision.

5-5 Comparisons of Extinguishing Systems.

5-5.1

There are a number of factors involved in comparing extinguishing systems. Initial cost, reliability, cost of agent, susceptibility to false operation, area of application, damage to records by fire and by extinguishing agent, and consequences of failure are all important factors to be considered. All automatic systems are damage-initiated; a fire that causes damage needs to occur before an automatic system detects it and activates. Generally, the smaller the fire a system can detect, the more sensitive the system, and the more likely it is to operate falsely. It is important that the alarms for all systems be connected to the municipal fire department so that it is notified of a fire when the system activates.

5-5.2

Automatic sprinklers are the most reliable and economic means of controlling fire in a records center. Wet-pipe sprinklers with hydraulically designed piping, adequate water supply, and supervised valves are reliable and trouble-free. Cyclic systems, pre-action systems, and dry-pipe systems, provided for insurance against water damage, introduce the potential for failure in the system and can slow system functioning during a fire, resulting in a larger fire. In the event of a fire, only sprinklers in the immediate vicinity of the fire are activated. In the Factory Mutual full-scale test series, with sprinklers located in positions as ineffective for extinguishment as possible, the three tests opened 6 sprinklers, 16 sprinklers, and 3 sprinklers, respectively. This covered 600 ft^2, 1600 ft^2, and 300 ft^2 (56 m^2, 149 m^2, and 28 m^2) using an installed array of 77 heads in a facility having approximately 400 heads. In these tests, as in most records fires, regardless of the extinguishment means, final extinguishment was by hose line. All records wetted but not burned were recoverable.

5-5.3

Detectors that react to a spark are available, but smoke detectors are the most sensitive types of detectors used in records centers. Where used to initiate the discharge of an agent, a smoke detector usually is desensitized by means of two detectors on alternate circuits that activate prior to agent discharge. Although smoke detectors activate promptly when exposed to smoke, a smoldering fire is not sufficiently buoyant to carry smoke to a high ceiling, and detectors generally react to a smoldering fire after a long period due to the process of diffusion. A strong heat column from a brisk flaming fire causes a smoke detector to operate promptly, but heat detectors, including sprinklers, also react quickly to this type of fire. Full-scale fire tests showed little advance warning of flaming fires in a records center by means of smoke detectors.

The principal value of system detectors is to initiate the extinguishing and life safety alarms. It is advantageous to initiate manual extinguishment by local forces, since an incipient fire could be discovered and extinguished with minimal damage by employees using extinguishers or hand hose. If the fire grows beyond the incipient stage, employees are at significant risk due to their lack of experience, breathing equipment, and protective gear. A municipal fire department is far better equipped for manual fire fighting due to their use of protective gear and heavy hose streams and their experience. The time needed for discovery, reporting, travel, and setup can result in an established fire that is beyond manual control by municipal forces, as occurred in the unsprinklered Military Personnel Records Center fire and many other fires in records centers.

5-5.4

Gaseous extinguishment has the potential for causing the least damage if all elements of the system perform as designed. Automatic operation of the system and automatic closure of leakage openings is essential to the success of these systems. Neither halon nor carbon dioxide can be expected to extinguish a deep-seated fire condition that occurs if an archives or records center fire is allowed to become well-developed before application of the extinguishing gas. Gas leakage through an open door, a temporary opening, or a fire-caused breach also could result in a failure. Gas extinguishing systems that are equipped with more sensitive detectors are used mainly on incipient fires to minimize damage and because the larger the fire, the less likely that extinguishment can be accomplished. However, using more sensitive detection can result in increased false operations, which are undesirable because of the high cost of agent and because of the hazards to personnel. All materials in the enclosure are exposed equally to the gas, whether near to or remote from the fire. Final extinguishment usually is performed by the fire department using hose streams. If the area is obscured by smoke, which is likely, directing hose streams could be haphazard and could result in widespread water damage.

5-5.5

High-expansion foam discharged through an automatic means has the capacity to overcome a well-established fire and, therefore, is far superior to gaseous extinguishment and is superior to the use of sprinklers. As in the case of gaseous extinguishment, high-expansion foam escapes through unenclosed openings, although a very lightweight partition such as fine mesh screen can contain it. In addition, as with gaseous agents, all materials in the enclosure are exposed equally to the extinguishing agent. Since foam dampens kraft boxes (and perhaps loosens identification labels), all materials in the enclosure become slightly damaged and need to be dried. Final extinguishment by fire department hose streams is likely to be necessary.

5-6 Installation and Maintenance of Systems and Equipment.

To ensure reasonably that a fire detection control system, appliance, or device performs satisfactorily, it is necessary for the installation to be in compliance with the recognized standards and the manufacturer’s instructions and that complete operational tests are conducted.

After installation, it is important that a complete routine scheduled maintenance program that follows recognized standards and manufacturer’s instructions be developed and followed. This may be permitted to be performed either by competent maintenance employees or by service contractors.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, should be consulted for inspection, testing, and maintenance of fire sprinkler systems and standpipe systems and all related water-based fire extinguishing systems.

Chapter 6 Construction

6-1 General Principles for New Construction.

6-1.1

The more important general principles for fire-safe records center and archives construction are described in this chapter. Detailed recommendations for good practice also are contained in various NFPA publications. In most localities, building codes and ordinances govern the type of construction to be used to a large extent.

Codes frequently provide for the safety of persons in the building but not for the preservation of the building or the collections. Therefore, it is of critical importance during the development of the project for the records custodian to specify the level of fire safety to be achieved in the construction. For single-story, aboveground facilities, consideration should be given to including a clause in the professional service contract(s) for the design of the project that mandates retaining and providing the consulting services of a qualified fire protection engineer, acceptable to the records custodian, to participate in the development of the fire safety system, including the determination of the requirements to be provided in the final project documentation. For multistory or below-grade facilities, the services of a qualified fire protection engineer are essential.

6-1.2

The design of the automatic sprinkler protection and other fire protection and detection systems and building construction are interrelated. In addition to protecting combustible contents and providing improved safety to life, automatic fire suppression systems can, in some cases, enable the use of less expensive construction than would be possible without them. Properly designed automatic sprinkler systems in all areas of an archives or records center are mandatory.

6-1.3

For records center and archives construction, it is desirable to select materials and types of construction that are either noncombustible or that have resistance to fire. Fire-resistive construction is desirable and is essential for multistory structures. Fire-resistive construction should be in accordance with NFPA 220, *Standard on Types of Building Construction*, and requires structural members, including walls, partitions, columns, and floor and roof construction to be of noncombustible materials and to have fire resistance ratings from 2 hr to 4 hr, depending on the structural members.

6-1.3.1 Columns within shelving are potentially exposed to high temperatures exceeding the fire resistance of steel. Therefore, building columns within the records storage area should be of 2-hr construction from the floor to the point where they meet the roof-forming system.

6-1.3.2 Standard sprinklers might not protect lightweight roof structures (such as bar joists) during early fire development. Quick-acting sprinklers could avoid this problem.

6-1.4

The contents of an archive, or even a records center, often are considered to be of very high value or even irreplaceable, but they are always combustible. Therefore, every effort should be made to construct the building so that it resists the spread of fire. This means that during a fire the walls, roof, floor, columns, and partitions should prevent the passage of flame, smoke, or excessive heat and should continue to support their loads. “Fire resistant” is not equivalent to “noncombustible.” A noncombustible structure might not keep a fire from spreading, since some materials that do not burn lose their strength when exposed to intense heat. This might cause walls or floors to collapse. Many types of construction using various building materials have been tested and rated according to the length of time they resist fire. The duration of the resistance needed by the archive or records center depends on the quantity of combustible material in the contents of each room as well as the structure itself. Different structural assemblies have fire resistance ratings ranging from less than 1 hr to more than 6 hr.

NOTE: NFPA 220, *Standard on Types of Building Construction*, classifies and defines various kinds of building construction. The *Building Materials List* published by Underwriters Laboratories Inc., under the heading “Fire Resistance Classification,” provides information on structural assemblies that have been tested in accordance with NFPA 251, *Standard Methods of Fire Tests of Building Construction and Materials*.

6-1.5

It is not advisable to construct records centers and archives of materials that contribute fuel to a fire and that, by the nature of the construction, create combustible concealed spaces. Voids between a ceiling and the floor above are good examples of concealed spaces through which fire can spread rapidly and where access for fire fighting is difficult.

6-1.6

The term “compartmentation” in fire prevention is used to mean the subdivision of a building into relatively small areas so that fire or smoke can be confined to the room or section in which it originates. This principle can be applied to records centers and archives without restricting the flexibility of the arrangement of stack areas or the flow of visitors. Compartmentation necessitates fire-resistive wall and floor construction with openings that are provided with self-closing or automatic fire doors having specific fire resistance ratings. A major records keeper limits records center storage in a single fire subdivision to about 40,000 ft^2 (3720 m^2) and archives storage in a single fire subdivision to 25,000 ft^2 (2325 m^2). Offices, research rooms, and other support facilities always should be separated from the records storage areas by a properly rated fire-resistive wall.

In a similar way, properly enclosed stairways equipped with fire doors prevent the spread of fire, smoke, and heat from one level to another. Elevator shafts, dumb-waiter shafts, and all other vertical openings that pass through the structure also should be safeguarded. Air-handling systems (ventilation, heating, and cooling) should be constructed and equipped to prevent the passage of smoke, heat, and fire from one fire area to another or from one level to another in accordance with in NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*.

6-1.7

Some architects have designed facilities that are located underground or largely underground, are windowless, or are completely ventilated by mechanical means. While these types of construction provide advantages in controlling temperatures, humidity, and air pollution, they do create problems for fire extinguishment and life safety in the event of fire. These problems are greatly magnified if loss of power impairs ventilating systems. Alternative means for allowing the escape of heat and smoke should be provided; adequate roof ventilation is particularly essential, since heated gases and smoke tend to rise. Provisions should be made for the safe emergency evacuation of people as well as for access by the fire department to the fire area. “Knockout” panels located to allow direct access to well-maintained aisles within the structure are invaluable for this purpose. Fire department officials should be consulted and should be aware of the existence of these panels to avoid unnecessary breaching of walls in the event of fire. Automatic sprinklers are essential in these types of buildings and are recommended. Smoke detection systems can provide critically important early detection to activate a smoke control system and provide early warning to occupants.

NOTE: See NFPA *101*®, *Life Safety Code*®, Chapter 30, for guidance in providing life safety measures for underground structures and windowless buildings.

6-1.8

Consideration should be given to the proper selection of interior finishes and furnishings. Highly flammable wall and ceiling finishes should be avoided. NFPA *101*, *Life Safety Code*, and most building codes should be consulted for specific minimum requirements for interior finish materials. Draperies, where used, should be noncombustible.

6-1.9

A high level of security often is a necessity for archives and records centers. Incompatibility between security and fire safety measures can be difficult to reconcile if not addressed in the building design. Security provided as an afterthought tends to conflict with the emergency evacuation requirements of the building and fire codes. Conflicts can be evaluated and minimized through simultaneous consideration of fire safety and security needs while the facility is still in the planning stage.

Fire walls, for example, not only compartmentalize to reduce the fire exposure but also permit the use of horizontal exits, whereby people are channeled into another building, rather than evacuated to the outside, when a fire occurs. Courtyards and fenced-in grounds can be secure places of refuge for persons evacuated from a high-security building and can lessen the chances of having to escape with valuable records through emergency exit doors.

6-2 Records Storage Areas.

6-2.1

Fuel loads in records storage areas can range from 30 lb/ft^2 to hundreds of lb/ft^2 (146 kg/m^2 to approximately 1000 kg/m^2), with corresponding fire durations greater than those of commonly used building construction. Furthermore, the higher fuel loading in records storage areas can result in fire durations that more closely resemble those in warehouse occupancies than those found in business occupancies. Analysis of the Military Personnel Records Center fire in St. Louis in 1973 indicates that a fire in a lower floor of a multistory building with sprinklers not installed, shut off, or inadequately designed results in total loss of the building, regardless of the way in which it is subdivided, unless the fire load is less than the structural fire resistance. There is no construction recognized that supports a building above an uncontrolled archives or records center fire.

6-2.2

In some archives and records centers, the part of the building used to house records is only a shell. The metal stacks are self-supporting and extend through several floor levels of the building. The stack floors are merely platforms that provide a walkway through the stacks. This results in slot-like openings between the stacks and the walkways, allowing a rapid, uninterrupted, upward flow of air, heat, smoke, and flames. In new records centers and archives, or in major renovations of existing structures, these types of stacks should be avoided. Floors should be of conventional building construction with appropriate fire resistance ratings, and the shelves installed thereon should be constructed as ordinary furniture.

6-2.3

In records storage areas where high-rise, self-supporting stacks are used, special attention should be given to fire protection as follows:

(a) The most efficient automatic fire detection available, together with suitable reporting means, should be provided;

(b) Complete automatic sprinkler protection should be provided, including waterflow alarms; and

(c) A plan of action should be established with the fire department in advance to determine the best means of gaining access to the stacks, venting smoke, and reaching and fighting a stack fire at its source.

6-2.4

The practice of mounting records storage shelves on tracks is appearing now in new records center and archives construction and renovations as an application of modern warehousing technology (compact storage). This practice results in a high fire load density that can lead to a fire that threatens even the strongest code-prescribed fire barriers and construction (e.g., structural collapse). Without sprinkler protection for compact storage, fire endurance could exceed the resistance of fire compartment walls and the ability of the fire service to control the fire. Automatic sprinklers should be mandatory.

Associated fire protection problems that should be given consideration include the following:

(a) Existing automatic fire detection and fire suppressant systems might have to be modified.

(b) Compact storage modules could conceal the origin of smoke, compounding the difficulty of locating and extinguishing the fire.

(c) Compact storage modules prevent the penetration of water from hose streams for fire extinguishment.

Proper engineering can solve these problems effectively.

NOTE: See Chapter 10, Section 2 of the NFPA *Fire Protection Handbook* for a discussion of fire protection in compact storage. Underwriters Laboratories Inc. conducted additional tests on August 29 and 31, 1989. The published results of these tests are available from the National Archives and Records Administration, Washington, DC 20408.

6-2.5 Service Aisles.

Otherwise dead-end service aisles should be terminated at least 18 in. (458 mm) from the wall to prevent entrapment by fire.

6-3 Protection Against Outside Exposure Fires.

6-3.1

Outside fires pose an exposure hazard. Clear space provides optimum protection. If sufficient clear space cannot be provided, the exterior walls of the records center or archives facing adjacent buildings should be of masonry or other adequately fire-resistive construction without doors, windows, or other openings. Where openings in an exposed wall are necessary, provision should be made to prevent the transmission of heat or flames from a nearby fire through such openings. Suitable protection includes fire windows with wired glass, fire doors, outside sprinklers, fire shutters, or a combination of these. Combustible roof coverings, window frames, and eaves could add to the hazard from an exposure fire and should be given special consideration in planning fire protection.

6-3.2

The requirements for protection from exposure fires are determined by the distance between the archives and records centers and neighboring buildings and the hazards associated with the individual occupancies (e.g., residence, factory, office building). With so many variables, the records center or archives need to consider the risk of fire spreading from neighboring occupancies, whether in other buildings or in the building housing the records center or archives (e.g., universities, museums, and other institutions). Determining the severity of such exposures is a matter of judgment based on the factors contributing to the hazard of radiant and convected heat.

NOTE: See NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*, for further guidance with regard to exposure fires.

Chapter 7 Building Equipment and Facilities

7-1 Heating Systems.

7-1.1

A major potential source of fires is malfunction of heating equipment. For this reason, boilers and furnaces of central heating systems should be cut off from the remainder of the structure by rated fire walls or separations.

7-1.2

Oil-fired and gas-fired heating equipment, piping, and fuel oil storage facilities should be installed and maintained in accordance with the requirements of recognized safe practices. Heating equipment should be inspected and serviced at least annually by qualified personnel or a service contractor. All heating units should have safety devices appropriate for the particular type of installation. Combustibles, such as paper, wood, and textiles, should be kept away from steam piping or other heat piping and ducts.

7-1.3

Open-flame (gas and oil) space heaters are not compatible with storage of archives and valuable records and should be avoided wherever possible. Piping of fuel should be avoided in the vicinity of records storage areas.

7-1.4

The requirements for safety and fire protection where gas is used as fuel for heating should be in accordance with NFPA 54, *National Fuel Gas Code*. The requirements for the use of liquefied petroleum gas as fuel should be in accordance with NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*. The installation of oil burners and equipment used with them should be in accordance with NFPA 31, *Standard for the Installation of Oil-Burning Equipment*. The requirements of NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, should be applied to air duct systems used for heating and ventilating. All these standards prescribe reasonable provisions for safety to life and property from fire.

7-2 Electrical Systems.

7-2.1 General.

Installation and modifications to provide for the changing needs of the records center or archives including lighting, TV, sound systems, shop machinery, and appliances should be made by licensed or qualified electricians in accordance with NFPA 70, *National Electrical Code*®. The equipment should be listed.

7-2.2 Light Fixtures.

Narrow aisle spaces [approximately 30 in. (800 mm)] mandate a limitation on the width of suspended, continuous lighting fixtures, since they can limit sprinkler penetration into the aisle. It has been shown that a 9-in. (230-mm) fixture in a 30-in. (800-mm) aisle does not interfere materially with water spray from a conventional sprinkler. Large-drop sprinklers have not been tested with respect to this problem. Lights installed tight against the ceiling can be arranged to avoid interference with sprinkler distribution.

7-3 Means of Egress.

7-3.1 General.

It is imperative that security measures do not impede the safe emergency evacuation of visitors and employees. Attendance can vary greatly with the time of year, the exhibits offered, and other special events. Therefore, in planning the capacity of exits, serious consideration should be given to the maximum number of people who might be expected to be in the building at any given time. NFPA *101*, *Life Safety Code*, contains information on construction, protection, and occupancy features designed to minimize danger to life from fire, smoke, fumes, and panic before buildings are vacated. NFPA *101* is the basis for legal requirements governing exit facilities in many government jurisdictions and should be consulted in planning life safety measures for a records center or archives.

7-3.2 Locking Devices.

It is common for records centers and archives security measures to funnel all occupants through a few exits that can be monitored closely. Unfortunately, this often means that other doors required for egress are locked in violation of NFPA *101*, *Life Safety Code*.

The 1994 edition of NFPA *101*, *Life Safety Code,* includes equivalency concepts that allow the authority having jurisdiction to permit locking systems on these doors, provided that such systems afford a level of life safety equivalent to that prescribed in the *Code*. There are electromechanical and electromagnetic locking devices available that satisfy this requirement where installed in a properly designed system. Some of these systems provide an appropriate time delay before opening. Hydraulic and pneumatic devices are available that might meet this requirement. A properly designed system should include the following:

(a) Any failure of the device or the system should cause the system to fail in the open condition (unlocked).

(b) Sprinkler system operation should cause the system to unlock in the fire zone of origin.

(c) Fire alarms in the building should cause the system to unlock.

1. A manual fire alarm box should be provided at each exit egress door that is controlled by the system and that leads directly outside the building.

2. A sign should be placed on each required exit door stating that the door unlocks within 15 seconds to 30 seconds after pushing the panic bar or when the fire alarm sounds. Letters used in the sign should be $1^1/_2$-in. (38-mm) high with a $^1/_4$-in. (6-mm) stroke.

(d) Smoke detection should cause the system to unlock.

(e) A daily functional test protocol should be conducted by an individual specifically assigned the responsibility.

NOTE: Use of these security devices or systems in combination with panic hardware maintains protection against unauthorized ingress while the system is unlocked for egress.

7-4 Air Conditioning and Ventilation Systems.

Central air conditioning equipment should be located and installed in a manner that does not increase fire hazards to records centers or archives visitors or collections. Air conditioning ducts should be equipped with automatic fire dampers and fan shutoffs in accordance with NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*.

7-5 Lightning Protection.

Lightning is always a potential fire hazard, more so in some areas or locations than in others. Lightning protection can be incorporated more effectively and economically in new construction than as an afterthought. NFPA 780, *Standard for the Installation of Lightning Protection Systems*, should be used in applying methods of protecting buildings from damage by lightning.

Chapter 8 Referenced Publications

8-1

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.

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 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 13, *Standard for the Installation of Sprinkler Systems*, 1994 edition.

NFPA 13E, *Guide for Fire Department Operations in Properties Protected by Sprinkler and Standpipe Systems*, 1995 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, 1995 edition.

NFPA 31, *Standard for the Installation of Oil-Burning Equipment*, 1992 edition.

NFPA 40, *Standard for the Storage and Handling of Cellulose Nitrate Motion Picture Film*, 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 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, 1993 edition.

NFPA *101*, *Life Safety Code*, 1994 edition.

NFPA 220, *Standard on Types of Building Construction*, 1995 edition.

NFPA 232, *Standard for the Protection of Records*, 1995 edition.

NFPA 780, *Standard for the Installation of Lightning Protection Systems*, 1995 edition.

NFPA *Fire Protection Handbook*, 17th Edition, 1991 edition.

Appendix A Salvage of Water-Damaged Library Materials

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

The following material is taken from *Procedures for Salvage of Water-Damaged Library Materials* by Peter Waters, Restoration Officer, Library of Congress, 1975 (a Library of Congress publication on the conservation of library materials). Although it is directed to the recovery of water-damaged books, many of the procedures, warnings, and structures also apply to other types of records and archival material. Additional references can be found in Appendix B.

Assessment of Damage and Planning for Salvage

Weather is the critical factor in determining which course to take after any flood or fire in which museum, archival, or library materials are damaged. When it is hot and humid, salvage must be initiated with a minimum of delay to prevent or control the growth of mold. When the weather is cold, more time can be taken to plan salvage operations and experiment with various drying procedures.

The first step is to establish the character and degree of damage. Once an accurate assessment of the damage has been made, firm priorities and plans for salvaging the damaged materials can be drawn up. These plans must include a determination of the special facilities and equipment required. Overcautious, unrealistic, or inadequate appraisals of damage can result in the loss of valuable materials. Speed is of the utmost importance, but careful planning is equally essential in the salvage effort.

Where water damage has resulted from fire fighting measures, cooperation with the fire marshal is vital for a realistic appraisal of the feasibility of salvage efforts. Fire marshals and safety personnel will decide when a damaged building is safe to enter. In some cases, areas involved in the fire may require a week or longer before they are cool enough to be entered. Occasionally, parts of a collection may be identified early in the salvage planning effort as being especially vulnerable to destruction unless they receive attention within a few hours after the fire has abated. If the fire marshal appreciates such needs, it may be possible to provide means of access to the area even when other parts of the building remain hazardous.

Once all entrances and aisles are cleared, the most important collections, including rare materials and those of permanent research value, should be salvaged first, unless other materials would be more severely damaged by prolonged immersion in water. Examples of the latter are books printed on paper of types widely produced between 1880 and 1946, now brittle or semibrittle. However, materials in this category that can be replaced should be left until last.

Salvage operations must be planned so that the environment of flooded areas can be stabilized and controlled both before and during the removal of the damaged materials. In warm, humid weather, mold growth may be expected to appear in a water-damaged area within 48 hours. In any weather, mold will appear within 48 hours in unventilated areas made warm and humid by recent fire in adjacent parts of the building. For this reason, every effort should be made to reduce high temperatures and vent the areas as soon as the water has receded or been pumped out. Water-soaked materials must be kept as cool as possible by good air circulation until they can be stabilized. To leave such materials more than 48 hours in temperatures above 70°F (21°C) and humidity above 70 percent will almost certainly result in heavy mold growth and lead to high restoration costs.

Damaged most by these conditions are volumes printed on coated stock and such highly proteinaceous materials as leather and vellum bindings. Starch-impregnated cloths, glues, adhesives, and starch pastes are affected to a lesser degree. As long as books are tightly shelved, mold will develop only on the outer edges of the bindings. Thus, no attempt should be made in these conditions to separate books and fan them open. Archival files packed closely together on the shelves in cardboard boxes or in metal file cabinets are the least affected.

As a general rule, damp books located in warm and humid areas without ventilation will be subject to rapid mold growth. Archival files that have not been disturbed will not be attacked as quickly by mold. Very wet materials, or those still under water, will not develop mold. As they begin to dry after removal from the water, however, both the bindings and the edges of books will be quickly attacked by mold, especially when in warm, unventilated areas. A different problem exists for books printed on coated stock, since, if they are allowed to dry in this condition, the leaves will be permanently fused together.

Summary of Emergency Procedures

1. It is imperative to seek the advice and help of trained conservators with experience in salvaging water-damaged materials as soon as possible. The Library of Congress is an excellent information source for technical advice where needed. Contact: Preservation Office, Library of Congress, Washington, DC (202) 287-5212.
2. Turn off heat and create free circulation of air.
3. Keep fans and air conditioning on at night, except when a fungicidal fogging operation is in process because a constant flow of air is necessary to reduce the threat of mold.
4. Brief each worker carefully before salvage operations begin, giving full information on the dangers of proceeding except as directed. Emphasize the seriousness of timing and the priorities and aims of the whole operation. Instruct workers on means of recognizing manuscripts, materials with water-soluble components, leather and vellum bindings, materials printed on coated paper stock, and photographic materials.
5. Do not allow workers to attempt restoration of any items on site. (This was a common error in the first ten days after the Florence flood, when rare and valuable leather- and vellum-bound volumes were subjected to scrubbing and processing to remove mud. This resulted in driving mud into the interstices of leather, vellum, cloth, and paper; caused extensive damage to the volumes; and made the later work of restoration more difficult, time consuming, and extremely costly.)
6. Carry out all cleaning operations, whether outside the building or in controlled environment rooms, by washing gently with fresh, cold, running water and soft cellulose sponges to aid in the release of mud and filth. Use sponges with a dabbing motion; do not rub. These instructions do not apply to materials with water-soluble components. Such materials should be frozen as quickly as possible.
7. Do not attempt to open a wet book (wet paper is very weak and will tear at a touch). Hold a book firmly closed when cleaning, especially when washing or sponging. A closed book is highly resistant to impregnation and damage.
8. Do not attempt to separate single-sheet materials unless they are supported on polyester film or fabric.
9. Do not attempt to remove all mud by sponging. Mud is best removed from clothes when dry; this is also true of library materials.
10. Do not remove covers from books, as they will help to support the books during drying. When partially dry, books may be hung over nylon lines to finish drying. Do not hang books from lines while they are very wet because the weight will cause damage to the inside folds of the sections.
11. Do not press books and documents mechanically when they are water-soaked. This can force mud into the paper and subject the materials to stresses that will damage their structures.
12. Use soft pencils for making notes on slips of paper, but do not attempt to write on wet paper or other artifacts.
13. Clean, white blotter paper, white paper towels, strong toilet paper, and unprinted newsprint paper may be used for interleaving in the drying process. When nothing better is available, all but the color sections of printed newspapers may be used. Great care must be taken to avoid rubbing the inked surface of the newspaper over the material being dried; otherwise, some offsetting of the ink may occur.

14. Under no circumstances should newly dried materials be packed in boxes and left without attention for more than a few days.

15. Do not use bleaches, detergents, water-soluble fungicides, wire staples, paper or bulldog clips, adhesive tape, or adhesives of any kind. Never use felt-tipped fiber or ballpoint pens or any marking device on wet paper. Never use colored blotting paper or colored paper of any kind to dry books and other documents.

Appendix B Referenced Publications and Informational 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 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*, 1993 edition.

NFPA *101*, *Life Safety Code*, 1994 edition.

NFPA 220, *Standard on Types of Building Construction*, 1995 edition.

NFPA 232, *Standard for the Protection of Records*, 1995 edition.

NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*, 1995 edition.

NFPA 910, *Recommended Practice for the Protection of Libraries and Library Collections*, 1991 edition.

NFPA *Fire Protection Handbook*, Section 2, Chapter 30, 17th edition, 1991.

Fire Journal, July 1974.

Beers, R. J., "High Expansion Foam Fire Control for Records Storage," *Fire Technology*, Vol. 2, No. 2, May 1966, pp. 108-117.

B-1.2 Other Publications.

American Archivist, October 1974.

Cunha, George M. and Dorothy G., *Conservation of Library Materials*, Metuchen, NJ, The Scarecrow Press, Inc. 1971, two volumes; LC# 77-163871.

Bryan, John L. *Automatic Sprinkler and Standpipe Systems*. Quincy: National Fire Protection Association, 1990, illus., bibliography.

This book is a detailed study of the functioning, engineering, and application of a variety of fire suppression systems utilizing water as the extinguishing agent.

Custer, Richard L. P. and R. G. Bright. "Fire Detection: The State-of-the-Art." NBS Technical Note 829. Washington, DC: National Bureau of Standards, U.S. Dept. of Commerce, June 1974, 110 pp., illus., bibliography.

Federal Fire Council Recommended Practice No. 2, *Salvaging and Restoring and Restoring Records Damaged by Fire and Water*.

Morris, John. “Managing the Library Fire Risk.” Berkeley: University of California Office of Insurance and Risk Management, 1975, 99 pp.

This is an investigation of various aspects of fire prevention and control, with emphasis on the value of automatic fire protection systems. It contains descriptions of several library fires and a chapter on the salvage of wet books. It includes photographs, chapter bibliographies, and articles reprinted from fire journals.

Advisory Committee on the Protection of Archives and Records Centers. “Protecting Federal Records Centers and Archives From Fire.” Washington, DC: U.S. General Services Administration, April 1977, 202 pp., illus., bibliography.

Following the disastrous fire in the Military Personnel Records Center in Overland, Missouri, in July 1973, GSA appointed a committee to review the present state-of-the-art in records protection and to make recommendations on improved fire protection practices for federal archives and records centers. This is the report of that committee.

Spawn, William. “After the Water Comes,” Bulletin of the Pennsylvania Library Association, Vol. 28, No. 6 (November 1973), pp. 243-251.

This is an outline of the general principles for salvaging water-damaged materials. It presents a hypothetical disaster and details recommended salvage procedures. The importance of planning for disaster recovery, the necessity for prompt action, and the value of freezing wet materials are highlighted. Photographs are included.

Waters, Peter. *Procedures for Salvage of Water-Damaged Library Materials*. Washington, DC: The Library of Congress, 1975, 30 pp.

This is the most comprehensive and up-to-date manual on the salvage of water-damaged materials. It also contains a list of individuals to contact for professional advice and sources for supplies, equipment, and services. Emphasis is placed on having a plan of action before an emergency occurs. It can be obtained at no cost from the Library of Congress.

NFPA 241

1996 Edition

Standard for Safeguarding Construction, Alteration, and

1996 Edition

This edition of NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*, was prepared by the Technical Committee on Construction and Demolition 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 241 was approved as an American National Standard on July 26, 1996.

Origin and Development of NFPA 241

Work on the subject of construction, alteration, and demolition operations began in 1930 when the NFPA Committee on Construction Operations developed the *Recommended Good Practice Requirements for Building Construction Operations*. This text was adopted by the National Fire Protection Association, with revisions, in 1933. In 1942, a tentative revision was submitted, and, while no official action was taken, the revision was published subsequently for information purposes in Volume III of the *National Fire Codes*® published by the NFPA.

The NFPA Committee on Building Construction had jurisdiction over this standard when a tentative text prepared by that committee was adopted at the 1957 NFPA Annual Meeting. That text was unanimously approved by the NFPA in 1958. Complete revisions were adopted by the NFPA in 1968 and 1973. An editorial revision was approved in 1975 that brought the standard into conformance with the NFPA *Manual of Style*. The standard was substantively reconfirmed in 1980.

The 1986 edition represented a complete rewrite. That rewrite was the result of a comprehensive review by the Technical Committee on Construction and Demolition. When the document was reconfirmed in 1980, it came under the Technical Committee on Building Construction.

The 1986 update changed the format in which the safeguards were presented. Chapters 1 through 5 were general in nature and applied to both construction and demolition processes. Chapter 6 presented the specifics associated only with construction processes. Chapter 7 addressed the specifics of demolition. A new Chapter 8 included mandatory references with which various provisions of the standard were required to comply. Nearly 20 NFPA codes and standards were referenced in a mandatory fashion.

That revision expanded the treatment of items related to an overall construction and demolition fire safety plan. Definitions were expanded and added to cover terms with meanings that are unique to the standard. Temporary heating equipment was required to be listed. The section on smoking was expanded. Trash disposal was broadened to include housekeeping. Outside chutes, fire cutoffs, and explosives used in demolition were addressed. Material on temporary standpipes was included from NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*.

The 1989 edition included a complete rewrite of the section on roofing operations and greatly expanded the associated appendix items to address torch-applied roofing in additional detail. A new chapter on underground operations was added.

In the 1993 edition, extensive editing by the committee was undertaken to clarify and update the standard.

In the 1996 edition, the committee revised and reorganized Chapter 9.

Technical Committee on Construction and Demolition

Kenneth A. Kander, *Chair*
K. A. Kander & Assoc., WA

Richard J. Davis, Factory Mutual Research Corp., MA

C. Dale Eggen, Kaiser Engr. Hanford, WA

Richard G. Kirsop, City of Tacoma Fire Dept., WA

Alan Landman, Town of Oyster Bay, NY

Jim E. Lapping, AFL-CIO, DC

Stephen G. Leeds, Lawrence Livermore Nat'l Laboratory, CA

Thomas C. McNerney, Thomas C. McNerney & Assoc., WA

Roger A. Neal, M&M Protection Consultants, WA

Robert Notholt, Florida State Fire Marshal, FL

James C. Watson, J. A. Jones Construction Co., NC

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 identification and control of fire hazards associated with the construction, alteration, and demolition of buildings, tunnels, and bridges not otherwise covered by other NFPA standards.

NFPA 241
Standard for
Safeguarding Construction, Alteration,
and Demolition Operations

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 B.

Chapter 1 General

1-1 Introduction.

1-1.1 Fires during construction, alteration, or demolition operations are an ever-present threat. The fire potential is inherently greater during these operations than in the completed structure due to previous occupancy hazard and the presence of large quantities of combustible materials and debris, together with such ignition sources as temporary heating devices, cutting/welding/plumber's torch operations, open fires, and smoking. The threat of arson is also greater during construction and demolition operations due to the availability of combustible materials on-site and the open access.

1-1.2

Fires during construction, alteration, or demolition operations can be eliminated or controlled through the early planning, scheduling, and implementation of fire prevention measures, fire protection systems, rapid communications, and on-site security. An overall construction or demolition fire safety program shall be developed; essential items to be emphasized include:

(a) Good housekeeping;

(b) On-site security;

(c) Installation of new fire protection systems as construction progresses;

(d) Preservation of existing systems during demolition;

(e) Organization and training of an on-site fire brigade;

(f) A prefire plan developed with the local fire department;

(g) Rapid communication;

(h) Consideration of special hazards resulting from previous occupancies; and

(i) Protection of existing structures and equipment from exposure fires resulting from construction, alteration, and demolition operations.

1-1.3

A fire safety program shall be included in all construction, alteration, or demolition contracts, and the right of the owner to administer and enforce this program shall be established, even if the building is entirely under the jurisdiction of the contractor.

1-1.4

This standard provides measures for preventing or minimizing fire damage during construction, alteration, and demolition operations. The public fire department and other fire protection authorities also shall be consulted for guidance. The unique and dangerous situations confronting fire fighters during such operations demand that a complete exchange of pertinent information be established and continued during the life of the project.

1-1.5

General requirements applying to construction and demolition are contained in Chapters 1 through 5; specific requirements for construction and alteration activities are found in Chapter 6; those requirements specific to roofing operations are covered in Chapter 7; those requirements specific to demolition activities are covered in Chapter 8; and specific requirements for activities in underground locations are contained in Chapter 9. Alteration activities shall be permitted to require the use of both the demolition and construction activity requirements, as applicable.

1-2 Scope.

This standard shall apply to structures in the course of construction, alteration, or demolition, including those in underground locations.

1-3 Purpose.

This standard is intended to prescribe minimum safeguards for construction, alteration, and demolition operations in order to provide reasonable safety to life and property from fire during such operations. Nothing in this standard is intended to restrict new technologies or alternate arrangements, provided that the level of safety prescribed by the standard is not lowered.

1-4 Definitions.

For the purpose of this standard, the following terms shall be defined as provided in this section.

Approved.* Acceptable to the authority having jurisdiction.

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

Hot Work. Operations including cutting, welding, Thermit welding, brazing, soldering, grinding, thermal spraying, thawing pipe, torch-applied roofing, or any other similar operation.

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.

Protected Structure. A structure equipped with operational automatic sprinkler systems or Class I, II, or III wet standpipe or dry standpipe systems for fire department use.

Qualified Agency. Any individual, firm, corporation, or company that, either in person or through a representative, is regularly engaged in such work, is familiar with all precautions required, and has complied with all the requirements of the authority having jurisdiction.

Roofing Kettle. Any container in excess of a 15-gal (56.8-L) capacity used for preheating tar, asphalt, pitch, or similar substances for waterproofing.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Single-Ply Roofing System. A single-layer roof covering made of plastic, synthetic rubber, or modified bitumen.

Structure. Includes, but is not limited to, buildings, piers, bridges, and underground installations.

Thermal Spraying. A group of welding or allied processes in which finely divided metallic or nonmetallic materials are deposited in a molten or semimolten condition to form a coating. The coating material shall be permitted to be in the form of a powder, a ceramic rod, a wire, or molten materials.

Thermit Welding. A welding process that produces coalescence of metals by heating them with superheated liquid metal resulting from a chemical reaction between a metal oxide and aluminum, with or without the application of pressure. Filler metal, where used, is obtained from the liquid metal.

Torch-Applied Roof System. A bituminous roofing system using membranes that are adhered by heating with a torch and melting an asphalt backcoating instead of mopping hot asphalt for adhesion.

Tunnel. An underground structure with a design length over 75 ft (22.86 m) and a 6-ft (1.83-m) diameter.

Underground Structure. A structure located in an underground tunnel, a shaft, a chamber, or a passageway; or cut and covered excavation.

Chapter 2 Temporary Construction, Equipment, and Storage

2-1 Temporary Offices and Sheds.

2-1.1*

Separation distances between buildings under construction and construction-related structures, such as temporary offices, trailers, sheds, and other facilities for the storage of tools and materials having combustible construction or contents, shall be in accordance with Table 2-1.1.

Table 2-1.1 Separation Distances

Temporary Structure Exposing Wall Length		Minumum Separation Distance	
(ft)	(m)	(ft)	(m)

20	6	30	9
30	9	35	11
40	12	40	12
50	15	45	14
60	18	50	15
>60	>18	60	18

Note 1: Where the separation distance between temporary structures is less than the minimum separation distance, then the exposing wall length shall be considered to be the sum of the individual exposing wall lengths of the temporary structure.

Note 2: A 75-percent reduction in separation distances shall be permitted to be applied, provided automatic sprinkler protection is used in the exposing structure.

Note 3: The separation distances apply to single-level structures only. This table does not apply to multilevel, unsprinklered structures. A level, where applying this table, is 12 ft (1.2 m).

2-1.2*

Detachment between temporary structures, adequate temporary fixed fire protection systems, and portable equipment shall be provided as required by the authority having jurisdiction.

2-1.3

Only safely installed approved heating devices shall be used in temporary offices and sheds. Ample clearance shall be provided around stoves and heaters and all chimney and vent connectors to prevent ignition of adjacent combustible materials in accordance with NFPA 31, *Standard for the Installation of Oil-Burning Equipment* (liquid fuel devices); NFPA 54, *National Fuel Gas Code* (fuel gas devices); and NFPA 211, *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances* (connectors and solid fuel). (*Where temporary heating devices are used, see Section 3-2*.)

2-2 Temporary Enclosures.

2-2.1

Only noncombustible panels or flame-resistant tarpaulins or approved materials of equivalent fire-retardant characteristics shall be used. Any other fabrics or plastic films used shall be certified as conforming to the requirements of the Large-Scale Test contained in NFPA 701, *Standard Methods of Fire Tests for Flame-Resistant Textiles and Films*.

2-2.2

Where used to enclose structures, forming equipment, and similar items, the enclosing material shall be fastened securely or guarded by construction so it cannot be blown by the wind against heaters or other sources of ignition.

2-2.3

Temporary enclosures shall be equipped with a minimum of one fire extinguisher suitable for all classes of fires that are expected inside the enclosure. Fire extinguishers shall be located so that travel distance to a fire extinguisher does not exceed 50 ft (15 m).

2-3 Equipment.

2-3.1*

Internal combustion engines and associated equipment, such as air compressors, hoists, derricks, pumps, and similar devices, shall be located so that the exhausts discharge well away from combustible materials. Where the exhausts are piped outside the structure under construction, alteration, or demolition, a clearance of at least 9 in. (230 mm) shall be maintained between such piping and combustible material.

2-3.2

Internal combustion engines and associated equipment shall be shut down and allowed to cool sufficiently prior to refueling.

2-3.3

Service areas for equipment shall not be located within structures under construction, alteration, or demolition.

2-3.4

Fuel for internal combustion engines shall not be stored within structures under construction, alteration, or demolition.

Exception: Where permitted by Section 3-5.

Chapter 3 Processes and Hazards

3-1 Hot Work Operations.

3-1.1*

A permit system shall be used for hot work operations on the job under the supervision of the fire prevention program manager. Permits shall be available for inspection by the authority having jurisdiction.

3-1.2 Fire watches shall be assigned no other duties.

3-1.3* A permit shall not be issued until:

(a) It has been determined that hot work can be safely conducted at the desired location;

(b) Combustibles have been moved away or covered by an approved tarpaulin;

(c) The atmosphere is nonflammable; and

(d) A fire watch (with dedicated extinguisher) is posted for the duration of the work and for 30 minutes thereafter [60 minutes for torch-applied roofing operations (*see 7-1-3.11*)] to ensure that sparks or drops of hot metal do not start fires. All cracks or openings in floors shall be safely covered or closed.

3-1.4

All gas-operated cutting and welding equipment and operations shall be in accordance with the applicable sections of NFPA 51, *Standard for the Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes*, and NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*.

3-1.5 Thermit Welding.

3-1.5.1* In Thermit welding, the mold shall be dried thoroughly before the charge is ignited and provided with a cover.

3-1.5.2* Bulk storage of Thermit welding materials shall be maintained in a detached shed at least 50 ft (15 m) from the main buildings. The shed shall be maintained dry, posted as a “no smoking” area, and kept locked.

3-1.5.3 Containers for the starting material shall be closed tightly immediately after each use.

3-1.5.4 The molds shall not be removed until at least 10 minutes to 12 minutes after the weld is made or after sufficient cooling has taken place.

3-1.5.5 Smoking shall not be permitted in areas where Thermit welding material is being used.

3-2 Temporary Heating Equipment.

3-2.1

Temporary heating equipment shall be listed and shall be installed, used, and maintained in accordance with the manufacturer’s instructions.

3-2.2

Chimney or vent connectors, where required from direct-fired heaters, shall be maintained at least 18 in. (457 mm) from combustibles and shall be installed in accordance with NFPA 211, *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances*.

3-2.3

Oil-fired heaters shall comply in design and installation features with NFPA 31, *Standard for the Installation of Oil-Burning Equipment*.

3-2.4

Fuel supplies for liquefied petroleum gas-fired heaters shall comply with NFPA 54, *National Fuel Gas Code*, and NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*.

3-2.5*

Refueling operations shall be conducted in an approved manner.

3-2.6

Heating devices shall be situated so that they are secured and shall otherwise be installed in accordance with their listing, including clearance to combustible material, equipment, or construction.

3-2.7*

Temporary heating equipment, where utilized, shall be monitored for safe operation and maintained by properly trained personnel.

3-3 Smoking.

3-3.1*

Smoking shall be prohibited at or in the vicinity of hazardous operations or combustible/flammable materials. "No smoking" signs shall be posted in these areas.

3-3.2

Smoking shall be permitted only in designated areas. Where smoking is permitted, safe receptacles for smoking materials shall be provided.

3-4 Waste Disposal.

3-4.1*

Accumulations of combustible waste material, dust, and debris shall be removed from the structure and its immediate vicinity at the end of each work shift or more frequently as necessary for safe operations.

3-4.2

Rubbish shall not be burned on the premises without first obtaining a permit from the authority having jurisdiction.

3-4.3

Materials susceptible to spontaneous ignition, such as oily rags, shall be stored in a listed disposal container.

3-5 Flammable and Combustible Liquids and Flammable Gases.

3-5.1 Storage.

3-5.1.1 Storage of flammable and combustible liquids shall be in accordance with NFPA 30, *Flammable and Combustible Liquids Code*.

Exception: Where modified by this section.

3-5.1.2* Storage of Class I and Class II liquids shall not exceed 60 gal (227 L) within 50 ft (15 m) of the structure.

3-5.1.3 Storage areas shall be kept free of weeds, debris, and combustible materials not necessary to the storage.

3-5.1.4 Open flames and smoking shall not be permitted in flammable and combustible liquids storage areas. Such storage areas shall be appropriately posted as "no smoking" areas.

3-5.2 Handling of Flammable and Combustible Liquids at Point of Final Use.

3-5.2.1 Class I and Class II liquids shall be kept in approved safety containers.

3-5.2.2 Means shall be provided to dispose of leakage and spills promptly and safely.

3-5.2.3* Class I liquids shall be dispensed only where there are no open flames or other sources of ignition within the possible path of vapor travel.

3-5.3 Storage and Handling of Combustible and Flammable Gases.

3-5.3.1 Storage and handling of combustible and flammable gases shall be in accordance with NFPA 54, *National Fuel Gas Code*, and NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*.

3-5.3.2 Open flames and smoking shall not be permitted in flammable gas storage areas.

3-6 Explosive Materials.

3-6.1

The storage, handling, and use of explosive materials shall be in accordance with NFPA 495, *Explosive Materials Code*.

3-6.2

All blasting operations shall be under the direct supervision of an individual who is legally licensed to use explosives and in possession of the required permits.

Chapter 4 Utilities

4-1 Electrical.

4-1.1

All construction-operation electrical wiring and equipment for light, heat, or power purposes shall be in accordance with the applicable provisions of NFPA 70, *National Electrical Code*®□.

4-1.2 Temporary Wiring.

4-1.2.1 Branch Circuits. All branch circuits shall originate in an approved power outlet or panelboard. Conductors shall be permitted within multiconductor cord or cable assemblies or as open conductors. All conductors shall be protected by overcurrent devices rated for the ampacity of the conductors. Runs of open conductors shall be located where the conductors are not subject to physical damage, and the conductors shall be fastened at intervals not exceeding 10 ft (3 m). Each branch circuit that supplies receptacles or fixed equipment shall contain a separate equipment grounding conductor where run as an open conductor.

4-1.2.2 Lighting.

4-1.2.2.1 Temporary lights shall be equipped with guards to prevent accidental contact with the bulb.

Exception: Guards shall not be required where construction of the reflector is such that the bulb is deeply recessed.

4-1.2.2.2 Temporary lighting fixtures, such as quartz, that operate at temperatures capable of igniting ordinary combustibles shall be fastened securely so that the possibility of their coming in contact with such materials is precluded.

4-1.2.2.3 Temporary lights shall be equipped with heavy-duty electrical cords with connections and insulation maintained in safe condition. Temporary lights shall not be suspended by their electrical cords. Splices shall have insulation equivalent to that of the cable.

Exception: Temporary lights shall be permitted to be suspended by their electrical cords where the cords and lights have been designed for the purpose.

4-1.2.3 Removal. Temporary wiring shall be removed immediately upon the completion of the construction or purpose for which the wiring was installed.

Chapter 5 Fire Protection

5-1 Owner's Responsibility for Fire Protection.

5-1.1*

The owner shall designate a person who shall be responsible for the fire prevention program and who shall ensure that it is carried out to completion. This fire prevention program manager shall have the authority to enforce the provisions of this and other applicable fire protection standards.

5-1.1.1 The fire prevention program manager shall have knowledge of the applicable fire protection standards, available fire protection systems, and fire inspection procedures.

5-1.1.2 Inspection records shall be available for review by the authority having jurisdiction.

5-1.2

Where guard service is provided, the manager shall be responsible for the guard service.

5-1.3 Prefire Plans.

5-1.3.1 Where there is public fire protection or a private fire brigade, the manager shall be responsible for the development of prefire plans in conjunction with the fire agencies. These plans shall be updated as necessary.

5-1.3.2* The prefire plan shall include provisions for on-site visits by the fire agency.

5-1.4

The manager shall be responsible for ensuring that proper training in the use of protection equipment has been provided.

5-1.5

The manager shall be responsible for the presence of adequate numbers and types of fire protection devices and appliances and for their proper maintenance.

5-1.6

The manager shall be responsible for supervising the permit system for hot work operations. (*See Section 3-1*.)

5-1.7

A weekly self-inspection program shall be implemented with records maintained and made available.

5-1.8*

Impairments to the fire protection systems or fire alarm, detection, or communications systems shall be authorized only by the fire prevention program manager.

5-1.8.1 Temporary protective coverings used on fire protection devices during renovations, such as painting, shall be removed promptly when work has been completed in the area.

5-1.9 Installation, Testing, and Maintenance.

Where fire alarm, detection, or protection systems are required, they shall be installed, maintained, and tested in accordance with the appropriate NFPA standards. (*See Chapter 10*.)

5-2 Site Security.

5-2.1*

Guard service shall be provided where required by the authority having jurisdiction.

5-2.2*

Where guard service is provided, the guard(s) shall be trained in the following:

(a) Notification procedures to call the fire department and management personnel;

(b) Knowledge of fire protection equipment; and

(c) Familiarization with fire hazards.

Guards shall be informed of any special status of emergency equipment or hazards.

5-2.3*

Security fences shall be provided where required by the authority having jurisdiction.

5-2.4*

Entrances (e.g., doors and windows) to the structure under construction, alteration, or demolition shall be secured where required by the authority having jurisdiction.

5-3* Fire Alarm Reporting.

There shall be a readily available public fire alarm box near the premises, telephone service to the responding fire department, or equivalent facilities. Instructions shall be issued for the immediate notification of the fire department in case of fire. Where telephone service is employed, the local fire department number and site address shall be conspicuously posted near each telephone.

5-4 Access for Fire Fighting.

5-4.1

A suitable location at the site shall be designated as a command post and provided with plans, emergency information, keys, communications, and equipment, as needed. The person in charge of fire protection shall respond to the location command post whenever fire occurs.

5-4.2

Where access to or within a structure or an area is unduly difficult because of secured openings or where immediate access is necessary for life-saving or fire-fighting purposes, the authority having jurisdiction shall be permitted to require a key box to be installed in an accessible location. The key box shall be an approved type and shall contain keys to gain access as required by the authority having jurisdiction.

5-4.3

Every building shall be accessible by fire department apparatus by means of roadways having an all-weather driving surface of not less than 20 ft (6 m) of unobstructed width, having the ability to withstand the live loads of fire apparatus, and having a minimum of 13 ft 6 in. (4 m) of vertical clearance. Dead-end fire department access roads in excess of 150 ft (46 m) in length shall be provided with approved provisions for turning around fire department apparatus.

Exception: The requirements of 5-4.3 shall be permitted to be modified where, in the opinion of the fire department, fire-fighting or rescue operations would not be impaired by such modification.

5-4.4

The required width of access roadways shall not be obstructed in any manner, including obstruction by parked vehicles. "No parking" signs or other appropriate notices, or both, prohibiting obstruction shall be permitted to be required and shall be maintained.

5-4.5

The access roadway shall be extended to within 150 ft (46 m) of all portions of the exterior walls of the first story of any building. Where an access roadway cannot be provided, an approved fire protection system or systems shall be provided as required and approved by the authority having jurisdiction.

5-4.6

Where a bridge is required to be used as access, it shall be constructed and maintained using design live loading sufficient to carry the imposed loads of the fire apparatus.

5-4.7

Access for use of heavy fire-fighting equipment shall be provided to the immediate job site at the start of the project and maintained until completion.

5-4.8

In all buildings over one story in height, at least one stairway shall be provided that is in usable condition at all times and that meets the requirements of 5-2.2 of NFPA *101*®□, *Life Safety Code*®□. This stairway shall be extended upward as each floor is installed in new construction and maintained for each floor still remaining during demolition. The stairway shall be lighted. During construction, the stairway shall be enclosed where the building exterior walls are in place.

5-4.9

Where hoists and elevators provide the only efficient means of transporting hose and other cumbersome fire-fighting equipment to upper floors, they shall be available to the fire department whenever necessary.

5-4.10

Free access from the street to fire hydrants and to outside connections for standpipes, sprinklers, or other fire extinguishing equipment, whether permanent or temporary, shall be provided and maintained at all times. Protective pedestrian walkways shall not be constructed so that they impede access to hydrants. No material or construction shall interfere with access to hydrants, siamese connections, or fire extinguishing equipment.

5-4.11*

Free access to permanent, temporary, or portable first-aid fire equipment shall be maintained at all times.

5-5 Standpipes.

In all new buildings in which standpipes are required or where standpipes exist in buildings being altered or demolished, such standpipes shall be maintained in conformity with the progress of building construction in such a manner that they are always ready for use.

5-6* First-Aid Fire-Fighting Equipment.

5-6.1

The suitability, distribution, and maintenance of extinguishers shall be in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*.

5-6.2

Wherever a toolhouse, storeroom, or other shanty is located in or adjacent to the building under construction or demolition, or where a room or space within that building is used for storage, a dressing room, or a workshop, at least one approved extinguisher shall be provided and maintained in an accessible location.

Exception: This requirement shall be permitted to be waived where the structure does not exceed 150 ft^2 (14 m^2) in floor area or is equipped with automatic sprinklers or other approved protection.

5-6.3

At least one approved fire extinguisher also shall be provided in plain sight on each floor at each usable stairway as soon as combustible material accumulates.

5-6.4

Suitable fire extinguishers shall be provided on self-propelled equipment.

Chapter 6 Safeguarding Construction and Alteration Operations

6-1 General.

The provisions of Chapters 1 through 5 shall be followed, as applicable, for all construction, in addition to the specific requirements of this chapter.

6-2* Scaffolding, Shoring, and Forms.

6-2.1

Accumulations of unnecessary combustible forms or form lumber shall be prohibited. Combustible forms or form lumber shall be brought into the structure only when needed. Combustible forms or form lumber shall be removed from the structure as soon as stripping is complete. Those portions of the structure where combustible forms are present shall not be used for the storage of other combustible building materials.

6-2.2*

During forming and stripping operations, portable fire extinguishers or charged hose lines shall be provided to protect the additional combustible loading adequately.

6-3 Construction Material and Equipment Storage.

6-3.1

Temporary storage of equipment to be installed, combustible construction materials, or combustible packing materials shall not be permitted in unprotected structures under construction or alteration.

Exception: Where authorized by the authority having jurisdiction.

6-3.2*

Storage shall not be permitted in protected structures until protection is in service.

6-3.3

Yard storage of equipment to be installed or combustible construction materials shall not be stored closer than 30 ft (9 m) from the structure under construction or alteration. (*See 2-1.1*.)

6-4 Permanent Heating Equipment.

The permanent heating equipment for a new building shall be installed and put into operation as soon as practicable.

6-5 Utilities.

6-5.1

The provisions of Chapter 4 shall apply in addition to the specific requirements of this section.

6-5.2 Gas.

6-5.2.1 Installation. The installation of gas piping for construction purposes, or modifications to existing gas piping, gas utilization equipment, or accessories, shall be performed only by a qualified agency. All such work shall be in accordance with NFPA 54, *National Fuel Gas Code*.

6-5.2.2 Modifications. All modifications to existing gas piping systems normally shall be performed with the gas turned off.

Exception: Hot taps shall be permitted to be made, provided they are installed by a trained and experienced crew utilizing equipment specifically designed for such purpose.

6-6 Fire Cutoffs.

Fire walls and exit stairways, where required for the completed building, shall be given construction priority for installation. Fire doors with approved closing devices and hardware shall be installed as soon as is practicable and preferably before combustible material is introduced. Fire doors, after installation in accordance with NFPA 80, *Standard for Fire Doors and Fire Windows*, shall not be obstructed from closing.

6-7 Fire Protection During Construction.

6-7.1

The provisions of Chapter 5 shall apply in addition to the specific requirements of this section.

6-7.2 Water Supply.

6-7.2.1* A water supply for fire protection, either temporary or permanent, shall be made available as soon as combustible material accumulates. There shall be no delay in the installation of fire protection equipment. (*See A-6-2.2*.)

6-7.2.2 Where underground water mains and hydrants are to be provided, they shall be installed, completed, and in service prior to construction work.

6-7.3 Sprinkler Protection.

6-7.3.1* If automatic sprinkler protection is to be provided, the installation shall be placed in service as soon as practicable. The details of installation shall be in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

6-7.3.2 Where sprinklers are required for safety to life, the building shall not be occupied until the sprinkler installation has been entirely completed and tested so that the protection is not susceptible to frequent impairment caused by testing and correction.

Exception: This provision shall not prohibit occupancy of the lower floors of a building, even where the upper floors are in various stages of construction or protection, provided the following conditions are satisfied:

(a) The sprinkler protection of the lower occupied floors is completed and tested in accordance with 6-7.3.2;

(b) The sprinkler protection of the upper floors is supplied by entirely separate systems and separate control valves so that the absence or incompleteness of protection in no way impairs the sprinkler protection of the occupied lower floors.

6-7.3.3 The operation of sprinkler control valves shall be permitted only by properly authorized personnel and shall be accompanied by the notification of duly designated parties. Where the sprinkler protection is regularly turned off and on to facilitate connection of newly completed segments, the sprinkler control valves shall be checked at the end of each work shift to ascertain that protection is in service.

6-7.4 Standpipes.

6-7.4.1 General.

6-7.4.1.1* The pipe size, hose valves, hose, water supply, and other details for new construction shall be in accordance with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*.

6-7.4.1.2 On permanent Type II and Type III standpipes, hose and nozzles shall be provided and made ready for use as soon as the water supply is available to the standpipe.

Exception: In combined systems where occupant hose is not required, temporary hose and nozzles shall be provided during construction.*

6-7.4.2 Standpipe Installations in Buildings Under Construction. Where required by the authority having jurisdiction, in buildings under construction, a standpipe system, either temporary or permanent in nature, shall be installed in accordance with 6-7.4.2.1 through 6-7.4.2.7.

6-7.4.2.1 The standpipes shall be provided with conspicuously marked and readily accessible fire department connections on the outside of the building at the street level and shall have at least one standard hose outlet at each floor.

6-7.4.2.2 The pipe sizes, hose valves, hose, water supply, and other details for new construction shall be in accordance with this standard.

6-7.4.2.3 The standpipes shall be securely supported and restrained at each alternate floor.

6-7.4.2.4* At each floor level, at least one approved hose valve for attaching fire department hose shall be provided. Valves shall be kept closed at all times and guarded against mechanical injury.

6-7.4.2.5 A hose valve(s) shall have NH standard external threads for the valve size specified in accordance with NFPA 1963, *Standard for Fire Hose Connections*.

Exception: Where local fire department connections do not conform to NFPA 1963, the authority having jurisdiction shall designate the connection to be used.

6-7.4.2.6* The standpipes shall be extended up with each floor and shall be securely capped at the top. Top hose outlets shall be not more than one floor below the highest forms, staging, and similar combustibles at all times.

6-7.4.2.7 Temporary standpipes shall remain in service until the permanent standpipe installation is complete.

Chapter 7 Safeguarding Roofing Operations

7-1 Roofing Operations.

7-1.1 General.

All roofing operations involving heat sources and hot processes shall be conducted by a qualified agency.

7-1.2 Asphalt and Tar Kettles.

7-1.2.1 Asphalt and tar kettles shall be located in a safe place outside of the building or on a noncombustible roof at a point that avoids the danger of ignition of combustible material below.

7-1.2.2 A lid that can be closed by means of gravity shall be provided on all roofing kettles. The tops and covers of all kettles shall be close-fitting and constructed of steel having a thickness of not less than No. 14 manufacturer's standard gauge [0.075 in. (2 mm)].

7-1.2.3* Used roofing mops and rags shall be cleaned of excessive asphalt and stored away from the building and combustible materials. Discarded roofing mops and rags shall not be in contact with combustibles.

7-1.2.4 Kettles shall be constantly attended when in operation.

7-1.3* Single-Ply and Torch-Applied Roofing Systems.

7-1.3.1* Single-ply and torch-applied roofing systems shall be installed using extreme caution. Torches or hot-air guns used to secure roofing membranes shall be used in accordance with the manufacturer's recommendations. In order to prevent smoking or ignition of roofing membranes, they shall not be overheated.

7-1.3.2* Caution shall be used where working near roof openings, penetrations, or flashings. The flame of the torch shall not come in direct contact with wood nailers, cant strips, or metal flashing. Small torches shall be used to heat the underside of the membrane at a distance from these areas before securement. Hot trowels shall be used to feather seams at laps and flashings.

The torch shall not be used in areas where the flame impingement cannot be fully viewed. Open flames shall not be left unattended.

7-1.3.3 The torch flame shall not be applied to a combustible substrate of the membrane. Base ply shall be used to cover wooden decks, combustible insulation (such as foam plastic, kraft-faced glass fiber, or wood fiber), small crevices, cant strips, plastic fastener plates, or any other combustible surface. Base ply shall be permitted to consist of either glass fiber felts or minimum 40-lb (18-kg) organic felts. Torch flames shall not come in contact with exposed plastic roofing cement.

7-1.3.4 The installation of torch-applied roofing and, in some cases, single-ply roofing systems is hot work and shall comply with Section 3-1, except where otherwise noted.

7-1.3.5* Protective clothing and personal protective equipment shall be worn by installers.

7-1.3.6 Proper equipment shall be used to heat roofing membranes. Torches shall be equipped with a pilot adjustment, a flame height adjustment, a minimum of 25 ft (8 m) to a maximum of 50 ft (15 m) of listed hose, a pressure gauge, and a regulator. A spark igniter shall be used. Torch trolleys and multiple torch head machines shall be equipped with listed safety valves.

7-1.3.7* Safety caps shall be attached to all fuel gas cylinders and installed on the valves whenever cylinders are not in use. The fuel gas cylinder shall be sized for the torch used. If frost buildup occurs on fuel gas cylinders and the rate of vapor withdrawal is no longer adequate for operating conditions, the cylinder shall not be placed on its side or heated with the torch flame. The hose shall be disconnected and a larger cylinder used.

7-1.3.8* Equipment shall be inspected thoroughly and repaired or replaced as needed prior to use.

7-1.3.9 Fuel gas cylinders shall not be hoisted by their valves. Straps placed around the cylinders shall be utilized.

7-1.3.10 Carts used to transport fuel gas cylinders shall be stable. Tall, narrow, standing cylinders shall be strapped or chained against walls or in proper carts.

7-1.3.11* A fire watch shall be conducted for at least 1 hour after torches have been extinguished.

7-1.4 Fire Extinguishers for Roofing Operations.

7-1.4.1* There shall be at least one portable fire extinguisher having a rating of not less than 20-B within 30 ft (9 m) of horizontal travel distance from every roofing kettle at all times while such a kettle is in operation.

7-1.4.2* There shall be at least one multipurpose 2-A:20-B:C portable fire extinguisher on the roof being covered or repaired, or other fire protection as determined by the authority having jurisdiction shall be provided.

7-1.4.3 There shall be at least one multipurpose 2-A:20-B:C portable fire extinguisher within 20 ft (6 m) of horizontal travel distance from torch-applied roofing equipment.

7-1.5 Fuel for Roofing Operations.

7-1.5.1 Fuel containers, burners, and related appurtenances of roofing equipment in which liquefied petroleum gas is used for heating shall comply with all the applicable requirements of

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*.

7-1.5.2 Fuel containers shall be located at least 10 ft (3 m) from the burner flame or at least 2 ft (0.6 m) therefrom where properly insulated from heat or flame.

Exception: Hand-held fuel containers with a maximum 1-lb (453-g) capacity.

7-1.5.3 Solid fuel or Class I liquids shall not be used as fuel for roofing kettles.

Chapter 8 Safeguarding Demolition Operations

8-1 General.

The provisions of Chapters 1 through 5 shall be followed, as applicable, for all demolition operations, in addition to the specific requirements of this chapter.

8-2 Special Precautions.

8-2.1

Special precautions shall be taken where demolition work is performed in areas where floors are soaked with oil or other flammable liquid, where dust accumulations are present, or where combustible insulation is present in floors, walls, or ceilings/roofs where hot work is being performed. In these situations, charged hose lines of an adequate number and size shall be provided.

8-2.2*

Flammable and combustible liquids shall be drained from tanks and machinery reservoirs in a safe manner and removed from the building immediately. Particular attention shall be paid to the removal of residue and sludge accumulations if hot work operations are involved.

8-3 Temporary Heating Equipment.

During cold-weather demolition operations, building heat shall be maintained to allow the operation of sprinklers, hose, and extinguishers in areas not in the process of demolition. The minimum temperature at the extremities of such areas equipped with wet sprinkler systems shall be 40°F (4°C).

8-4* Smoking.

Smoking shall be prohibited throughout the demolition areas.

8-5* Demolition Using Explosives.

If explosives are used in demolition work (implosion), hose lines [at least two of $1^1/_2$ in. (38 mm) or one of $2^1/_2$ in. (64 mm)] shall be provided in the immediate vicinity of the demolition site during the actual detonation. These lines shall be of sufficient length to be capable of extinguishing any small fire anywhere on the demolition site after detonation.

8-6 Utilities.

8-6.1 Electrical Service.

Electrical service shall be reduced to a minimum, and the identity of energized circuits shall be ensured to avoid any uncertainty.

8-6.2 Gas.

Prior to demolition, gas supplies shall be turned off and capped at a point outside the building. Gas lines within the building shall be purged after capping.

Exception: Gas lines shall not be required to be purged where permitted by the authority having jurisdiction.

8-7* Fire Cutoffs.

Vertical and horizontal cutoffs shall be retained until razing operations necessitate their removal as permitted by the authority having jurisdiction. Fire doors shall be closed at the end of each working day.

8-8 Fire Protection During Demolition.

8-8.1

The provisions of Chapter 5 shall apply in addition to the specific requirements of this section.

8-8.2*

Where a building is equipped with sprinklers, the sprinkler protection shall be retained in service as long as the condition requiring the use of sprinklers exists.

8-8.3

The operation of sprinkler control valves shall be permitted only by properly authorized personnel and shall be accompanied by the notification of designated parties. Where the sprinkler protection is regularly turned off and on to facilitate removal and capping of segments, the sprinkler control valves shall be checked at the end of each work shift to ascertain that protection is in service.

8-8.4

Standpipes shall be maintained in conformity with the progress of demolition activity in such a manner that they are always ready for fire department use.

8-8.5*

Fire extinguishing equipment shall be available subject to the authority having jurisdiction.

Chapter 9 Safeguarding Underground Operations

9-1* General.

9-1.1*

The provisions of Chapters 1 through 8 shall be followed, for all underground operations, in addition to the specific requirements of this chapter.

Exception: Where modified by this chapter.

9-1.2

Drainage systems shall be properly designed and installed to remove water from sprinkler discharge and fire hose streams.

9-1.3

Fire safety for existing, operating, fixed guideway underground transportation systems undergoing alteration or renovation shall be in accordance with NFPA 130, *Standard for Fixed Guideway Transit Systems*.

9-1.4

Means of egress for existing, operating, underground structures shall be in accordance with NFPA *101*, *Life Safety Code*.

9-1.5

At each aboveground entrance, underground operations shall have a check-in/check-out system, supervised by a qualified individual at all times, that provides an accurate record of each person who is underground. The location of the check-in/check-out system shall be within 25 ft (8 m) of the entrance and shall be easily identified.

9-1.6

Completed or unused sections of the underground facility shall be barricaded, properly marked, and made off limits.

9-1.7

Compartmentation by means of the installation of fire and smoke barriers shall be at intervals that limit the extent and severity of the fire and that provide areas of refuge for occupants.

9-1.8

A fire protection water supply system shall be provided in accordance with 6-7.2.1. A standard fitting with outlet threads compatible with the equipment of the local fire department shall be provided so that travel distance does not exceed 150 ft (46 m).

9-2 Emergency Procedures.

9-2.1*

A written fire prevention, fire suppression, and emergency evacuation plan shall be developed, maintained, and kept current. The authority having jurisdiction shall be provided with a copy of the current plan for its review and shall have the opportunity to comment on the plan. Special attention shall be given to rescue and smoke-venting procedures, to means of ingress/egress, and to training and orientation of employees and visitors.

9-2.2

All personnel, including visitors, shall be trained in emergency and evacuation procedures and informed of the hazards prior to going underground.

9-2.3

Underground operations shall conduct disaster and evacuation drills for each shift at least once at the start of underground operations and every 6 months, or more frequently as appropriate. A record of such drills shall be maintained.

9-3 Fire Detection, Protection, and Communications Systems.

9-3.1* Fire Detection and Protection Systems.

9-3.1.1 Fire protection extinguishing equipment applicable to the hazard shall be provided at the head, tail, drive, and take-up pulley areas of belt conveyors and at intervals along belt conveyor lines that shall not exceed 300 ft (91 m).

9-3.1.2 Belt conveyors installed in underground locations shall meet the following minimum requirements:

(a) Conveyor belting shall be approved.

(b) Entrances in which belt conveyors are installed shall be kept free of accumulations such as muck, debris, and combustibles.

(c) All belt conveyors shall be equipped with an approved slippage switch system designed to shut down the belt when sliding friction develops between the drive pulley(s) and the belt. The slippage switch system shall be tested weekly. On each new installation, the slippage switch system shall be tested before the conveyor is used.

(d) All conveyor belt systems shall be equipped with approved interlock systems that shut down belt conveyors when any conveyor in the system stops or reduces its normal speed or upon activation of any required fire protection system.

(e) Fixed combustible materials such as posts, cribbing, and roof supports shall be either guarded from contact by the belt using metal or located at a distance of at least $^1/_2$ the width of the belt from any idler or pulley. An alternate method for minimizing potential frictional ignition is the use of alignment switches at intervals sufficient to prevent the belt from contacting such materials. Guarding for machinery in the drive area and at other points along the belt shall be of noncombustible material.

(f) New installations of belt conveyors shall utilize a structure that does not provide a deck between the upper and lower strands of the belt.

Exception: Belts that carry the load of the belt on a low-friction metal deck without rollers.

9-3.1.3 Suitable fire extinguishers shall be installed so that travel distance from any one point in a tunnel does not exceed 300 ft (91 m) on a horizontal plane.

9-3.1.4 Audible and visible alarm and emergency lighting for safe evacuation shall be required.

9-3.2 Fire Communications Systems.

9-3.2.1 Two means of communications with the surface shall be available at all times from all areas of the underground facility.

9-3.2.2 All communications systems shall be tested weekly.

9-4 Electrical.

9-4.1*

Electrical cords and plugs shall be heavy duty and suitable for use in damp locations.

9-4.2

Conductors shall be located or guarded so as to be protected from physical damage. Multiconductor portable cable shall be permitted to supply mobile equipment. An equipment grounding conductor shall be run with circuit conductors inside the metal raceway or inside the multiconductor cable jacket. The equipment grounding conductor shall be permitted to be insulated or bare.

9-4.3

Oil-filled transformers shall not be used underground.

Exception: Where located in a fire-resistant enclosure suitably vented to the outside and surrounded by a dike to retain the contents of the transformers in the event of rupture.

9-4.4

Bare terminals of transformers, switches, motor controllers, and other equipment shall be enclosed to prevent accidental contact with energized parts. Enclosures for use in tunnels shall be raintight, rainproof, or watertight as defined in NFPA 70, *National Electrical Code*, where necessitated by the environmental conditions.

9-4.5

Special attention shall be given to maintaining clear access and adequate work space around electrical equipment in accordance with NFPA 70E, *Standard for Electrical Safety Requirements for Employee Workplaces*. Proper housekeeping shall be maintained to avoid fire hazards.

9-4.6

All nonenergized metal parts of electrical equipment and metal raceways and cable sheaths shall be effectively grounded and bonded to all metal pipes and rails at the portal and at intervals not exceeding 1000 ft (300 m) throughout the tunnel.

9-5 Hazardous Operations and Procedures.

9-5.1

Hot work operations shall be in accordance with NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*. A suitable fire extinguisher or other fire control device shall be ready for instant use in any location where any hot work is performed.

9-5.2

Acetylene, liquefied petroleum gas (LPG), liquefied oxygen (LOX), and methylacetylene propadiene stabilized gas (MPS) shall be permitted to be used underground only for welding, cutting, and hot work and only if the quality of air is within permitted limits in accordance with the ACGIH *Threshold Limit Values and Biological Exposure Indices for 1992-1993*.

9-5.3

The quantity of combustible materials to be used underground shall be kept to a minimum. Advance planning shall provide for the use of materials having the most favorable combination of high ignition points, low rates of combustion, and low emissions of smoke and harmful gases.

9-5.4*

Class I flammable liquids shall not be taken, stored, or used underground or within 100 ft (30 m) of a tunnel portal or shaft opening.

9-5.5

Class II and Class III liquids shall be transported and stored in approved closed containers, safety cans, or tanks. Quantities shall be limited to those necessary for one work shift.

9-5.6

Lubricating oils, greases, and rope dressings taken underground shall be in closed and reclosable approved containers that do not allow the contents to leak or spill.

9-5.7

Oil, grease, and diesel fuel stored underground shall be kept in tightly sealed containers in fire-resistant areas located at least 100 ft (30 m) from shafts and inclines. Storage areas shall be positioned or diked so that the contents of ruptured or overturned containers cannot flow from the storage area.

9-5.8

Areas within 25 ft (8 m) of major electrical installations and unburied tanks for storage of combustible liquids shall be free of transient combustible materials.

9-5.9

Fan houses, fan bulkheads for main and booster fans, and air ducts connecting main fans to underground openings shall be constructed of noncombustible materials.

9-6 Storage.

9-6.1

No combustible structure shall be erected and no combustible materials shall be stored within 100 ft (30 m) of an access shaft, shaft hoist, or other entry.

9-6.2

Metal containers with self-closing lids shall be provided and used to store combustible waste and debris and shall be removed and taken to the surface daily.

9-7 Equipment.

9-7.1

Less hazardous hydraulic fluids that are listed shall be used in underground machinery and equipment.

Exception: Where the machinery and equipment are protected by an approved fire suppression system or by approved multipurpose fire extinguishers rated at least 4A:40BC.

9-7.2

Wherever self-propelled equipment is used underground, a fire suppression system or a fire extinguisher rated at least 4A:40BC shall be provided on the equipment.

9-7.3* Ventilation.

9-7.3.1 Where single-entry shafts/tunnel ventilation systems are used, they shall be reversible from a location outside and in close proximity to the shaft/tunnel.

9-7.3.2 The ventilation system shall be sufficient for the number of personnel and equipment underground.

9-7.3.3 Air-sampling logs shall be maintained. Air tests shall be conducted before each shift or after each shift. Air-sampling logs shall be available to the authority having jurisdiction.

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 13, *Standard for the Installation of Sprinkler Systems*, 1996 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1996 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 1996 edition.

NFPA 31, *Standard for the Installation of Oil-Burning Equipment*, 1992 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*, 1996 edition.

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, 1995 edition.

NFPA 70, *National Electrical Code*, 1996 edition.

NFPA 70E, *Standard for Electrical Safety Requirements for Employee Workplaces*, 1995 edition.

NFPA 80, *Standard for Fire Doors and Fire Windows*, 1995 edition.

NFPA *101, Life Safety Code*, 1994 edition.

NFPA 130, *Standard for Fixed Guideway Transit Systems*, 1995 edition.

NFPA 211, *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances*, 1996 edition.

NFPA 495, *Explosive Materials Code*, 1996 edition.

NFPA 701, *Standard Methods of Fire Tests for Flame-Resistant Textiles and Films*, 1996 edition.

NFPA 1963, *Standard for Fire Hose Connections*, 1993 edition.

10-1.2 Other Publications.

10-1.2.1 ACGIH Publication. American Conference of Governmental Industrial Hygienists, 6500 Glenway Avenue, Cincinnati, OH 45211.

ACGIH *Threshold Limit Values and Biological Exposure Indices for 1992-1993*.

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-1-4 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-2-1.1 Separation distances less than those shown in Table 2-1.1 may be permitted to be used, provided the construction is noncombustible and the combustible loading is limited. For multilevel unsprinklered structures, the authority having jurisdiction should be consulted for separation distances.

A-2-1.2 Where located 30 ft (9 m) or more from the structure and constructed of combustible materials, it is recommended that temporary support buildings be divided into small, detached units to minimize fire loss. Large construction support complexes should be protected with adequate fire protection (e.g., automatic sprinklers, yard hydrants, hose, and extinguishers) as required by the authority having jurisdiction.

A-2-3.1 See NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*.

A-3-1.1 For a sample permit and procedure, see NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*. Additional fire watches should be provided during welding or cutting operations where sparks or molten metal could drop several floors.

A-3-1.3 If welding operations have been conducted during a work shift, the guard for the following work shift (*see 5-2.1*) should be alerted to check the location where welding was performed as part of his/her regular rounds. Where watch service is not provided, the use of gas-operated welding or cutting equipment should be discontinued a minimum of 1 hour before the end of the work shift.

Where practicable, 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 finish material.

If the structure has a combustible floor, the floor should be wet down or covered with damp sand or sheet metal before and after welding or cutting operations are conducted. Adequate precautions should be taken so that wetting down does not introduce a personnel safety hazard.

A-3-1.5.1 When the charge for Thermit welding has been ignited, the operator should stand several steps away [at least 10 ft (3 m)] and should wear goggles. Burns can occur from metal splashings, by upsetting the crucible, by breaking the mold, or by allowing the molten metal to come into contact with moisture in the mold, on the floor, or on the ground.

A-3-1.5.2 Where storage near the point of use is necessary, it should be kept at least 10 ft (3 m) away from that point and limited to a supply necessary for one workday. A listed flammable liquid cabinet should be used. The area should be kept dry and the cabinet should be locked.

It has been reported that moisture can cause ignition. Ferric oxide and powdered aluminum can be used in a metal cylinder as an incendiary bomb, which creates increased concern for keeping storage areas locked.

A-3-2.5 This can necessitate the removal of the heater prior to refueling. The appliance also should be allowed to cool prior to refueling.

A-3-2.7 Misuse of temporary heating devices has resulted in numerous fires and millions of dollars in property loss. Temporary heating equipment, while operating, should be visually inspected every hour to ensure that combustibles have not blown or fallen over near the temporary heating device. During windy periods, it might be necessary to reduce the interval between inspections. Any object near the temporary heating device that is hot to the touch should be moved, or the temporary heating device should be relocated. The visual inspection also should ensure that the appliance is operating properly. Any appliance that is not operating properly should be turned off until repairs have been made.

A-3-3.1 Areas where smoking should be prohibited include, but are not limited to, temporary holding areas for combustible construction materials, storage areas, and areas where oil, gasoline, propane, or flammable material is stored or used.

A-3-4.1 If a chute is employed for removal of debris, it should be erected on the outside of the building. The chute should be of noncombustible construction, and the main artery of the chute should be as straight as practicable to avoid accumulations or clogging within the chute.

Failure to remove scrap and trash accumulations provides fuel for the rapid expansion of a fire that might otherwise be confined to a small area. These accumulations also provide a convenient fuel source for malicious fires.

A-3-5.1.2 The reference to “structure” is intended to apply to those structures under construction, alteration, or demolition and not to temporary structures on the construction site.

Additionally, existing properly protected storage within 50 ft (15 m) of the structure or inside an existing structure under alteration is not intended to be regulated by this provision.

A-3-5.2.3 The vapors given off by flammable liquids generally have vapor densities greater than those of air. Therefore, these vapors tend to collect in low spots and travel at floor level. Being invisible, these vapors are difficult to detect without the aid of proper instruments designed specifically for the purpose.

Proper ventilation is, therefore, important in the prevention of accidental ignition of these vapors. Proper ventilation can be accomplished by either natural or mechanical means.

A-5-1.1 One person should be made responsible for the protection of property from fire. This person should ensure that the proper procedures for controlling fire hazards are established and should have full authority to enforce them.

The responsible person should be appointed by the owner. Where an entirely new structure is being constructed, the owner should ensure that specifications for new buildings contain a clause stating that the "contractor will take all reasonable precautions against fire in accordance with good fire protection engineering practice."

The responsibility for loss prevention is the owner's. However, loss prevention recommendations normally are accomplished by the contractor. To ensure that recommendations are carried out promptly, the owner's assistance might be needed.

Fire prevention education should be a topic at contractor safety meetings ("tailgate talks") at least once a month. Topics that could be discussed include maintaining clear access to fire-fighting equipment, reinforcing cutting and welding procedures, flammable liquids use and storage, use of first-aid fire-fighting equipment, roofing operations, and precautions for the use of temporary heating equipment.

All fires should be investigated by the manager, and necessary fire prevention improvements that are identified by the investigation should be communicated to all employees as soon as possible.

A-5-1.3.2 Large-scale construction sites change rapidly as construction progresses. The prefire plan should be flexible to allow for different stages of construction. Critical stages that should be considered include access, installation of water mains and fire hydrants, framing/exterior shell, roofing, covering of interior partitions, installation of fixed fire protection, concrete form work, installation of building systems, and construction safety hazards.

Since construction projects do change, the local fire department should be encouraged to visit the site on a regular basis. Prefire plan visits should be scheduled by the manager at least semiannually and when there have been major revisions to the fire prevention plan. Since municipal fire departments work rotating shifts, a series of prefire plan visits might be necessary to allow all responding fire fighters an opportunity to visit the site. In rural areas and smaller cities, the local fire department might be a volunteer organization or might have only a small career fire fighter crew on duty during the day. It might be necessary for the manager to schedule the prefire plan visit during the evening hours to meet the needs of the local fire department.

A-5-1.8 See NFPA 72, *National Fire Alarm Code*, for impairment notification.

A-5-2.1 Due to the growing threat of arson, guard service should be provided on major projects even where not required by the authority having jurisdiction. The requirements for guard service also should be based on, but should not be limited to, the hazards at the site, the size of the risk, the difficulty of the fire-fighting situation, the exposure risk, and the physical security of the site.

A-5-2.2 It is recommended that areas in buildings should be patrolled at all times when construction, alteration, and demolition operations are not in progress by a competent guard registered on an approved security tour supervision system (watch clock) with stations covering all parts of the building in accordance with NFPA 601, *Standard for Security Services in Fire Loss Prevention*. Guard rounds should include all parts of the buildings and outside areas where hazardous equipment or materials are located. Rounds should be conducted every $^1/_2$ hour for 2 hours after suspension of work for the day and every hour thereafter during the night and nonworking days and shall include tours of all accessible work areas. (*See NFPA 601, Chapter 6.*)

A-5-2.3 The requirements for security fencing should be based on, but should not be limited to, the hazards at the site, the size of the risk, the difficulty of the fire-fighting situation, the exposure risk, and the presence of guard service.

A-5-2.4 Securing the openings (doors and windows) to the structure, where possible, reduces the chance of entry by unauthorized persons. This, in turn, reduces the chance of arson or accidental fires. It could, in some instances, eliminate the need for guard service or security fencing. It also helps prevent freezing or wind damage to fire protection equipment and prevents combustible material from being blown against heating devices and igniting.

A-5-3 In large projects or tall structures, or both, the use of an audible device for an evacuation signal in case of fire or other emergency is recommended.

A-5-4.11 Clear and unobstructed access to all first-aid fire-fighting equipment should be maintained. Fire-fighting equipment also should be clearly visible from surrounding areas. If visibility to first-aid fire-fighting equipment is obstructed, signs in accordance with NFPA 170, *Standard for Fire Safety Symbols*, should be installed to indicate the position of the fire-fighting equipment.

A-5-6 Portable fire extinguishers, water pails, small hose lines, and $1^1/_2$-in. (38-mm) standpipe hose are considered first-aid fire-fighting equipment. To be effective, first-aid fire-fighting equipment should be used in the incipient stage of a fire.

A-6-2 Steel scaffolding or approved fire-retardant lumber and planking should be used on both the outside and inside of the structure. Construction materials (e.g., forms, shoring, bracing, temporary stairways, platforms, tool boxes, plan boxes, solvents, paints, tarpaulins, and similar items) should be of the noncombustible, fire-retardant, safety solvent, or high flash point type, as the case necessitates. A concerted effort should be made to attain as high a level of noncombustibility of materials as possible. (*See also NFPA 703, Standard for Fire Retardant Impregnated Wood and Fire Retardant Coatings for Building Materials*.)

A-6-2.2 The authority having jurisdiction should be contacted regarding the adequacy of water supplies for hose lines.

A-6-3.2 Accepted good practice provides sprinklered areas for the storage of interior finish materials and building mechanical equipment, much of which could be received in combustible packaging and which cannot be stored outside due to the absence of exterior space, weather, or security. Even where construction combustibles are not a factor, sprinkler protection should be available for unanticipated early delivery of combustible contents to be used for the permanent occupancy. Where necessary, it is not unusual to plug the extremity of a partially installed sprinkler system temporarily so that a portion can be placed in automatic service.

A-6-7.2.1 No minimum water supply is specified due to the wide range of construction types, sites, and sizes. However, unless combustibles are essentially nonexistent in the completed structure and occupancy, a minimum of 500 gpm (1893 lpm) should be provided. In most instances, the required supply is greater, and authorities having jurisdiction should be consulted.

A-6-7.3.1 With proper scheduling and contracting, it is possible for the sprinkler installation to follow the building construction closely as it progresses. This is frequently done in multiple-story buildings to facilitate protection on the lower floors before the upper floors have been built.

A-6-7.4.1.1 Threaded plugs should be inserted in fire department hose connections, and they should be guarded properly against physical damage.

A-6-7.4.1.2 Exception The intent of this exception is to permit the permanent standpipes to be used as temporary standpipes during construction.

A-6-7.4.2.4 A substantial box, preferably of metal, in which a sufficient amount of hose to reach all parts of the floor, appropriate nozzles, spanner wrenches, and hose straps are kept should be maintained at the highest hose outlet.

A-6-7.4.2.6 A supply of fire hose and nozzles should be ordered in advance so that it is available as soon as the standpipes are ready. Hose lines should be connected in areas where construction is in progress.

A-7-1.2.3 Many flammable and combustible liquids, including roofing asphalts, combine readily with the oxygen in air and produce heat. Where these liquids are present on rags and mops used in roofing operations, the heat can concentrate inside the mass faster than it can be dissipated and can result in spontaneous combustion.

Fires in mops can be prevented by “spinning” or cleaning excessive asphalt out of the mop or rag after its work period is finished.

A-7-1.3 For additional information, see the ARMA publication, *Torch-Applied Roofing, Dos and Don’ts*, and the Factory Mutual technical advisory Bulletin 1-29, *Safeguarding Torch-Applied Roof Installations*.

A-7-1.3.1 Torch-applied roofing can be a potentially hazardous construction process, and extreme caution should be exercised during installation. The exposed outer surface of the membrane coil should be heated until a slight sheen develops. The compound should not be overheated. A slight smoke vapor can be seen when the compound is overheated. The flame from a hand-held torch should be moved from side to side constantly. If a mobile heating apparatus is used, it should be kept in constant motion while in operation.

Some roof membranes, such as polyvinyl chloride (PVC) or chloro-sulfonated polyethylene (CSPE or hypalon), might necessitate heating or the use of solvents in order to form lap joints or to secure the membrane.

A-7-1.3.2 Roof openings/vents and crevices should be covered with a stable, noncombustible cover to prevent the ignition of building contents.

Extreme caution should be used near penetrations such as exhaust vents. Flames could ignite grease accumulations from kitchen vents and lint accumulations from laundry vents. Such accumulations should be cleaned before roofing work is begun.

Areas equipped with air conditioning units and ventilating fans should be shut down before torch work is performed.

A torch stand should be used to direct the flame upward while momentarily suspending the use of the flame. The cylinder valve should be closed to burn off propane in the line before shutting off the torch head. The gas supply should be shut off whenever a propane odor is detected.

Torches should not be used near gas lines or electrical wires.

A-7-1.3.5 Protective clothing should include acceptable fabrics, a long-sleeve shirt, long pants, gloves, and eye protection. The safe handling of hand torches and hot trowels necessitates the use of proper protective clothing and personal protective equipment.

A-7-1.3.7 Liquid fuel gas cylinders can be of either the vapor withdrawal or liquid withdrawal type. The vapor withdrawal type draws vapor off the torch head. Vapor withdrawal cylinders are equipped with female cylinder valves. Liquid withdrawal cylinders transfer the liquid, via a dipstick, from the cylinder to the torch head where it is vaporized. Liquid withdrawal cylinders have male cylinder valves, which can come equipped with adapters.

Frost buildup occurs only with vapor withdrawal cylinders. This can be the result of a cylinder that is undersized for the torch or air temperatures that are low. When vapor is drawn off more quickly than it is replaced, heat is absorbed and frost buildup occurs on the outside of the cylinder. Vapor pressure then further declines. Consequently, liquid withdrawal cylinders are recommended. However, where vapor withdrawal cylinders are used, 40-lb or 100-lb (18.2-kg or 45.5-kg) cylinders should be used with larger torches (such as those used on the field of the roof) or where temperatures are low [below 20°F (–7°C)].

A-7-1.3.8 Fuel gas cylinders should be inspected for dents. If dents larger than a quarter are found, the cylinder should be replaced. Torch and cylinder connectors should be inspected visually and checked for leaks with a soap and water solution. An open flame should not be used to test for leaks.

Leaky equipment should not be used. Regulator adjustments and pressure gauges should be checked to ensure that they are operable. The vent on the regulator should be checked to ensure that it is not blocked. If an unstable flame occurs (e.g., roars loudly and tends to blow itself out), the equipment should be repaired or replaced immediately.

A-7-1.3.11 All roof areas under repair should be checked for hot spots and signs of smoldering. The inside of the building also should be inspected for signs of fire or smoke. Particular attention should be paid to cants, flashings, and areas around penetrations such as vent pipes, air vents, and skylights. Where available, infrared scanners should be used to detect hot spots. All fires should be reported to the fire department, even when extinguished. Smoldering can continue after extinguishment, can occur for hours before flaming begins, and can occur in areas unsuspected by laypersons. (*Also see A-3-1.1* and *A-3-1.3*.)

A-7-1.4.1 Additional information regarding the safe use and operation of roofing kettles can be found in NFPA 1, *Fire Prevention Code*, Section 3-12.

A-7-1.4.2 For large roof areas, additional protection, such as charged hose lines or additional extinguishers, is recommended.

A-8-2.2 Tanks and piping formerly containing flammable liquids are likely to contain flammable vapors and should be removed prior to the demolition of a building. If this is not feasible, these hazards should be placarded or otherwise identified for careful removal. Purging with inert materials should be done as early as practicable in the demolition operation in order to minimize the possibility of explosion. Remaining residue or sludge could constitute a fire or explosion hazard. Guidance on draining and inerting tanks can be found in NFPA 30, *Flammable and Combustible Liquids Code*, and NFPA 327, *Standard Procedures for Cleaning or Safeguarding Small Tanks and Containers Without Entry*.

A-8-4 Areas where smoking should be prohibited include, but are not limited to, temporary holding areas for combustible construction materials, storage areas, and areas where oil, gasoline, propane, or flammable material is stored or used.

A-8-5 If buildings are demolished by explosives, work should be performed only by experienced personnel with procedures approved by the authority having jurisdiction.

A-8-7 In situations where adjacent structures are to remain standing, demolition should be started immediately adjacent to the structures to be left standing, thereby creating a space separation between the structures that will remain and the balance of the demolition work.

Vertical open shafts in buildings under demolition have been a major factor in the rapid spread of fire throughout such buildings. Outside chutes should be used where possible so that floor-to-floor integrity can be maintained.

A-8-8.2 The existing sprinklers should be retained in service as long as is reasonable by cutting off and capping the system at the floor or area being razed. Modification of the sprinkler systems to allow alterations or additional demolition should be done under the direction of the authority having jurisdiction and should be expedited so that automatic protection can be restored as quickly as possible.

A-8-8.5 During demolition operations, charged hose lines supplied by hydrants or sprinkler-riser adapters should be available.

A-9-1 The following publications should be consulted for additional information on underground operations and related subjects:

ACGIH *Threshold Limit Values and Biological Exposure Indices for 1992-1993*

ANSI A10.16, *Construction and Demolition — Tunnels, Shafts, and Caissons*

Title 29, *Code of Federal Regulations*, Part 1926, "Safety and Health Regulations for Construction," Subpart S, "Tunnels and Shafts, Caissons, Cofferdams and Compressed Air"

Title 30, *Code of Federal Regulations*, Part 57, "Safety and Health Standards — Underground Metal and Nonmetal Mines"

Title 30, *Code of Federal Regulations*, Part 75, "Mandatory Safety Standards — Underground Coal Mines"

NFPA *Fire Protection Handbook*

NFPA 121, *Standard on Fire Protection for Self-Propelled and Mobile Surface Mining Equipment*

NFPA 122, *Standard for Fire Prevention and Control in Underground Metal and Nonmetal Mines*.

A-9-1.1 Underground structures and construction activities present unique fire protection problems, since fires can quickly create temperatures and smoke levels that are intolerable to workers and fire fighters. Due to the unusual circumstances, the complexity and variety of activities regarding underground operations, fire prevention, fire suppression, and emergency evacuation plans should be reviewed with responding fire departments and medical facilities. It is further recommended that fire-fighting personnel be given periodic tours of the underground work areas.

A-9-2.1 An underground emergency evacuation plan should be developed, and the first and foremost consideration of this plan should be the prompt and safe removal of all persons underground. This plan should include, as a minimum the following:

(a) Emergency communications and alarm system;

(b) Clear, concise, and uncomplicated emergency instructions;

(c) Location of means of egress from the underground work areas;

(d) Availability and location of self-rescuer air breathing units and first-aid supplies;

(e) Emergency ventilation methods; and

(f) Location of any refuge stations.

A-9-3.1 If an underground location is classified as gassy by the regulatory authorities, additional fire protection and equipment might be needed. For example, continuous monitoring for flammable gas, explosionproof electrical equipment, and other related requirements could be necessary. The authority having jurisdiction over the project should be consulted to determine specific safety and fire prevention needs.

A-9-4.1 See NFPA 70, *National Electrical Code*.

A-9-5.4 The use of hazardous materials, liquids, or chemicals underground should be minimized and eliminated where feasible. Strict controls including fire-resistant storage areas vented to the outside should be used.

A-9-7.3 For ventilation requirements, see Title 29, *Code of Federal Regulations*, Part 1926.800, Subpart S.

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 1, *Fire Prevention Code*, 1992 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 1996 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 70, *National Electrical Code*, 1996 edition.

NFPA 72, *National Fire Alarm Code*, 1996 edition.

NFPA 121, *Standard on Fire Protection for Self-Propelled and Mobile Surface Mining Equipment*, 1996 edition.

NFPA 122, *Standard for Fire Prevention and Control in Underground Metal and Nonmetal Mines*, 1995 edition.

NFPA 170, *Standard for Fire Safety Symbols*, 1996 edition.

NFPA 327, *Standard Procedures for Cleaning or Safeguarding Small Tanks and Containers Without Entry*, 1993 edition.

NFPA 601, *Standard for Security Services in Fire Loss Prevention*, 1996 edition.

NFPA 703, *Standard for Fire Retardant Impregnated Wood and Fire Retardant Coatings for Building Materials*, 1995 edition.

Fire Protection Handbook, 17th edition.

B-1.2 Other Publications.

B-1.2.1 ACGIH Publication. American Conference of Governmental Industrial Hygienists, 6500 Glenway Avenue, Cincinnati, OH 45211.

ACGIH *Threshold Limit Values and Biological Exposure Indices for 1992-1993*.

B-1.2.2 ANSI Publication. American National Standards Institute, 1430 Broadway, New York, NY 10018.

ANSI A10.16, *Construction and Demolition — Tunnels, Shafts, and Caissons*, 1988.

B-1.2.3 ARMA Publication. Asphalt Roofing Manufacturer's Association, 6288 Montrose Road, Rockville, MD 20852.

Torch-Applied Roofing, Dos and Don'ts, 1986.

B-1.2.4 FMRC Publication. Factory Mutual Research Corp., 1151 Boston-Providence Turnpike, Norwood, MA 02062.

Bulletin 1-29, *Safeguarding Torch-Applied Roof Installations*, 1988.

B-1.2.5 U.S. Government Publications. U.S. Government Printing Office, Washington, DC 20402.

Title 29, *Code of Federal Regulations*, Part 1926, "Safety and Health Regulations for Construction," Subpart S, "Tunnels and Shafts, Caissons, Cofferdams and Compressed Air."

Title 30, *Code of Federal Regulations*, Part 57, "Safety and Health Standards — Underground Metal and Nonmetal Mines."

Title 30, *Code of Federal Regulations*, Part 75, "Mandatory Safety Standards — Underground Coal Mines."

NFPA 251

1995 Edition

Standard Methods of Tests of Fire Endurance of Building

Construction and Materials

1995 Edition

This edition of NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*, was prepared by the Technical Committee on Fire Tests 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 251 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 251

NFPA 251 originated in the recommendations of the International Fire Prevention Congress in London in 1903. It was presented to the NFPA by the Committee on Fire-Resistive Construction in 1914. It was adopted officially in a revised form in 1918. Successive editions were published in 1918, 1926, 1934, 1941, 1955, 1958, 1959, 1960, 1961, 1963, 1969, 1979, 1985, and 1990. It was overseen, in succession, by the Technical Committee on Fire-Resistive Construction, the Technical Committee on Building Construction, and, for the last three editions, by the Technical Committee on Fire Tests.

The 1995 edition of this document is a reconfirmation of the earlier edition with only a few items being addressed. Substantial investigation and record research was done on the topic of the hose stream application on test specimens. The findings of the committee could not support modification of the provision that permits a test assembly to be tested one-half the time required for an hourly rating and then to be tested by a hose stream.

The committee also chose to modify the title of this document in response to the research done to convey a truer sense of the standard's proper application.

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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.

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 251
Standard Methods of Tests of Fire Endurance of Building Construction and 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 15 and Appendix H.

Chapter 1 General

1-1* Scope.

1-1.1

These methods of fire tests shall apply to assemblies of masonry units and to composite assemblies of structural materials for buildings, including bearing and other walls and partitions, columns, girders, beams, slabs, and composite slab and beam assemblies for floors and roofs. They also shall apply to other assemblies and structural units that constitute permanent integral parts of a finished building.

1-1.2*

It is intended that classifications shall be based on performance during the period of exposure and shall not be used to determine suitability for use after fire exposure.

1-1.3

The results of these tests are one factor in assessing fire performance of building construction and assemblies. These methods prescribe a standard fire exposure for comparing the performance of building construction assemblies. Application of these test results to predict the performance of actual building construction requires careful evaluation of test conditions.

1-2 Purpose.

This standard outlines methods of fire test for the fire-resistive properties of building members and assemblies.

1-3 Significance.

1-3.1

This standard is intended to evaluate the duration for which the types of assemblies noted in Section 1-1 contain a fire, retain their structural integrity, or exhibit both properties, depending on the type of assembly involved during a predetermined test exposure.

1-3.2

The test exposes a specimen to a standard fire exposure controlled to achieve specified temperatures throughout a specific time period. In some instances, the fire exposure is followed by the application of a specified standard fire hose stream. The exposure, however, shall not be considered representative of all fire conditions, which vary with changes in the amount, nature, and distribution of fire loading, ventilation, compartment size and configuration, and heat sink characteristics of the compartment. The test does, however, provide a relative measure of fire performance of comparable assemblies under these specified fire exposure conditions. Any variation from the construction or conditions (i.e., size, method of assembly, and materials) that are tested substantially varies the performance characteristics of the assembly.

1-3.3

The test standard provides the following:

(a) In walls, partitions, and floor or roof assemblies:

1. Measurement of the transmission of heat;

2. Measurement of the transmission of hot gases through the assembly sufficient to ignite cotton waste;

3. Measurement of the load-carrying ability of the test specimen during the test exposure where load-bearing elements are included.

(b) For individual load-bearing assemblies such as beams and columns, measurement of the load-carrying ability under the test exposure with some consideration for the end support conditions (i.e., restrained or unrestrained) is provided.

1-3.4

The test standard does not provide the following:

(a) Full information on the performance of assemblies constructed with components or lengths other than those tested;

(b) Evaluation of the degree to which the assembly contributes to the fire hazard by generation of smoke, toxic gases, or other products of combustion;

(c) Measurement of the degree of control or limitation of the passage of smoke or products of combustion through the assembly;

(d) Simulation of the fire behavior of joints between building elements, such as floor-to-wall or wall-to-wall, connections;

(e) Measurement of flame spread over the surface of the tested element;

(f) The effect on fire endurance of conventional openings in the assembly (i.e., electrical receptacle outlets, plumbing pipe) unless specifically provided for in the construction tested.

1-4 Definitions.

Shall. Indicates a mandatory requirement.

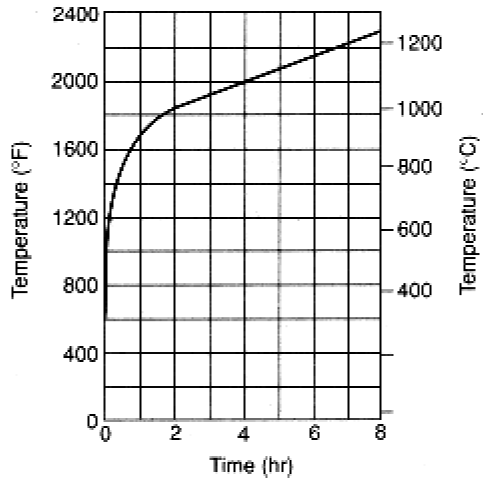
Should. Indicates a recommendation or that which is advised but not required.

Chapter 2 Control of Fire Tests

2-1 Temperature—Time Curve.

2-1.1

The conduct of fire tests of materials and construction shall be controlled by the standard temperature—time curve shown in Figure 2-1.1. The points on the curve that determine its character are provided.



1000°F (538°C).............................at 5 minutes
1300°F (704°C).............................at 10 minutes
1550°F (843°C).............................at 30 minutes
1700°F (927°C).............................at 1 hour
1850°F (1010°C)...........................at 2 hours
2000°F (1093°C)...........................at 4 hours
2300°F (1260°C)...........................at 8 hours or over

Figure 2-1.1 Temperature—time curve.

2-1.2

For a more precise definition of the temperature—time curve, see Appendix B.

2-1.3

The temperature inside the furnace shall be ambient when the test begins.

2-2* Furnace Temperatures.

2-2.1*

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, roof, wall, or partition and not less than eight thermocouples for a structural column, symmetrically disposed and distributed to show the temperature near all parts of the sample, the thermocouples being enclosed in protection tubes of such materials and dimensions that the time constant of the protected thermocouple assembly lies within the range of 5.0 minutes to 7.2 minutes. The exposed length of the pyrometer tube and thermocouple in the furnace chamber shall be not less than 12 in. (305 mm). Other types of protecting tubes or pyrometers shall be permitted to be used that, under test conditions, provide the same time range specified above within the accuracy requirement that applies for the measurement of furnace temperature. For floors and columns, the junction of the thermocouples shall be placed 12 in. (305 mm) away from the exposed face of the specimen at the beginning of the test and, during the test, shall not touch the sample as a result of its deflection. In the case of walls and partitions, the thermocouples shall be placed 6 in. (152 mm) away from the exposed face of the specimen at the beginning of the test and shall not touch the specimen during the test in the event of deflection.

2-2.2

The temperatures shall be measured at intervals not exceeding 1 minute during the test period.

2-2.3

The accuracy of the furnace control shall be such that the area under the temperature—time curve, obtained by averaging the results from the pyrometer readings, is within 10 percent of the corresponding area under the standard temperature—time curve shown in Figure 2-1.1 for fire tests of 1 hour or less, within 7.5 percent for those over 1 hour and not more than 2 hours, and within 5 percent for tests exceeding 2 hours.

2-3 Temperatures of Unexposed Surfaces of Floors, Roofs, Walls, and Partitions.

2-3.1*

Temperatures of unexposed surfaces shall be measured with thermocouples placed under dry, felted pads. The properties of these pads shall meet the requirements of Appendix C. 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 $3^1/_2$ in. (90 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 for the thermocouple in the length covered by the pad shall be not heavier than No. 18 AWG [0.04 in. (1.02 mm)] and shall be electrically insulated with heat-resistant and moisture-resistant coatings.

2-3.2

Temperature measurements shall be obtained from at least nine points on the surface, as follows:

(a) Five thermocouples shall be symmetrically disposed; one shall be located approximately at the center of the specimen and four shall be located approximately at the center of each quadrant. The other four thermocouples shall be located at the discretion of the testing authority to obtain representative information on the performance of the construction under test.

(b) All of the thermocouples shall be located at a distance of at least $1^1/_2$ times the thickness of the construction or 12 in. (305 mm) from the edges of the test specimen.
Exception: Where an element of the assembly is located near the edge only.

(c) None of the thermocouples shall be located opposite or on top of beams, girders, pilasters, or other structural members if temperatures at such points are obviously lower than at more representative locations.

(d) None of the thermocouples shall be located opposite or on top of fasteners such as screws, nails, or staples that are obviously higher or lower in temperature than at more representative locations if the aggregate area of any part of such fasteners projected to the unexposed surface is less than 1 percent of the area within any 6-in. (152-mm) diameter circle. Such fasteners shall not be required to extend through the assembly.

2-3.3

Temperature readings shall be measured at intervals not exceeding 1 minute.

2-3.4

Where the conditions of acceptance place a limitation on the rise of 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.

Exception: Where a temperature rise of 30 percent in excess of the specified limit occurs at any one of these points, all other points shall be ignored and the fire endurance period shall be judged as ended.

2-4 Furnace Pressure.

2-4.1

The pressure-sensing probes shall be as shown in Figure 2-4.1(a) or (b).

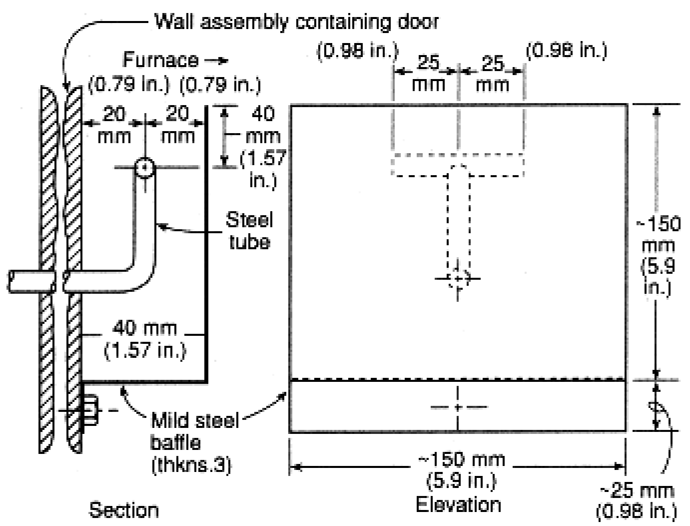


Figure 2-4.1(a) Static pressure-measuring device dimensions.

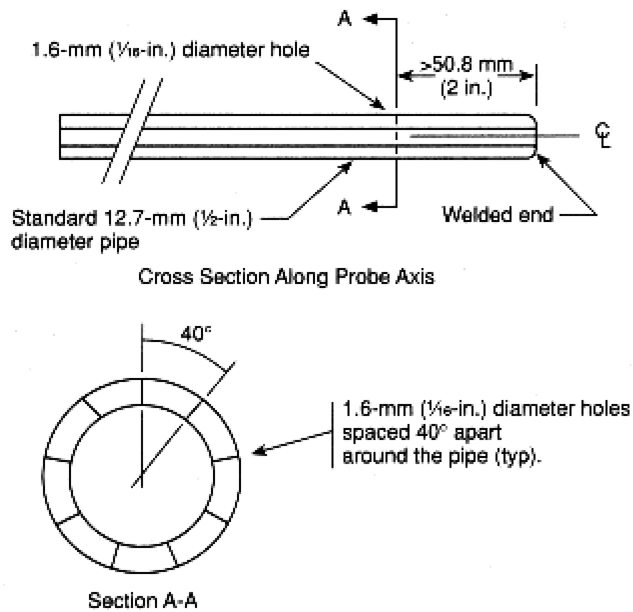


Figure 2-4.1(b) Pressure-sensing probe.

2-4.2

The pressure shall be measured using a differential pressure instrument capable of reading in increments no coarser than 0.01 in. wg (2.5 Pa) with a precision of not less than ± 0.005 in. wg (± 1.25 Pa). The differential pressure measurement instrument(s) shall be located to minimize “stack” effects caused by vertical runs of pressure tubing between the furnace probe(s) and instrument locations.

2-4.3

The furnace pressure(s) shall be measured and recorded at intervals not exceeding 1 minute throughout the test.

2-4.4

Control of the furnace pressure shall be established no later than 10 minutes after the start of the test and shall be maintained throughout the remainder of the test.

For vertical specimens, the vertical pressure distribution within the furnace shall be measured by at least two probes separated by a vertical distance [minimum of 6 ft (1.8 m)] within the furnace. Based on their vertical separation and their pressure differences, a calculation of the neutral plane’s (zero differential pressure) location shall be made. The pressure measurements made inside the furnace along with the calculation showing the position of the neutral plane with respect to the top of the vertical assembly during the test shall be reported.

For horizontal specimens, the pressure shall be measured at two locations along the centerline of the specimen and 12 in. (300 mm) below the specimen. The pressure (the average of the two readings) during the test shall be reported.

Chapter 3 Test Specimen

3-1 Specimen.

3-1.1

The test specimen shall be a true representation of the construction for which classification is to be determined with respect to materials, workmanship, and details such as dimension of parts. The specimen shall be built under conditions representative of those properties that are practically applied in building construction and operation. The physical properties of the materials and ingredients used in the test specimen shall be determined and recorded.

3-1.2

The size and dimensions of the test specimen described in the standard are intended to apply in rating constructions of dimensions within the usual general range used in buildings. If the conditions of use limit the construction to smaller dimensions, a proportionate reduction shall be permitted to be made in the dimensions of the specimens for a test used to qualify them for such restricted use.

3-1.3

Where it is desired to include a built-up roof covering, the test specimen shall have a roof covering of 3-ply, 15-lb (6.8-kg)-type felt not in excess of 120 lb (54.4 kg) per 100 ft^2 (9.3 m^2) of hot mopping asphalt without gravel surfacing. Tests of assemblies with this covering shall not preclude the field use of other built-up roof coverings.

3-2 Protection and Conditioning of Test Specimen.

3-2.1

The test specimen shall be protected during and after fabrication to ensure its quality and condition when tested. It shall not be tested until close to its full strength, and, if it contains moisture, until the excess moisture has been removed to achieve an air-dry condition in accordance with the requirements of 3-2.1.1 through 3-2.1.3. The testing equipment and sample undergoing the fire test shall be protected from any condition of wind or weather that might lead to abnormal results. The ambient air temperature at the beginning of the test shall be within the range of 50°F to 90°F (10°C to 32°C). The velocity of air across the unexposed surface of the sample, measured immediately before the test begins, shall not exceed 4.4 ft/sec (1.3 m/sec) as determined by an anemometer placed at right angles to the unexposed surface. If mechanical ventilation is used during the test, an airstream shall not be directed across the surface of the specimen.

3-2.1.1* Prior to the fire test, the construction shall be conditioned with the objective of providing, within a reasonable time, a moisture condition within the specimen approximately representative of that likely to exist in similar construction in buildings. For purposes of standardization, this condition shall be considered to be that which would exist at equilibrium as a result of drying in an ambient atmosphere of 50 percent relative humidity at 73°F (23°C). However, with some constructions, it could be difficult or impossible to achieve such uniformity within a reasonable time. Accordingly, where this is the case, specimens shall be permitted to be tested when the dampest portion of the structure [i.e., the portion at 6 in. (152 mm) depth below the surface of massive constructions] has achieved a moisture content corresponding to drying to equilibrium with air in the range of 50 percent to 75 percent relative humidity at 73°F ± 5°F (23°C ± 3°C). In the event that specimens dried in a heated building fail to meet these requirements after a 12-month conditioning period, or in the event that the nature of the construction is such that it is evident that drying of the specimen interior is prevented by hermetic sealing, these requirements shall be permitted to be waived.

Exception: The requirement for testing of the specimen only after nearing its full strength shall not be permitted to be waived.

3-2.1.2 If, during the conditioning of the specimen it appears desirable or is necessary to use accelerated drying techniques, it is the responsibility of the laboratory conducting the test to avoid procedures that significantly alter the structural or fire endurance characteristics of the specimen, or both, from those produced as the result of drying in accordance with procedures in 3-2.1.1.

3-2.1.3* Within 72 hours prior to the fire test, information on the actual moisture content and distribution within the specimen shall be obtained. The information shall be included in the test report.

Chapter 4 Conduct of Fire Tests

4-1 Fire Endurance Test.

4-1.1

A fire endurance test on the specimen, including its applied load, if any, shall be continued until failure occurs, or until the specimen has withstood the test conditions for a period equal to that herein specified in the conditions of acceptance for the given type of construction.

4-1.2

For the purpose of obtaining additional performance data, the test shall be permitted to be continued beyond the time the fire endurance classification is determined.

4-2 Hose Stream Test.

4-2.1

Where required by the conditions of acceptance, a duplicate specimen shall be subjected to a fire exposure test for a period equal to one-half of that indicated as the resistance period in the fire endurance test, but not for more than 1 hour, immediately after which the specimen shall be subjected to the impact, erosion, and cooling effects of a hose stream directed first at the middle and then at all parts of the exposed face, with changes in direction made slowly.

Exception: The hose stream test shall not be required in the case of construction having a resistance period, as specified in the fire endurance test, of less than 1 hour.

4-2.2

The stream shall be delivered through a $2^1/_2$-in. (64-mm) hose discharging through a national standard play pipe as specified in ANSI/UL 385, *Standard for Safety Play Pipes for Water*

Supply Testing in Fire Protection Service. The play pipe shall have an overall length of 30 in. (762 mm) and shall be equipped with a $1^{1}/_{8}$-in. (28.4-mm) discharge tip of the standard-taper, smooth bore pattern without shoulder at the orifice. The play pipe shall be fitted with a $2^{1}/_{2}$-in. (64-mm) inside diameter × 6-in. (153-mm) long nipple mounted between the hose and the base of the play pipe. The pressure tap for measuring the water pressure at the base of the nozzle shall be normal to the surface of the nipple, centered in its length, and shall not protrude into the water stream. The water pressure shall be measured with a suitable pressure gauge [as a minimum 0 psi to 50 psi (0 kPa to 345 kPa)] graduated in no more than 2 psi (13.8 kPa) increments. The water pressure and duration of application shall be as specified in Table 4-2.2.

Table 4-2.2 Hose Stream Test

	Water Pressure at Base of Nozzle		Duration of Application Exposed Area	
Resistance Period (min/100 ft^2)	**(psi) (min/m^2)**			**(kPa)**
8 hr and over	45	310	6	0.65
4 hr and over if less than 8 hr	45	310	5	0.54
2 hr and over if less than 4 hr	30	207	$2^{1}/_{2}$	0.27
$1^{1}/_{2}$ hr and over if less than 2 hr	30	207	$1^{1}/_{2}$	0.16
1 hr and over if less than $1^{1}/_{2}$ hr	30	207	1	0.11
Less than 1 hr, if desired	30	207	1	0.11

4-2.3 Nozzle Distance.

The nozzle orifice shall be 20 ft (6 m) from the center of the exposed surface of the test sample if the nozzle is so located that, when directed at the center, its axis is normal to the surface of the test sample. If otherwise located, its distance from the center shall be less than 20 ft (6 m) by a distance equal to 1 ft (0.3 m) for each 10 degrees of deviation from normal.

Chapter 5 Tests of Bearing Walls and Partitions

5-1 Size of Specimen.

The area exposed to fire shall be not less than 100 ft^2 (9.3 m^2), with neither dimension less than 9 ft (2.7 m). The test specimen shall not be restrained on its vertical edges.

5-2* Loading.

Throughout the fire endurance and fire and hose stream tests, a constant superimposed load shall be applied to simulate a maximum load condition. The applied load shall be, as nearly as practicable, the maximum load permitted by design under nationally recognized structural design criteria. The tests also shall be permitted to be conducted by applying to the specimen a load less than the maximum. Such tests shall be identified in the test report as having been conducted under restricted load conditions. The applied load, and the applied load expressed as a percentage of the maximum permitted design load, shall be included in the report. A double-wall assembly shall be loaded during the test to simulate field use conditions, with either side loaded separately or both sides loaded together. The method used shall be reported.

5-3 Conditions of Acceptance.

The test shall be regarded as valid if the following conditions are met:

(a) The wall or partition shall have sustained the applied load during the fire endurance test, without passage of flame or gases hot enough to ignite cotton waste, for a period equal to that required for the classification desired.

(b) The wall or partition shall have sustained the applied load during the fire and hose stream test, as specified in Section 4-2, without passage of flame, of gases hot enough to ignite cotton waste, or of the hose stream. The assembly shall be considered to have failed the hose stream test if an opening develops that allows a projection of water from the stream beyond the unexposed surface during the hose stream test.

(c) Transmission of heat through the wall or partition during the fire endurance test shall not be sufficient to raise the temperature on its unexposed surface more than 250°F (121°C) above its initial temperature.

Chapter 6 Tests of Nonbearing Walls and Partitions

6-1 Size of Specimen.

The area exposed to fire shall be not less than 100 ft^2 (9.3 m^2), with neither dimension less than 9 ft (2.7 m). The test specimen shall be restrained on all four edges.

6-2 Conditions of Acceptance.

The test shall be regarded as valid if the following conditions are met:

(a) The wall or partition shall have withstood the fire endurance test, without passage of flame or gases hot enough to ignite cotton waste, for a period equal to that required for the classification desired.

(b) The wall or partition shall have withstood the fire and hose stream tests, as specified in Section 4-2, without passage of flame, of gases hot enough to ignite cotton waste, or of the hose stream. The assembly shall be considered to have failed the hose stream test if an opening develops that allows a projection of water from the stream beyond the unexposed surface during the hose stream test.

(c) Transmission of heat through the wall or partition during the fire endurance test shall not be sufficient to raise the temperature on its unexposed surface more than 250°F (121°C) above its initial temperature.

Chapter 7 Tests of Columns

7-1 Size of Specimen.

The length of the column exposed to fire shall, where practicable, approximate the maximum clear length contemplated by the design and, for building columns, shall be not less than 9 ft (2.7 m). The contemplated details of connections, and their protection, if any, shall be applied according to the methods of acceptable field practice.

7-2 Loading.

7-2.1

Throughout the fire endurance test, the column shall be exposed to fire on all sides and shall be loaded in a manner calculated to develop as nearly as practicable, in theory, the working stresses contemplated by the design. Provision shall be made for transmitting the load to the exposed portion of the column without unduly increasing the effective column length.

7-2.2

If the submitter and the testing body jointly so decide, the column shall be permitted to be subjected to $1^3/_4$ times its designed working load before the fire endurance test is undertaken. The fact that such a test has been performed shall not be construed as having had a deleterious effect on the fire endurance test performance.

7-3 Conditions of Acceptance.

The test shall be regarded as valid if the column sustains the applied load during the fire endurance test for a period equal to that required for the classification desired.

Chapter 8 Alternative Test of Protection for Structural Steel Columns

8-1 Application.

This test procedure shall not require column loading at any time and shall be permitted to be used at the discretion of the testing laboratory to evaluate steel column protection that is not required by design to carry any of the column load.

8-2 Size and Character of Specimen.

8-2.1

The size of the steel column used as a specimen shall be a true representation of the design, materials, and workmanship required for the classification desired. The protection shall be applied in accordance with the methods of acceptable field practice. The length of the protected column shall be at least 8 ft (2.4 m). The column shall be vertical during application of the protection and during the fire exposure.

8-2.2

The applied protection shall be restrained against longitudinal temperature expansion greater than that of the steel column by rigid steel plates or reinforced concrete attached to the ends of the steel column before the protection is applied. The size of the plates or amount of concrete shall be adequate to provide direct bearing for the entire transverse area of the protection.

8-2.3

The ends of the specimen, including the means for restraint, shall be provided with sufficient thermal insulation to prevent appreciable direct heat transfer from the furnace.

8-3 Temperature Measurement.

The temperature of the steel in the column shall be measured by at least three thermocouples located at each of four levels. The upper and lower levels shall be 2 ft (0.6 m) from the ends of the steel column, and the two intermediate levels shall be spaced equally. The thermocouples at each level shall be placed to measure significant temperatures of the component elements of the steel section.

8-4 Exposure to Fire.

Throughout the fire endurance test, the specimen shall be exposed to fire on all sides for its full length.

8-5 Conditions of Acceptance.

The test shall be considered to be valid if the transmission of heat through the protection during the period of fire exposure required for the classification desired does not raise the average (arithmetical) temperature of the steel at any one of the four levels above 1000°F (530°C) or does not raise the temperature above 1200°F (649°C) at any one of the measured points.

Chapter 9 Tests of Floor and Roof Assemblies

9-1 Application.

9-1.1

This test procedure shall apply to floor and roof assemblies with or without attached, furred, or suspended ceilings and requires application of fire exposure to the underside of the specimen under test.

9-1.2*

Two fire endurance classifications shall be determined for assemblies restrained against thermal expansion:

(a) A restrained assembly classification based upon the conditions of acceptance specified in Sections 9-5(a), (b), (c), (d), and (e); and

(b) An unrestrained assembly classification based upon the conditions of acceptance specified in Sections 9-6(a) and (b) in addition to Section 9-6(c), (d), (e), or (f).

9-1.3

One fire endurance classification shall be determined from tests of assemblies not restrained against thermal expansion based on the conditions of acceptance specified in Sections 9-6(a) and (b).

9-1.4

Individual unrestrained classifications shall be permitted to be determined for beams tested in accordance with this test method using the conditions of acceptance specified in Section 11-3(a), (b), or (c).

9-2 Size and Characteristics of Specimen.

9-2.1

The area exposed to fire shall be not less than 180 ft^2 (16.7 m^2) with neither dimension less than 12 ft (3.6 m). Structural members, if a part of the construction under test, shall lie within the combustion chamber and shall have a side clearance of not less than 8 in. (203 mm) from its walls.

9-2.2

The specimen shall be installed in accordance with recommended fabrication procedures for the type of construction and shall be representative of the design for which classification is desired. Where a restrained classification is desired, specimens representing forms of construction in which restraint to thermal expansion occurs shall be reasonably restrained in the furnace.

9-3 Loading.

Throughout the fire endurance test, a superimposed load shall be applied to the specimen to simulate a maximum load condition. The maximum load condition shall be as nearly as practicable the maximum load allowed by the limiting condition of design under nationally recognized structural design criteria. A fire endurance test shall be permitted to be conducted by applying a restricted load condition to the specimen that shall be identified for a specific load condition other than the maximum permitted load condition.

9-4 Temperature Measurement.

9-4.1

For specimens using structural members (e.g., beams, open-web steel joists) spaced at more than 4 ft (1.2 m) on center, the temperature of the steel in these structural members shall be measured by thermocouples at three or more sections spaced along the length of the members, with one section preferably located at midspan.

Exception: In cases where the cover thickness is not uniform along the specimen length, at least one of the sections at which temperatures are measured shall include the point of minimum cover.

9-4.2

For specimens using structural members (e.g., beams, open-web steel joists) spaced at 4 ft (1.2 m) on center or less, the temperature of the steel in these structural members shall be measured by four thermocouples placed on each member. No more than four members shall be so instrumented. The thermocouples shall be placed at significant locations, such as at midspan, over joints in the ceiling, and over light fixtures.

9-4.3

For reinforced or prestressed concrete structural members, thermocouples shall be located on each of the tension-reinforcing elements unless there are more than eight such elements, in which case thermocouples shall be placed on eight elements selected to obtain representative temperatures of all the elements.

9-4.4

For steel structural members, there shall be four thermocouples located at each section. Where only four thermocouples are required on a member, the thermocouples shall be permitted to be distributed along the member at significant locations as specified in 9-4.2. Two shall be located on the bottom of the bottom flange or chord, one on the web at the center, and one on the top flange or chord. Examples of thermocouple distribution at each section are shown in Figure 9-4.4.

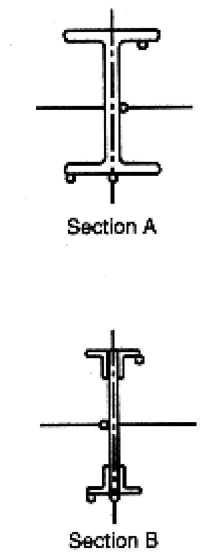


Figure 9-4.4 Examples of thermocouple distribution.

9-4.5

For steel floor or roof units, four thermocouples shall be located on each section (a section shall equal the width of one unit). One shall be located on the bottom plane of the unit at an edge joint, one on the bottom plane of the unit remote from the edge, one on a sidewall of the unit, and one on the top plane of the unit. The thermocouples shall be applied, where practicable, to the surface of the units that are remote from fire and shall be spaced across the width of the unit. Not more than four nor fewer than two sections shall be required to be so instrumented in each representative span. The groups of four thermocouples shall be placed in representative locations. Typical thermocouple locations for a unit section are shown in Figure 9-4.5.

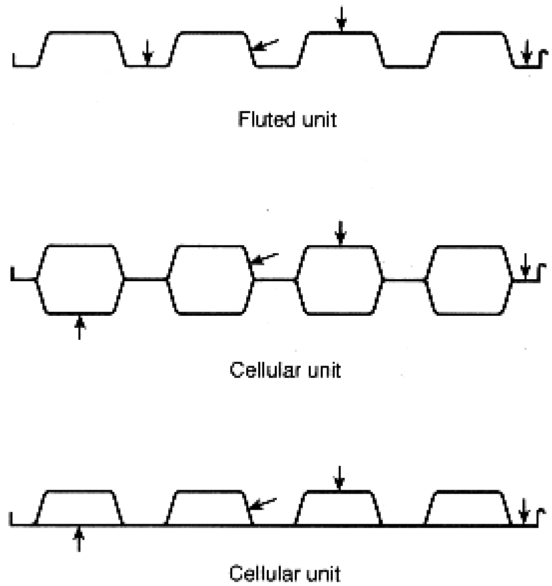


Figure 9-4.5 Typical location of thermocouples.

9-5 Conditions of Acceptance — Restrained Assembly.

In obtaining a restrained assembly classification, the following conditions shall be met:

(a) The specimen shall sustain the applied load during the classification period without developing unexposed surface conditions that ignite cotton waste.

(b) The transmission of heat through the specimen during the classification period shall not raise the average temperature on its unexposed surface more than 250°F (121°C) above its initial temperature.

(c) For specimens using steel structural members (e.g., beams, open-web steel joists) spaced more than 4 ft (1.2 m) on center, the beams shall achieve a fire endurance classification on the basis of the temperature criteria specified in Section 9-6(c), (d), (e), or (f) for assembly classifications up to and including 1 hour. For classifications greater than 1 hour, these temperature criteria shall apply for a period equal to one-half the period for the classification of the assembly or 1 hour, whichever is greater.

(d) For specimens using steel structural members (e.g., beam, open-web steel joists) spaced 4 ft (1.2 m) or less on center, the assembly shall achieve a fire endurance classification on the basis of the temperature criteria specified in 9-6(d) for assembly classifications up to and including 1 hour. For classifications greater than 1 hour, these temperature criteria shall apply for a period equal to one-half the period for the classification of the assembly or 1 hour, whichever is greater.

(e) For specimens using conventionally designed concrete beams spaced more than 4 ft (1.2 m) on center, the assembly shall achieve a fire endurance classification on the basis of the temperature criteria specified in 9-6(e) for assembly classifications up to and including 1 hour. For classifications greater than 1 hour, these temperature criteria shall apply for a period equal to one-half the period for the classification of the assembly or 1 hour, whichever is greater.

9-6 Conditions of Acceptance — Unrestrained Assembly.

In obtaining an unrestrained assembly classification, the following conditions shall be met:

(a) The specimen shall sustain the applied load during the classification period without developing unexposed surface conditions that ignite cotton waste.

(b) The transmission of heat through the specimen during the classification period shall not raise the average temperature on its unexposed surface more than 250°F (121°C) above its initial temperature.

(c) For specimens using steel structural members (e.g., beams, open-web steel joists) spaced more than 4 ft (1.2 m) on center, the temperature of the steel shall not exceed 1300°F (704°C) at any location during the classification period, nor shall the average temperature recorded by four thermocouples at any section exceed 1100°F (593°C) during the classification period.

(d) For specimens using steel structural members (e.g., beams, open-web steel joists) spaced 4 ft (1.2 m) or less on center, the average temperature recorded by all joist or beam thermocouples shall not exceed 1100°F (593°C) during the classification period.

(e) For specimens using conventionally designed concrete structural members (excluding cast-in-place concrete slabs having spans equal to or less than those tested), the average temperature of the tension steel at any section shall not exceed 800°F (426°C) for cold-drawn prestressing steel or 1100°F (593°C) for reinforcing steel during the classification period.

(f) For specimens using steel floor or roof units intended for use in spans greater than those tested, the average temperature recorded by all thermocouples located on any one span of the floor or roof unit shall not exceed 1100°F (593°C) during the classification period.

Chapter 10 Tests of Loaded Restrained Beams

10-1 Application.

An individual classification of a restrained beam shall be permitted to be determined by this test procedure and shall be based on the conditions of acceptance specified in Section 10-4. This fire endurance classification shall apply to the beam where used with a floor or roof construction that has a comparable or greater capacity for heat dissipation from the beam than the floor or roof with which it is tested. The fire endurance classification determined by this method shall not apply to beams smaller than those tested.

10-2 Size and Characteristics of Specimen.

The test specimen shall be installed in accordance with the recommended fabrication procedures for the type of construction and shall be representative of the design for which classification is to be determined. The length of beam exposed to the fire shall be not less than 12 ft (3.7 m), and the member shall be tested in its normal horizontal position. A section of a representative floor or roof construction not more than 7 ft (2.1 m) wide, symmetrically located with reference to the beam, shall be permitted to be included with the test specimen and exposed to the fire from below. The beam, including that part of the floor or roof element forming the complete beam as designed (such as composite steel or concrete construction), shall be restrained against longitudinal thermal expansion in a manner simulating the restraint in the construction represented. The perimeter of the floor or roof element of the specimen shall not be supported or restrained.

Exception: That part of the perimeter of the floor or roof element specimen that forms part of a beam as designed shall be required to be supported or restrained.

10-3 Loading.

Throughout the fire endurance test a superimposed load shall be applied to the specimen. This load, together with the weight of the specimen, shall be as nearly as practicable the maximum theoretical dead and live loads permitted by nationally recognized design standards.

10-4 Conditions of Acceptance.

The following conditions shall be met:

(a) The specimen shall sustain the applied load during the classification period.

(b) The specimen shall achieve a fire endurance classification on the basis of the temperature criteria specified in Section 9-6(c), (d), or (e) equal to one-half the period for the classification of the assembly or 1 hour, whichever is greater.

Chapter 11 Alternative Classification Procedure for Loaded Beams

11-1 Application.

Individual unrestrained classifications shall be permitted to be determined for beams tested as part of a floor or roof assembly as described in Sections 9-1 through 9-4 (except 9-1.3) or for restrained beams tested in accordance with the procedure described in Sections 10-1 through 10-3. These fire endurance classifications shall apply to beams where used with a floor or roof construction that has a comparable or greater capacity for heat dissipation from the beam than the floor or roof with which it is tested. The fire endurance classification determined by this method shall not apply to beams smaller than those tested.

11-2 Temperature Measurement.

11-2.1

The temperature of the steel in structural members shall be measured by thermocouples at three or more sections spaced along the length of the members, with one section preferably located at midspan.

Exception: In cases where cover thickness is not uniform along the specimen length, at least one of the sections at which temperatures are measured shall include the point of minimum cover.

11-2.2

For steel beams, four thermocouples shall be placed at each section; two shall be located on the bottom of the bottom flange, one on the web at the center, and one on the bottom of the top flange.

11-2.3

For reinforced or prestressed concrete structural members, thermocouples shall be located on each of the tension-reinforcing elements unless there are more than eight such elements, in which case thermocouples shall be placed on eight elements selected to obtain representative temperatures of all the elements.

11-3 Conditions of Acceptance.

In obtaining an unrestrained beam classification the following conditions shall be met:

(a) The specimen shall sustain the applied load during the classification period.

(b) For steel beams, the temperature of the steel shall not exceed 1300°F (704°C) at any location during the classification period nor shall the average temperature recorded by four thermocouples at any section exceed 1100°F (593°C) during this period.

(c) For conventionally designed concrete beams, the average temperature of the tension steel at any section shall not exceed 800°F (426°C) for cold-drawn prestressing steel or 1100°F (593°C) for reinforcing steel during the classification period.

Chapter 12 Alternative Test of Protection for Solid Structural Steel Beams and Girders

12-1 Application.

Where the loading required in Section 9-3 is not feasible, this alternative test procedure shall be permitted to be used to evaluate the protection of steel beams and girders without application of design load, provided that the protection is not required by design to function structurally in resisting applied loads. The conditions of acceptance of this alternative test do not apply to tests performed under design load as provided in tests for floors and roofs in Sections 9-2, 9-5, and 9-6.

12-2 Size and Character of Specimen.

12-2.1

The size of the steel beam or girder shall be a true representation of the design, materials, and workmanship required for the classification desired. The protection shall be applied in accordance with the methods of acceptable field practice, and the projection below the ceiling, if any, shall be representative of the conditions of intended use. The length of the beam or girder exposed to the fire shall be not less than 12 ft (3.7 m), and the member shall be tested in a horizontal position. A section of a representative floor construction not less than 5 ft (1.5 m) wide, symmetrically located with reference to the beam or girder and extending its full length, shall be included in the test assembly and exposed to fire from below. The rating of performance shall not apply to beams or girders smaller than those tested.

12-2.2

The applied protection shall be restrained against longitudinal expansion greater than that of the steel beam or girder by rigid steel plates or reinforced concrete attached to the ends of the specimen before the protection is applied. The ends of the specimen, including the means for restraint, shall be provided with sufficient thermal insulation to prevent appreciable direct heat transfer from the furnace to the unexposed ends of the specimen or from the ends of the specimen to the outside of the furnace.

12-3 Temperature Measurement.

The temperature of the steel in the beam or girder shall be measured with not less than four thermocouples located at each of four sections equally spaced along the length of the beam and symmetrically disposed and not nearer than 2 ft (0.6 m) from the inside face of the furnace. The thermocouples at each section shall be placed symmetrically so as to measure significant temperatures of the component elements of the steel section.

12-4 Conditions of Acceptance.

The test shall be accepted as valid if the transmission of heat through the protection during the period of fire exposure required for the classification desired does not raise the average (arithmetical) temperature of the steel at any one of the four sections above 1000°F (538°C) or does not raise the temperature above 1200°F (649°C) at any one of the measured points.

Chapter 13 Performance of Protective Membranes in Wall, Partition, Floor, or Roof Assemblies

13-1 Application.

Where determining the thermal protection afforded by membrane elements in wall, partition, floor, or roof assemblies, the nonstructural performance of protective membranes shall be obtained by following the procedure outlined in Sections 13-2 through 13-4. The performance of protective membranes is supplementary information only and shall not be used as a substitute for the fire endurance classification determined by Chapters 5 through 12.

13-2 Characteristics and Size of Sample.

13-2.1

The characteristics of the sample shall conform to 3-1.1.

13-2.2

The size of the sample shall conform to Section 5-1 for bearing walls and partitions, Section 6-1 for nonbearing walls and partitions, or 9-2.1 for floors or roofs.

13-3 Temperature Performance of Protective Membranes.

13-3.1

The temperature performance of protective membranes shall be measured with thermocouples, the measuring junctions of which shall be in intimate contact with the exposed surface of the elements being protected. The diameter of the wires used to form the thermo-junction shall not be greater than the thickness of sheet metal framing or panel members to which they are attached and in no case shall be greater than No. 18 AWG gauge [0.040 in. (1.02 mm)]. The lead shall be electrically insulated with heat-resistant and moisture-resistant coatings.

13-3.2

For each class of elements protected, temperature readings shall be taken at not less than five representative points. None of the thermocouples shall be located nearer to the edges of the test assembly than 12 in. (30.5 cm). An exception shall be permitted to be made. None of the thermocouples shall be located opposite, on top of, or adjacent to fasteners such as screws, nails, or staples where such locations are excluded for thermocouple placement on the unexposed surface of the test assembly in 2-3.2.

Exception: In those cases in which there exists an element or feature of the construction that is not otherwise represented in the test assembly, thermocouples shall be permitted to be located closer to the edges of the test assembly than 12 in. (30.5 cm).

13-3.3

Thermocouples shall be located to obtain representative information on the temperature of the interface between the exposed membrane and the substratum or element being protected.

13-3.4

Temperature readings shall be taken at intervals not exceeding 1 minute for the duration of the test.

13-4 Conditions of Performance.

Unless otherwise specified, the performance of protective membranes shall be considered to be the time at which the following conditions occur:

(a) The average temperature rise of any set of thermocouples for each class of element protected is more than 250°F (121°C) above the initial temperature; or

(b) The temperature rise of any one thermocouple of the set for each class of element protected is more than 325°F (163°C) above the initial temperature.

Chapter 14 Report of Results

14-1 Classification as Determined by Test.

14-1.1

Results shall be reported in accordance with the performance specifications in the tests prescribed in these methods. The time of resistance shall be expressed as the nearest integral minute.

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, continued flaming, and production of smoke.

14-1.2

Reports of tests involving wall, floor, beam, or ceiling constructions in which restraint is provided against expansion, contraction, or rotation of the construction shall describe the method used to provide this restraint.

14-1.3

Reports of tests in which other than maximum load conditions (*see Section 9-3*) are imposed shall define the conditions of loading used in the test fully and shall be designated in the title of the test report as a restricted load condition.

14-1.4*

Where the indicated resistance period is $^1/_2$ hour or more, as determined by the average or maximum temperature rise on the unexposed surface or within the test specimen, or by failure under load, an adjustment shall be made for variation of the furnace exposure from that prescribed, in those cases where it will affect the classification, by multiplying the indicated resistance period by two-thirds of the difference in the area between the curve of the average furnace temperature and the standard curve for the first three-fourths of the period and then dividing the product by the area between the standard curve and a baseline of 68°F (20°C) for the same portion of the indicated period. The latter area shall be increased by 54° Fahrenheit-hour or 30° Centigrade-hour (3240° Fahrenheit-minute or 1800° Centigrade-minute) to compensate for the thermal lag of the furnace thermocouples during the first part of the test. For fire exposure that occurs during the test that is higher than standard, the indicated resistance period shall be increased by the amount of the correction and shall similarly be decreased for fire exposure below standard.

14-1.5

Asymmetrical wall assemblies shall be permitted to be tested with either side exposed to the fire, and the report shall indicate the side so exposed. Both sides shall be permitted to be tested, and the report shall indicate the fire endurance classification applicable to each side.

14-2 Test of Floor and Roof Assemblies.

14-2.1

The fire endurance classification of a restrained assembly shall be reported as that developed by applying the conditions of acceptance specified in Sections 9-5(a), (b), (c), (d), and (e).

14-2.2

The fire endurance classification of an unrestrained assembly shall be reported as that determined by applying the conditions of acceptance to a specimen tested in accordance with this test procedure as specified in Sections 9-6(a) and (b) and, where applicable, Section 9-6(c), (d), (e), or (f).

14-3 Performance of Protective Membranes.

14-3.1

The protective membrane performance for each class of element being protected shall be reported to the nearest integral minute.

14-3.2

The test report shall identify each class of element being protected and shall show the location of each thermocouple.

14-3.3

The test report shall show the time—temperature data recorded for each thermocouple and the average temperature for the set of thermocouples on each element being protected.

14-3.4

The test report shall record any visual observations that are pertinent to the performance of the protective membrane.

14-4 Tests of Load-Bearing Assemblies.

14-4.1

Reports of tests in which loading is used shall describe how the applied load was calculated, the design standard used, the governing stress in each structural member (e.g., bending, shear), the details of the system used to apply the load, and the time of load application relative to the start and finish of the test.

Chapter 15 Referenced Publications

15-1

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 each reference is the current edition as of the date of the NFPA issuance of this document.

15-1.1 UL Publication.

Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

ANSI/UL 385, *Standard for Safety Play Pipes for Water Supply Testing in Fire Protection Service*, 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-1-1

The performance of walls, columns, floors, and other building members under fire exposure conditions is an issue of major importance in ensuring construction that is safe and not a menace to neighboring structures or the public. This is recognized by the codes of many authorities, municipal and otherwise. It is important to create a balance among the many units in a single building, and in buildings of like character and use in a community, and also to promote uniformity in the requirements of the various authorities throughout the country. Therefore, it is necessary that the fire-resistive properties of materials and assemblies be measured and specified in accordance with a common standard expressed in terms that are applicable to a wide variety of materials, situations, and conditions of exposure.

These test methods are such a standard. They prescribe a standard exposing fire of controlled extent and severity. Performance is defined as the period of resistance to standard exposure elapsing before the first critical point in behavior is observed. Results are reported in units in which field exposures can be judged and expressed.

The methods are cited as the “Standard Fire Tests,” and the performance or exposure is expressed as “2-hr,” “6-hr,” “$^1/_2$-hr,” etc.

Where a factor of safety exceeding that inherent in the test conditions is desired, a proportional increase should be made in the specified time-classification period.

A-1-1.2

A method of fire hazard classification based on rate of flame spread is covered in NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*.

A-2-2

The following provides guidance on the desired characteristics of instrumentation for recording the flow of fuel to the furnace burners. Fuel flow data is useful for a furnace heat balance analysis, for measuring the effect of furnace or control changes, and for comparing the performance of assemblies of different properties in the fire endurance test.

The integrated (cumulative) flow of gas (or other fuel) to the furnace burners should be recorded at 10 minutes, 20 minutes, 30 minutes, and every 30 minutes thereafter or more frequently. The total gas consumed during the test period also should be determined. A recording flow meter has advantages over periodic readings on an instantaneous or totalizing flow meter. A measuring and recording system should be selected to provide flow rate readings accurate to within ± 5 percent.

The type of fuel, its higher (gross) heating value, and the fuel flow [corrected to standard conditions of 60°F (16°C) and 30.0 in Hg] as a function of time should be reported.

A-2-2.1

A typical thermocouple assembly meeting specified time constant requirements can be fabricated by fusion-welding the twisted ends of No. 18 AWG Chromel-Alumel wires, mounting the leads in porcelain insulators, and inserting the assembly so the thermocouple bead is $^1/_2$ in. (13 mm) from the sealed end of a standard weight nominal $^1/_2$-in. (13-mm) iron, steel, or Inconel pipe. The time constant for this and for several other thermocouple assemblies was measured in 1976. The time constant is also calculated from knowledge of the thermocouple assembly's physical and thermal properties.

A-2-3.1

Under certain conditions, it is unsafe or impracticable to use thermometers.

For the purpose of testing roof assemblies, the unexposed surface is defined as the surface exposed to ambient air.

A-3-2.1.1 A recommended method for determining the relative humidity within a hardened concrete specimen with electric sensing elements is described in Appendix I of "A Method for Determining the Moisture Condition of Hardened Concrete in Terms of Relative Humidity." A similar procedure with electric sensing elements can be used to determine the relative humidity within fire test specimens made with other materials.

With wood constructions, the moisture meter based on the electrical resistance method can be used, where appropriate, as an alternative to the relative humidity method to indicate when wood has attained the proper moisture control. Electrical methods are described on pages 320 and 321 of the 1955 edition of the "Wood Handbook of the Forest Products Laboratory," U.S. Department of Agriculture. The relationships between relative humidity and moisture content are illustrated by the graphs in Figure 23 on p. 327 of this publication. They indicate that wood has a moisture content of 13 percent at a relative humidity of 70 percent for a temperature of 70°F to 80°F (21°C to 27°C).

A-3-2.1.3 If the moisture condition of the fire test assembly is likely to change drastically from the sample taken 72 hours prior to this test, the sample should be taken not later than 24 hours prior to the test.

A-5-2

The choice depends on the intended use and whether the load on the exposed side will be transferred to the unexposed side after it has failed. If, in the intended use, the load from the structure above is supported by both walls as a unit and would be or is transferred to the unexposed side in the event of collapse of the exposed side, both walls should be loaded for the test by a single unit. If, in the intended use, the load from the structure above each wall is supported by each wall separately, the walls should be loaded separately for the test by separate load sources. If the intended use of the construction system being tested involves situations of both loading conditions described above, the walls should be loaded separately for the test by separate load sources. In tests conducted with the walls loaded separately, the condition of acceptance requiring the walls to maintain the applied load is based on the time at which the first wall fails to sustain the load.

A-9-1.2

Appendix E should be consulted for guidance in determining the conditions of thermal restraint that apply to floor and roof constructions and individual beams in actual building construction.

A-14-1.4

The correction can be expressed by the following formula:

$$C = \frac{2I(A - As)}{3(As + L)}$$

where:

C = correction in the same units as *I*

I = indicated fire resistance period

A = area under the curve of the indicated average furnace temperature for the first three-fourths of the indicated period

As = area under the standard furnace curve for the same part of the indicated period

L = lag correction in the same units as *A* and *As* [54°F-hr or 30°C-hr (3240°F-min or 1800°C-min)].

Appendix B Standard Temperature Time Curve for Control of Fire Tests

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

Time	Temperature	Area Above 68°F Base		Temperature	Area Above 20°C Base	
(hr:min)	(°F)	(°F-min	(°F-hr)	(°C)	(°C-min)	(°C-hr)

0:00	68	00	0	20	00	0
0:05	1000	2330	39	538	1290	22
0:10	1300	7740	129	704	4300	72
0:15	1399	14,150	236	760	7860	131
0:20	1462	20,970	350	795	11 650	194
0:25	1510	28,050	468	821	15 590	260
0:30	1550	35,360	589	843	19 650	328
0:35	1584	42,860	714	862	23 810	397
0:40	1613	50,510	842	878	28 060	468
0:45	1638	58,300	971	892	32 390	540
0:50	1661	66,200	1103	905	36 780	613
0:55	1681	74,220	1287	916	41 230	687
1:00	1700	82,330	1372	927	45 740	762
1:05	1718	90,540	1509	937	50 300	838
1:10	1735	98,830	1647	946	54 910	915
1:15	1750	107,200	1787	955	59 560	993
1:20	1765	115,650	1928	963	64 250	1071
1:25	1779	124,180	2070	971	68 990	1150
1:30	1792	132,760	2213	978	73 760	1229
1:35	1804	141,420	2357	985	78 560	1309
1:40	1815	150,120	2502	991	83 400	1390
1:45	1826	158,890	2648	996	88 280	1471
1:50	1835	167,700	2795	1001	93 170	1553
1:55	1843	176,550	2942	1006	98 080	1635
2:00	1850	185,440	3091	1010	103 020	1717
2:10	1862	203,330	3389	1017	112 960	1882
2:20	1875	221,330	3689	1024	122 960	2049
2:30	1888	239,470	3991	1031	133 040	2217
2:40	1900	257,720	4295	1038	143 180	2386
2:50	1912	276,110	4602	1045	153 390	2556
3:00	1925	294,610	4910	1052	163 670	2728
3:10	1938	313,250	5221	1059	174 030	2900

3:20	1950	332,000	5533	1066	184 450	3074
3:30	1962	350,890	5848	1072	194 940	3249
3:40	1975	369,890	6165	1079	205 500	3425
3:50	1988	389,030	6484	1086	216 130	3602
4:00	2000	408,280	6805	1093	226 820	3780
4:10	2012	427,670	7128	1100	237 590	3960
4:20	2025	447,180	7453	1107	248 430	4140
4:30	2038	466,810	7780	1114	259 340	4322
4:40	2050	486,560	8110	1121	270 310	4505
4:50	2062	506,450	8441	1128	281 360	4689
5:00	2075	526,450	8774	1135	282 470	4874
5:10	2088	546,580	9110	1142	303 660	5061
5:20	2100	566,840	9447	1149	314 910	5248
5:30	2112	587,220	9787	1156	326 240	5437
5:40	2125	607,730	10,129	1163	337 630	5627
5:50	2138	628,360	10,473	1170	349 090	5818
6:00	2150	649,120	10,819	1177	360 620	6010
6:10	2162	670,000	11,167	1184	372 230	6204
6:20	2175	691,010	11,517	1191	383 900	6398
6:30	2188	712,140	11,869	1198	395 640	6594
6:40	2200	733,400	12,223	1204	407 450	6791
6:50	2212	754,780	12,580	1211	419 330	6989
7:00	2225	776,290	12,938	1218	431 270	7188
7:10	2238	797,920	13,299	1225	443 290	7388
7:20	2250	819,680	13,661	1232	455 380	7590
7:30	2262	841,560	14,026	1239	467 540	7792
7:40	2275	863,570	14,393	1246	479 760	7996
7:50	2288	885,700	14,762	1253	492 060	8201
8:00	2300	907,960	15,133	1260	504 420	8407

Appendix C Recommendations for Thermocouple Pads

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

C-1 Refractory Fiber Pads.

Comparative fire tests have demonstrated that a refractory fiber material designated Ceraform 126®, placed with the softer surfaces in contact with the thermocouple, can be substituted for the previously specified asbestos pad where the distortion of the unexposed face of the sample is minimal. The pads are relatively rigid and should not be used on surfaces subject to sharp distortions or discontinuities during the test. The properties of Ceraform 126® material are as follows:

(a) Length and width, 6 in. ± $^1/_8$ in. (152 mm ± 3 mm).

(b) Thickness, 0.375 in. ± 0.063 in. (9.5 mm ± 1.6 mm). The thickness measurement is made under the light load of a $^1/_2$-in. (13-mm) diameter pad of a dial micrometer gauge.

(c) Dry weight, 0.147 lb ± 0.053 lb (67 g ± 24 g).

(d) Thermal conductivity [at 150°F (66°C)], 0.37 Btu in./hr ft^2-F ± 0.03 Btu in./hr ft^2-F (0.053 W/m-k ± 0.004 W/m-K).

(e) Hardness indentation on soft face should be 0.075 in. ± 0.025 in. (1.9 mm ± 0.6 mm). Indentation is determined in accordance with ASTM C569, *Test for Indentation Hardness of Performed Thermal Insulations*. Modified Brinell values of hardness are obtained from the following equation:

$$\text{Hardness} = \frac{2.24}{y}$$

(f) The pads are shaped by wetting, forming, and then drying to constant weight to provide complete contact on sharply contoured surfaces.

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[1]Ceraform 126® is a registered trade name of Manville Specialty Products Group, P.O. Box 5108, Denver, CO 80217.

[2]Supporting data are available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103. Request RR:E05-1004.

Appendix D Sample Report Form

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

NFPA 251

(Title Page, Preferably Cover)

Laboratory ____

Project number ____

NFPA 251 (edition)

Standard Fire Endurance Test

Fire endurance time ____

Construction ____

Date tested ____

Sponsor ____

Material ____

Material ____

Maximum load condition, or restricted load conditions (as the conditions of the test dictate) ____

____

(Identify if test is part of a research program)

(Add table of contents)

D-1 Description of Laboratory Test Facility.

Describe items such as the furnace, restraining frame, and details of end conditions, including wedges, and bearing.

(a) If construction is to be tested under load, indicate how the load is applied and controlled (provide loading diagram). Indicate whether the load is a maximum load condition or a restricted load condition, and, for either condition, report the specific loads and the basis for limitation, such as bending stress, and shear. A restricted load condition is reported as a percentage of the maximum load condition.

(b) If construction is to be tested as nonload-bearing, indicate whether the frame is rigid or moves during the test, or whether the test is for temperature rise only.

D-2 Description of All Materials.

Describe type, size, class, strength, densities, trade name, and any additional data necessary to define materials. The testing laboratory should indicate whether materials meet NFPA standards by markings, by statement of sponsor, or by physical or chemical test by the testing laboratory.

D-3 Description of Test Assembly.

(a) Provide size of test specimen.

(b) Provide details of structural design, including safety factors of all structural members in test assembly.

(c) Include plan, elevation, principal cross section, and other sections as needed for clarity.

(d) Provide details of attachment of test panel in frame.

(e) Provide location of thermocouples, deflection points, and other items for test.

(f) Describe general ambient conditions for all of the following times:

1. Time of construction

2. During curing (time from construction to test)

3. Time of test.

D-4 Description of Test.

(a) Report temperature at start of test and every 1 minute thereafter. If charts are included in report, clearly indicate time and temperature for all of the following:

1. In furnace space

2. On unexposed surface

3. On protected framing members as stipulated in standard.

NOTE: It is recommended that temperature observations that are not required by the standard, but that are useful, be reported in the appendix to the report. These include temperatures on the face of framing members in back of protection and others that are required by various building codes.

(b) Report furnace pressure at start of test and every 1 minute thereafter.

(c) Report deflections every 5 minutes for first 15 minutes of test and during the last hour. In between, report every 10 minutes.

(d) Report appearance of exposed face as follows:

1. Every 15 minutes

2. At any noticeable development, provide details and time (e.g., cracks, buckling, flaming, smoke, loss of material)

3. At end of test, include items such as amount of dropout, condition of fasteners, and sag.

(e) Report appearance of unexposed face as follows:

1. Every 15 minutes

2. At any noticeable development, including cracking, smoking, and buckling, provide details and time

3. At end of test.

(f) Report time of failure caused by the following:

1. Temperature rise

2. Failure to carry load

3. Passage of flame, heat, and smoke.

(g) If a hose stream test is required, repeat appropriate parts of Sections D-1 and D-3. If failure occurs in hose stream test, provide description.

D-5 Official Comments.

(a) Include a statement to the effect that the construction is a true representation of field construction. If the construction does not represent typical field construction, note the deviations.

(b) If construction is asymmetrical (different details on each face), be sure to specify face exposed to fire with comments on fire resistance from opposite side.

(c) Comment on fire test.

D-6 Summarize Results.

A summary of results should include the following:

(a) Endurance time

(b) Nature of failure

(c) Hose stream test results.

D-7 List Official Observers.

Provide signatures of responsible persons.

D-8 Appendix.

Include all data not specifically required by test standard but useful to better understanding of test results. Special observations for building code approvals should be included in appendix.

D-9 Photographs.

Photographs should be used to show items not covered in report or to clarify and should include the following:

(a) Assembly in construction

(b) Exposed face prior to fire test

(c) Unexposed face at start of endurance test; include recording equipment where possible

(d) Unexposed face at end of fire endurance test

(e) Exposed face at end of fire endurance test

(f) Unexposed face at end of fire exposure before hose test

(g) Exposed face at end of fire exposure before hose test

(h) Exposed face after hose stream test

(i) Unexposed face after hose stream test.

D-10 Other Pertinent Information.

It is essential to include the following:

(a) Detailed drawing of test assembly

(b) Photographs [*see Sections D-9(a), (d), (h), and (i)*] for every test report.

Appendix E Guide for Determining Conditions of Restraint for Floor and Roof Assemblies and for Individual Beams

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

E-1 Introduction.

The revisions adopted in 1970 introduced, for the first time in the history of the standard, the concept of fire endurance classifications based on two conditions of support: restrained and unrestrained. As a result, most specimens are fire tested in a manner that seeks to derive these two classifications.

E-1.1

A restrained condition in fire tests, as used in this method, is one in which expansion at the supports of a load-carrying element resulting from the effects of fire is resisted by forces external to the element. An unrestrained condition is one in which the load-carrying element is free to expand and rotate at its supports.

E-1.2

It is recognized that there can be some difficulty in determining the condition of restraint that is anticipated at elevated temperatures in actual structures. Until a more satisfactory method is developed, this guide recommends that all construction should be classified temporarily as either restrained or unrestrained. This classification enables the architect, engineer, or building official to correlate the fire endurance classification, based on conditions of restraint, with the construction type under consideration.

E-1.3

For the purpose of this guide, restraint in buildings is defined as follows: Floor and roof assemblies and individual beams in buildings are considered restrained where the surrounding or supporting structure is capable of resisting substantial thermal expansion throughout the range of anticipated elevated temperatures. Construction not complying with this definition is assumed to be free to rotate and expand and therefore is considered as unrestrained.

E-1.4

This definition of restraint in buildings necessitates the exercise of engineering judgment to determine what constitutes restraint to substantial thermal expansion. Restraint can be provided by the lateral stiffness of supports for floor and roof assemblies and intermediate beams forming part of the assembly. In order to develop restraint, connections must adequately transfer thermal thrusts to such supports. The rigidity of adjoining panels or structures should be considered in assessing the capability of a structure to resist thermal expansion. Continuity, such as that occurring in beams acting continuously over more than two supports, induces rotational restraint that usually adds to the fire resistance of structural members.

E-1.5

Table E-1.5 specifies only the common types of constructions. These classifications, as well as the philosophy expressed in A-1-1, are helpful in determining the less common types of construction.

Table E-1.5 Construction Classifications, Restrained and Unrestrained

I. Wall Bearing	
Single span and simply supported end spans of multiple bays:[1]	
(1) Open-web steel joists or steel beams, supporting concrete slab, precast units, or metal decking	unrestrained
(2) Concrete slabs, precast units, or metal decking	unrestrained
Interior spans of multiple bays:	
(1) Open-web steel joists, steel beams or metal decking, supporting continuous concrete slab	restrained
(2) Open-web steel joists or steel beams, supporting precast units or metal decking	unrestrained
(3) Cast-in-place concrete slab systems	restrained
(4) Precast concrete where the potential thermal expansion is resisted by adjacent construction[2]	restrained
II. Steel Framing.	
(1) Steel beams welded, riveted, or bolted to the framing members	restrained
(2) All types of cast-in-place floor and roof systems (such as beams-and-slabs, flat slabs, pan joists, and waffleslabs) in which the floor or roof system is secured to the framing members	restrained
(3) All types of prefabricated floor or roof systems in which the structural members are secured to the framing members and the potential thermal expansion of the floor or roof system is resisted by the framing system or the adjoining floor or roof construction[2]	restrained
III. Concrete Framing.	
(1) Beams securely fastened to the	

framing members	restrained
(2) All types of cast-in-place floor or roof systems (such as beam-and-slabs, flat slabs, pan joists, and waffle slabs) where the floor system is cast with the framing members	restrained
(3) Interior and exterior spans of precast systems with cast-in-place joints resulting in restraint equivalent to that which exists in condition III(1)	restrained
(4) All types of prefabricated floor or roof systems in which the structural members are secured to such systems and the potential thermal expansion of the floor or roof system is resisted by the framing system or the adjoining floor or roof construction[2]	restrained
IV. Wood Construction.	
All types.	unrestrained

[1]Floor and roof systems can be considered restrained where they are tied to walls with or without tie beams, the walls being designed and detailed to resist thermal thrust from the floor or roof system.

[2]Resistance to potential thermal expansion is considered to be achieved where:
(a) Continuous structural concrete topping is used.
(b) The space between the ends of precast units or between the ends of the units and the vertical face of supports is filled with concrete or mortar.
(c) The space between the ends of precast units and the vertical faces of supports, or between the ends of solid or hollow core slab units does not exceed 0.25 percent of the length for normal weight concrete members or 0.1 percent of the length for structural lightweight concrete members.

E-1.6

The foregoing methods of establishing the presence or absence of restraint according to type and detail of construction are considered to be temporary but necessary for the determination of dual fire endurance classifications. It is anticipated that methods for realistically predetermining the degree of restraint applicable to a particular fire endurance classification will be developed soon after this predetermination.

Appendix F Method of Correcting Fire Endurance for Concrete Slabs Determined by Unexposed Surface Temperature Rise for Nonstandard Moisture Content

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

F-1 Scope.

(a) The standard fire endurance is the time determined by the unexposed surface temperature rise of a test specimen at a standard moisture level.

(b) This appendix provides a procedure for correction of the fire endurance of unprotected vertical or horizontal slabs (solid or hollow), made from essentially inorganic building materials and conditioned on both sides, where moisture content at the time of test is other than at a standard moisture level.

(c) Among the common inorganic building materials, only the hydrated Portland cement products can hold (after due conditioning in accordance with Section 3-2) sufficient amounts of moisture to affect the result of the fire test significantly. Consequently, correcting the experimental fire endurance of constructions containing less than 5 volume percent of Portland cement paste is not necessary.

F-2 Symbols.

The symbols used in this appendix are defined as follows:

A = factor characterizing the drying conditions (*see Table F-2*)

b = factor characterizing the permeability of the specimen (*see Table F-3*)

FE = fire endurance of specimen, h

RH = relative humidity

m = moisture content, volume fraction ft^3/ft^3 or cm^3/cm^3

m_a = average moisture content of test specimen

m_c = average moisture content of cement paste

m_e = nominal equilibrium moisture content of cement paste for a given RH (*see Table F-1*)

m_{es} = equilibrium moisture content of cement paste at the standard RH level (*see Table F-1*)

m_s = average moisture content of a standard conditioned concrete specimen of same concrete and cement paste volume as the test specimen

v = volume fraction of cement paste, ft^3/ft^3 or cm^3/cm^3.

F-3 Calculation of Moisture Content.

(a) The average moisture content, m_a, is the volume fraction of moisture [ft^3/ft^3 (cm^3/cm^3)] in the material relative to its dry condition, where dry condition is defined as that resulting when the material is heated in an oven at 221°F ± 1°F (105°C ± 0.5°C) until no further weight loss occurs.

(b) The average moisture content of the cement paste can be estimated from the known value of *RH* at middepth (assuming the material has never been subject to rewetting) by calculating first the moisture content in the cement paste as follows:

$$m_c = A \bullet m_e$$

(c) The average moisture content of the test specimen then is calculated as follows:

$$m_a = v \cdot m_a$$

(d) The average moisture content of a standard conditioned specimen is calculated as follows:

$$m_s = v \cdot m_{es}$$

where m_{es} is the value ofm_e in Table F-1 pertaining to the standard *RH* level.

F-4 Correction Procedure.

The correction procedure begins with the selection of an empirical factor to reflect the permeability of the material as suggested in Table F-3. The known values of m_a and m_s are used to calculate the products bm_a and bm_s. On the nomograph *(see Figure F-1)* lines are drawn from point *R* to values of bm_a and bm_s on the right-hand scale. From the point representing the actual fire endurance time *(FE)* on the left-hand scale, a line is drawn parallel to R-bm_a to intersect the curve. From this point on the curve, a line is drawn parallel to R-bm_s and the corrected fire endurance is determined from the FE scale.

F-5 Example.

A wall made from normal weight concrete having 23.2 volume percent of paste is conditioned at 200°F (93°C) and 5 percent *RH* until the *RH* at its middepth is reduced to 70 percent. It has a 2.90-hour fire endurance. The adjusted fire endurance is calculated as follows:

1. Calculate m_a as follows:

For 70 percent *RH*:

$m_e = 0.225$ (*see Table F-1*)

For 200°F (93°C) and 5 percent *RH* conditioning, for normal weight concrete:

$A = 0.45$ (*see Table F-2*)

$m_c = 0.45 \times 0.225 = 0.101$ [*see F-3(b)*]

For $v = 0.232$:

$m_a = 0.232 \times 0.101 = 0.0234$ [*see F-3(c)*]

that is, the concrete contains 2.34 volume percent moisture at time of test.

2. Calculate m_s as follows:

Example: If the standard moisture level is assumed to correspond to a middepth *RH* of 75 percent, $m_e = 0.24$

$m_s = 0.232 \times 0.24 = 0.0557$ [*see F-3(d)*]

that is, the standard moisture level is 5.57 volume percent.

3. Calculate b_m as follows*:*

$$b = 5.5 \text{ (\textit{see Table F-3})}$$
$$bm_a = 5.5 \times 0.0234 = 0.129$$
$$bm_s = 5.5 \times 0.0557 = 0.306$$

4. Draw lines on the nomogram from point *R* to bm_a and bm_s *(see Figure F-1*).
5. Draw a line from the *FE* ordinate, 2.90, parallel to line R-bm_a to intersect the curve.
6. Draw a line parallel to R-bm_s from a point on the curve to intersect the *FE* ordinate scale.

The value, *FE* = 3.19, is the adjusted fire endurance; that is, the fire endurance if the specimen had been tested at the standard moisture level, which is assumed in this example to correspond to 75 percent *RH* at middepth.

Table F-1 Equilibrium Moisture Content (Desorption) of Cement Paste at Given Relative Humidity

RH **at Middepth (%)**	m_e
90	0.30
85	0.274
80	0.255
75	0.24
70	0.225
65	0.21
60	0.195
55	0.185
50	0.175
45	0.16
40	0.15

Table F-2 Factor Characterizing Drying Conditions

		Factor A for Portland Cement	
Conditioning Environment	**Middepth *RH* of Test Specimen(%)**	**Normal Weight Concrete**	**Lightweight Concrete**
60°F to 80°F (15.6°C to 26.7°C) atmospheric conditions	any	1.0	1.0
120°F to 160°F (48.9°C to	70 to 75	0.7	0.7

71.1°C) 20 to 35 percent RH			
190°F to 200°F (87.8°C to 93.3°C) 0 to 5 percent RH	70 to 75	0.45	0
120°F to 200°F (48.9°C to 93.3°C) 5 to 35 percent RH	less than 70	0	0

Table F-3 Factor Characterizing Permeability of Test Specimen

Material	*b*
Normal weight and gun-applied concrete [dry unit weight greater than 135 lb/ft^3 (2162 kgm/m^3)]	5.5
Lightweight concrete [dry unit weight 85 lb/ft^3 to 115 lb/ft^3 (1361 kgm/m^3 to 1841 kgm/m^3)]	8.0
Lightweight insulating concrete [dry unit weight less than 50 lb/ft^3 (801 kg/m^2)]	10.0

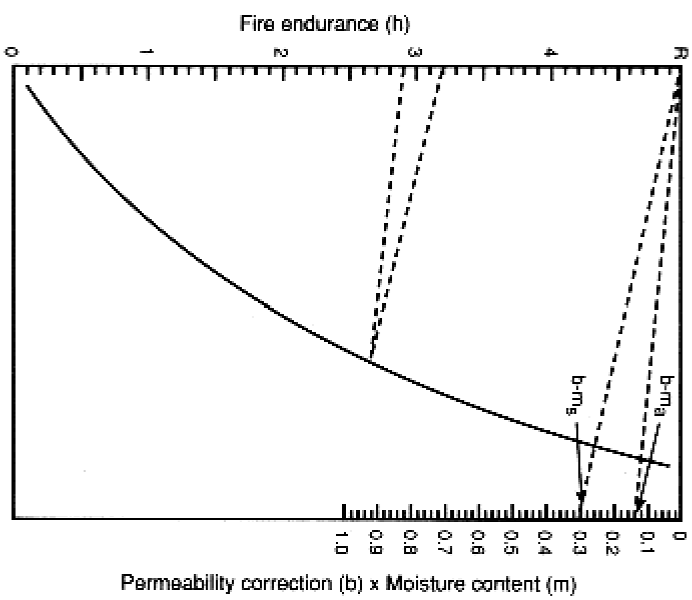

Figure F-1 Nomograph for correcting fire endurance for nonstandard moisture content.

Appendix G Commentary

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

G-1 Introduction.

G-1.1

This commentary has been prepared to provide the user of this standard with background information on the development of the standard and its application in the fire protection of buildings. It also provides guidance in the planning and performance of fire tests and in the reporting of results. No attempt has been made to incorporate all the available information on fire testing in this commentary. The serious student of fire testing is strongly urged to consult the referenced documents for a better appreciation of the history of fire-resistant design and the intricate problems associated with testing and with interpretation of test results.[1, 2]

G-1.2

Floors and walls designed as fire separations have been recognized for many years as efficient tools in restricting fires to the area of origin or limiting their spread.[3, 4, 5, 6, 7, 8, 9, 10, 11] Prior to 1900, relative fire safety was achieved by mandating use of specific materials. By the year 1900, the appearance of a multitude of new materials and innovative designs and constructions accelerated the demand for performance standards. The British Fire Prevention Committee, established in 1894, was the first to produce tables that provided fire-resistive floors, ceilings, doors, and partitions.[5] Test furnaces in the United States were constructed shortly after 1900 at the Underwriters Laboratories Inc., Columbia University, and the National Bureau of Standards (NBS).[1, 12] These early furnaces eventually led to the development of ASTM E119, *Standard Test Methods for Fire Tests of Building Construction and Materials*, and its counterpart, NFPA 251.

G-2 Historical Aspects.

ASTM E119, *Standard Test Methods for Fire Tests of Building Construction and Materials*, was first published as ASTM C19 in 1918. A number of refinements have been made in the standard since that time. However, several provisions, including the temperature—time curve, the major apparatus, and the acceptance criteria remain essentially unchanged. The roots of fire testing as defined today can be traced back to about 1800. A comprehensive review of early fire testing has been published.[1]

G-3 Fire Load Concept.

G-3.1

Specifications for fire resistance in regulatory documents continue to be based largely on the fire load concept developed by NBS in the 1920s and reported in the 1928 NFPA *Quarterly* by S. H. Ingberg. The concept incorporates the premise that the duration of a fire is proportional to the fire loading (i.e., the mass of combustible materials per unit floor area). The relationship between the mass of combustible materials and fire duration was established on the basis of burnout tests in structures incorporating materials having calorific or potential heat values equivalent to wood and paper, [i.e., 7000 Btu/lb to 8000 Btu/lb (16.3 MJ/kg to 18.6 MJ/kg)]. The fire loads of noncellulosic materials, such as oils, waxes, and flammable liquids, were interpreted on the basis of their equivalent calorific content.[5, 13, 14, 15] In the simplest terms, the above premise states that 10 lb (50 kg) of combustible materials per ft^2 (m^2) of floor area produce a fire of 1-hour duration.

G-3.2

Increasing sophistication in the understanding of materials and the fire process is the result of numerous research activities.[9, 11, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27] It is now generally conceded that fire severity as well as the temperature—time relationship of a fire depends on several factors, including:

(a) Amount and type of the fire load.

(b) Distribution of the fire load.

(c) Specific surface characteristics of the fire load.[5, 27]

(d) Ventilation, as determined by the size and shape of openings.[17, 18, 19, 21, 27, 28, 29]

(e) Geometry (the size and shape) of the fire compartment.

(f) Thermal characteristics of the enclosure boundaries.

(g) Relative humidity of the atmosphere.

For the purposes of this appendix, fire severity is defined in terms of temperature (one measure of an effect of fire intensity) and fire duration. It is expressed in terms of minutes or hours of fire exposure and, in NFPA 251, is assumed to be equivalent to that defined by the standard temperature—time (*T*-*t*) curve, (i.e., the area under the *T*-*t* curve).[27]

G-4 Scope and Significance.

G-4.1

This standard is intended to evaluate, in terms of endurance time, the ability of an assembly to contain a fire or to retain its structural integrity, or both, during the test conditions imposed by the standard. It also contains standard conditions for measuring heat transfer through membrane elements protecting combustible framing or surfaces.

G-4.2

The end-point criteria by which the test result is assessed are related to the following:

(a) Transmission of heat through the test assembly;

(b) Ability of the test assembly to withstand the transmission of flames or gases hot enough to ignite combustible material;

(c) Ability of the assembly to carry the load and withstand restraining forces during the fire test period;

(d) Temperature of the steel under some conditions.

G-4.3

It is the intent that classifications should reflect performance during the period of exposure and performance should not be construed as having determined suitability for use after the exposure.

G-4.4

This standard, although specific regarding the assembly to be tested, enables the testing laboratory to determine whether the specimen is a true representation of the assembly intended for evaluation. This is necessary because of the wide variation in assemblies. For instance, wall test specimens generally do not contain electric switches and outlets, which in some designs can affect test results. Floor test specimens might or might not contain electrical raceways and outlets or pull boxes for power and communication wiring. Cover plates over trench headers also are present in some designs. The testing laboratory is in the best position to judge the effects of such components.

G-5 Test Furnaces.

This standard does not provide specific construction details for the furnace. Users are urged to consult reference documents for a more comprehensive review of furnace design and performance.[25]

G-6 Temperature—Time Curve.

G-6.1

A specific temperature—time relationship for the test fire is defined in the standard and in Appendix B. The actual recorded temperatures in the furnace are required to be within specified percentages of those of the standard curve. Accuracy in measuring temperature generally is easier to achieve after 1 hour due to stabilizing of the furnace and the slope of the *T*-*t* curve. The number and type of temperature-measuring devices are outlined in the standard. Specific standard practices for location and use of these temperature-measuring devices also are outlined in the standard. However, no uniformity of the temperatures within the fire chamber is specified.

G-6.2

The standard *T*-*t* curve used in this standard represents a severe building fire.[5] The curve was adopted in 1918 as a result of several conferences by eleven technical organizations, including testing laboratories, insurance underwriters, fire protection associations, and technical societies.[1, 16, 30] The *T*-*t* relationship of these test methods represents only one fire situation. Data is available to evaluate the performance of assemblies under fire exposure conditions that are more representative of particular fire situations (i.e., using different *T*-*t* relationships to simulate specific fire conditions).[9, 11, 16, 19, 22, 23, 27, 29, 31, 32]

G-6.3

Furnace pressure is not specified and is generally slightly negative. The pressure can have an effect on the test results, and the test conditions always should be controlled carefully.

G-7 Test Specimen.

G-7.1

The test specimen is required to represent as closely as possible the actual construction in the field subject to the limits imposed by the test facilities.

G-7.2

All specimens are required to be conditioned so as to attain a moisture content comparable to that in the field prior to testing. For uniformity, the standard moisture content is defined as that in equilibrium with an atmosphere of 50 percent relative humidity at 73°F (23°C). Massive concrete units that need unusually long drying periods can be fire tested after a 12-month conditioning period. Appendix F describes how the test result should be corrected to account for any variation from the standard moisture condition.[33]

G-7.3

With few exceptions, only the interior face of exterior wall assemblies and the ceiling portion or underside of floor or roof assemblies are exposed to the standard fire.[24, 25] This practice is rationalized based on the assumption that the outside face of exterior walls is not usually subjected to the same fire as the interior face and that the fire exposure of the upper side of a floor or roof assembly is seldom as intense as that of the underside.

G-7.4

Although this standard does not contain specific criteria for judging the impact of through-joints or “poke-through” devices, such as electrical or telephone outlets, it should be recognized that these components should be evaluated with respect to structural performance and temperature-rise criteria if they constitute a significant part of the tested assembly.

G-7.5

For obvious reasons, symmetrical walls and partitions are tested only on one side. Asymmetrical walls and partitions might be required to be tested with either or both sides individually exposed to the fire. If both sides are exposed, the report should indicate the fire endurance classification for each case.

G-8 Loading.

G-8.1

Floors and roofs generally are loaded during tests to provide a maximum load condition determined by the applicable nationally recognized design criteria. This practice is intended to accommodate those designs that are loaded to maximum design conditions in actual intended use. Through the application of engineering principles, those fire endurance ratings developed can be applied to assemblies having spans greater than those tested.

G-8.2

Where a floor or roof assembly is designed for a specific use, such as in prefabricated housing units, the assembly can be tested with a restricted load condition. The loading condition used for such tests is to be defined in the test report. This standard does not require specific loading devices. Some laboratories use large containers of water; others use a system of hydraulic rams for floor and roof assemblies. Where a uniformly distributed load is simulated by point-loading (several small-area loads), it is recommended that the load at any such area not exceed 25 percent of the total load and that the individual load have a width at least equal to the depth of the floor. Wall furnaces generally are equipped with hydraulic rams.

G-8.3

This standard requires that load-bearing walls and partitions sustain the applied test load during the fire endurance and hose stream tests. A former provision that required load-bearing walls and partitions to sustain twice the specified superimposed test load after cooling but within 72 hours of the test period has been deleted from the method as being unrealistic. Nonbearing walls and partitions are not loaded during the test but are restrained on all sides. This restraint could impose more stress than a load on top. The ASTM Committee E-5 has reviewed the loading procedures for framed walls and partitions several times. It was the committee's unanimous decision that such a wall be tested either with calculated maximum design load or with a load expected to occur in practice. The method used to compute the design loads needs to be reported.

G-8.4

Some important stresses, such as those caused by creep and shrinkage in the wall itself and its supporting frame, are present, and the designer should recognize these stresses in the analysis. The ASTM Committee E-5 has investigated the possibility of openings occurring in joints at the corners of nonload-bearing enclosures due to differential movement. While the possibility exists that this will occur, the committee has not found it feasible to amend the test based on available data.

G-8.5

Double walls pose a unique problem for load application. Which wall should be loaded? Should both walls be loaded simultaneously? The ASTM Committee E-5 devoted considerable time to debating this problem and recommends the decision be made by the user after an analysis of the loading conditions anticipated in service both before and after a fire. Such loading conditions are to be reported.

G-9 Integrity.

All walls and partitions that qualify for a fire endurance classification of 1 hour or more are required to be subjected to the cooling impact and erosion effects of a stream of water from a $2^1/_2$-in. (63.5-mm) hose discharging through a standard playpipe equipped with a $1^1/_8$-in. (28.6-mm) tip under specified pressures. In this hose stream test, the ability of the construction to resist disintegration under adverse conditions is examined. The requirement for a hose stream test was removed from the test procedure for columns and floor or roof assemblies because of impracticality and the possibility of excessive damage to the furnace.

G-10 Conditions of Tests.

G-10.1

Columns generally are tested with all four sides exposed to the test fire. However, it is possible to test a column with three sides exposed (with the fourth side against a wall). This standard requires that specimens be tested under conditions contemplated in the design. The former general practice of testing columns with pin connection at the top and bottom to simulate the most critical condition is no longer a criterion.

G-10.2

Columns are required to sustain successfully the design load during the test period. This standard also permits columns to be loaded up to $1^3/_4$ times the design load prior to the fire test if desired by the submitter. Such loading, however, should not be construed as having had a deleterious effect on the fire endurance test performance. Instead of loading, steel columns, whose protective covering does not carry a load, can be assigned a fire resistance classification on the basis of the temperature of the steel only. With such columns, the protective cover should be restrained against longitudinal expansion. Wood columns are tested for load-carrying ability only.

G-10.3

Test results have established that variations of restraint conditions can influence the time of fire resistance for a structure or a structural element considerably. Restraints generally are beneficial to fire resistance; however, there are conditions under which restraint can have a detrimental effect on the performance of a specimen during a fire resistance test.[34, 35] The users of test results are advised to study the reference documents as well as Appendix E and Table E-6.

G-10.4

An unrestrained classification for a steel beam or a reinforced concrete beam used as part of an assembly tested in restrained condition can be assessed from the temperature records obtained for the steel or the reinforcing steel, respectively (*see Chapter 11*). It is also possible to evaluate the protective cover of steel beams by measuring the temperature of the steel that is protected (*see Chapter 12*). The fire endurance classification determined under the provisions of Chapter 11 is applicable only to beams used with a floor or roof construction that has a comparable or greater capacity for heat dissipation from the beam than the floor or roof with which it is tested.

G-11 Other Observations.

G-11.1

No limitation is imposed on the deformation of the specimen during or after the test period. It is assumed that the deflection or deformation of an assembly is limited only by its ability to stay in place (under load, where specified) during the test period.

G-11.2

A complete record of deformation during the endurance test is helpful in the application of test results and should be reported.

G-11.3

Other observations, such as the evolution of unusual quantities of visible smoke, vapors, or gases that could affect the proper decision regarding use of the test results, should be reported.

G-12 Protective Membranes.

This standard provides criteria for evaluating the protection that membrane elements can offer to combustible framing and paneling (e.g., joists, wall studs, and paneling or boards on the unexposed side of an assembly and other combustible materials). The results of these tests are reported as protective membrane ratings.

[1]Vytenis Babrauskas and Robert Brady Williamson, “Historical Basis of Fire Resistance Testing,” Part I and Part II, *Fire Technology*, Vol. 14, No. 3 and No. 4, 1978, pp. 184-194, 304-316.

[2]Harry Shoub, “Early History of Fire Endurance Testing in the United States,” *Symposium on Fire Test Methods*, ASTM STP 301, American Society for Testing and Materials, 1961, pp. 1-9.

[3]C. H. Dilam et al., *Modern Building Inspection*, R. C. Colling and Associates, Los Angeles, CA, 1942.

[4]*Facts About Fires*, National Fire Protection Assn., Quincy, MA, 1971.

[5]Bird and Docking, *Fire in Buildings*, D. Van Nostrand Co., Inc., New York, 1949.

[6]R. S. Ferguson, “Principles of Fire Protection,” *National Building Code of Canada*, Technical Paper No. 272, Division of Building Research, National Research Council of Canada, Ottawa, 1970.

[7]L. Konicek and T. T. Lie, “Temperature Tables for Ventilation Controlled Fires,” Building Research Note No. 94, National Research Council of Canada, Sept. 1974.

[8]C. C. Gordon, *Considerations of Life Safety and Building Use*, DBR Paper No. 699, National Research Council of Canada, Ottawa, Jan. 1977.

[9]G. W. Shorter, “Fire Protection Engineer and Modern Building Design,” *Fire Technology*, Vol. 4, No. 3, Aug. 1968, pp. 206-213.

[10]T. Z. Harmathy, *Performance of Building Elements in Spreading Fire*, DBR Paper No. 752, National Research Council of Canada, NRCC 16437, Fire Research Vol. 1, 1977/78, pp. 119-132.

[11]T. Z. Harmathy, “Design Approach to Fire Safety in Buildings,” *Progressive Architecture*, NRCC 14076, Apr. 1974, pp. 82-87.

[12]“Rule 508   Industrial Code,” New York State Labor Law, *New York City Building Code*, p. 513, 1934 Edition.

[13]A. E. Robertson and D. Gross, “Fire Load, Fire Severity, and Fire Endurance,” *Fire Test Performance*, ASTM STP 464, American Society for Testing and Materials, 1970, pp. 3-29.

[14]BMS 92, *Building Materials and Standards*, National Bureau of Standards, Washington, DC, Oct. 1942.

[15]S.H. Ingberg et al., “Combustible Contents in Buildings,” BMS 149, National Bureau of Standards, Washington, DC, Jul. 1957.

[16]L. G. Seigel, *The Severity of Fires in Steel Framed Buildings*, Her Majesty’s Stationary Office, 1968, London, Proceedings of the Symposium held at the Fire Research Station, Boreham Woods, Herts (England), Jan. 24, 1967, pp. 59-63.

[17]D. Gross, *Field Burnout Tests of Apartment Dwelling Units*, Building Science Series 10, U. S. Dept. of Commerce, National Bureau of Standards, Sept. 29, 1967.

[18]Margaret Law, *Radiation from Fires in a Compartment*, Fire Research Technical Paper No. 20, Her Majesty’s Stationary Office, London, 1968.

[19]A. J. M. Heselden, *Parameters Determining the Severity of Fire*, Symposium No. 2, Her Majesty’s Stationary Office, 1968, London, Proceedings of the Symposium held at the Fire Research Station, Boreham Woods, Herts (England), Jan. 24, 1967, pp. 19-27.

[20]D. Sfintesco, *Furnace Tests and Fire Resistance*, Building Science Series 10, U. S. Dept. of Commerce, National Bureau of Standards, Sept. 29, 1967.

[21]D. Gross and A. F. Robertson, *Experimental Fires in Enclosures*, Tenth Symposium (International) on Combustion, The Combustion Institute, 1965, pp. 931-942.

[22]Kai Odeen, *Theoretical Study of Fire Characteristics in Enclosed Spaces*, Division of Building Construction, Royal Institute of Technology, Stockholm, Sweden, 1965.

[23]J. E. Ryan, “Perspective on Methods of Assessing Fire Hazards in Buildings,” *Ignition, Heat Release, and Noncombustibility of Materials*, ASTM STP 502, American Society for Testing and Materials, 1972, pp. 11-23.

[24]T. Z. Harmathy, *Performance of Building Elements in Spreading Fire*, DBR Paper No. 752, National Research Council of Canada, NRCC 16437, Fire Research Vol. 1, 1977/78, pp. 119-132.

[25]T. Z. Harmathy, “Design of Fire Test Furnaces,” *Fire Technology*, Vol. 5, No. 2, May 1969, pp. 146-150.

[26]T. Z. Harmathy, “Fire Resistance versus Flame Spread Resistance,” *Fire Technology*, Vol. 12, No. 4, Nov. 1976, pp. 290-302, 330.

[27]T. Z. Harmathy, “A New Look at Compartment Fires,” Part I and Part II, *Fire Technology*, Vol. 8, No. 3 and No. 4, Aug. and Nov. 1972, pp. 196-217; 326-351.

[28]F. Satsberg, Illinois Institute of Technology Research Institute Limited release on research data conducted for U. S. Dept. of Civil Defense.

[29]T. Z. Harmathy, *Designers Option Fire Resistance on Ventilation*, Technical Paper No. 436, Division of Building Research, National Research Council of Canada, Ottawa, NRCC 14746.

[30]*Fire Protection Handbook*, Sixteenth edition, National Fire Protection Assn., Quincy, MA, 1986.

[31]Sven-Erik Magusson and Ove Petersson, ISO/TE-WG5 Report, March 9-10, 1967, Copenhagen, Denmark (Sweden-B)-Exhibit 14. Preliminary report on some theoretical studies for structural elements of the effect on their fire resistance of variations of T-t curve for cooling down period.

[32]J. E. Ryan and A. F. Robertson, “Proposed Criteria for Defining Load Failure of Beams, Floors, and Roof Construction During Fire Tests,” *Journal of Research of the National Bureau of Standards*, Washington, DC, Vol. 63C, No. 2, 1959.

[33]T. Z. Harmathy, “Experimental Study on Moisture and Fire-Endurance,” *Fire Technology*, Vol. 2, No. 1, Feb. 1966.

[34]C. C. Carlson, S. L. Selvaggio, and A.H. Gustaferro, *A Review of Studies of the Effects of Restraint on the Fire-Resistance of Prestressed Concrete*, Feuerwider-stansfahigkeit von Spannbeton, Ergebnisse einer Tagung der F.I.P. in Braunschweig, Jun. 1965, Wiesbaden-Berlin, 1966, p. 32.

[35]L. A. Issen, A. H. Gustaferro, and C. C. Carlson, “Fire Tests of Concrete Members; An Improved Method for Estimating Thermal Restraint Forces,” *Fire Test Performance*, ASTM STP 464, American Society for Testing and Materials, 1970, pp. 153-185.

Additional references used in the development of this appendix:

G. K. Castle, “The Nature of Various Fire Environments and the Application of Modern Material Approaches for Fire Protection of Exterior Structural Steel,” presented at American Institute of Chemical Engineers Loss Prevention Symposium, Nov. 1973, Philadelphia, PA.

D. Crowley et al., “Test Facilities for Measuring the Thermal Response of Materials to the Fire Environment,” *Journal of Testing and Evaluation*, Vol. 1, No. 5.

S. H. Ingberg, “The Hose-Stream Test as a Part of Fire-Testing Procedure,” Symposium on Fire Test Methods 1962, ASTM STP 344, American Society for Testing and Materials, 1963, pp. 57-68.

Richard Stone, “Danger-Flammable,” *Wall Street Journal*, New York, NY, Dec. 8, 1970.

J. H. Warren and A. A. Corona, “This Method Tests Fire Protective Coatings,” *Hydrocarbon Processing*, Jan. 1975.

Appendix H Referenced Publications

H-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.

H-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.

H-1.2 Other Publication.

H-1.2.1 ASTM Publication. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103

ASTM C569, *Test for Indentation Hardness of Performed Thermal Insulations*, 1989.

H-1.3 Additional References.

Carl A. Menzel, “A Method for Determining the Moisture Condition of Hardened Concrete in Terms of Relative Humidity,” Proceedings, American Society for Testing and Materials, Vol. 55, p. 1085 (1955).

U.S. Department of Agriculture, “Wood Handbook of the Forest Products Laboratory,” pp. 320-321 (1955).

1995 Edition

This edition of NFPA 252, *Standard Methods of Fire Tests of Door Assemblies*, 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 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.

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 252

The Standard *Methods of Fire Tests of Door Assemblies* was adopted as a tentative standard by the ASTM in 1940 and was formally adopted in 1941. In 1942, this standard was adopted by the NFPA and approved by the American Standards Association. It was reaffirmed by the Committee on Fire Tests of Building Construction and Materials and adopted in 1950. In 1953, a new NFPA Committee on Fire Tests was formed by action of the Board of Directors, and recommendations for revision of the standard made from that committee were adopted in 1958, 1969, 1972, 1976, 1979, 1984, and 1990.

The basic procedure covered by this standard was developed by Underwriters Laboratories Inc. and has not undergone any significant revisions to the original concept of procedures. The 1995 edition introduces a new provision to address the neutral plane of the furnace. This provision permits the testing agency to establish the neutral plane of the test furnace to the specification of the particular need, i.e., positive pressure at a 40-in. level, top of the opening, or test at atmospheric pressure.

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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.

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 where such documents 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; and act in a liaison capacity between NFPA and the committees of other organizations writing fire test standards. The Committee shall not be responsible for fire tests that are used to evaluate extinguishing agents, devices, or systems.

NFPA 252
Standard Methods of
Fire Tests of Door Assemblies

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 Purpose.

This standard outlines methods of fire tests for door assemblies.

1-2 Scope.

1-2.1

These methods of fire tests are applicable to door assemblies of various materials and types of construction used in wall openings to retard the passage of fire.

1-2.2

Tests made in conformity with these test methods demonstrate the performance of door assemblies during the test exposure; but such tests shall not be construed as determining the suitability of door assemblies for use after their exposure to fire.

1-2.3

It is intended that tests made in conformity with these test methods will develop data that enable regulatory bodies to determine the suitability of door assemblies for use in locations where fire resistance of a specified duration is required.

1-3 Significance.

1-3.1

These test methods are intended to evaluate the ability of a door assembly to remain in an opening during a predetermined test exposure.

1-3.2

The tests expose a specimen to a standard fire exposure that is controlled to achieve specified temperatures throughout a specified time period, followed by the application of a specified standard fire hose stream. The exposure, however, will not be representative of all fire conditions, which can vary with changes in the amount, nature, and distribution of fire loading, ventilation, compartment size and configuration, and heat sink characteristics of the compartment. The exposure does, however, provide a relative measure of the fire performance of door assemblies under these specified fire exposure conditions.

1-3.3

Any variation in the construction or conditions that are tested could substantially change the performance characteristics of the assembly.

1-3.4

The test methods do not provide the following:

(a) Full information on the performance of all door assemblies in walls constructed of materials other than those tested.

(b) An evaluation of the degree to which a door assembly contributes to the fire hazard through generation of smoke, toxic gases, or other products of combustion.

(c) A measurement that determines a limit on the number of openings allowed in glazed areas or the number and size of lateral openings between the door and frame.

(d) A measurement of the degree of control or limitation of the passage of smoke or products of combustion through the door assembly.

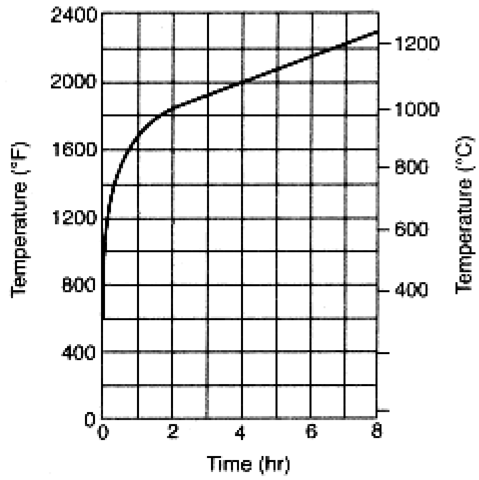
(e) A measurement that determines a temperature limit on the unexposed side of the door assembly.

Chapter 2 Control of Fire Tests

2-1 Time Temperature Curve.

2-1.1

The fire exposure of door assemblies shall be controlled to conform to the applicable portion of the standard time temperature curve shown in Figure 2-1.1. The points that determine the curve are specified immediately below Figure 2-1.1:



1000°F (538°C)............................at 5 minutes
1300°F (704°C)............................at 10 minutes
1550°F (843°C)............................at 30 minutes
1638°F (892°C)............................at 45 minutes
1700°F (927°C)................................at 1 hour
1792°F (978°C)............................at 1.5 hours
1925°F (1052°C)..............................at 3 hours

Figure 2-1.1 Time temperature curve.

2-1.2

For a more detailed time temperature curve, see Table 2-1.2.

Table 2-1.2 Standard Time Temperature Curve for Control of Fire Tests

Time	Temperature	Area Above 68°F Base		Temperature	Area Above 20°C Base	
(hr/min)	(°F)	(°F–min)	(°F–hr)	(°C)	(°C–min)	(°C–hr)
0:00	68	00	0	20	00	0
0:05	1000	2330	39	538	1290	22
0:10	1300	7740	129	704	4300	72
0:15	1399	14,150	236	760	7860	131
0:20	1462	20,970	350	795	11 650	194
0:25	1510	28,050	468	821	15 590	260
0:30	1550	35,360	589	843	19 650	328
0:35	1584	42,860	714	862	23 810	397
0:40	1613	50,510	842	878	28 060	468
0:45	1638	58,300	971	892	32 390	540
0:50	1661	66,200	1103	905	36 780	613
0:55	1681	74,220	1237	916	41 230	687
1:00	1700	82,330	1372	927	45 740	762
1:05	1718	90,540	1509	937	50 300	838
1:10	1735	98,830	1647	946	54 910	915
1:15	1750	107,200	1787	955	59 560	993
1:20	1765	115,650	1928	963	64 250	1071
1:25	1779	124,180	2070	971	68 990	1150
1:30	1792	132,760	2213	978	73 760	1229
1:35	1804	141,420	2357	985	78 560	1309
1:40	1815	150,120	2502	991	83 400	1390
1:45	1826	158,890	2648	996	88 280	1471
1:50	1835	167,700	2795	1001	93 170	1553
1:55	1843	176,550	2942	1006	98 080	1635
2:00	1850	185,440	3091	1010	103 020	1717
2:10	1862	203,330	3389	1017	112 960	1882
2:20	1875	221,330	3689	1024	122 960	2049
2:30	1888	239,470	3991	1031	133 040	2217
2:40	1900	257,720	4295	1038	143 180	2386
2:50	1912	276,110	4602	1045	153 390	2556
3:00	1925	294,610	4910	1052	163 670	2728
3:10	1938	313,250	5221	1059	174 030	2900
3:20	1950	332,000	5533	1066	184 450	3074
3:30	1962	350,890	5848	1072	194 940	3249
3:40	1975	369,890	6165	1079	205 500	3425
3:50	1988	389,030	6484	1086	216 130	3602
4:00	2000	408,280	6805	1093	226 820	3780
4:10	2012	427,670	7128	1100	237 590	3960
4:20	2025	447,180	7453	1107	248 430	4140
4:30	2038	466,810	7780	1114	259 340	4322
4:40	2050	486,560	8110	1121	270 310	4505
4:50	2062	506,450	8441	1128	281 360	4689
5:00	2075	526,450	8774	1135	292 470	4874
5:10	2088	546,580	9110	1142	303 660	5061
5:20	2100	566,840	9447	1149	314 910	5248
5:30	2112	587,220	9787	1156	326 240	5437
5:40	2125	607,730	10,129	1163	337 630	5627
5:50	2138	628,360	10,473	1170	349 090	5818
6:00	2150	649,120	10,819	1177	360 620	6010
6:10	2162	670,000	11,167	1184	372 230	6204
6:20	2175	691,010	11,517	1191	383 900	6398
6:30	2188	712,140	11,869	1198	395 640	6594
6:40	2200	733,400	12,223	1204	407 450	6791
6:50	2212	754,780	12,580	1211	419 330	6989
7:00	2225	776,290	12,938	1218	431 270	7188
7:10	2238	797,920	13,299	1225	443 290	7388
						7590
						7792
						7996
7:50	2288	885,700	14,762	1253	492 060	8201
8:00	2300	907,960	15,133	1260	504 420	8407

2-1.3

The temperature inside the furnace at the start of the test shall be ambient.

2-2 Furnace Temperatures.

2-2.1

Test exposure temperatures shall be determined by using the average temperature obtained from the readings of not fewer than nine thermocouples symmetrically disposed and distributed to indicate the temperature near all parts of the test assembly. The thermocouples shall be protected by sealed porcelain tubes having $^3/_4$-in. (19-mm) outside diameter and $^1/_8$-in. (3-mm) wall thickness, or, as an alternate, in the case of base metal thermocouples, protected by $^1/_2$-in. (13-mm) wrought steel or wrought iron pipe of standard weight. The junction of the thermocouples shall be located 6 in. (152 mm) from the exposed face of the test assembly, or from the masonry in which the assembly is installed, during the entire test exposure.

2-2.2

The temperatures shall be measured at intervals not exceeding 1 minute during the test period.

2-2.3

The accuracy of the furnace control shall be such that the area under the time temperature curve, obtained by averaging the results from the thermocouple readings, is within 10 percent of the corresponding area as specified in Table 2-1.2 for fire tests of 1 hour or less duration, within 7.5 percent for those tests lasting more than 1 hour and not more than 2 hours, and within 5 percent for tests exceeding 2 hours duration.

2-3 Unexposed Surface Temperatures.

2-3.1

Unexposed surface temperatures shall be recorded and shall be determined in the following manner:

(a) Unexposed surface temperatures shall be taken at not fewer than three points, with at least one thermocouple in each 16-ft^2 (1.5-m^2) area of the door. Thermocouples shall not be located over reinforcements extending through the door, over vision panels, or nearer than 12 in. (305 mm) from the edge of the door.

(b)* Unexposed surface temperatures shall be measured with thermocouples placed under dry, felted pads meeting the requirements specified in A-2-3.1(b). The pads shall be held firmly against the surface of the door and shall fit closely about the thermocouples. The thermocouple leads shall be positioned under the pad for a distance of not less than 3$^1/_2$ in. (89 mm), with the hot junction under the center of the pad. The thermocouple leads under the pads shall not be heavier than No. 18 AWG (0.82 mm^2) and shall be electrically insulated with heat-resistant and moisture-resistant coatings.

(c) Unexposed surface temperatures shall be measured at intervals not exceeding 1 minute during the first 30 minutes of the test.

Exception: Single-layer metal doors need not comply with 2-3.1 (a) through (c).

Chapter 3 Test Assemblies

3-1 Construction and Size.

3-1.1

The construction and size of a test door assembly, which can include single doors, doors in pairs, special-purpose doors (e.g., Dutch doors, double-egress doors), or multisection doors, shall be representative of that type of assembly for which the classification or rating is desired.

3-1.2

A floor structure shall be provided as part of the opening to be protected. The floor segment shall be of noncombustible material and shall project into the furnace for a distance that is approximately twice the thickness of the test door or to the limit of the frame, whichever is greater.

Exception: A floor structure shall not be required to be part of the protected opening where the floor interferes with operation of the door.

3-2 Mounting.

3-2.1

Swinging doors shall be mounted to open into the furnace chamber.

3-2.2

Sliding and rolling doors shall be mounted on the exposed side of the opening in the wall enclosing the furnace chamber.

Exception: Horizontal slide-type elevator doors.

3-2.3

Horizontal slide-type elevator doors shall be mounted on the unexposed side of the opening in the wall enclosing the furnace chamber.

3-2.4

Access-type doors and their frame assemblies and chute-type doors and their frame assemblies shall be mounted to have one assembly open into the furnace chamber and another assembly open away from the furnace chamber.

3-2.5

Dumbwaiter doors and frame assemblies and service-counter doors and frame assemblies shall be mounted on the exposed side of the opening in the wall.

3-2.6

Door frames shall be evaluated when mounted to verify that the doors open either away from or into the furnace chamber, at the discretion of the testing authority, to obtain representative information on the performance of the construction under test.

3-2.7

Surface-mounted hardware (fire-exit devices) for use on fire doors shall be evaluated under conditions where it is installed in one door assembly that swings into the furnace chamber and in another door assembly that swings away from the furnace chamber.

3-2.8

The mountings of all doors shall be such that they fit snugly within the frame, against wall surfaces, or in guides, but such mounting shall not prevent free and easy operation of the test door.

3-3 Clearances.

3-3.1

Clearances for swinging doors shall be as follows:

With a minus $^1/_{16}$-in. (1.6-mm) tolerance: $^1/_8$ in. (3 mm) along the top, $^1/_8$ in. (3 mm) along the hinge and latch jambs, $^1/_8$ in. (3 mm) along the meeting edge of doors in pairs, $^3/_8$ in. (10 mm) at the bottom edge of a single swinging door, and $^1/_4$ in. (6 mm) at the bottom of a pair of doors.

3-3.2

Clearances for horizontal sliding doors not mounted within guides shall be as follows:

With a minus $^1/_8$-in. (3-mm) tolerance: $^1/_2$ in. (12.7 mm) between door and wall surfaces, $^3/_8$ in. (10 mm) between door and floor structure, and $^1/_4$ in. (6 mm) between the meeting edges of center-parting doors. A maximum overlap of 4 in. (102 mm) of the door over the wall opening at sides and top shall be provided.

3-3.3

Clearances for vertical sliding doors moving within guides shall be as follows:

With a minus $^1/_8$-in. (3-mm) tolerance: $^1/_2$ in. (12.7 mm) between the door and wall surfaces along top or bottom door edges, or both, with guides mounted directly to the wall surface, and $^3/_{16}$ in. (5 mm) between meeting edges of bi-parting doors or $^3/_{16}$ in. (5 mm) between the door and the floor structure or sill.

3-3.4

Clearances for horizontal slide-type elevator doors shall be as follows:

With a minus $^1/_8$-in. (3-mm) tolerance: $^3/_8$ in. (10 mm) between the door and wall surface, $^3/_8$ in. (10 mm) between multisection door panels, and $^3/_8$ in. (10 mm) from the bottom of a panel to the sill. Multisection door panels shall overlap $^3/_4$ in. (19 mm). Door panels shall overlap the wall opening $^3/_4$ in. (19 mm) at sides and top.

Chapter 4 Conduct of Tests

4-1 Test Assembly.

4-1.1

The wall or partition in which the door assembly is tested shall be adequate to retain the assembly throughout the fire and the hose stream test; it shall be constructed of masonry or other materials representative of wall or partition construction.

4-1.2

Door frame wall anchors, where used, shall be suitable for the wall or partition construction.

4-2 Fire Endurance Test.

4-2.1 Furnace Pressure.

(a) The vertical pressure distribution within the furnace shall be measured in the following manner:

1. The vertical pressure distribution within the furnace shall be measured by at least two probes separated by a vertical distance [minimum of 6 ft (1.8 m)] within the furnace. Based on the vertical separation and pressure differences of the probes, a calculation of the neutral plane (zero differential pressure) location shall be made.

2. The pressure-sensing probes shall be as shown in either Figure 4-2.1(a) or (b).

3. The pressure-sensing probes shall be located as near as practical to the vertical centerline of the furnace opening.

4. The pressure at each location shall be measured using a differential pressure instrument capable of reading in graduated increments no greater than 0.01 in wg (2.5 Pa) with a precision of not less than ± 0.005 in wg (± 1.25 Pa). The differential pressure measurement instrument shall be located to minimize "stack" effects caused by vertical runs of pressure tubing between the furnace probe and instrument locations.

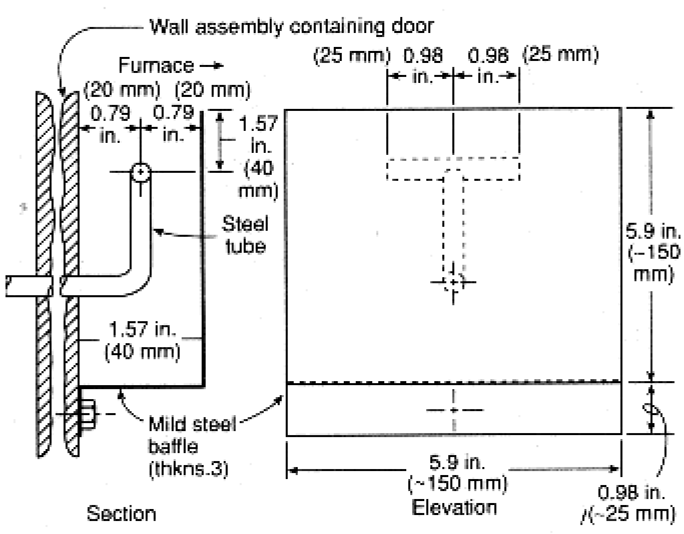


Figure 4-2.1(a) Static pressure-measuring device dimensions.

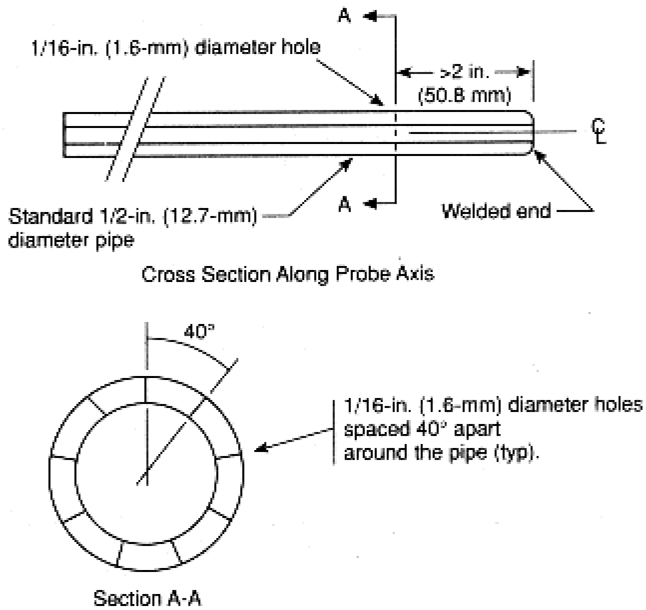


Figure 4-2.1(b) Pressure probe.

(b) The furnace pressure shall be measured and recorded throughout the test at intervals not exceeding 1 minute.

(c) Control of the furnace pressure shall be established beginning no longer than 10 minutes after the start of the test and shall be maintained throughout the remainder of the test period.

4-2.2

The test shall be continued until the exposure period of the desired classification or rating is reached, unless the conditions of acceptance required in Chapter 5 are exceeded in a shorter period.

4-3 Hose Stream Test.

4-3.1*

Immediately following the fire endurance test, the test assembly shall be subjected to the impact, erosion, and cooling effects of a hose stream directed first at the middle and then at all parts of the exposed surface, making changes in direction slowly.

Exception: For 20-minute rated test assemblies, at the option of the test sponsor, the hose stream test shall not be required to be performed.*

4-3.2

The stream shall be delivered through a $2^1/_2$-in. (64-mm) hose discharging through a national standard play pipe as described in UL 385, *Standard for Safety Play Pipes for Water Supply Testing in Fire-Protection Service*. The play pipe shall have an overall length of 30 in. (762 mm) and shall be equipped with a $1^1/_8$-in. (28.5-mm) discharge tip of the standard-taper, smooth-bore pattern without shoulder at the orifice. The play pipe shall be fitted with a $2^1/_2$-in. (64-mm) inside dimension × 6-in. (153-mm) long nipple mounted between the hose and the base of the play pipe. The pressure tap for measuring the water pressure at the base of the nozzle shall be normal to the surface of the nipple, shall be centered in its length, and shall not protrude into the water stream. The water pressure shall be measured with a suitable pressure gauge [minimum 0-50 psi (0-344.8 kPa)] graduated in no greater than 2 psi (13.8 kPa) increments. The water pressure and duration of application shall be as specified in Table 4-3.2.

Table 4-3.2 Water Pressure at Base of Nozzle and Duration of Application

Desired Rating	Water Pressure at Base of Nozzle psi (kPa)	Duration of Application sec/ft^2 (sec/m^2)
3 hr and over	45 (310)	3.0 (32)
$1^1/_2$ hr and over, if less than 3 hr	30 (207)	1.5 (16)
1 hr and over, if less than $1^1/_2$ hr	30 (207)	0.0 (10)
Less than 1 hr	30 (207)	0.6 (6)

4-3.3

The tip of the nozzle shall be located 20 ft (6 m) from and on a line normal to the center of the test door. If impossible to be so located, the nozzle shall be permitted to be on a line deviating not more than 30° from the line normal to the center of the test door. Where so located, the distance from the center shall be less than 20 ft (6 m) by a length equal to 1 ft (0.3 m) for each 10° of deviation from the normal.

Chapter 5 Report

5-1 Results.

5-1.1

Results shall be reported based on performance in the tests specified in these test methods. The report shall include:

(a) The performance for the desired exposure period chosen from the following: 20 minutes, 30 minutes, $^3/_4$ hour, 1 hour, $1^1/_2$ hours, or 3 hours and over (in hourly increments);

(b) The temperature measurements of the furnace;

(c) The temperature measurements of the unexposed side;

(d) The pressure measurements made inside the furnace and the calculation showing the position of the neutral plane with respect to the top of the door assembly during the test;

(e) All observations having a bearing on the performance of the test assembly;

(f) Flaming, if any, on the unexposed surface of the door leaf;

(g) The amount of movement of any portion of the edges of the door adjacent to the door frame from the original position (*see Chapter 6*);

(h) The materials and the construction of the door, frame, and wall or partition and the details of the installation, hardware, door frame, and wall anchors, hangers, guides, trim, finish and clearance or lap shall be recorded or appropriately referenced to ensure positive identification or duplication in all respects.

Chapter 6 Conditions of Acceptance

6-1 General.

6-1.1

A door assembly shall be considered as meeting the requirements for acceptable performance where it remains in the opening during the fire endurance test and the hose stream test under the following conditions:

(a) The test assembly shall withstand the fire endurance test and the hose stream test without developing any openings through the assembly.

NOTE: Openings, for purposes of this provision, are defined as through-holes in the assembly that can be seen from the unexposed side when observing the location of the suspected opening from a position perpendicular to the plane of the assembly.

Exception No. 1: Dislodging of small portions of glass light during the hose stream test.

Exception No. 2: Permitted separation between meeting edges of pairs of doors in accordance with 6-2.4, 6-3.4, and 6-3.10.

Exception No. 3: Permitted openings between the bottom edges of doors and sills in accordance with 3-3.1 through 3-3.4 and 6-3.3.

(b) No flaming shall occur on the unexposed surface of a door assembly during the first 30 minutes of the classification period.

(c) After 30 minutes, some intermittent light flames [approximately 6 in. (152 mm) long], shall be permitted to occur along the edges of doors for periods not to exceed 5 minutes.

(d) Light flaming shall be permitted to occur during the last 15 minutes of the classification period on the unexposed surface area of the door, provided it is contained within a distance of $1^1/_2$ in. (38 mm) from a vertical door edge and within 3 in. (76 mm) from the top edge of the door and within 3 in. (76 mm) from the top edge of the frame of a vision panel.

(e) Where hardware is evaluated for use on fire doors, it shall secure the door closed in accordance with the conditions of acceptance for an exposure of 3 hours and, in addition, the latch bolt shall remain projected and shall be intact after the test. The hardware shall not be required to be operable following the test.

6-2 Swinging Doors.

6-2.1

The movement of swinging doors shall not result in any portion of the edges adjacent to the door frame moving in a direction that is perpendicular to the plane of the door a distance from its original position that is greater than the thickness of the door during the first half of the classification period, or greater than $1^1/_2$ times the door thickness during the entire classification period, or moving as a result of the hose stream test.

6-2.2

The movement of swinging doors mounted in pairs shall not result in any portion of the meeting edges moving from its original position a distance that is greater than the thickness of the door away from the adjacent door edge in a direction that is perpendicular to the plane of the doors during the entire classification period, or as a result of the hose stream test.

6-2.3

An assembly consisting of a pair of swinging doors incorporating an astragal shall not separate in a direction parallel to the plane of the doors by more than $^3/_4$ in. (19 mm) or a distance equal to the throw of the latch bolt at the latch location.

6-2.4

An assembly consisting of a pair of swinging doors, without an overlapping astragal, for a fire and hose stream exposure of $1^1/_2$ hours or less, shall not separate along the meeting edges by more than $^3/_8$ in. (10 mm), including the initial clearance between doors.

6-2.5

An assembly consisting of a single swinging door shall not separate by more than $^1/_2$ in. (13 mm) at the latch location.

6-2.6

Door frames to be evaluated with doors shall remain securely fastened to the wall on all sides and shall not permit through-openings between the frame and the doors or between the frame and the adjacent wall.

6-3 Sliding Doors.

6-3.1

Doors mounted on the face of the wall shall not move from the wall sufficiently to develop a separation of more than $2^7/_8$ in. (73 mm) during the entire classification period or as a result of the hose stream test.

6-3.2

Doors mounted in guides shall not release from the guides, and the guides shall not loosen from the fastenings.

6-3.3

The bottom bar of rolling steel doors shall not separate from the floor structure by more than $^3/_4$ in. (19 mm) during the entire classification period or as a result of the hose stream test.

6-3.4

The meeting edge of center-parting horizontal sliding doors and bi-parting vertical sliding doors shall not separate by a distance greater than the door thickness measured in a direction perpendicular to the plane of the doors.

6-3.5

The meeting edges of center-parting horizontal sliding doors and bi-parting vertical sliding doors without an overlapping astragal, for a fire and hose stream exposure of $1^1/_2$ hours or less, shall not separate in a direction parallel to the plane of the doors by more than $^3/_8$ in. (10 mm) along the meeting edges, including the initial clearance between doors.

6-3.6

The meeting edges of center-parting horizontal sliding doors incorporating an astragal shall not separate in a direction parallel to the plane of the doors by more than $^3/_4$ in. (19 mm) or a distance equal to the throw of the latch bolt along the meeting edges.

6-3.7

The bottom edge of service-counter doors or single-slide dumbwaiter doors shall not separate from the sill by more than $^3/_8$ in. (10 mm).

6-3.8

A resilient astragal, if provided, shall not deteriorate sufficiently to result in through-openings during the fire endurance test, but small portions shall be permitted to be dislodged during the hose stream test.

6-3.9

The lap edges of horizontal slide-type elevator doors, including the lap edges of multisection doors, shall not move from the wall or adjacent panel surfaces sufficiently to develop a separation of more than $2^7/_8$ in. (73 mm) during the entire classification period or immediately following the hose stream test.

6-3.10

The meeting edges of center-parting horizontal slide-type elevator door assemblies, for a fire and hose stream exposure of $1^1/_2$ hours or less, shall not move apart more than $1^1/_4$ in. (32 mm) as measured in any horizontal plane during the entire classification period or immediately following the hose stream test.

Chapter 7 Referenced Publications

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 UL Publication.

Underwriters Laboratories, 333 Pfingsten Road, Northbrook, IL 60062.

UL 385, *Standard for Safety Play Pipes for Water Supply Testing in Fire-Protection Service*, 1993.

Appendix A Explanatory Material

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

A-2-3.1

(b) **Refractory Fiber Pads.** Comparative fire tests have demonstrated that a refractory fiber material designated Ceraform 126®,[1] placed with the softer surfaces in contact with the thermocouple, should be substituted for the previously specified asbestos pad where the distortion of the unexposed face of the sample is minimal. The pads are relatively rigid and should not be used on surfaces subject to sharp distortions or discontinuities during the test.[2] The specifications for Ceraform 126 material are as follows:

(a) Length and width, 6 in. ± $^1/_8$ in. (152 mm ± 3 mm).

(b) Thickness, 0.375 in. ± 0.063 in. (9.5 mm ± 1.6 mm). The thickness measurement should be made under the light load of a $^1/_2$-in. (13-mm) diameter pad of a dial micrometer gauge.

(c) Dry weight, 0.147 lb ± 0.053 lb (67 g ± 24 g).

(d) Thermal conductivity [at 150°F (66°C)], 0.37 Btu in./h ft^2-F ± 0.03 Btu in./h ft^2-F (0.053W/m-K) ± 0.004 W/m-K.

(e) Hardness indentation on the soft face shall be 0.075 in. ± 0.025 in. (1.9 mm ± 0.6 mm). Indentation shall be determined in accordance with ASTM Test Method C569. Modified Brinell values of hardness are determined by the following equation:

[1]Ceraform 126 is a registered trade name of Manville Specialty Products Group, P.O. Box 5108, Denver, CO 8-217.
[2]Supporting data are available from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103, Request RR:E05-1004

$$\text{Hardness} = \frac{2.24}{y}$$

where y = the measured indentation in inches.

(f) The pads should be shaped by wetting, forming, and then drying to constant weight to provide complete contact on sharply contoured surfaces.

A-4-3.1

Additional information on the hose stream application can be found in Section B-13.

A-4-3.1 Exception.

The elimination of the hose stream test for some 20-minute rated assemblies is based on their field application.

A-4-3.2 Table.

The exposed area is permitted to be calculated using the outside dimensions of the test specimen, including a frame, hangers, tracks, or other parts of the assembly, if provided, but normally not including the wall into which the specimen is mounted. Where multiple test specimens are mounted in the same wall, the rectangular or square wall area encompassing all of the specimens is considered the exposed area, since the hose stream has to traverse this area during its application.

Appendix B Commentary

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

The numbers in parentheses refer to the list of references at the end of this appendix.

B-1 Introduction.

This commentary has been prepared to provide the user of NFPA 252, *Standard Methods of Fire Tests of Door Assemblies*, with background information on the development of the standard and its application in the fire protection of buildings. It also provides guidance in the planning and performance of fire tests and in the reporting of results. No attempt has been made to incorporate all of the available information on fire testing in this commentary. The serious student of fire testing is strongly urged to examine the referenced documents for a better appreciation of the history of fire-resistant design and the intricate problems associated with testing and with interpretation of test results.

B-2 Application.

B-2.1

Compartmentation of buildings by fire-resistive walls has been recognized for many years as an efficient method of restricting fires to the area of origin [1, 2, 5, 6, 7, 8, 16] or limiting their spread. The functional use of buildings, however, demands a reasonable amount of communication between compartments necessitating openings in these fire-resistive walls. Fire door assemblies are utilized to protect these openings and maintain the integrity of the fire barrier [11]. Openings in walls have been classified by fire protection standards [8, 9, 15] and building codes in accordance with the location and purpose of the wall in which the opening exists, and these standards and codes specify the fire rating of the assembly required to protect the openings.

B-2.2

These fire protection standards and building codes permit labeled wire glass panels and other penetrations, such as labeled ventilation louvers, in some rated doors. Refer to the model building codes, NFPA 80, *Standard for Fire Doors and Fire Windows* [8], and the specific fire door manufacturer's label service for information on the types and sizes of these openings.

B-2.3

Fire doors should be properly installed to maintain their fire rating. NFPA 80, *Standard for Fire Doors and Fire Windows* [8], and the specific fire door manufacturer's label service should be consulted for details on the installation of fire door assemblies and for limitations on the application of specific labeled fire doors.

B-3 Historical Aspects.

The first effort to test fire doors was reported in a series of tests conducted in Germany in 1893 [3, 4, 10]. The British Fire Prevention Committee began testing in 1899 and produced a *Standard Table of Fire Resisting Elements*, including *Fire Resisting Doors* [1]. Underwriters Laboratories Inc. was involved in testing and listing fire doors shortly after 1900, using its own standards. In 1941, ASTM adopted ASTM E152, *Standard Methods of Fire Tests of Door Assemblies*, on fire door assembly tests.

B-4 Scope and Significance.

B-4.1

NFPA 252 provides methods for measuring the relative performance of fire door assemblies where exposed to predetermined standard fire conditions. The standard provides for testing of several classifications, types, and methods of door operation including swinging, sliding, rolling, and sectional doors [8]. Since the effectiveness of the opening protection is dependent upon the entire assembly, proper attention should be paid to the installation as a unit. Accordingly, fire door assemblies are required to be tested as an assembly of all necessary elements and equipment, including the door frame and hardware.

B-4.2

Fire protection ratings are assigned to indicate that the assembly has continued to perform as required for periods of $^1/_3$, $^1/_2$, $^3/_4$, 1, $1^1/_2$, 3, or more hours. Labels on assemblies also carry the letter designations of A, B, C, D, or E. These letter designations are not a part of the NFPA 252 standard classification system but are used to designate the class of opening for which the door is designed as determined by other standards [8, 9].

B-4.3

The $^1/_3$-hour or 20-minute fire-rated door is relatively new. Concern about the uniform adequacy of the $1^3/_4$-in. (44.5-mm) solid bonded wood core construction and the difficulty of determining the equivalency of other types of doors led to a voluntary consensus to test such doors for 20 minutes in the test furnace described in this document using the same acceptance criteria specified for door assemblies traditionally tested for a longer period of time, with the exception that the hose stream test is required by the test method but might not be required by regulatory codes.

B-4.4

It is common for a fire door to have a fire protection rating lower than the wall in which it is installed; for example, a $1^1/_2$-hour fire-rated door in a wall having a fire resistance rating of 2 hours. This is justified in part by the fact that, under normal conditions of use, the potential fire exposure in the vicinity of a door opening is decreased, since there will be a clear space on both sides of the opening for traffic purposes. Wall assemblies are put together at the site, and their uniformity is not as certain as a fire-rated door assembly that is factory assembled (e.g., undesigned penetrations tend to show up in wall assemblies). For this reason, any factor of safety that is tacitly called for in a wall assembly requirement should exceed that of a door assembly. If the opening is not used, combustibles could be piled against the door, and the assumed enclosure protection will not be maintained. In these instances, ratings for the openings should be equivalent to the rating of the wall, or precautions should be taken to prevent storage of combustibles against the doors [2, 8].

B-5 Limitations.

B-5.1

The test methods intend that the door be tested until the conditions of acceptance are met for the desired exposure period unless the conditions of acceptance are exceeded in a shorter period. It is not intended that a fire door subjected to a building fire is satisfactory for use following the fire.

B-5.2

The variations in material performance preclude any prediction of an assembly's performance in walls other than those types used in the test. The standard also makes no provisions for measuring the generation of smoke and gases or other products of combustion from the unexposed side of the door. Temperature measurements on the unexposed side, where recorded, are stopped after 30 minutes.

B-6 Furnace.

B-6.1

The methods provide details on the operating characteristics and temperature-measurement requirements of the test furnace. The walls of the furnace typically should be of furnace refractory materials and should be sufficiently rugged to maintain the overall integrity of the furnace during the fire exposure period.

B-6.2

The thermocouples in the furnace are located 6 in. (152 mm) from the face of the door or the wall in which the door is installed. Otherwise, no furnace depth is specified. A depth of 8 in. to 18 in. (203 mm to 457 mm) is considered desirable by most laboratories. Reference documents should be consulted for a more comprehensive review of furnace design and performance [12, 13].

B-7 Time Temperature Curve.

B-7.1

A specific time temperature relationship for the test fire is defined in the standard and in Table 2-1.2. The actual recorded time temperature condition obtained in the furnace is required to be within specified percentages of those of the standard curve. The number and type of temperature-measuring devices are outlined in the standard. Specific standard practices for location and use of these temperature-measuring devices are also outlined in the standard.

B-7.2

The standard time temperature (t-T) curve used in NFPA 252 represents a severe building fire [5]. The curve was adopted in 1918 as a result of several conferences by eleven technical organizations, including testing laboratories, insurance underwriters, fire protection associations, and technical societies [14, 15, 16]. It should be recognized that the t-T relationship of these test methods represents only one real fire situation [14, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27].

B-8 Furnace Control.

The standard contains specific instruction for measuring temperatures in the furnace and for selection of the required thermocouples. Thermocouples of the design specified are sufficiently rugged to retain accuracy throughout anticipated test periods. However, their massive construction results in a significant time delay in response to temperature change and results in temperatures exceeding the indicated temperatures during the early stages of the test period when the temperature rises rapidly. The iron or porcelain tubes surrounding the junction and leads of the thermocouple provide a shield against degradation of the junction and increase the thermal inertia. It is customary for laboratories to replace furnace thermocouples after three or four accumulated hours of use.

B-9 Unexposed Surface Temperature.

B-9.1

Conditions of acceptance for fire-resistive walls specify that the temperature increase on the unexposed side of the wall not exceed an average of 250°F (121°C) above ambient, and that there be no passage of flames or gases hot enough to ignite combustibles. It is obvious that the necessity of maintaining some clearances for efficient operation of the door and the possibility of warping preclude completely any attempt to restrict escape of gases and minor flames on the periphery of doors.

B-9.2

The standard describes a standard procedure for measuring the unexposed surface temperatures. However, unexposed surface temperatures are not a condition of acceptance for NFPA 252. Building regulations do restrict temperature transmission for some wall-opening protectives [8, 9]. For instance, it is usual for codes to limit the temperature rise on the unexposed side of fire doors protecting exit stairways to 450°F (232°C) during the first 30 minutes of test. This criterion assumes that a higher temperature would provide enough radiant heat to discourage if not prevent occupants from passing by the door during an emergency. It is current practice for testing laboratories to provide labels on fire doors indicating that the maximum transmitted temperature on the unexposed side is 250°F, 450°F, or 650°F (121°C, 232°C, or 343°C) above ambient. If not indicated on the label, the temperature rise during the first 30 minutes might or might not be in excess of 650°F (343°C). Temperature rise on the unexposed side of glass panels and louvers is not measured.

B-10 Test Assemblies.

B-10.1

NFPA 252 provides a relative measure of performance for door assemblies. In order to establish confidence that the tested doors will perform in a building as expected, the tested assembly and its installation in the test frame need to be representative of actual use conditions. Therefore, NFPA 80, *Standard for Fire Doors and Fire Windows* [8], or such other standards or specifications should be consulted before testing an assembly.

B-10.2

The standard provides additional minimum requirements including direction of door swing, location in relation to the exposed side of the wall, and specific clearance between the door and its frame or wall, or both. Regardless of other specifications, these instructions should be followed in order to make a comparative judgment on test results.

B-11 Conduct of Tests.

The test frame or wall in which a door assembly is installed should be rugged enough to endure exposure to the fire during the specified period without affecting the door assembly. Traditionally, this wall has been of masonry construction. Today, fire doors are installed in other than masonry walls and have been tested in walls framed with metal and wood studs covered with a number of materials.

B-12 Furnace Pressures.

B-12.1

A fire in a building compartment creates both negative and positive pressures on door assemblies depending on atmospheric conditions, height above ground, wind conditions, and ventilation of the compartment at the start of and during the fire.

B-12.2

In the past, NFPA 252 specified that the pressure in the furnace be maintained as nearly equal to atmospheric pressure as possible. This method of test generally resulted in the test assembly being subjected to a negative pressure during the test, since most laboratories set the neutral plane in the furnace at or above the top of the assembly. As revised, the standard permits tests to be conducted under any pressure, depending on the needs and/or requirements of the manufacturer, test laboratory, or the authority having jurisdiction. The pressure in the furnace is required to be measured and reported.

B-13 Hose Stream Test.

Immediately following a fire test, the test frame is removed from the furnace, and the door assembly is subjected to the impact, erosion, and cooling effects of a stream of water from a $2^1/_2$-in. (63.5-mm) hose discharging through a standard play pipe equipped with a $1^1/_8$-in. (28.5-mm) tip under specified pressures. Just as the standard fire exposure is not intended to be representative of any or all actual fire conditions, the standard hose stream exposure is not intended to be representative of any actual fire-fighting or fire suppression activity. The fire exposure test and the hose stream test provide a relative measure of the performance of constructions and assemblies under specified, standard exposure conditions.

The hose stream test provides a method for evaluating the integrity of constructions and assemblies and eliminating inadequate materials or constructions. The cooling, impact, and erosion effects of the hose steam provide important tests of the integrity of the specimen being evaluated.

The rapid cooling and thermal shock imposed by the hose stream test following the fire exposure test eliminates materials that are subject to failure under such conditions. The orthogonal load imposed by the hose stream subjects vertical specimens to a load in a direction perpendicular to the normal dead load on the specimen. This effect eliminates construction or assemblies with marginal factors of safety for structural loading. The erosion effects of the hose stream might remove char formed during the standard fire exposure that provide minimal contribution to the structural strength of the assembly.

The hose stream test provides a real and measurable load on the specimen. Testing by Ingberg at the National Bureau of Standards reported that the standard hose stream test produced a 57.7-lb (26.2 kg) force on the specimen.

The combined effects of the hose stream test provide a method for screening the integrity of a specimen that cannot be achieved by any other means.

B-14 Conditions of Acceptance.

The standard provides a specific set of conditions by which the performance of the door is measured, the most important being that the door remain in place during both the fire test and the hose stream test. Instructions for conducting the hose stream test are detailed in the standard.

B-15 References.

[1] Bird and Docking, *Fire in Buildings*, D. Van-Nostrand Co., Inc., New York, 1949.

[2] Ferguson, R. S., "Principles of Fire Protection," National Building Code of Canada Technical Paper No. 272, Div. of Building Research, National Research Council of Canada, Ottawa, March 1970.

[3] Shoub, Harry, "Early History of Fire Endurance Testing in the United States," Symposium on Fire Test Methods, ASTM STP 301, American Society of Testing and Materials, 1961.

[4] Konicek, L. and Lie, T. T., "Temperature Tables for Ventilation Controlled Fires," Building Research Note No. 94, National Research Council of Canada, September 1974.

[5] Gordon, C., "Considerations of Life Safety and Building Use," DBR Paper No. 699, Division of Building Research, National Research Council of Canada, Ottawa, January 1977.

[6] Gross, D., "Field Burnout Tests of Apartment Dwelling Units," Building Science Series 10, U.S. Dept. of Commerce, National Bureau of Standards, Sept. 29, 1967.

[7] Law, Margaret, "Radiation from Fires in a Compartment," Fire Research Technical Paper No. 20, Her Majesty's Stationery Office, London, 1968.

[8] NFPA 80, *Standard for Fire Doors and Fire Windows*, 1992, National Fire Protection Association.

[9] Model Building Codes: *Basic Building Code*, Building Officials and Code Administrators International Inc.; *Uniform Building Code*, International Conference of Building Officials Inc.; *Standard Building Code*, Southern Building Code Congress International.

[10] Babrauskas, Vytenis and Williamson, Robert Brady, "The Historical Basis of Fire Resistance Testing, Part I and Part II," *Fire Technology*, Vol. 14, No. 3 and No. 4, 1978, pp. 184-194, 304-316.

[11] Shoub, H. and Gross, D., "Doors as Barriers to Fire and Smoke," Building Science Series 3, National Bureau of Standards, March 25, 1966.

[12] Seigel, L. G., "Effects of Furnace Design on Fire Endurance Test Results," Fire Test Performance, ASTM STP 464, American Society of Testing and Materials, 1970, pp. 56-67.

[13] Harmathy, T. Z., "Design of Fire Test Furnaces," *Fire Technology*, Vol. 5, No. 2, May 1969, pp. 140-150.

[14] Seigel, L. G., "The Severity of Fires in Steel-Framed Buildings," Symposium No. 2, Her Majesty's Stationery Office, 1968, London. Proceedings of the Symposium held at the Fire Research Station, Boreham Woods, Herts (England), January 1967.

[15] *Fire Protection Handbook*, Revised Fourteenth Edition, National Fire Protection Association, Boston, 1978.

[16] Harmathy, T. Z., "Designer's Option: Fire Resistance or Ventilation," Technical Paper No. 436, Division of Building Research, National Research Council of Canada, Ottawa, NRCC 14746, 1974.

[17] Odeen, Kai, "Theoretical Study of Fire Characteristics in Enclosed Spaces," Bulletin No. 10, Royal Institute of Technology, Division of Building Construction, Stockholm, 1963.

[18] Shorter, G. W., "The Fire Protection Engineer and Modern Building Design," *Fire Technology*, Vol. 4, No. 3, August 1968, pp. 206-213.

[19] Stone, Richard, "Danger—Flammable," *Wall Street Journal*, Dec. 8, 1970.

[20] Ryan, J. E., "Assessment of Fire Hazards in Buildings, Ignition, Heat Release, and Noncombustibility of Materials," ASTM STP 502, American Society of Testing and Materials, 1972.

[21] Harmathy, T. Z., "Design Approach to Fire Safety in Buildings," *Progressive Architecture*, April 1974, pp. 82-87, National Research Council of Canada, Ottawa, NRCC 14076.

[22] Harmathy, T.Z., "A New Look at Compartment Fires Part I and Part II," *Fire Technology*, Vol. 8, No. 3 and No. 4, 1972, pp. 196-217, 326-351.

[23] Robertson, A. F. and Gross, Daniel, "Fire Load, Fire Severity, and Fire Endurance," Fire Test Performances, ASTM, STP 464, American Society of Testing and Materials, 1970.

[24] Ingberg et al., "Combustible Contents in Buildings," National Bureau of Standards BMS 149, July 1957.

[25] Heselden, A. J. M., "Parameters Determining the Severity of Fire," Symposium No. 2, Her Majesty's Stationery Office, 1968, London. Proceedings of the Symposium held at the Fire Research Station, Boreham Woods, Herts (England), January 1967.

[26] Gross, Daniel and Robertson, A. F., "Experimental Fires in Enclosures," Tenth Symposium (International) on Combustion, The Combustion Institute, 1965, pp. 731-942.

[27] Harmathy, T. Z., "Performance of Building Elements in Spreading Fire," DBR Paper No. 752, National Research Council of Canada, NRCC 16477, *Fire Research*, Vol. 1, 1977/1978, pp. 119-132.

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 ASTM Publications.

American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM C569, *Standard Test Method for Indentation Hardness of Performed Thermal Insulation*, 1983 (Discontinued 1989).

ASTM Research Report E05-1004, Research Report: *Support Data for Alternate Pads for E119 and B152*, May 1982.

NFPA 253

1995 Edition

Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source

1995 Edition

This edition of NFPA 253, *Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source*, was prepared by the Technical Committee on Fire Tests 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.

The 1995 edition of this document has been approved by the American National Standards Institute.

Origin and Development of NFPA 253

Experience suggests that during the early stages of a fire, floor covering systems seldom have acted as a fire spread medium. However, in a few fires involving multiple occupancy buildings, the floor covering materials in corridors were primarily responsible for fire spread over a considerable distance. This caused grave concern and pointed to the need for a realistic test to evaluate the flame spread of floor covering systems.

The flooring radiant panel test had its inception with the Armstrong Cork Company in 1966. In 1972, conceptualization of critical radiant flux (W/cm^2 at extinguishment) as a measure of flame spread hazard was underway at the National Bureau of Standards. It was determined in the course of NBS work on model corridor fire tests that the radiant energy levels incident on the floor covering had a considerable influence on whether or not flaming combustion would propagate. Accordingly, it was natural to apply the critical radiant flux concept, and, in 1973, the National Bureau of Standards prepared a draft of the flooring radiant panel test.

In 1975, the Technical Committee on Fire Tests began its evaluation of the proposed test methods, which culminated in the adoption of this test as an official NFPA standard in May 1978. The standard was revised in 1984 and 1990.

The 1995 edition includes significant improvements based on work conducted by NIST and the carpet industry. These findings improve the overall application of the standard and provide measured improvement in test precision. Other changes include a new pilot burner and reduction of the variation in the airflow through the chamber, which reduces the variability of data. Revisions also were made to eliminate “permissive” language. These revisions create closer harmony with ASTM E648, *Standard Test Method for Critical Radiant Flux of Floor-Covering Systems Using a Radiant Heat Energy Source.*

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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.

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 253

Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source

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 E.

Chapter 1 General

1-1 Scope.

1-1.1

This fire test response standard describes a procedure for measuring critical radiant flux behavior of horizontally mounted floor covering systems exposed to a flaming ignition source in a graded, radiant heat energy environment within a test chamber. The specimen can be mounted over underlayment or over a simulated concrete structural floor, bonded to a simulated structural floor, or otherwise mounted in a typical and representative way.

1-1.2

This fire test response standard measures the critical radiant flux at flameout. It provides a basis for estimating one aspect of fire exposure behavior for floor covering systems.

The imposed radiant flux simulates the thermal radiation levels likely to impinge on the floors of a building whose upper surfaces are heated by flames or hot gases, or both, from a fully developed fire in an adjacent room or compartment. The standard was developed to simulate an important fire exposure component in fires that develop in corridors or exitways of buildings and is not intended for routine use in estimating flame spread behavior of floor covering in building areas other than corridors or exitways. Appendix F provides information on the proper application and interpretation of the results of this test.

1-1.3

The values stated in SI units are to be regarded as the standard.

1-1.4

This standard shall be used to measure and describe the response of materials, products, or assemblies to heat and flame under controlled conditions and shall not be used to describe or appraise the fire hazard or fire risk of materials, products, or assemblies under actual fire conditions. However, the results of the test shall be permitted to be used as elements of a fire hazard assessment or a fire risk assessment that takes into account all factors that are pertinent to an assessment of the fire hazard or fire risk of a particular end use.

1-1.5

This standard does not purport to address all safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use. Specific safety precautions are provided in Chapter 4.

1-2 Significance and Use.

1-2.1

This fire test response standard is designed to provide a basis for estimating one aspect of the fire exposure behavior of a floor covering system installed in a building corridor. The test environment simulates conditions that have been observed and defined in full-scale corridor experiments.

1-2.2

The test is suitable for regulatory statutes, specification acceptance, design purposes, or development and research.

1-2.3

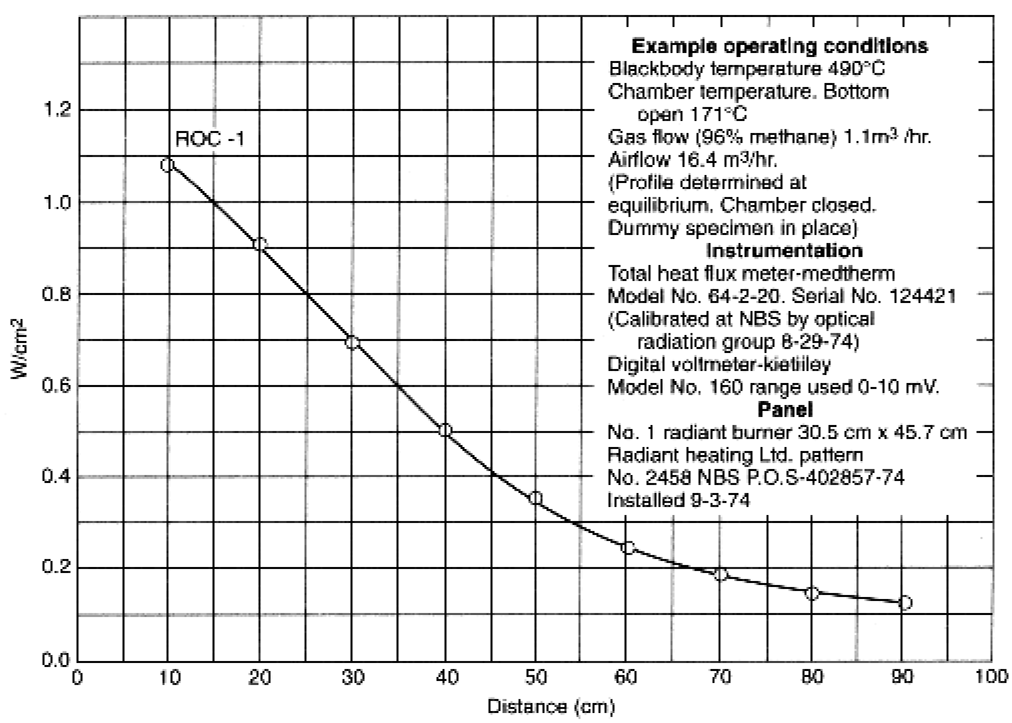
The fundamental assumption inherent in the test is that “critical radiant flux” is one measure of the sensitivity to flame spread of floor covering systems located in a building corridor.

1-2.4

The test is applicable to floor covering system specimens that follow or simulate accepted installation practice. Tests on the individual elements of a floor system are not valid for evaluation of the flooring system.

1-3 Summary of Test Method.

The basic elements of the test chamber include an air-gas-fueled radiant heat energy panel inclined at 30 degrees to and directed at a horizontally mounted floor covering system specimen. The radiant panel generates a radiant energy flux distribution along the 100-cm length of the test specimen from a nominal maximum of 1.0 W/cm^2 to a minimum of 0.1 W/cm^2. The test is initiated by open-flame ignition from a pilot burner. The distance burned to flameout is converted to W/cm^2 from the flux profile graph shown in Figure 1-3 and is reported as critical radiant flux W/cm^2.



Note: in. = cm x 0.3937; Btu/ft^2 • sec = W/cm^2 x 1.135.

Figure 1-3 Standard radiant heat energy flux profile.

1-4 Definitions.

Blackbody Temperature. The temperature of a perfect radiator; a surface with an emissivity of unity and, therefore, a reflectivity of zero (0).

Corridor. An enclosed space connecting a room or compartment with an exit. The corridor includes normal extensions, such as lobbies and other enlarged spaces.

Critical Radiant Flux. The level of incident radiant heat energy on the floor covering system at the most distant flameout point. It is reported as W/cm^2.

Flameout. The time at which the last vestige of flame or glow disappears from the surface of the test specimen, frequently accompanied by a final puff of smoke; time zero (0) is the time at which the specimen is moved into the chamber and the door is closed. (*See Section 6-3.*)

Floor Covering. A separate or secondary surface applied over a flooring and including underlayment materials, carpeting, resilients, and coating systems.

Floor Covering System. A flooring or a combination of flooring and floor covering.

Flooring. A primary floor surface or a final floor surface.

Flux Profile. The curve of incident radiant heat energy on the specimen plane relative to the distance from the point of initiation of flaming ignition (i.e., 0 cm).

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Standard Cushion. *Type II — Rubber Coated Jute and Animal Hair or Fiber*, Federal Specification DDD-C-001023 (GSA-FSS), Amendment 1, March 10, 1972 (minimum 9.53 mm thick, 1.47 kg/0.836 m^2).

Standard Simulated Concrete Subfloor. Uncoated fiber-reinforced cement board with a nominal thickness of 6.3 mm and a density of 1762 $kg/m^3 \pm 80$ kg/m^3.

Total Flux Meter. The instrument used to measure the level of radiant heat energy incident on the specimen plane at any point.

Chapter 2 Test Apparatus

2-1 Radiant Panel Test Apparatus.

The apparatus shall be essentially as shown in Figures 2-1(a) and (b).

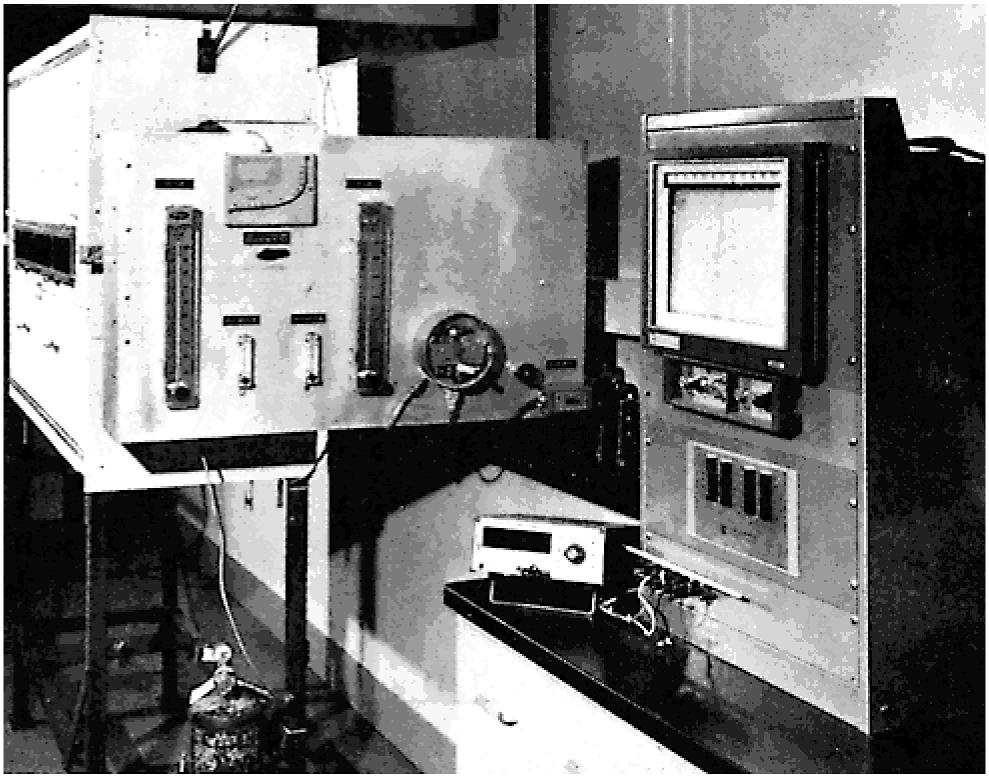


Figure 2-1(a) Flooring radiant panel test apparatus.

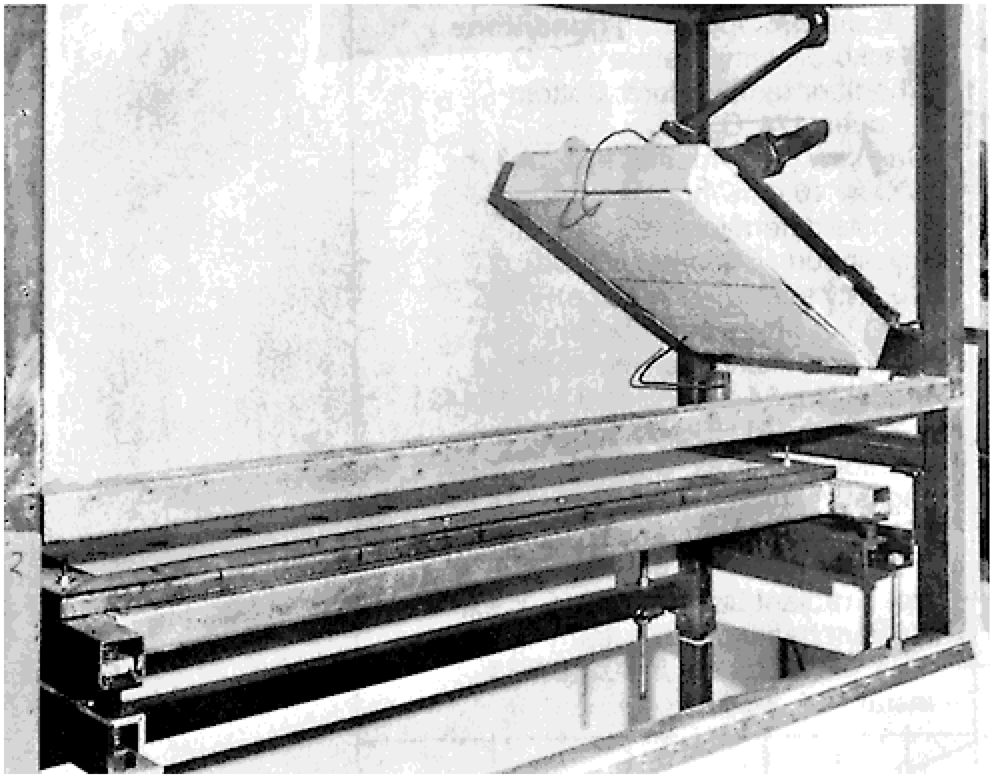


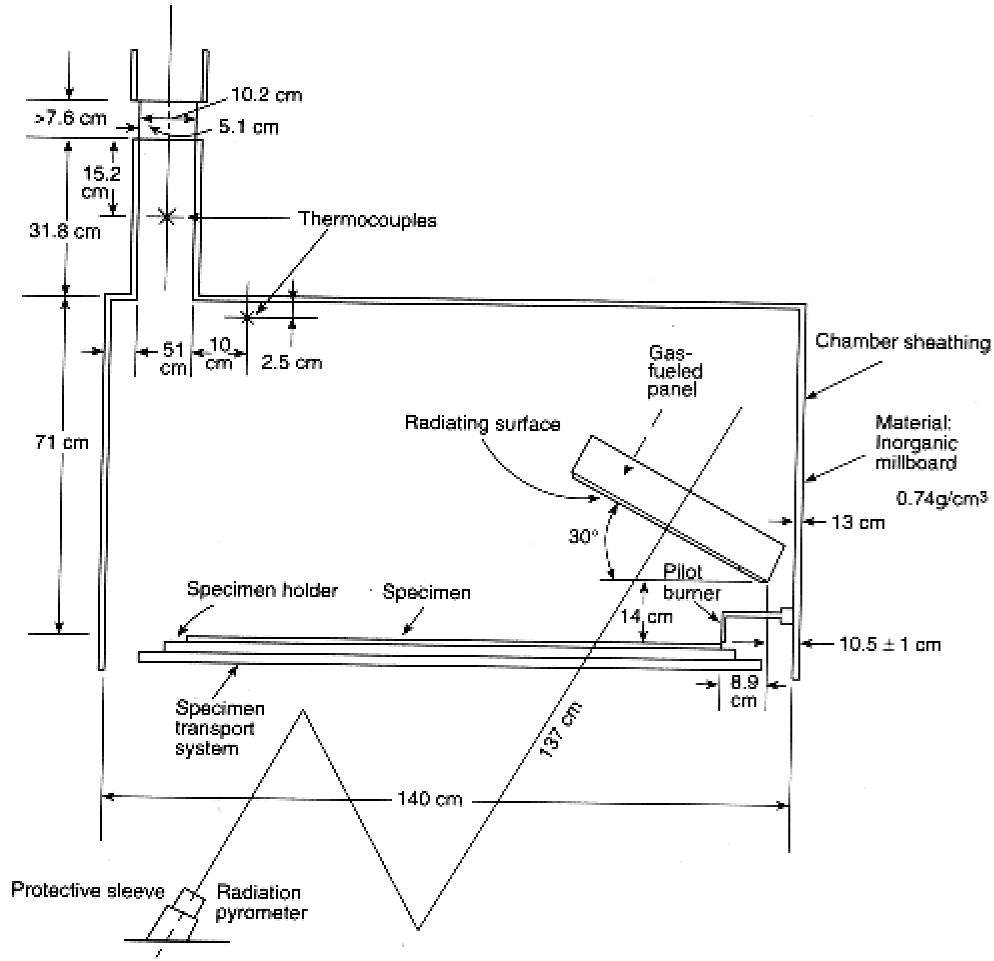
Figure 2-1(b) Flooring radiant panel test showing carpet specimen and gas-fueled panel.

2-2 Test Chamber.

The flooring radiant panel test chamber employed for this test shall be located in a draft-protected laboratory.

2-2.1

The flooring radiant panel test chamber [*see Figures 2-2.1(a) and (b)*] shall consist of an enclosure 1400 mm long × 500 mm wide × 710 mm high above the test specimen. The sides, ends, and top shall be of 13-mm calcium silicate board, of 0.74 g/cm^3 nominal density insulating material, and shall have a thermal conductivity at 177°C of 0.128 W/(m•K). One side shall be provided with an approximately 100-mm × 1100-mm, draft-tight, fire-resistant glass window so that the entire length of the test specimen can be observed from outside the fire test chamber. On the same side and below the observation window, there shall be a door that, when open, allows the specimen platform to be moved out for mounting or removal of test specimens. Where necessary for observation, a draft-tight, fire-resistant observation window shall be installed at the low flux end of the chamber.



Note: in. = cm x 0.3937.

Figure 2-2.1(a) Flooring radiant panel tester schematic (side elevation).

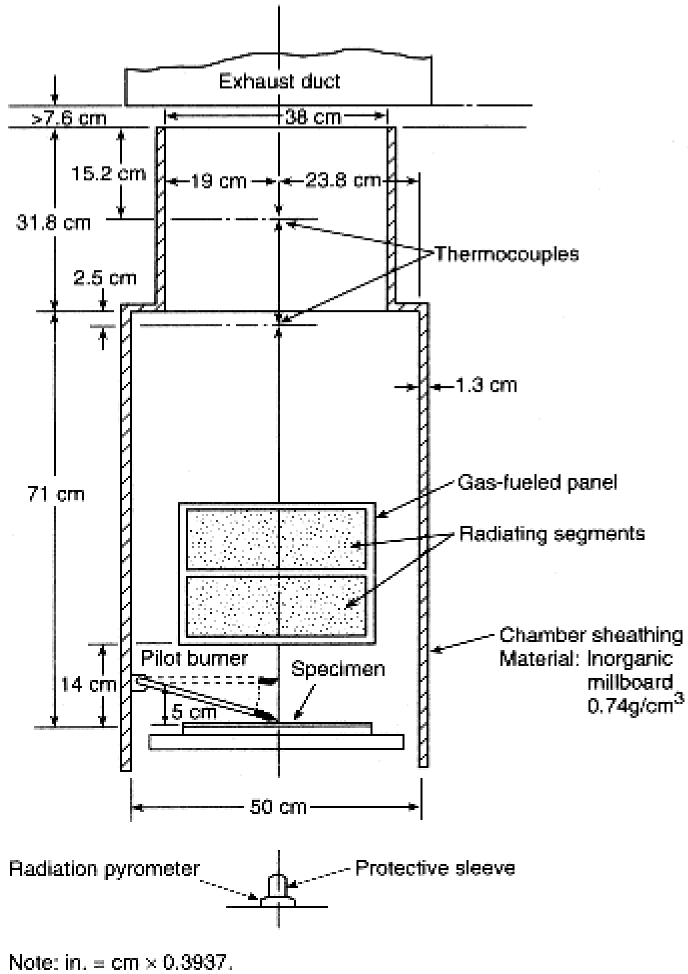


Figure 2-2.1(b) Flooring radiant panel tester schematic (low flux elevation).

2-2.2

The bottom of the test chamber shall consist of a sliding steel platform that has provisions for rigidly securing the test specimen holder in a fixed and level position.

2-2.2.1 The test specimen holder shall be level when in place and shall be secured to the specimen mounting platform.

2-2.2.2 The free, or air access, area around the platform shall be 2580 cm^2 to 3225 cm^2.

2-2.3

The top of the chamber shall have an exhaust stack with interior dimensions of 102 mm ± 3 mm wide × 380 mm ± 3 mm deep × 318 mm ± 3 mm high at the opposite end of the chamber from the radiant panel.

2-3 Radiant Heat Energy Source.

(a) The radiant heat energy source shall be a panel consisting of a porous refractory material mounted in a cast-iron frame or steel frame and having a radiation surface of 305 mm × 457 mm. It shall be capable of operating at temperatures up to 816°C.

(b) The panel fuel system shall consist of a venturi-type aspirator for mixing gas and air at approximately atmospheric pressure, a clean, dry air supply capable of providing 28.3 NTP m^3/hr at 76 mm of water column, and suitable instrumentation for monitoring and controlling the flow of fuel to the panel. The radiant heat energy panel shall be fired by propane, methane, or natural gas.

2-3.1

The radiant heat energy panel shall be mounted at 30 degrees to the horizontal specimen plane. The horizontal distance from the zero (0) mark on the specimen fixture to the bottom edge (projected) of the radiating surface of the panel shall be 89 mm.

The panel-to-specimen vertical distance shall be 140 mm [*see Figures 2-2.1(a) and (b)*]. The angle and dimension given above shall be followed to obtain the required radiant flux profile.

2-3.2

The radiation pyrometer for standardizing the thermal output of the panel shall be suitable for viewing a circular area 254 mm in diameter at a distance of about 1.37 m. It shall be calibrated over an operating blackbody temperature range of 490°C to 510°C in accordance with the procedure described in Appendix B.

2-3.3

A high impedance voltmeter or potentiometric voltmeter with a suitable millivolt range shall be used to monitor the output of the radiation pyrometer described in 2-3.2.

2-4* Specimen Holder.

The specimen holder (*see Figure 2-4*) shall be constructed from heat-resistant stainless steel having a thickness of 1.98 mm, and an overall dimension of 1140 mm × 320 mm, with a specimen opening of 200 mm × 1000 mm. Six slots shall be cut in the flange on either side of the holder to reduce warping. The holder shall be fastened to the platform with two stud bolts at each end.

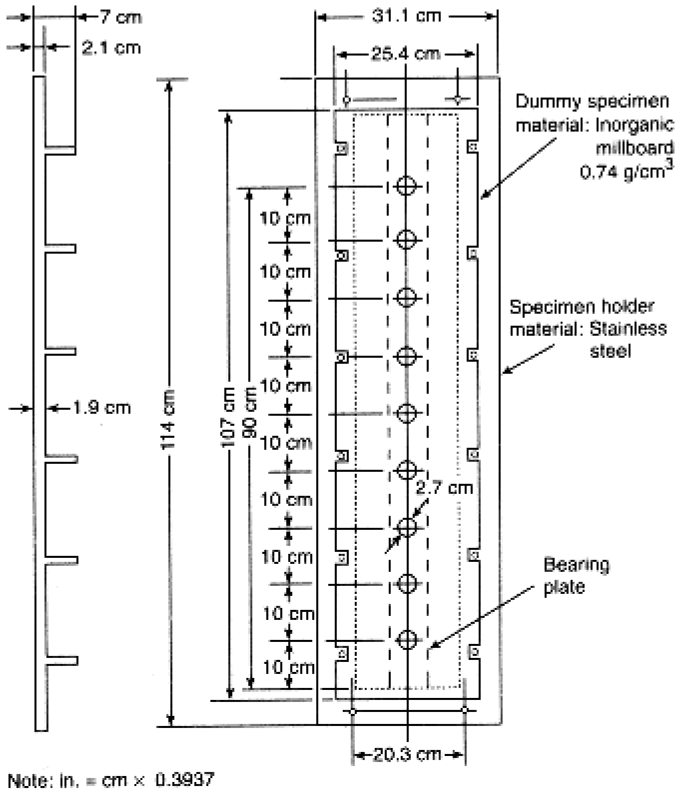


Figure 2-4 Dummy specimen in specimen holder.

2-5 Pilot Burner.

2-5.1

The pilot burner used to ignite the specimen shall be a nominal 6-mm inside diameter, 10-mm outside diameter stainless steel tube line burner having nineteen evenly spaced 0.7-mm diameter (no. 70 drill) holes drilled radially along the centerline and sixteen evenly spaced 0.7-mm diameter (no. 70 drill) holes drilled radially 60 degrees below the centerline (*see Figure 2-5.1*). In operation, the gas flow is adjusted to a flow rate of 0.085 m^3/hr to 0.100 m^3/hr (air scale). With the gas flow properly adjusted and the pilot burner in the test position, the pilot flame shall extend from approximately 63.5 mm at either end to approximately 127 mm at the center.

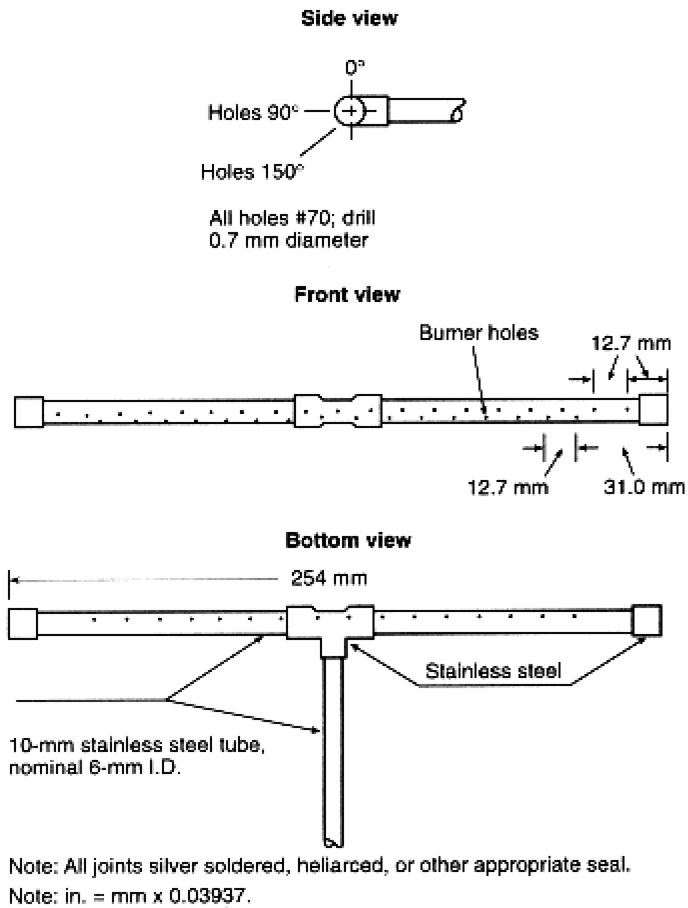


Figure 2-5.1 Pilot burner.

2-5.1.1 The pilot burner shall be positioned no more than 5 degrees from the horizontal, so that the flame generated impinges on the specimen at the zero (0) distance burned point [*see Figures 2-2.1(a) and (b)*]. When not being applied to the specimen, the burner shall be capable of being moved at least 50 mm away from the specimen.

2-5.1.2 The holes in the pilot burner shall be kept clean. A soft wire brush shall be used to remove surface contaminants. Nickel-chromium or stainless steel wire or its equivalent with an outside diameter of 0.5 mm shall be used for opening the holes.

2-6 Thermocouples.

2-6.1

A 3.2-mm stainless steel-sheathed, grounded junction, Chromel-Alumel thermocouple shall be located in the flooring radiant panel test chamber. [*See Figures 2-2.1(a) and (b).*]

2-6.1.1 The thermocouple shall be kept clean to ensure the accuracy of the readout.

2-6.1.2 The chamber thermocouple shall be located in the longitudinal central vertical plane of the chamber, 25 mm down from the top and 102 mm back from the inside of the exhaust stack.

2-6.2

An indicating potentiometer with a range of 100°C to 500°C shall be used to determine the chamber temperature prior to the test.

2-7* Exhaust Hood.

An exhaust duct with a capacity of 28.3 NTP m^3/min to 85 NTP m^3/min, decoupled from the chamber stack by at least 76 mm on all sides, and with an effective canopy area larger than the plane area of the chamber with the specimen platform in the out position, shall be used to remove combustion products from the chamber. With the panel turned on and the dummy specimen in place, the airflow rate through the stack shall be 76.2 m/min ± 15.2 m/min when measured with a hot wire anemometer 30 seconds after insertion of the probe into the center of the stack opening at a distance of 152 mm down from the top of the stack opening.

2-8 Dummy Specimen.

2-8.1

The dummy specimen, which is used in the flux profile determination, shall be made of 19-mm inorganic calcium silicate board, with a nominal density of 0.74 g/cm^3 (*see Figure 2-4*). It shall measure 250 mm × 1070 mm with 27-mm diameter holes located on the centerline at points ranging from 100 mm to 900 mm, spaced in 100-mm increments, starting at the maximum flux end of the specimen.

To provide proper and consistent seating of the flux meter in the hole openings, a stainless steel or galvanized steel bearing plate shall be mounted and secured firmly to the underside of the calcium silicate board with holes corresponding to those specified above. The bearing plate shall run the length of the dummy specimen and shall have a minimum width of 76 mm. The thickness of the bearing plate shall vary to maintain the flux meter height specified in 5-1.6 up to the maximum of 3.2 mm.

2-8.1.1* The total heat flux transducer used to determine the flux profile of the chamber in conjunction with the dummy specimen (*see 2-3.3*) shall have a range of 0 W/cm^2 to 1.5 W/cm^2 and shall be calibrated over the operating flux level range of 0.10 W/cm^2 to 1.5 W/cm^2 in accordance with the procedure outlined in Appendix B. A source of cooling water at 15°C to 25°C shall be provided for this instrument.

2-8.1.2 A high impedance voltmeter or potentiometric voltmeter with a range of 0 mv to 10 mv and reading to 0.01 mv shall be used to measure the output of the total heat flux transducer during the flux profile determination.

2-9 Timer.

A timer reading to the nearest 0.1 minute shall be used to measure preheating, pilot contact, and flameout times.

Chapter 3 Test Specimens

3-1 Sampling Procedure.

3-1.1

The sample selected for testing shall be representative of the product.

3-1.2

ASTM sampling practice shall be followed.

3-2 Specimen Size and Mounting.

3-2.1

The test specimen shall be a floor covering system sized to provide for adequate clamping in the mounting frame. Its minimum dimensions shall exceed the frame width (200 mm nominal) and length (1000 mm nominal) by about 50 mm. Holes shall be made in the specimen to accommodate the mounting frame bolts. (*See Figure 2-4.*)

3-2.2

The floor covering system specimen shall simulate actual installation practice insofar as possible. Typical examples of floor covering systems are as follows:

(a) A hardwood floor nailed to a plywood subfloor, sanded and finished according to standard practice;

(b) A carpet with or without integral cushion pad bonded to a high density inorganic sheet simulating a concrete subfloor;

(c) A carpet mounted over the standard cushion or the standard simulated concrete subfloor;

(d) A carpet mounted over the actual cushion pad or a carpet mounted over the actual subfloor to be used in the installation;

(e) A resilient floor bonded to a high density inorganic sheet simulating a concrete subfloor.

3-2.3

A minimum of three specimens per sample shall be tested.

3-3 Specimen Conditioning.

Test specimens shall be conditioned at 21°C ± 3°C and a relative humidity of 50 percent ± 5 percent horizontally or vertically in open racks for optimum air circulation for a minimum of 48 hours; carpet specimens that have been glued down shall be conditioned for a minimum of 96 hours. Conditioning shall be conducted in accordance with ASTM E171, *Standard Specification for Standard Atmospheres for Conditioning and Testing Flexible Barrier Materials*.

Chapter 4 Safety Precautions

4-1 Gas-Air Fuel Explosions.

The possibility of a gas-air fuel explosion in the test chamber shall be recognized. Suitable safeguards consistent with sound engineering practice shall be installed in the panel fuel supply system. Safeguards shall include one or more of the following:

(a) A gas feed cutoff activated when the air supply fails;

(b) A fire sensor directed at the panel surface that stops fuel flow when the panel flame goes out;

(c) A commercial gas water heater or gas-fired furnace pilot burner control thermostatic shutoff that is activated when the gas supply fails, or other suitable approved device.

Safeguards shall be arranged for a manual reset.

4-2 Exhaust System.

The exhaust system shall be designed and operated so that the laboratory environment is protected from smoke and gas. Operator exposure to combustion products shall be minimized by following sound safety practice. The operator shall ensure that the exhaust system is working properly and shall wear appropriate clothing, including gloves.

Chapter 5 Radiant Heat Energy Flux Profile Standardization

5-1 Procedure.

5-1.1

In a continuing program of tests, the flux profile shall be determined at least weekly. Where the time interval between tests is greater than one week, the flux profile shall be determined at the start of the test series.

5-1.2

The dummy specimen shall be mounted in the mounting frame, and the assembly shall be attached to the sliding platform.

5-1.3

With the sliding platform outside the chamber, the radiant panel shall be ignited. The unit shall heat for $1^1/_2$ hours. The pilot burner shall be off during this determination. The fuel mixture shall be adjusted to provide an air-rich flame. Fuel flow shall be set to bring the panel blackbody temperature to about 500°C, and the chamber temperature shall be recorded.

5-1.4

When equilibrium has been established, the specimen platform shall be moved into the chamber and the door shall be closed.

5-1.5

The closed chamber shall be allowed to equilibrate for 30 minutes.

5-1.6

The radiant heat energy flux level shall be measured at the 400-mm point with the total flux meter instrumentation. This shall be accomplished by inserting the flux meter into the opening so that its detecting plane is 1.6 mm to 3.2 mm above and parallel to the plane of the dummy specimen and then reading its output after 30 sec ± 10 sec. If the level is within the limits specified in 5-1.7, the flux profile determination shall be started. Otherwise, the necessary adjustments in panel fuel flow shall be made. Data shall be recorded using the flux profile data log format shown in Appendix D, or equivalent.

5-1.7

The test shall be run under chamber operating conditions that provide a flux profile as shown in Figure 1-3. The radiant heat energy incident on the dummy specimen shall be as follows:

(a) Between 0.87 W/cm^2 and 0.95 W/cm^2 at the 200-mm point;

(b) Between 0.48 W/cm^2 and 0.52 W/cm^2 at the 400-mm point; and

(c) Between 0.22 W/cm^2 and 0.26 W/cm^2 at the 600-mm point.

5-1.8

The flux meter shall be inserted into the 100-mm opening following the procedure outlined in 5-1.6. The mv output shall be read at 30 sec ± 10 sec. The same procedure shall be repeated at the 200-mm point. The 300-mm to 900-mm flux levels shall be determined in the same manner. Following the 900-mm measurement, a reading check shall be made at 400 mm. The test chamber is in calibration when it is within the limits set forth in 5-1.7 and the profile determination is completed. Otherwise, the fuel flow shall be adjusted carefully, allowing 30 minutes for equilibrium, and the procedure shall be repeated.

5-1.9

The radiant heat energy flux data shall be plotted as a function of distance along the specimen plane on rectangular coordinate graph paper. The best smooth curve shall be drawn carefully through the data points. This curve is hereafter referred to as the flux profile curve.

5-1.10

The open chamber temperature and radiant panel blackbody temperature identified with the standard flux profile shall be determined by opening the door and moving the specimen platform outside the chamber. The chamber shall be allowed to equilibrate for 30 minutes. The chamber temperature and optical pyrometer output that indicate the panel blackbody temperature shall be read and recorded in degrees Celsius. These temperature settings shall be used in subsequent test work instead of measuring the dummy specimen radiant flux at 200 mm, 400 mm, and 600 mm.

Chapter 6 Test Procedure

6-1 Pretest Heating.

With the sliding platform outside the chamber, the radiant panel shall be ignited. The unit shall be allowed to heat for $1^1/_2$ hours. A sheet of inorganic millboard, such as calcium silicate, or equivalent, shall be used to cover the opening when the hinged portion of the front panel is open and the specimen platform is moved out of the chamber. The millboard shall be used to prevent heating of the specimen and to protect the operator. The panel blackbody temperature and the chamber temperature shall be read. If these temperatures are in agreement to within ± 5°C of those determined in accordance with 5-1.10, the chamber is ready for use.

6-2 Sample Mounting.

The sample holder shall be inverted on a workbench and the flooring system shall be inserted. The steel bar clamps shall be placed across the back of the assembly and the nuts shall be tightened firmly. The sample holder shall be returned to its upright position, the test surface shall be cleaned with a vacuum, and the sample holder shall be mounted on the specimen platform. Carpet specimens shall be brushed to raise the pile to its normal position.

6-3 Ignition of Pilot Burner.

The pilot burner shall be ignited, keeping it at least 50 mm away from the specimen, the specimen shall be moved into the chamber, and the door shall be closed. The timer shall be started. After 5 minutes, the chamber shall be preheated. With the pilot burner on and at least 50 mm away from the specimen, the pilot burner flame shall be brought into contact with the specimen at the zero (0) mm mark. The pilot burner flame shall remain in contact with the specimen for 5 minutes. It then shall be removed to a position at least 50 mm away from the specimen and the pilot burner flame shall be extinguished.

6-4 Flame Propagation of Specimen.

If the specimen does not propagate flame within 5 minutes following pilot burner flame application, the test shall be terminated. For specimens that do propagate flame, the test shall be continued until the flame goes out. Significant phenomena such as melting, blistering, and penetration of flame to the substrate shall be observed and recorded.

6-5 Completion of Test.

When the test is completed, the door shall be opened and the specimen platform shall be pulled out. The protective inorganic millboard sheet shall be put in place.

6-6 Data Collection and Recording.

The distance burned shall be measured (i.e., the point of farthest advance of the flame front to the nearest 1 mm). The distance to W/cm^2 critical radiant heat flux at flameout shall be converted from the flux profile curve. Data shall be recorded using the data log format shown in Appendix D, or equivalent.

6-7 Removal of Specimen.

The specimen and its mounting frame shall be removed from the movable platform.

6-8 Subsequent Testing.

The succeeding test shall be started as soon as the panel blackbody and chamber temperatures are verified (*see 5-1.10*). The test assembly shall be at room temperature prior to start-up.

Chapter 7 Calculations

7-1 General.

The mean, standard deviation, and coefficient of variation of the critical radiant flux test data on the three specimens shall be calculated in accordance with ASTM Manual 7, *Manual on Quality Control of Materials*.

$$S = \sqrt{\frac{(\Sigma X^2 - n\bar{X}^2)}{n - 1}} \quad \text{and} \quad V = \frac{S}{X} \times 100$$

where:

S = Estimated standard deviation

X = Value of single observation

n = Number of observations

X = Arithmetic mean of the set of observations

V = Coefficient of variation.

Chapter 8 Report

8-1 Required Information.

The report shall include the following:

(a) Description of the floor covering system tested, including its elements;

(b) Description of the procedure used to assemble the floor covering system specimen;

(c) Number of specimens tested;

(d) Individual values of critical radiant flux;

(e) Average critical radiant flux, standard deviation, and coefficient of variation;

(f) Observations of the burning characteristics of the specimen during the testing exposure, such as delamination, melting, sagging, and shrinking.

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 ASTM Publications.

American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM, Manual 7, *Manual on Quality Control of Materials*.

ASTM E171, *Standard Specification for Standard Atmospheres for Conditioning and Testing Flexible Barrier Materials*, 1994.

9-1.2 U.S. Government Publication.

General Services Administration, 18th and F Streets NW, Washington, DC 20405.

Type II—Rubber Coated Jute and Animal Hair or Fiber, Federal Specification DDD-C-001023 (GSA-FSS), Amendment 1, March 10, 1972.

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

An acceptable heat-resistant stainless steel is AISI Type 300 (UNA-NO8 330) or equivalent.

A-2-7

An acceptable anemometer is an Omega HH-615 HT hot-wired anemometer manufactured by Omega Engineering Inc., Stamford, CT.

A-2-8.1.1 An acceptable heat flux transducer is a Schmidt-Boelter-type Medtherm 64-2-20, manufactured by Medtherm Corporation, Huntsville, AL.

Appendix B Procedure for Calibration of Apparatus

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

B-1 Radiation Pyrometer.

B-1.1

The radiation pyrometer should be calibrated by means of a conventional blackbody enclosure placed within a furnace and maintained at uniform temperatures of 490°C, 500°C, and 510°C. The blackbody enclosure can consist of a closed Chromel metal cylinder with a small sight hole in one end. The radiation pyrometer is sighted on the opposite end of the cylinder where a thermocouple indicates the blackbody temperature. The thermocouple is placed within a drilled hole and in good thermal contact with the blackbody. When the blackbody enclosure has reached the appropriate temperature equilibrium, the output of the radiation pyrometer should be read. This procedure is repeated for each temperature.

B-1.2

As an alternative to the procedure described in B-1.1, a laboratory may be permitted to utilize the services of an outside agency to provide calibration traceable to the National Institute of Standards and Technology (NIST).

B-2 Total Heat Flux Meter.

B-2.1

The total flux meter should be developed by transfer calibration methods with a NIST-calibrated flux meter. This calibration should make use of the flooring radiant panel tester as the heat source. Measurements should be made at each of the nine dummy specimen positions, and the mean value of these results should be used to constitute the final calibration.

B-2.2

Each laboratory should maintain a dedicated, calibrated reference flux meter against which one or more working flux meters can be compared as needed. The working flux meters should be calibrated at least annually.

Appendix C Mounting Methods

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

C-1 Introduction.

This appendix has been compiled as an aid in selecting a method for mounting various flooring materials in the fire test chamber. These mountings are recommended for test method uniformity and convenience.

C-2 Mounting Procedures.

C-2.1 Carpet and Cushion Pad over Concrete, Simulated.

Carpet specimens should be cut in the machine direction To mount a specimen, the holder should be inverted on a clean, flat surface. The test specimen should be inserted into the holder. The cushion pad then is inserted with the pattern side facing the carpet, followed by nominal 6.3-mm thick, fiber-reinforced, high density (762 kg/m^3 ± 80 kg/m^3) cement board and a 13-mm inorganic millboard with a density of 0.74 g/cm^3.[1] Finally, the steel bar clamps should be placed across the assembly and tightened firmly. The test assembly should be mounted on the specimen transport frame so that the pile lay faces the panel.

[1]The fiber-reinforced cement board might spall during a test. This can be avoided by heating for 12 hours at 163°C.

C-2.2

Carpet with or without Integral Cushion Pad Bonded to Concrete, Simulated. Carpet specimens should be cut in the machine direction. The adhesive used should be that which is recommended by the carpet manufacturer.[2] The adhesive needs to be applied to the smooth side of the fiber-reinforced cement board in accordance with the directions provided by the adhesive manufacturer.[3] A nominal 9.1-kg roller with a diameter of 76 mm and a width approximately that of the specimen should be used to apply the adhesive across the top of the specimen to ensure good contact with the substrate. Specimens may be permitted to be stacked under a dead load after bonding specimens to the fiber-reinforced cement board for no more than 24 hours prior to conditioning (*see Section 3-3 for storage and conditioning requirements*). The specimen should be mounted in the testing frame as described in C-2.1 and should be tested in accordance with standard procedure.

[2]In the absence of a manufacturer's recommendation, a multipurpose adhesive typical of commercial installation shall be selected by the laboratory.

[3]In the absence of a manufacturer's recommendation, the adhesive should be applied with a 3.2-mm V-notched trowel.

C-2.3 Carpet, Other.

The actual subfloor may be permitted to be substituted for the standard fiber-reinforced cement board substrate.

C-3 Resilient Flooring.

Commercial installation practice should be followed or simulated, or both. In most instances, this necessitates bonding to the standard fiber-reinforced cement substrate.

C-4 Hardwood Flooring.

Commercial installation practice should be followed or simulated, or both. In a typical system, the substrate is a 16-mm plywood sheet covered with building paper. The oak flooring strips are nailed to the plywood and then sanded, sealed, and waxed. The assembly should be tested with the moisture content of the oak at 7 percent to 8 percent.

Appendix D Sample Data Log

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

D-1 Radiant Flux Profile Data Log.

Date ______________________________

Blackbody temperature __________ mv __________ °C

Gas flow ______________________ NTP m^3/hr

Airflow ______________________ NTP m^3/hr

Room temperature ______________________ °C

Pressure: Air ________ cm of H_2O; Gas __________ cm of H_2O

Flux meter radiometer no. ______________

Conversion factor from calibration on ______________

Distance (cm)	**mv**	**W/cm^2**
10	____________	____________
20	____________	____________
30	____________	____________
40	____________	____________
50	____________	____________
60	____________	____________
70	____________	____________
80	____________	____________
90	____________	____________

Signed ______________________________

D-2 Flooring Radiant Panel Test Data Log.

Test no. ______________ Date ________________ Time ______________________

Laboratory ____

Specimen identification/code no. ____

Test Assembly

Panel: Angle __________ degrees; Temperature ______________ °C

Flow: Gas ____________ NTP m^3/hr; Air ______________ NTP m^3/hr

Pressure, initial:

Air ______________ cm of H_2O; Gas ______________ cm of H_2O

Chamber temperature:

Initial ________________ °C; Maximum ______________ °C

Room temperature ____ °C

Hood draft ____ cm of H_2O

Flame Front Advance

Distance (cm)	Time (min)				
__________	__________	__________	__________	__________	__________
__________	__________	__________	__________	__________	__________
__________	__________	__________	__________	__________	__________
__________	__________	__________	__________	__________	__________
__________	__________	__________	__________	__________	__________
__________	__________	__________	__________	__________	__________
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__________	__________	__________	__________	__________	__________
__________	__________	__________	__________	__________	__________
__________	__________	__________	__________	__________	__________

Total burn length ____ cm

Critical radiant flux ____ W/cm^2

Flame front out ______________ min; Flux profile reference ______________________

All flame out ______________________________________ min

Observations

Signed ____

Appendix E Commentary on Critical Radiant Flux Test

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

E-1 Introduction.

E-1.1

The development and behavior of fires in buildings and rooms or compartments are complex phenomena and are not well understood. As a result, efforts to establish safety requirements must, for the present, be based on the selection and use of those components of the fire system that might become involved and that can be regulated. These efforts, together with experienced engineering rationale, must serve until a more valid technical basis for fire engineering design has been determined.

E-1.2

When fire develops in a building, experience suggests that the traditional floor covering systems have seldom served as a medium for fire spread during the early stages of a fire. During several fires in the early 1970s, floor covering materials in corridors became involved for considerable distances. The test method that is described in this standard has been recommended as a means to control potential fire spread in floor covering systems.

E-1.3

Since the quantity and nature of room furnishing items cannot at present be controlled with regard to fire involvement of the full room, it is necessary to assume that floor involvement can and will, on occasion, occur. It is appropriate to recommend the application of only those floor covering systems meeting high levels of resistance to fire involvement based on critical radiant flux for use in corridors. Building codes cover interior finish in general, and it appears that only in corridors do the requirements for floor covering systems need to be more restrictive.

E-1.4

This appendix is intended to provide information on the technical relevance of the test method to the problem of fires. It is intended to provide both the technical and lay public with a basis for interpreting the significance and limitations of the data resulting from the test.

E-2 Nature of the Test.

E-2.1

Convective heat flow cannot serve as a major feedback mechanism in most cases of fires involving floor covering systems because of the buoyancy of the flames and hot gases. Therefore, these horizontal surfaces of building finishes seldom have been recognized as primary hazards in the spread of flames. However, corridor fire tests conducted at NIST together with building fire incidents have indicated that fire spread can occur in corridors exposed to burnout conditions in adjacent rooms.[1, 2] Fires were observed to propagate the full length of the corridor where little, if any, combustible other than the floor covering system was involved in the corridor finish. Analysis of the measurements made during such tests has made clear the importance of radiant heat transfer from upper corridor surfaces, flame, smoke, and gases in serving a fire-support role. Therefore, the sensitivity of a floor covering system to the radiant support of combustion is recommended as a basis for ranking floor covering systems with respect to fire behavior.[3,4] Critical radiant flux, the heat flux level below which surface flame spread will not occur, was selected as the floor covering system fire property of controlling importance. If a room fire does not impose a radiant flux that exceeds this critical level on a corridor floor covering system, flame spread will not occur.

E-2.2

Critical radiant flux does not provide information on the irradiance level to which the flooring is exposed when fire occurs. This is influenced largely by other variables that include:

(a) The nature, quantity, and arrangement of the fire load in the compartment where ignition occurs.

(b) The ventilation conditions in the portion of the building that becomes exposed to fire.

(c) The geometry of the compartment and ventilation passages.

(d) The heat release rate of the fire load and the floor covering system.

(e) The heat capacity of the enclosing walls, ceiling, and floors.

E-3 Experimental Studies of Relevance.

E-3.1

One important fire property of floor covering systems has been identified that, if the effective irradiance level can be predicted when fire occurs, can provide information on the extent of fire spread possibility. The use of this property alone, at least in some cases, is inadequate for the prediction of fire spread under severe exposure conditions. For instance, Figure E-3.1 shows a plot of the maximum heat flux to the floor surface of the NIST full-scale corridor where no combustible floor covering system or other interior finish is present in the corridor. These data were obtained with a fire load in the adjoining room of 10.7 kg/m^2 with a measured burning rate (maximum) of 80 g/sec. The two curves, designated by triangles, show the envelope resulting from two series of experiments.[5] The data plotted as circles on Figure E-3.1 represent the critical radiant flux of twelve floor covering systems versus the extent of flame propagation in the corridor as tested using the full-scale tests.[6] In all cases, the heat flux to the floor covering system at the doorway between the room and corridor was higher than the critical radiant flux for the material. Therefore, flame spread should be expected to include involvement of the corridor, and this was observed.

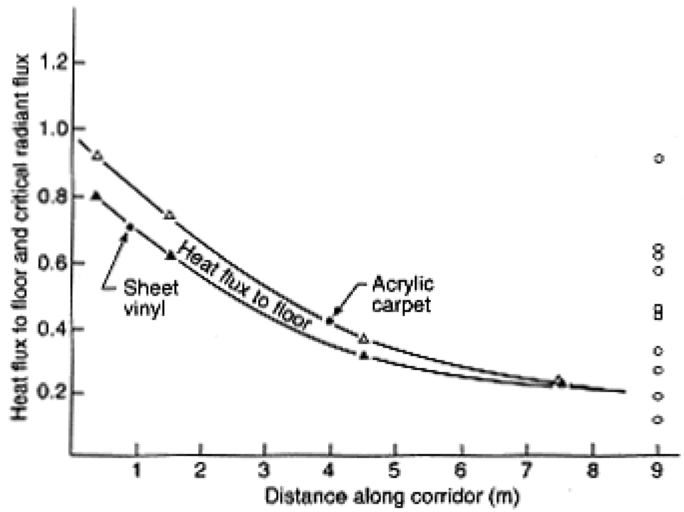

Figure E-3.1 Heat flux to floor with bare corridor versus distance along corridor and fire propagation distance of various floor covering systems versus critical radiant flux (NIST corridor with four 18-kg cribs in burn room — fuel load of 10.7 kg/m^2).

E-3.2

It is evident that only two of the twelve floor covering systems stopped burning at distances corresponding to their critical radiant flux as shown on the flux—distance curve for the corridor without combustible linings. The reason for this difference in behavior is apparently that the flux to the floor surface was sufficiently augmented by the heat release from the flooring itself after rapid flame spread commenced. This usually followed a period of relatively slow flame spread away from the doorway. It also seems likely that changes in ventilation of the compartment fire might have modified the location at which pyrolysis gases burn (i.e., in the corridor above the floor) and influenced the flame height of the floor fire. These effects greatly increased the radiant flux incident on the floor. To date, these effects are not well understood, and no firm guidance can be provided on the way they should be introduced to predict the overall behavior of such a fire system.

E-3.3

Other data are available to illustrate the merit of the test under less severe exposure. These data are the result of a series of experiments involving crib or furniture item fires in a room 2.4 m in height with an open door measuring 3.4 m × 2.7 m that had been fitted with floor covering assemblies of known critical radiant flux characteristics. In these tests, the crib or furniture and the floor covering assembly were the only combustibles in the room.

E-3.4

The results of this study have been published, and Figure E-3.4 shows some of the data developed.[7] This curve shows the extent of fire propagation from the source as a function of critical radiant flux. The four floor covering systems used were carpets that all qualified as having passed the pill test. The data are interesting, since they show that, under the conditions of the experiments, the distance of fire propagation is inversely related to critical radiant flux. In addition, while not demonstrated by this curve, the data show that the burning ceased at positions on the floor covering system somewhat below those at which flux measurement during the test corresponded to the critical radiant flux of the floor covering system being studied. Therefore, in this situation, which did not involve room flashover, critical radiant flux appears to provide a method of ranking the fire spread behavior of the carpets.

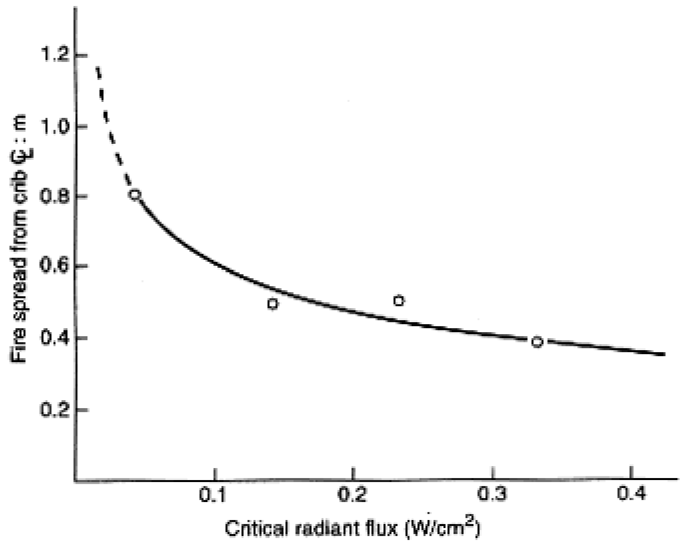

Figure E-3.4 Room burn tests — fire spread from 6.4-kg cribs.

E-3.5

The current version of this test procedure is a result of a recent study conducted at NIST.[8] The purpose of this work was to resolve a perceived problem with ignitibility of and continued flame propagation across some carpet specimens and to reduce the variability of test results obtained by different laboratories. As a result, three significant changes were made in the standard:

(a) Specimen preparation and conditioning;

(b) Tighter control of the airflow through the chamber during calibration and conduct of the test; and

(c) Replacement of the propane torch pilot burner with a propane line burner.

The ignitibility and flame propagation issues appear to have been resolved by the use of the new line burner. The variability of test results among different laboratories has been shown to be markedly improved by the aforementioned changes in the standard, at least for one carpet fabric. Previous proficiency rounds performed by the National Voluntary Laboratory Accreditation Program resulted in coefficients of variation ranging from 18 percent to 35 percent; the coefficient of variation obtained using the revised standard was less than 12 percent. A complete discussion of the research conducted by NIST can be found in the referenced report.

E-4 Summary.

E-4.1

It should be recognized that the critical radiant flux test method provides a useful way of ranking floor covering systems on the basis of this important fire property. However, this is only one of several parameters that determine the fire behavior of floor covering systems. Critical radiant flux indicates the threshold above which flame spread occurs. To use this property in fire safety estimates, the probable heat flux exposure to the floor from the initiating fire needs to be judged. Such estimates must, for the present, depend on judgment or data from prototype experiments. Once a fire is initiated in a corridor, other parameters such as critical radiant flux for ignition and rate of flame spread, as well as corridor configuration and the presence of combustibles such as ceiling and wall linings, can be important in determining the ultimate spread of fire.

E-4.2

Therefore, establishment of criteria for critical radiant flux of floor covering systems can be expected to reduce, but not to eliminate, the incidents of extensive flame spread of floor covering systems.

E-4.3

In this procedure, the specimens are subjected to one or more specific sets of laboratory fire test exposure conditions. If different test conditions are substituted or the anticipated end-use conditions are changed, it might not be possible to predict changes in the performance characteristics measured by using this test. Therefore, the results are valid only for the fire test exposure conditions described in this procedure.

E-4.4

If the test results obtained by this standard are to be considered in the total assessment of fire risk, then all pertinent established criteria for fire risk assessment are to be included in the consideration.

E-5 Research and Development.

E-5.1

For research and development purposes, it might be desirable to measure the rate of flame spread advance.

E-5.2

A metal scale marked at 10-mm intervals can be installed on the back of the platform or on the back wall of the chamber.

E-5.3

For fire hazard assessment purposes, it might be desirable to measure the extent of flame travel after a prescribed burning period (e.g., 15 minutes). The use of the metal scale described in E-5.2 is adequate for this purpose.

[1]Fung, F. C. W., Suchomel, M. R., and Oglesby, P. L., “The NBS Program on Corridor Fires,” *Fire Journal*, Vol. 61, No. 3, 1973, pp. 41-48.

[2]Quintere, James and Huggett, Clayton, “An Evaluation of Flame Spread Test Methods for Floor Covering Materials,” National Bureau of Standards Special Publication 411, U.S.

Government Printing Office, Washington, DC, November 1974, pp. 59-89.

[3]Benjamin, I. and Adams, H., “The Flooring Radiant Panel Test and Proposed Criteria,” *Fire Journal*, Vol. 70, No. 2, March 1976.

[4]Quintere, James, “The Application and Interpretation of a Test Method to Determine the Hazard of Floor Covering Fire Spread in Building Corridors,” International Symposium on Fire Safety of Combustible Materials, University of Edinburgh, October 1975.

[5]Quintiere, James, private communication.

[6]Hartzel, L. G., “Development of a Radiant Panel Test for Flooring Materials,” National Bureau of Standards, NBSIR 74-495, May 1974.

[7]Tu, King-Mon and Davis, Sanford, “Flame Spread of Carpet Systems Involved in Room Fires,” National Bureau of Standards, NBSIR 76-1013, June 1976.

[8]Davis, Sanford, Lawson, J. Randall, and Parker, William J., “Examination of the Variability of the ASTM E648 *Standard with Respect to Carpets*,” National Institute of Standards and Technology, NISTIR 89-4191, October 1989.

Appendix F Precision and Bias

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

F-1 Introduction.

This statement is based on the results of two factorially designed experiments performed by thirteen laboratories in which a total of eighteen floor covering systems were tested.

F-2 Test Results.

Defining a test result as the average of three replicate determinations, the repeatability (within laboratory variability) was about 20 percent of the measured value and the reproducibility (among laboratory variability) was about 35 percent of the measured value. Based upon changes that have been made in this standard, a new precision and bias statement is being prepared.

NOTE 1: “Repeatability” is a quantity that is exceeded only about 5 percent of the time by the difference, taken in absolute value, of two randomly selected results obtained by the same laboratory on a given material.[1]

NOTE 2: “Reproducibility” is a quantity that is exceeded only about 5 percent of the time by the difference, taken in absolute value, of two single test results made on the same material by two, randomly selected laboratories.

[1]Mandel, John, “Repeatability and Reproducibility,” *Materials Research and Standards*, MTRSA, Vol. 11, No. 8, p. 8.

NFPA 255

1996 Edition

Standard Method of Test of Surface Burning Characteristics of Building Materials

1996 Edition

This edition of NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, 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.

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 255 was approved as an American National Standard on February 2, 1996.

Origin and Development of NFPA 255

The test procedure covered by this standard was originally developed by Underwriters Laboratories Inc., and a descriptive article on the procedure was published in the *NFPA Quarterly* in July 1943. Subsequently, the test method was considered by Committee E-5 of the American Society for Testing and Materials and adopted by the ASTM as a tentative standard in 1950. Subsequent to NFPA action on this standard, on recommendation of the Committee on Building Construction in 1953, a new NFPA Committee on Fire Tests was created to provide the machinery for NFPA action on fire test standards in cooperation with the American Society for Testing and Materials. At the 1955 NFPA Annual Meeting, the Committee on Fire Tests, by a divided vote, recommended continuing tentative status, but, in view of the recommendation of the NFPA Committee on Building Construction and also of the NFPA Committee on Safety to Life, which use this standard in connection with interior finish requirements (*see NFPA 101®, Life Safety Code®*), the standard was officially adopted in 1955. Revised editions were released in 1958, 1961, 1966, 1969, 1972, 1979, 1984, and 1990.

This 1996 edition of NFPA 255 contains minor revisions that include the method of calculating the test results and some editorial revisions. Plans to study the effect of the retaining element used to support test specimens within the test chamber are in progress. Future editions will reflect these findings.

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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.

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 255

Standard Method of Test of Surface Burning Characteristics of Building Materials

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, Section D-9, and Appendix E.

Chapter 1 General

1-1 Scope.

This method of testing surface burning characteristics of building materials is applicable to any type of building material that, by its own structural quality or the manner in which it is applied, is capable of supporting itself in position or is supported in the test furnace to a thickness comparable to its recommended use.

1-2 Purpose.

1-2.1

The purpose of the test is to determine the comparative burning characteristics of the material under test by evaluating the flamespread over its surface, when exposed to a test fire, thus establishing a basis on which surface burning characteristics of different materials can be compared without specific consideration of all end-use parameters that might affect the surface burning characteristics.

1-2.2

The smoke density, as well as the flamespread rate, is recorded in this test. However, there is not necessarily a relationship between these measurements.

1-2.3*

It is the intent of this method of test to register performance during the period of exposure and not to determine suitability for use after the test exposure.

1-2.4

This method does not establish ratings of standards of performance for specific uses, as these depend on service requirements.

1-2.5

The values stated in U.S. customary units are to be regarded as the standard.

1-3 Definitions.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Chapter 2 Test Equipment and Specimens

2-1 Fire Test Chamber.

2-1.1*

The fire test chamber, shown in Figures 2-1.1(a) and (b), shall consist of a horizontal duct having an inside width of $17^3/_4$ in. ± $^1/_4$ in. (451 mm ± 6.3 mm), measured at the ledge location alongside walls, and $17^5/_8$ in. ± $^3/_8$ in. (448 mm ± 9.5 mm) at all other points; a depth of 12 in. ± $^1/_2$ in. (305 mm ± 12.7 mm) measured from the bottom of the test chamber to the ledge of the inner walls on which the specimen is supported [including the $^1/_8$-in. (3.1-mm) thickness of woven fiberglass gasketing tape]; and a length of 25 ft (7.62 m). The sides and base of the duct shall be lined with insulating masonry as illustrated by Figure 2-1.1(b), consisting of A. P. Green G-26 refractory fire brick or equivalent. One side shall be provided with double observation windows with the inside pane flush mounted [*see Figure 2-1.1(b)*]. Exposed inside glass shall be $2^3/_4$ in. ± $^3/_8$ in. × 11 in. + 1 in./-2 in. (70 mm ± 9.5 mm × 279 mm + 25.4 mm/-51 mm). The centerline of the exposed area of the inside glass shall be in the upper half of the furnace wall, with the upper edge not less than 2.5 in. (61.9 mm) below the furnace ledge. The window shall be located so that not less than 12 in. (305 mm) of the specimen width can be observed. Multiple windows shall be located along the tunnel so that the entire length of the test sample is able to be observed from outside the fire chamber. The windows shall be pressuretight as described in 2-3.2.

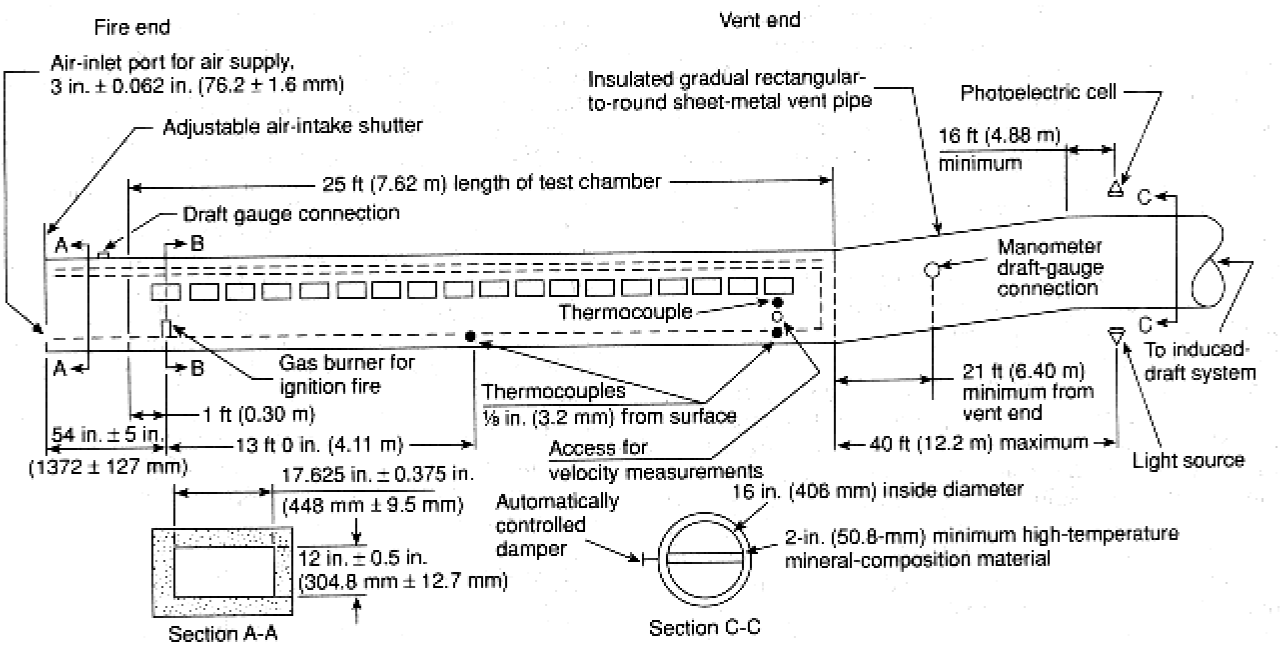

Figure 2-1.1(a) Fire test chamber.

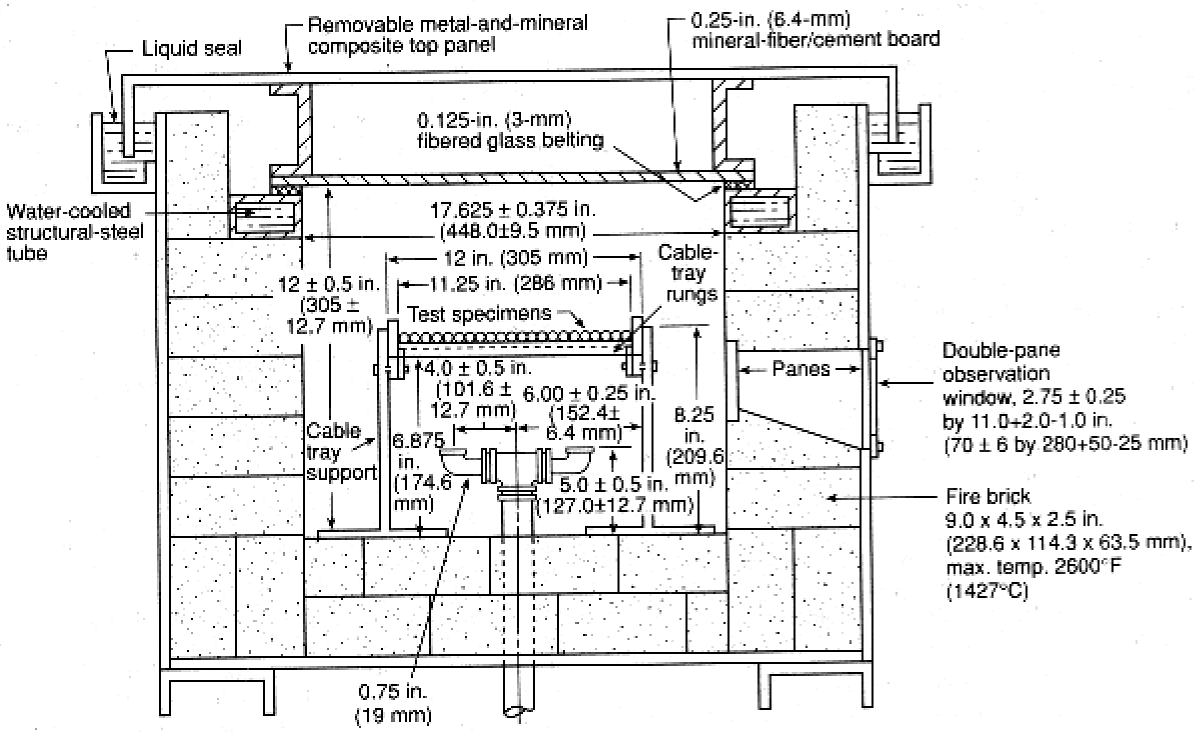

Figure 2-1.1(b) Fire test chamber, side view.

2-1.2*

The ledges shall be fabricated of structural materials capable of withstanding the abuse of continuous testing, shall be level with respect to the length and width of the chamber and each other, and shall be maintained in a state of repair commensurate with the frequency, volume, and degree of testing at all times.

2-1.3*

To provide air turbulence for proper combustion, turbulence baffling shall be provided by positioning six A. P. Green G-26 refractory fire bricks or equivalent [long dimension vertical, $4^1/_2$-in. (114-mm) dimension along the wall] along the side walls of the chamber at distances of 7 ft, 12 ft, and 20 ft ± $^1/_2$ ft (2.1 m, 3.7 m, and 6.1 m ± 0.02 m) on the window side and $4^1/_2$ ft, $9^1/_2$ ft, and 16 ft ± $^1/_2$ ft (1.4 m, 2.9 m, and 4.9 m ± 0.02 m) on the opposite side.

2-1.4*

The top lid shall consist of a removable noncombustible (metal and mineral composite) structure, insulated with nominal 2-in. (51-mm) thick mineral composition material as shown in Figure 2-1.1(b), and shall be of a size necessary to cover the fire test chamber and the test samples completely. The lid shall be maintained in an unwarped and flat condition. The mineral composition material shall have physical characteristics comparable to the following:

Maximum effective temperature	1200°F (649°C)

Bulk density	21 lb/ft^3 (336 kg/m^3)
Thermal conductivity at	0.50 Btu to 0.71 Btu
	•in./hr•ft^2•°F
300°F to 700°F (149°C to 371°C)	(0.072 W/m•K)

KpC product

$$1 \text{ to } 4 \ \frac{\text{Btu}^2 \bullet \text{in.}}{\text{ft}^5 \bullet \text{h} \bullet {}^\circ\text{F}^2} \left(1 \times 10^4 \text{ to } 4 \times 10^4 \ \frac{\text{W}^2 \bullet \text{S}}{\text{m}^4 \bullet \text{K}^2}\right)$$

NOTE: KpC is equal to the thermal conductivity times the density times the specific heat.

The entire lid assembly shall be protected with flat sections of high density [nominal 110/lb ft^3 (1762 kg/m^3)] $^1/_4$-in. (6.3-mm) inorganic-reinforced cement board, maintained in an unwarped and uncracked condition through continued replacement. This protective board shall be permitted to be either secured or not secured to the furnace lid. When in place, the top shall be sealed completely against the leakage of air into the fire test chamber during the test.

2-1.5

One end of the test chamber, designated as the fire end, shall be provided with two gas burners delivering flames upward against the surface of the test sample. The burners shall be spaced 12 in. (305 mm) from the fire end of the test chamber, and 7 in. ± $^1/_2$ in. (178 mm ± 12.7 mm) below the undersurface of the test sample. The air intake shutter shall be located 54 in. ± 5 in. (1372 mm ± 127 mm) upstream of the burner, as measured from the burner centerline to the outside surface of the shutter. Gas to the burners shall be provided through a single inlet pipe, distributed to each port burner through a tee section. The outlet shall be a $^3/_4$-in. (19-mm) elbow. The plane of the port shall be parallel to the furnace floor so that the gas is directed up toward the specimen. Each port shall be positioned with its centerline 4 in. ± $^1/_2$ in. (102.0 mm ± 12.7 mm) from each side of the centerline of the furnace so that the flame is evenly distributed over the width of the exposed specimen surface [*see Figure 2-1.1(b)*]. The controls used to ensure a constant flow of gas to the burners during the period of use shall consist of a pressure regulator, a gas meter calibrated to read in increments of not more than 0.1 ft^3 (2.8 L), a manometer to indicate gas pressure in inches of water, a quick-acting gas shutoff valve, a gas metering valve, and an orifice plate in combination with a water manometer to assist in maintaining uniform gas-flow conditions. An air intake fitted with a vertically sliding shutter extending the entire width of the test chamber shall be provided at the fire end. The shutter shall be positioned to provide an air inlet port 3 in. ± $^1/_{16}$ in. (76 mm ± 1.6 mm) high, measured from the floor level of the test chamber, at the air intake point.

2-1.6

The other end of the test chamber, designated as the “vent end,” shall be fitted with a gradual rectangular-to-round transition piece of not less than 20 in. (508 mm) in length and having a cross-sectional area of 200 in.^{2} (1290 cm^2) at any point. The transition piece shall, in turn, be fitted to a flue pipe 16 in. (406 mm) in diameter. The movement of air shall be by an induced draft system having a total draft capacity of at least 0.15 in. (3.8 mm) water column with the sample in place, the shutter at the fire end open to the normal 3 in. ± $^1/_{16}$ in. (76 mm ± 1.6 mm), and the damper in the fully open position. A draft gauge to indicate static pressure shall be inserted through the top at the midwidth of the tunnel, 1 in. ± $^1/_2$ in. (25.4 mm ± 12.7 mm) below the ceiling, 15 in. ± $^1/_2$ in. (381 mm ± 12.7 mm) downstream from the inlet shutter.

2-1.7*

A photometric system consisting of a light source and photocell shall be mounted on a horizontal section of the 16-in. (406-mm) diameter vent pipe at a point where it is preceded by a straight run of pipe [at least 12 diameters or 16 ft (4.88 m) and not more than 30 diameters or 40 ft (12.2 m)] from the vent end of the chamber, and with the light beam directed upward along the vertical axis of the vent pipe. The vent pipe shall be insulated with at least 2 in. (51 mm) of high temperature mineral composition material from the vent end of the chamber to the photometer location. A photoelectric cell with an output that is directly proportional to the amount of light received shall be mounted over the light source and connected to a recording device having a minimum operating chart width of 5 in. (127 mm) with an accuracy within ± 1 percent of full scale for the purpose of indicating changes in the attenuation of incident light caused by the passing smoke, particulate, and other effluent. The distance between the light source lens and the photocell lens shall be 36 in. ± 4 in. (914 mm ± 102 mm). The cylindrical light beam shall pass through 3-in. (76-mm) diameter openings at the top and bottom of the 16-in. (406-mm) diameter openings at the top and bottom of the 16-in. (406-mm) diameter duct, with the resultant light beam centered on the photocell.

2-1.8

The linearity of the photometer system shall be verified periodically by interrupting the light beam with calibrated neutral density filters. The filters shall cover the full range of the recording instrument. Transmittance values measured by the photometer, using neutral density filters, shall be within ± 3 percent of the calibrated value for each filter.

2-1.9

An automatically controlled damper to regulate the draft pressure shall be installed in the vent pipe downstream of the smoke-indicating attachment. The damper shall be provided with a manual override.

2-1.10

Other manual, automatic, or combination manual and automatic draft regulation devices shall be permitted to be incorporated to maintain fan characterization and airflow control throughout test periods.

2-1.11

A No. 18 AWG (1.02-mm) thermocouple with $^3/_8$ in. ± $^1/_8$ in. (9.5 mm ± 3.1 mm) of the junction exposed in the air shall be inserted through the floor of the test chamber so that the tip is 1 in. ± $^1/_{32}$ in. (25.4 mm ± 0.8 mm) below the top surface of the woven fiberglass gasketing tape and 23 ft ± $^1/_2$ in. (7.0 m ± 12.7 mm) from the centerline of the burner ports, at the center of the burner width.

2-1.12

A No. 18 AWG (1.02-mm) thermocouple embedded $^1/_8$ in. (3.1 mm) below the floor surface of the test chamber shall be mounted in refractory or portland cement, carefully dried to avoid cracking, at distances of 13 ft ± $^1/_2$ in. (3.96 m ± 12.7 mm) and 23$^1/_4$ ft ± $^1/_2$ in. (7.09 m ± 12.7 mm) from the centerline of the burner ports.

2-1.13

The room in which the test chamber is located shall have provision for a free inflow of air during the test to maintain the room at atmospheric pressure during the entire test run.

2-2 Test Specimens.

2-2.1

The test specimen shall be at least 2 in. (51 mm) wider [nominally 20$^1/_4$ in. ± $^3/_4$ in. (514 mm ± 19 mm)] than the interior width of the tunnel and a total of 24 ft ± $^1/_2$ in. (7.32 m ± 12.7 mm) in length. The specimen shall be permitted to be one, continuous, unbroken length or to consist of sections joined end-to-end. A 14-in. ± $^1/_8$ in. (356-mm ± 3.1 mm) length of uncoated 16-gauge (0.053-in. to 0.060-in.) steel sheet shall be placed on the specimen mounting ledge in front of and under the specimen in the upstream end of the tunnel. The specimen shall be truly representative of the material for which test results are desired. Properties adequate for identification of the materials or ingredients, or both, from which the test specimen is made shall be recorded.

2-2.2

The test specimen shall be conditioned to a constant weight at a temperature of 73.4°F ± 5°F (23°C ± 2.8°C) and at a relative humidity of 50 percent ± 5 percent.

2-3 Calibration of Test Equipment.

2-3.1

A $^1/_4$-in. (6.3-mm) inorganic-reinforced cement board shall be placed on the ledge of the furnace chamber, and the removable lid of the test chamber then shall be placed in position.

2-3.2

With the $^1/_4$-in. (6.3-mm) inorganic-reinforced cement board in position on top of the ledge of the furnace chamber and with the removable lid in place, a draft shall be established to produce a 0.15-in. (3.8-mm) water column reading on the draft manometer, with the fire end shutter open 3 in. ± $^1/_{16}$ in. (76 mm ± 1.6 mm), by manually setting the damper in relationship to the fan performance. The fire end shutter then shall be closed and sealed without changing the damper position. The manometer reading shall increase to at least 0.375 in. (9.53 mm), indicating that no excessive air leakage exists.

2-3.3

In addition, a supplemental leakage test shall be conducted periodically with the fire shutter and exhaust duct beyond the differential manometer tube sealed by placing a smoke bomb in the chamber. The bomb shall be ignited and the chamber pressurized to 0.375 in. ± 0.135 in. (9.53 mm ± 3.43 mm) water column. All points of leakage observed in the form of escaping smoke particles shall be sealed. A draft reading within the range of 0.055 in. to 0.085 in. (1.40 mm to 2.16 mm) water column shall be established. The required draft gauge reading shall be maintained throughout the test by the automatically controlled damper.

2-3.4*

The air velocity shall be recorded at seven points, 23 ft (7.0 m) from the centerline of the burner ports, 6 in. ± $^{1}/_{4}$ in. (152 mm ± 6.3 mm) below the plane of the specimen mounting ledge. These seven points shall be determined by dividing the width of the tunnel into seven equal sections and recording the velocity at the geometrical center of each section. During the measurement of velocity, the turbulence bricks (*see 2-1.3*) and the exposed 23-ft (7.0-m) thermocouple shall be removed and 24-in. (610-mm) long straightening vanes shall be placed 16 ft to 18 ft (4.88 m to 5.49 m) from the burner. The straightening vanes shall divide the furnace cross section into nine uniform sections. The velocity shall be determined with the furnace air temperature at 73.4°F ± 5°F (23°C ± 2.8°C) using a velocity transducer. The velocity, determined as the arithmetic average of the seven readings, shall be 240 ft/min ± 5 ft/min (73.2 m/min ± 1.5 m/min).

2-3.5

The air supply shall be maintained at 73.4°F ± 5°F (23°C ± 2.8°C) and the relative humidity at 50 percent ± 5 percent.

2-3.6

The fire test chamber shall be supplied with natural (municipal) or methane (bottled) gas fuel of uniform quality with a heating value of nominally 1000 Btu/ft^3 (37.3 MJ/m^3). The gas supply shall be adjusted initially at approximately 5000 Btu/min (5.3 MJ/min). The gas pressure, the pressure differential across the orifice plate, and the volume of gas used in each test shall be recorded. Unless otherwise corrected for, where bottled methane is used, a length of coiled copper tubing shall be inserted into the gas line between the supply and metering connection to compensate for possible errors in the indicated flow due to reductions in gas temperature associated with the pressure drop and expansion across the regulator. With the draft and gas supply adjusted as indicated in 2-3.3 and 2-3.6, the test flame shall extend downstream to a distance of 4$^{1}/_{2}$ ft (1.37 m) over the specimen surface, with negligible upstream coverage.

2-3.7

The test chamber shall be preheated with the $^{1}/_{4}$-in. (6.3-mm) inorganic-reinforced cement board and the removable lid in place and with the fuel supply adjusted to the required flow. The preheating shall be continued until the temperature indicated by the floor thermocouple at 23$^{1}/_{4}$ ft (7.09 m) reaches 150°F ± 5°F (66°C ± 2.8°C). During the preheat test, the temperatures indicated by the thermocouple at the vent end of the test chamber shall be recorded at intervals not longer than 15 seconds, and these readings shall be compared to the preheat temperature shown in the temperature-time curve in Figure 2-3.7. The preheating is for the purpose of establishing the conditions that exist following successive tests that indicate the control of the heat input into the test chamber. If appreciable variation from the temperature shown in the representative preheat curve is observed, suitable adjustments in the fuel supply shall be permitted based on red oak calibration tests.

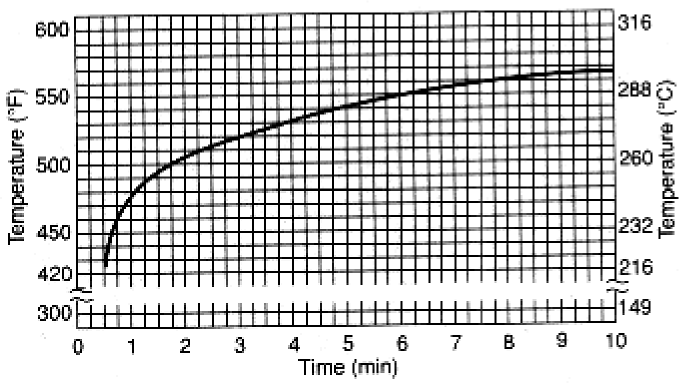

Figure 2-3.7 Temperature-time chart for preheat temperature.

2-3.8

The furnace shall be allowed to cool after each test. When the floor thermocouple at 13 ft (3.96 m) indicates a temperature of 105°F ± 5°F (40.5°C ± 2.8°C), the next specimen shall be placed in position for testing.

2-3.9

With the test equipment adjusted and conditioned as described in 2-3.2 through 2-3.8, a test or series of tests shall be made using nominal $^{25}/_{32}$-in. (19.8-mm) select grade red oak flooring as a specimen that has been conditioned to 6 percent to 8 percent moisture content as determined by the 221°F (105°C) oven dry method described in ASTM D 2016, *Tests for Moisture Content of Wood*. Observations shall be made at maximum distance intervals of 2 ft (0.61 m) and maximum time intervals of 30 seconds, and the time at which the flame reaches the end of the specimen that is 19$^{1}/_{2}$ ft (5.94 m) from the end of the ignition fire shall be recorded. The end of the ignition fire shall be considered to be 4$^{1}/_{2}$ ft (1.37 m) from the burners. The flame shall reach the end point in 5$^{1}/_{2}$ minutes ± 15 seconds. The temperatures measured by the thermocouple near the vent end shall be recorded at least every 15 seconds. The photoelectric cell output shall be recorded immediately prior to the test and at least every 15 seconds during the test. The flame shall be permitted to be considered as having reached the end point when the vent end thermocouple registers a temperature of 980°F (527°C).

2-3.10

The flamespread distance, temperature, and change in photoelectric cell readings shall be plotted separately on suitable coordinate paper. Figures 2-3.10(a), (b), and (c) are representative curves for red oak temperature-time, absorption-time smoke density, and distance-time flamespread, respectively. Flamespread shall be determined from the observed distance, less 4$^{1}/_{2}$ ft (1.37 m).

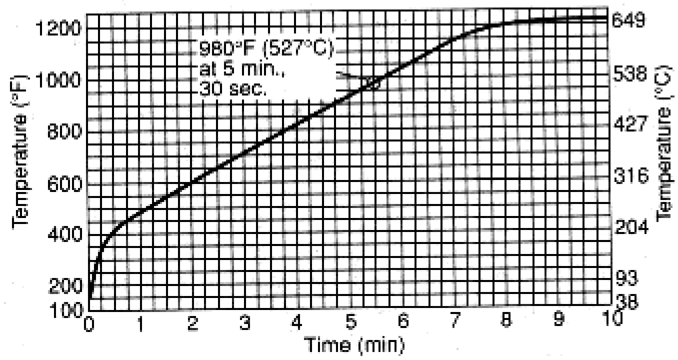

Figure 2-3.10(a) Temperature-time curve for red oak.

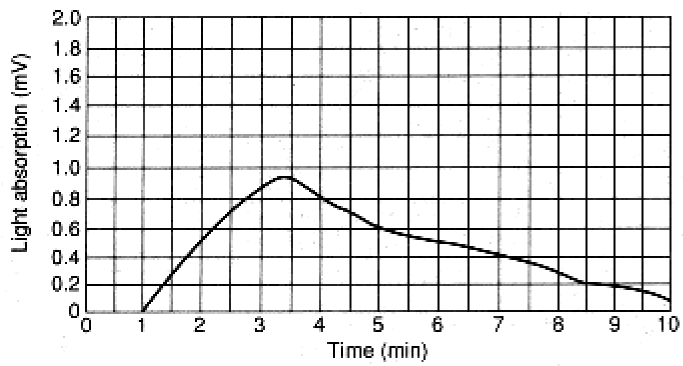

Figure 2-3.10(b) Absorption-time curve for smoke density of red oak.

Figure 2-3.10(c) Distance-time curve for flamespread of red oak.

2-3.11

Following the calibration tests for red oak, a similar test or tests shall be conducted on samples of $^{1}/_{4}$-in. (6.3-mm) inorganic-reinforced cement board. The results shall be considered as representing a classification of zero (0). The temperature readings shall be plotted separately on suitable coordinate paper. Figure 2-3.11 is a representative curve for temperature-time development for inorganic-reinforced cement board.

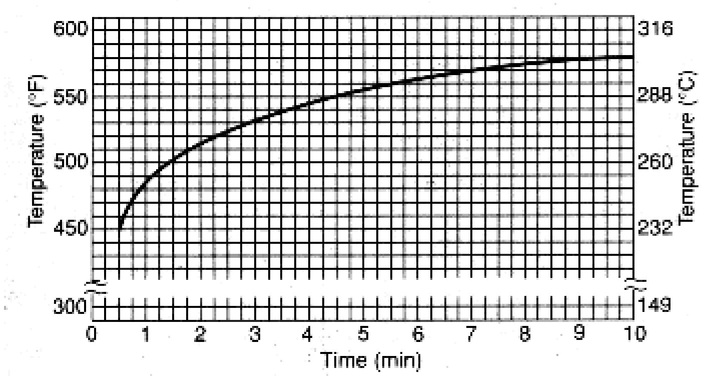

Figure 2-3.11 Temperature-time curve for inorganic-reinforced cement board.

Chapter 3 Conduct of Tests

3-1 Test Procedure.

3-1.1

With the furnace draft operating, the test specimen shall be placed on the test chamber ledges that have been completely covered with nominal $^{1}/_{8}$-in. (3.1-mm) thick × $1^{1}/_{2}$-in. (38.1-mm) wide woven fiberglass tape. The specimen shall be positioned as quickly as is practicable. The removable lid shall be placed in position over the specimen.

3-1.2

The completely mounted specimen shall remain in position in the chamber with the furnace draft operating for 120 seconds ± 15 seconds prior to the application of the test flame.

3-1.3

The burner gas shall be ignited. The distance and time of maximum flame front travel shall be observed and recorded with the room darkened. The test shall continue for 10 minutes.

Exception: The test shall be permitted to be terminated prior to 10 minutes, provided the specimen is completely consumed in the fire area and no further progressive burning is evident and the photoelectric cell reading has returned to the baseline.

3-1.4

The photoelectric cell output shall be recorded immediately prior to the test and at least every 15 seconds during the test.

3-1.5

The gas pressure, the pressure differential across the orifice plate, and the volume of gas used for each test shall be recorded.

3-1.6

When the test is completed, the gas supply shall be shut off, smoldering and other conditions within the test duct shall be observed, and the specimen shall be removed for further examination.

3-1.7

The flamespread distance, temperature, and change in photoelectric cell readings shall be plotted separately on the same type of coordinate paper used in 2-3.10 in order to determine the flamespread and smoke development classifications outlined in Section 3-3. The flamespread observations shall be recorded at maximum distance intervals of 2 ft (0.61 m) or maximum time intervals of 30 seconds. In addition, the peak and its time of occurrence shall be recorded. Flamespread shall be determined as the observed distance, less $4^1/_2$ ft (1.37 m).

3-2 Analysis of Products of Combustion.

Although not required as a part of this method, products of combustion shall be permitted to be drawn from the test duct for chemical analysis or during the test.

3-3 Classification.

The flamespread index (FSI) shall be determined as specified in 3-3.1 through 3-3.4.

3-3.1

The total area (A_T) under the flamespread distance-time curve shall be determined by ignoring any flame front recession. For example, in Figure 3-3.1, the flamespread shown is 10 ft (3.05 m) in $2^1/_2$ minutes and then recedes. The area is calculated as if the flame had spread to 10 ft (3.05 m) in $2^1/_2$ minutes and then remained at 10 ft (3.05 m) for the remainder of the test or until the flame front again passed 10 ft (3.05 m). This is indicated by the broken line in Figure 3-3.1. The area (A_T) used for calculating the flamespread classification is the sum of areas A_1 and A_2 in Figure 3-3.1.

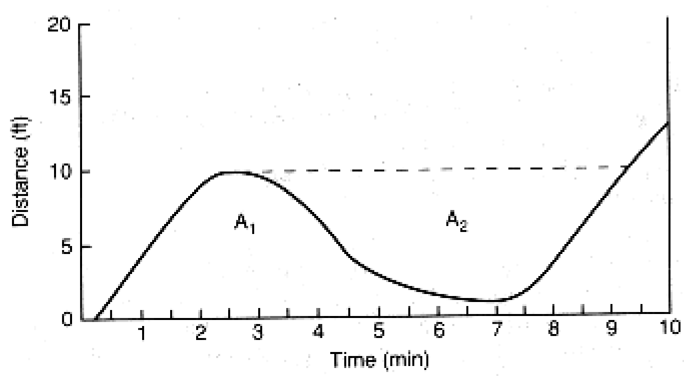

Figure 3-3.1 Example of distance-time curve with flame front recession.

3-3.2

If the total area (A_T) is less than or equal to 97.5 min-ft (29.7 min-m), the flamespread index equals 0.515 times the total area (FSI = 0.515 A_T).

3-3.3

If the total area (A_T) is greater than 97.5 min-ft (29.7 min-m), the flamespread index equals 4900 divided by the difference between 195 and the total area (A_T) [FSI = 4900/(195-A_T)].

3-3.4

The test results for smoke shall be plotted using the coordinates in 2-3.10. The area under the curve shall be divided by the area under the curve for red oak and multiplied by 100 to establish a numerical index by which the performance of the material can be compared with that of inorganic-reinforced cement board and select grade red oak flooring, which have been arbitrarily established as 0 and 100, respectively. Allowance shall be permitted to be made for accumulation of soot and dust on the photoelectric cell during the test by establishing a revised baseline. The revised baseline shall be a straight line drawn from the zero (0) point (point on baseline where incipient light attenuation occurs) to the point established after the sample has been removed.

3-4 Report.

The report shall include the following:

(a) A description of the material being tested;

(b) Test results as calculated in Section 3-3 and the following also shall apply:

1. The individual flamespread data values shall be rounded to the nearest multiple of 5 points.

2. The individual smoke development data values shall be rounded to the nearest multiple of 5 points.

(c) Details of the method used in placing the specimen in the test chamber; and

(d) Observations of the burning characteristics of the specimen during test exposure such as, but not limited to, delamination, sagging, shrinkage, and fallout.

Chapter 4 Referenced Publications

4-1

The following document or portions thereof is referenced within this standard and shall be considered part of the requirements of this standard. The edition indicated for the reference is the current edition as of the date of the NFPA issuance of this document.

4-1.1 ASTM Publication.

American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM D 2016, *Tests for Moisture Content of Wood*, 1974 (discontinued).

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

See NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*, for procedures for determining the performance, under fire exposure conditions, of building constructions and materials where incorporated in a test structure and subject to a standard exposing fire of controlled extent and severity.

A-2-1.1

The following information can be useful in obtaining materials for the construction of the fire test chamber:

(a) Woven fiberglass tape, $1^1/_2$ in. × $^1/_8$ in. (38.1 mm × 3.1 mm), No. 8817K35 from McMaster-Carr, P.O. Box 54960, Los Angeles, CA 90054, or an equivalent, is suitable for this purpose.

(b) This method of lining the sides and base of the duct with insulating masonry is based upon the use of G-26 fire brick manufactured by A.P. Green Refractories, Green Boulevard, Mexico, MO 65265.

(c) Double observation windows should be constructed of heat-resistant glass. Vycor, 100 percent silica glass, nominal $^1/_4$ in. (6.3 mm) thick, is suitable for the interior pane; Pyrex® glass, nominal $^1/_4$ in. (6.3 mm) thick, is suitable for the exterior pane.

A-2-1.2

High temperature furnace refractory Zircon has been found suitable for this purpose.

A-2-1.3

This method for turbulence baffling is based upon the use of G-26 fire brick, manufactured by A. P. Green Refractories, Green Boulevard, Mexico, MO 65265.

A-2-1.4

For inorganic-reinforced cement board, Manville Building Materials Corporation Flexboard II and Tunnel Building Products sterling board are suitable materials for this purpose.

A-2-1.7

A Weston Instruments No. 856BB photronic cell and 12-V sealed beam, clear lens, autolamp with an overall light-to-cell path length of 36 in. ± 4 in. (914 mm ± 102 mm) is suitable for this purpose.

A-2-3.4

A Thermo Systems Inc. Model 1610 velocity transducer (thermal anemometer), using a readout device accurate to 0.001 V, is suitable for this purpose.

Appendix B Guide to Mounting Methods

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

B-1 Introduction.

B-1.1

This guide has been compiled as an aid in selecting a method for mounting various building materials in the fire test chamber. These mountings are recommended for test method uniformity and convenience; they are not meant to imply restriction in the specific details of field installation.

B-1.2

For some building materials, it is possible that none of the methods described are applicable. In such cases, other means of support might need to be devised.

B-1.3

These recommended mounting methods are grouped according to building materials to be tested that are identified broadly by either the usage or the form of the material.

B-1.4

Wherever inorganic-reinforced cement board is specified as a backing in subsequent paragraphs, the material should be nominal $^1/_4$ in. (6.3 mm) thick, high density [110 lb/ft^3 ± 5 lb/ft^3 (1762 kg/m^3 ± 80 kg/m^3)], and uncoated. Where metal rods are specified as supports, $^1/_4$-in. (6.3-mm) metal rods spanning the width of the tunnel should be used. Rods should be placed approximately 2 in. (51 mm) from each end of each panel, and additional rods should be placed approximately at 2-ft (0.61-m) intervals starting with the first rod at the fire end of each panel.

B-2 Acoustical and Other Similar Panel Products of Less than 20 in. (508 mm).

B-2.1

For acoustical materials and other similar panel products with a maximum dimension of less than 20 in. (508 mm), metal splines or wood furring strips and metal fasteners should be used.

B-2.2

Steel tee splines for mounting kerfed-acoustical tile should be nominal $^1/_2$-in. (12.7-mm) web × $^3/_4$-in. (19-mm) flange, formed No. 24 MS gauge sheet metal.

B-2.3

Wood furring frames for mounting acoustical materials and other similar panel products of less than 20 in. (508 mm) should be nominal 1-in. × 2-in. (25.4-mm × 51-mm) wood furring joined with corrugated metal fasteners. Two frames should be used, as shown in Figure B-2.3.

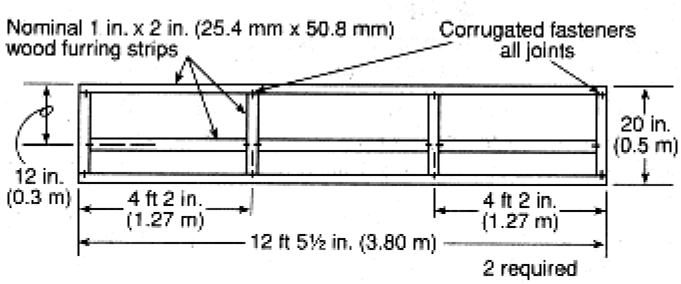

Figure B-2.3 Wood frame for acoustical materials and other similar panel products of less than 20 in. (508 mm).

B-3 Adhesives.

To determine the surface burning characteristics of adhesives, they are to be mixed as specified in the manufacturer's instructions and applied to inorganic-reinforced cement board in the thickness or at the coverage rate recommended by the manufacturer. The adhesive application should be cured prior to testing.

B-4 Batt or Blanket-type Insulating Materials.

Batt or blanket materials that do not have sufficient rigidity or strength to support themselves should be supported by metal rods inserted through the material and positioned so that the bottom of the rod is approximately $^1/_4$ in. (6.3 mm) from the surface to be exposed to the flame. It is recommended that batt or blanket materials less than 1 in. (25.4 mm) thick not be mounted for testing in this manner.

B-5 Coating Materials, Cementitious Mixtures, and Sprayed Fibers.

B-5.1

Coating materials, cementitious mixtures, and sprayed fibers are to be mixed and applied to the substrate as specified in the manufacturer's instructions at the thickness, coverage rate, or density recommended by the manufacturer.

B-5.2

Materials intended for application to wood surfaces should be applied to a substrate made of nominal $^{25}/_{32}$-in. (19.8-mm) tongue and groove red oak flooring or to other materials for which the surface burning characteristic is to be measured. The pieces are placed side by side and secured with four nailing strips spaced approximately $3^1/_2$ ft (1.07 m) apart to hold the pieces together (*see Figure B-5.2*). Two decks placed end-to-end are to be used.

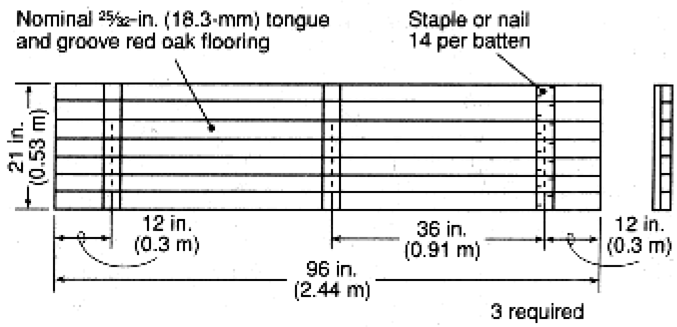

Figure B-5.2 Wood deck for coating material.

B-5.3

Materials intended for application to particular combustible surfaces, but not wood, should be applied to the specific surfaces for which they are intended.

B-5.4

Materials intended for field application to noncombustible surfaces only should be applied to $^{1}/_{4}$-in. (6.3-mm) inorganic-reinforced cement board.

B-6 Loose Fill Insulation.

Loose fill insulation should be placed on galvanized steel screening with openings of approximately $^{3}/_{64}$ in. (1.2 mm) supported on a test frame 20 in. (508 mm) wide × 2 in. (51 mm) deep, made from steel angles of 2 in. × 3 in. × $^{3}/_{16}$ in. (51 mm × 76 mm × 4.8 mm). Three frames are needed (see *Figure B-6*). The insulation should be packed to the density specified by the manufacturer.

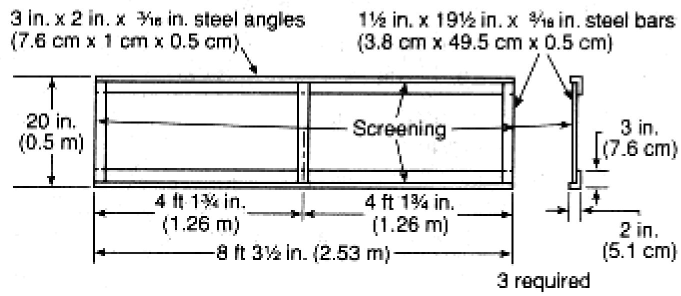

Figure B-6 Steel frame for loose fill materials.

B-7 Plastics.

B-7.1

The term plastics includes foams, reinforced panels, laminates, grids, and transparent or translucent sheets.

B-7.2

Where any plastic remains in position in the tunnel during a fire test, no additional support is necessary. Thermoplastic materials and other plastics that do not remain in place should be supported by $^{1}/_{4}$-in. (6.3-mm) round metal rods or $^{3}/_{16}$-in. (4.8-mm) thick × 2-in. (51-mm) wide steel bars, or 2-in. (51-mm) galvanized hexagonal wire mesh supported with metal bars or rods spanning the width of the tunnel.

B-8 Thin Membranes.

Single-layer membranes of thin laminates consisting of a limited number of similar or dissimilar layers can be supported on poultry netting placed on metal rods as provided in Section B-4. Netting should be 20-gauge (51-mm) hexagonal galvanized steel poultry netting conforming to ASTM A 390, *Standard Specification for Zinc-Coated (Galvanized) Steel Poultry Fence Fabric (Hexagonal and Straight Line)*. The specimen should be tested while bonded to a substrate representative of a field installation.

B-9 Wall Coverings.

Wall coverings of various types should to be mounted to $^{1}/_{4}$-in. (6.3-mm) inorganic-reinforced cement board with the adhesive specified by the manufacturer in a manner consistent with field practice.

B-10 Bonding.

Where the surface burning characteristics of the material itself are required, specimens should be mounted on inorganic-reinforced cement board with Sairmix No. 7 high temperature bonding mortar or the equivalent. If the specimen cannot be adhered using Sairmix No. 7, Kentile No. 9 epoxy has been found to be a suitable alternative. The application should be determined by a $^{3}/_{32}$-in. (2.4-mm) notched trowel held at an 80-degree to 90-degree angle using a random pattern. The adhesive should be applied only to the specimen back. The specimen then should be placed on the smooth side of the inorganic-reinforced cement board and rolled using a 100-lb (54.4-kg) roller [nominal 5-in. (127-mm) long sections placed end-to-end for a total length of 15 in. (381 mm)]. The prepared samples can be dead-stacked overnight but should be transferred to separate storage racks until tested. Each sample should be vacuumed prior to testing.

NOTE 1: Sairmix No. 7 high temperature bonding mortar is manufactured by A.P. Green Refractories, Green Boulevard, Mexico, MO 65265.

NOTE 2: Kentile No. 9 epoxy is manufactured by Kentile Floors, Inc., Brooklyn, NY 11215.

Appendix C Derivation of Flamespread Area Formulas in Section 3-3

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

C-1 Introduction.

C-1.1

This appendix contains an abbreviated discussion of the derivations of the flamespread area formulas used to calculate the flamespread value in this test method. This appendix not only provides the derivations of the formulas but illustrates the relationship between this method of flamespread calculation and a previous method.

C-1.2

In these calculations, it is assumed that the flame front never recedes. Therefore, in Figure 3-3.1, there is an imaginary line bordering the upper edge of area A_2.

C-2 Formula 1 Constant.

In Figure C-2, an idealized straight-line flamespread distance-time is plotted. The plots for 0A, 0A`, and 0A" create a combined area, 0RA, 0RA having a maximum possible area of 97.5 min-ft ($^1/_2 \times 10$ min $\times$ 19.5 ft) [29.7 min-m ($^1/_2 \times 10$ min $\times$ 5.94 m)]. These straight-line plots represent a steady progression of the flame front to a maximum distance at the end of the 10-minute test.

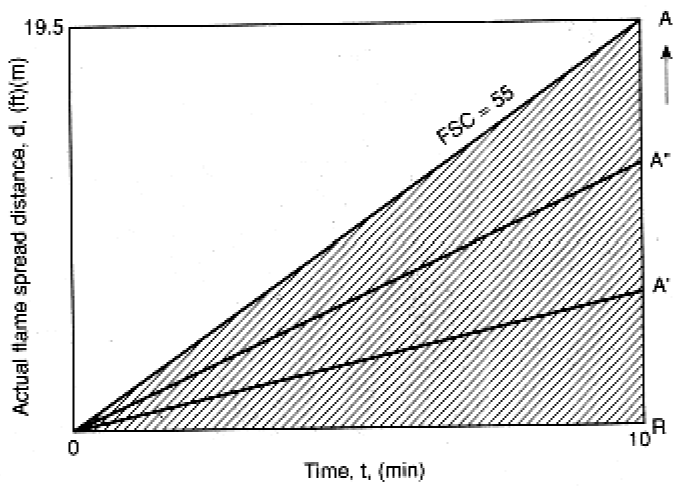

Figure C-2 Idealized straight-line flamespread distance-time curve for total areas less than or equal to 97.5 min-ft (29.7 min-m).

C-2.1

Where the flame front spreads for its maximum distance of 19.5 ft (5.94 m) in 10 minutes, a formula used in Section 3-3 would yield the following:

$$FSI = \frac{550}{t} = \frac{550}{10}$$

C-2.2

Where the flame front is maximized at 19.5 ft (5.94 m) in 10 minutes, the area in Figure C-2, 0RA, is maximized to 97.5 min-ft (29.7 min-m).

C-2.3

To relate the current formula, which is of the straight-line, origin intercept type, to the previous formula, it is necessary to express the two as follows:

$$FSI = \frac{550}{t} = KA$$

where:

K = the proportionality constant for equations of the current formula

A_T = the total area under area 0RA

If A_T = 97.5 min-ft at t = 10 min

then:

$$FSC = \frac{550}{10} = K \times 97.5$$

$$\text{and } K = \frac{550}{10 \times 97.5} = 0.564$$

NOTE: 97.5 min-ft = 29.7 min-m

C-2.4

Therefore, the formula in 3-3.2 for areas (A_T) of 97.5 min-ft (29.7 min-m) or less is as follows:

$$FSI = 0.564\ A_T$$

C-3 Formula 2 Constant.

In the idealized straight-line flamespread distance-time curve of Figure C-3, lines 0I, 0I`, and 0I" create a group of trapezoidal areas, 0RBI, ranging from 97.5 min-ft to 195 min-ft (29.7 min-m to 59.4 min-m) [$^1/_2 \times$ 10 min $\times$ 19.5 ft (59.4 m) to 10 min $\times$ 19.5 ft (59.4 m)]. This represents a flame front progression to the end of the specimen within the 10-minute test. The area (A_T) of 0RBI is expressed as follows:

$$(^1/_2 \times 19.5 \times 0R) + [^1/_2 \times 19.5 \times (10 - AI)]$$

which is equal to:

195 - 9.75 AI, since 0R is always 10 minutes.

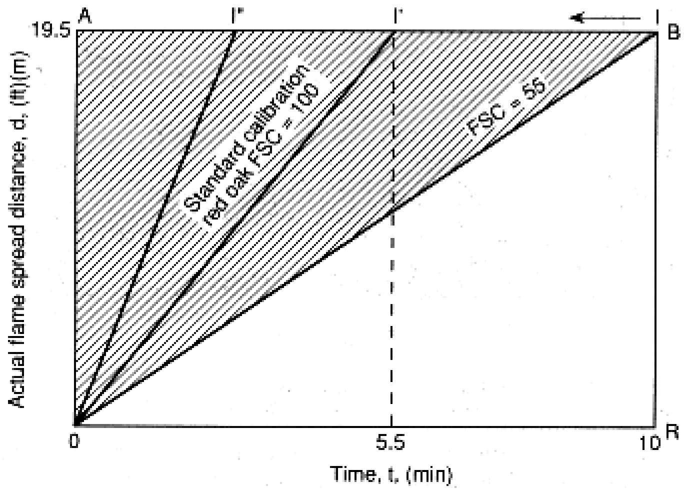

Figure C-3 Idealized straight-line flame distance-time curve for total areas greater than 97.5 min-ft (29.7 min-m).

C-3.1

The triangular area, 0IA, divided into a proportionality constant, K, determines the relationship between flamespread values and the rate and distance of flame propagation. The total area available is 195 min-ft (59.4 min-m); therefore, area 0IA is equal to 195 0RBI. Thus, a new flamespread formula can be derived as follows:

$$FSI = \frac{K}{OIA} = \frac{K}{195 - ORBI} = \frac{K}{195 - A_T}$$

C-3.2

To establish K, a relationship between the current and previous formulas is established at the red oak calibration point of 19.5 ft (29.7 min-m) progression at 5.5 minutes as follows:

$$FSI = \frac{550}{I} = \frac{K}{195 - A_T}$$

where: A_T = 195 - [9.75 (5.5)] = 141.38 min-ft and I = 5.5 min.

Thus:

$$FSI = \frac{550}{I} = \frac{K}{195 - 141.38}$$

$$\text{or } K = \frac{550 \times (53.63)}{5.5} = 5363$$

C-4 Formulas 1 and 2.

C-4.1

To account for the disproportionate increase that can occur in FSI values at the lower end of the index scale, for K = 0.564 in Formula 1 and K= 5363 in Formula 2, a further mathematical modification is made.

C-4.2

In order to establish the relationship between the constants (K) in Sections C-2 and C-3, it is necessary to consider the forms of the basic formulae, which are as follows:

$$FSI = \frac{K_1}{195 - A_T} \quad (A > K_2)$$

$$FSI = K_3 A_T \; (A < K_2)$$

where:

K_1 = 100 (195 - R)

R = the area under the curve that is to be associated with an index of 100

K_2 = an arbitrary choice within the limits of 0 and 195

$K_3 = K_1/[(K_2 (195-K_2)]$

C-4.3

Choosing K_2 = 195 ÷ 2 produces a minimum value of K_3; that is, any other K_2 value will result in a higher K_3 value; and choosing R, the area under a red oak calibration plot, as a median value of 146 implies the following:

$$K_1 = 100\ (195 - 146) = 4900$$

C-4.4

Using 97.5 as the value for K_2, the formula for K_3 is as follows:

$$K_3 = 4900/(97.5 \times 97.5) = 0.515$$

C-4.5

Therefore, the formula for the flamespread index in 3-3.2 is as follows:

$$FSI = 0.515\ A_T$$

C-4.6

Therefore, the formula for the flamespread index in 3-3.3 is as follows:

$$FSI = \frac{4900}{195 - A_T}$$

Appendix D Commentary

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

D-1 Introduction.

D-1.1

This commentary has been prepared to provide the user of NFPA 255 with background information, including references, on the development and use of this method. It also provides the reader and user with the basis for the methods that have been used for deriving numerical flamespread indexes; an appreciation of the variability of the test; and comments on its application and limitations for testing selected types of materials.

D-1.2

On November 28, 1942, 490 people died in a fire in the Coconut Grove Nightclub in Boston. On June 5, 1946, 61 people died in the La Salle Street Hotel fire in Chicago. On December 7, 1946, a fire in the Winecoff Hotel in Atlanta, Georgia, claimed the lives of 119 people. These fires had one thing in common. In all three fires, rapid flamespread along the surfaces of interior finish was judged to be a major factor in fire growth. Two of the structures had burlap wall coverings and the other had an early type of plywood that had seriously delaminated. The fire protection authorities investigated several test methods with the objective of providing one that could be used to regulate interior finish materials and minimize repetition of such fires. These tests included: The Forest Products Laboratory Fire Tube Test (now ASTM E 69, *Standard Test Method for Combustible Properties of Treated Wood by the Fire-Tube Apparatus*); Federal Specification SS A118b (acoustical tile/bunsen burner test, replaced by SS-A-118a-7/63, referencing ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials*); New York City Timber Test and Shavings Test (now obsolete); the Crib Test, ASTM Specification C160-41 T (now ASTM E 160, *Test Method for Combustible Properties of Treated Wood by the Crib Test*); and The Swedish Schlyter Test.[1] All of these were relatively small laboratory tests. ASTM E 84/NFPA 255 was developed on the premise that a large test would provide a more realistic and comprehensive test, and it has since been widely adopted for use by the building code authorities to regulate the use of interior finish materials. Subsequently, during this same period, two other test methods were developed for use in the research and development of new materials: the NBS radiant panel test (ASTM E 162, *Standard Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source*) and the FPL 8-foot tunnel test (ASTM E 286, *Test Method for Surface Flammability of Building Materials Using an 8-ft (2.44-m) Tunnel Furnace*). These test methods have been widely used for research and development purposes.

D-2 History of ASTM E 84/NFPA 255.

D-2.1

The first tunnel-type furnace was built at Underwriters Laboratories Inc., around 1922, when fireproofing paints and specifically whitewash were actively promoted. The equipment consisted of a long bench with a noncombustible top. The sample consisted of a wood trough about 16 ft long × 18 in. wide × 18 in. deep (4.88 m long × 0.457 m wide × 0.457 m deep), placed upside down on the bench. The inside of the trough was coated with the paint. A known quantity of wood at one end furnished the ignition source.

D-2.2

In 1927 and 1928, chemically impregnated wood was being developed, and Underwriters Laboratories used a tunnel 36 in. wide × 23 ft long × 13 in. deep (0.914 m wide × 7.0 m long × 0.33 m deep) to evaluate its performance. It was during this time that red oak flooring was selected as a control to be used to calibrate the furnace. The sample formed the top of the tunnel. The fuel and draft also were controlled.

D-2.3

In the early 1940s, a desire to reduce the flammability of wood-based products and the introduction of new building materials and combinations of materials created a need to improve the tunnel further. The development of the third tunnel furnace is explained fully in Underwriters Laboratories Bulletin of Research No. 32.[2] Subsequent refinements were incorporated, and the first formal test method was published as UL 723, *Standard for Safety Test for Surface Burning Characteristics of Building Materials*, by Underwriters Laboratories in August 1950. Revised editions were published in 1958, 1960, 1971, 1977, and 1979. The National Fire Protection Association adopted the method as NFPA 255 in 1955, with revisions in 1958, 1961, 1966, 1970, 1972, 1979, and 1984. The test was adopted by the American Society for Testing and Materials as a tentative standard in 1950 and formally adopted in 1961, with revisions made in 1967, 1968, and 1970 and from 1975 through 1980.

D-2.4

The tunnel has been designated the “Steiner Tunnel” by Underwriters Laboratories in honor of Albert J. Steiner who spent much time developing this and many other fire test methods.

D-2.5

Since 1950, the flamespread properties of materials, as measured by this method, have been reported as ratings, classifications, or indexes. An index is considered more indicative of the nature of the results and is the present terminology used in the standard. The original method of determining flamespread index was based on either the ratio of the time at which flames traveled the full tunnel length or the partial flame travel distance relative to that of red oak. In 1968, a change was made in the FSI calculation to account for an anomaly between results for flamespread greater than or less than $13^1/_2$ ft (4.1 m). In 1976, the flamespread index was revised to be based on area. The total area under the distance-time curve, ignoring any flame-front recession, was compared to a specified area typical of the burning of red oak flooring. The current calculation method (*see Appendix B*) uses a formula that takes the rate of flame travel into account.

D-2.6

The sensitivity study by Endicott and Bowhay in 1970 has led to a concerted effort by the ASTM tunnel operators group to address concerns identified by that study.[3] Since 1975, a series of changes have been specified in the standard. These include defining the duration of furnace preheating, the incorporation of a floor thermocouple, and the specification of the details of furnace construction and standardization.

D-2.7

Particular attention has been paid to the refinement of the apparatus and procedure involved in the measurement of the smoke generated during testing. Round-robin tests that have been conducted to date have indicated large differences in smoke development values for interlaboratory tests on replicate specimens.[4]

D-2.8

Some of these revisions include standardization of the smoke-density measuring equipment, its location in the exhaust duct, and its orientation. The measurement of smoke density is reported in terms of the area under the light absorption-time curve relative to a similar curve for red oak. Since the quality of vision-obscuring particles in the smoke column is not linearly related to light absorption, this procedure has been criticized by some parties. The method does, however, provide a basis for comparisons.

D-2.9

In 1970, a revision to the scope of this standard was adopted to emphasize that there was no direct relationship between the flamespread index (FSI) and the fuel contributed or smoke density index (SDI). This revision was deemed necessary because some enforcement officials were assigning equal significance to the values.

D-2.10

Prior to 1978, the report of tests included an evaluation of the fuel contribution as well as the FSI and SDI. However, it is now recognized that the rise in temperature of the thermocouple located near the end of the tunnel, where the thermocouple is based, does not provide a valid measure of fuel contribution. Therefore, although the data are recorded during the test, this information is no longer normally reported.

D-2.11

Appendix A, adopted in 1968, is intended as a guide for the mounting of specimens. It is not a mandatory part of the method, since the intent of the method is that the specimen be tested as closely as possible to the manner in which it is to be applied in general use. In 1978, revisions were made that dealt with the testing of adhesives, the description of a wood substrate for testing coatings, and the definition of the properties of the inorganic-reinforced cement board used as a standard backing and the metal rods used as supports.

D-3 Fire Exposure Conditions.

D-3.1

The tunnel test fire exposure is provided by a $4^1/_2$-ft (1.37-m) long test flame covering approximately 7 ft^2 (0.65 m^2) of the 36 ft^2 (3.34 m^2) of the exposed specimen surface during the 10-minute test period. It releases heat at a rate of approximately 5000/Btu/min (88 kW) and creates gas temperatures near the specimen surface of up to 1600°F (900°C).

D-3.2

The size and heat release rate of the exposing flame developed after repeated experiment tests, although not optimum fire conditions, were selected to produce a flamespread over the entire length of the calibration material in about $5^1/_2$ minutes.[5] It was found that conditions could be changed so that flames would spread faster, but these conditions caused the flame to spread too fast to make the necessary observations of the flamespread, smoke density, and temperature rise of the thermocouple.

D-4 Furnace Calibration.

D-4.1

Select red oak was chosen as a control material because it is a fairly uniform grade of lumber that is nationally recognized, whereas many other types have a purely local significance. It is readily available, usually uniform in thickness and moisture content, and generally provides repetitive results. In recent years, experiments have used man-made materials, such as particle board, in the hope of further refining repeatability; however, red oak is still used as a calibrating material.

D-4.2

The operating conditions of the tunnel are adjusted if necessary to ensure that the flame spreads to the end of the tunnel in 5.5 minutes ± 0.25 minutes using a specimen of red oak flooring. Tests are run with an inorganic-reinforced cement board (ACB) specimen to establish the distance of the exposing flame at $4^1/_2$ ft (1.37 m). The calibration specifies only the time at which the flame passes over the end of the specimen. The FSI is determined by dividing the area under the flamespread by the time curve. Therefore, the FSI of red oak is no longer exactly 100 as originally specified.

D-4.3

Recognition of the importance of turbulence, including the role of fire bricks and of window recesses, resulted in a revision in the method in 1976.

D-5 Repeatability and Reproducibility.

D-5.1

Four round-robin tests have been conducted: the first took place in 1958 and was conducted by Underwriters Laboratories and Southwest Research Institute[4]; the second, in 1959, was sponsored by the former Acoustic Tile Association and was conducted by four laboratories using four different tiles; the third, in 1973, was conducted on floor coverings by the National Bureau of Standards in cooperation with 11 laboratories[6]; the fourth, in 1978, on loose-fill cellulosic insulation, was conducted by the Consumer Product Safety Commission using six laboratories. Other tests are now in progress under the auspices of ASTM Committee E-5. A precision and accuracy statement is being prepared. In the interim, the reader is directed to the round-robin reports if information on precision and accuracy is needed.

D-5.2

An ASTM task group of Subcommittee E05.22, composed of tunnel operators, is reviewing comprehensive design and operational and procedural revisions to improve uniformity among facilities.

D-6 Advantages and Problems.

D-6.1

Test results from this standard generally have shown performance similar to that observed during accidental building fires for some materials and exposure. It should be emphasized, however, that it is the intent of the method to provide only comparative classifications.

D-6.1.1 The test method provides a large, flaming fire exposure, with specimen thermal exposure and area coverage sufficient to bring about progressive surface burning and combustible volatile generation characteristics of the materials under evaluation, resulting in a moving, wind-aided flame front.

D-6.1.2 The test method involves a large specimen, nominally 36 ft^2 (3.34 m^2) of exposed area, which allows realistic fire involvement of material surfaces and the development of physical and structural failures (e.g., collapse, buckling, large ruptures, or cracks) that can influence flammability performance during the test.

D-6.1.3 The test method can be applied to a wide range of materials, including composite constructions of faced or laminated boards, panels, units, or sections in actual field-installed thicknesses.

D-6.1.4 The test method can be used to measure the effects of density, thickness, surface contour, surface finish, delamination, strength, and joint design on the surface flammability of the specimen.

D-6.1.5 The test method characterizes most high flamespread materials that have been involved in rapidly developing field fires (e.g., highly combustible coatings on wood products, certain cellulosic acoustical materials, and insulation facings applied with combustible adhesives) and provides an accurate characterization of the performance of some low flamespread materials in actual fires (e.g., gypsum and mineral products).

D-6.1.6 Although the test measures surface burning characteristics, the visual observation of flame travel is based on maximum flame extension anywhere within the tunnel volume, not necessarily directly on a specimen surface that might not be clearly visible. Surface flammability measurements of building materials do not yield a unique material property. Rather, the measurement is highly influenced by the method of test used.

D-7 Uses and Limitations.

D-7.1

The orientation of the specimen in this method is in a horizontal ceiling position. This orientation places some limitations on the type of material that can be realistically mounted during testing. Prior to 1960, the tunnel was used primarily for the investigation of the surface burning characteristics of homogeneous compositions of ceiling and wall finishes, such as acoustical tiles, wall coverings, coatings, and various types of decorative panel, with all materials able to remain in the ceiling position throughout the test.

D-7.2

Through adaptation (*see Appendix B*), the procedure was expanded to include the evaluation of composites and assemblies. Appendix B contains mounting recommendations for a number of individual categories of product classification including acoustical and similar panel products; composite building units; adhesive; batt and blanket insulation; fire retardant and general-purpose coatings; loose-fill thermal insulations; treated and untreated plywoods; lumber and wood composition boards; foamed, molded, reinforced, and laminated plastics; and sheet-type wall coverings.

D-7.3

The difficulty of defining materials that contribute little or no fuel to a fire has in the past led to the use of ASTM E 84/NFPA 255 to provide information about the combustibility of materials. ASTM Committee E-5 and the NFPA Technical Committee on Fire Tests do not and have not ever recommended that the results of these tests alone be used to describe material combustibility.

D-7.4

Composite assemblies or panels that use metal or mineral facings and combustible interior cores, and that remain essentially impermeable to flame throughout the test, might not be completely evaluated for surface burning behavior by this method, since the interior cores are not fully challenged.

D-7.5

Some materials require support to remain in place during the test, such as loose-fill insulation supported by a metal screen. The supporting screen tends to produce low flamespread indexes (FSI) relative to those obtained for materials that are not so supported. Conversely, materials that are supported on rods, such as batt insulation, can produce higher FSI if retained on the ceiling rather than allowed to burn on the floor.

D-7.6

Some materials, such as composites, can delaminate during the test. This can cause two possible responses: the material can expose two or more surfaces to the flame, increasing the FSI; or the material can sag or one end can drop into the fire chamber, impeding further flamespread.

D-7.7

Some materials, such as cellular plastics and thermoplastic and thermosetting materials, can be difficult to evaluate. Thermoplastic and thermosetting materials that are not mechanically fastened often fall to the floor of the tunnel and usually produce relatively low FSI. If supported on wire screen, rods, or other supports, these materials can become completely engulfed in flame, thereby creating a questionable comparison between the surface flamespread of nominal

1-in. (25.4-mm) thick red oak and the burning rate of these materials. Where the entire specimen is consumed, as opposed to the surface burning of red oak, much more oxygen is used and higher smoke developed indexes are usually obtained for these materials.

D-7.8

The materials described in this section, (i.e., those that drip, melt, delaminate, draw away from the fire, or need artificial support) present unique problems and necessitate careful interpretation of the test results. Some of these materials that are assigned a low FSI based on this test method can exhibit an increasing propensity for generating flameover conditions during room fire tests with increasing area of material exposure and increasing intensity of fire exposure. The result, therefore, might not be indicative of their performance if evaluated under large-scale test procedures. Alternative means of testing might be necessary to fully evaluate some of these materials.

D-7.9

In order to provide needed technical data, flammability evaluations of cellular plastics for building construction using the Steiner Tunnel began with the testing and classification of a flame-retardant formulation of polystyrene foam board in 1960, with subsequent evaluation of polyurethane-type boards incorporating flame-retardant resin systems (first generation) beginning in 1964, polymerically and chemically modified flame-retardant polyurethane-type formulations (second generation) in 1965, polyisocyanurate-type foams initiated in 1968, and, most recently, urea-formaldehyde-type, cavity-fill foams. Spray-applied and poured-in-place cellular foam systems were first subjected to the test in 1968 and 1972, respectively.

D-7.10

From 1960 through 1973, over 2000 tunnel tests have been conducted on flame-retardant and general-purpose polystyrene, polyurethane, polyisocyanurate and urea-formaldehyde cellular plastics, in board-stock, spray-applied or poured-in-place forms, yielding flamespread values ranging from less than 5 to over 2000.[7]

D-7.11

The flamespread index of some materials varies depending on environmental conditions. The prescribed limits on the temperature and relative humidity for specimen conditioning and tunnel air supply [both 73.4°F ± 5°F (23°C ± 2.8°C), 50 percent rh ± 5 percent rh] were selected to minimize these effects.

D-8 Correlation with Other Fire Conditions.

Several studies have examined the relationship of the FSI test results on materials to the performance of the same materials in large-scale fire growth experiments and in other laboratory test methods. Some comparisons with large-scale experiments are provided in the footnotes. Comparisons also have been made between ASTM E 84/NFPA 255, ASTM E 162, *Standard Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source*, ASTM E 286, *Test Method for Surface Flammability of Building Materials Using an 8-ft (2.44-m) Tunnel Furnace*, the 2-ft tunnel test, the “corner test,” and other tests.

D-9 Footnotes to Appendix D.

[1] Steiner, A. J., Building Officials Conference of America Yearbook, 1949-1950, pp. 115-116.

[2] Underwriters Laboratories Inc., “Fire Hazard Classification of Building Materials,” Bulletin of Research No. 32, Chicago, IL, September 1947.

[3] Endicott, L. E. and Bowhay, R. B., “A Statistical Evaluation of the Fire Hazard Classification Furnace,” (ASTM E 84-68), ASTM Materials Research and Standards, May 1970, pp. 19-21, 50-52.

[4] “Round-Robin Tests on Tunnel Type Flame Spread Furnaces,” for ASTM Project No. 1-811-2, Final Report, Southwest Research Institute, San Antonio, TX., April 16, 1959.

[5] Steiner, A. J., “Burning Characteristics of Building Materials,” *Fire Engineering*, May 2, 1951.

[6] Lee, T. G. and Huggett, C., “Interlaboratory Evaluation of the ASTM E 84-70 Tunnel Test Applied to Floor Coverings,” *Journal of Testing and Evaluation*, Vol. 3, No. 1, ASTM 1975.

[7] Underwriters Laboratories Inc., “Flammability Studies of Cellular Plastics and Other Building Materials Used for Interior Finish,” Subject 723, UL Inc., Northbrook, IL, June 13, 1975.

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 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*, 1995 edition.

E-1.2 Other Publication.

E-1.2.1 ASTM Publication. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187.

ASTM A 390, *Standard Specification for Zinc-Coated (Galvanized) Steel Poultry Fence Fabric (Hexagonal and Straight Line)*, 1992.

1993 Edition

Standard Methods of Fire Tests of Roof Coverings

1993 Edition

This edition of NFPA 256, *Standard Methods of Fire Tests of Roof Coverings*, 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.

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 256

The test procedure covered by this standard was developed prior to 1920 by Underwriters Laboratories Inc. The test procedure was put in standard form by the E5 Committee on Fire Standards of the American Society for Testing and Materials, adopted by ASTM as a tentative standard in 1955, and revised in 1956. It was adopted by the NFPA on May 22, 1958, on recommendation of the Committee on Fire Tests and was subsequently published as NFPA 256, in May 1958. It was adopted by ASTM as a standard later in 1958 and published by ASTM as E108-58. It was also published by Underwriters Laboratories Inc., as No. 790, September 1958. Revised NFPA editions were published in 1964, 1970, 1976, 1981, and 1987. The 1993 edition of NFPA 256 was revised editorially to bring this document into conformance with its ASTM and UL counterparts.

To the User

Metric units of measurement in this standard are in accordance with the modernized metric system known as the International System of Units (SI). The unit liter, which is outside of but recognized by SI, is commonly used and is therefore used in this standard. In this standard, values for measurements are followed by an equivalent in SI units. The first stated value shall be regarded as the requirement because the given equivalent value may be approximate.

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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.

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 256
Standard Methods of
Fire Tests of Roof Coverings

1993 Edition

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

Chapter 1 General

1-1 Scope.

1-1.1

These methods are intended to measure the relative fire characteristics of roof coverings under a simulated fire originating outside the building. They shall be applicable to roof coverings intended for installation on either combustible or noncombustible decks, when applied as intended for use.

The following methods are included:

(a) Intermittent Flame Exposure Test (*see Chapter 6*)

(b) Spread of Flame Test (*see Chapter 7*)

(c) Burning Brand Test (*see Chapter 8*)

(d) Flying Brand Test (*see Chapter 9*)

(e) Rain Test (*see Chapter 10*)

(f) Weathering Test (*see Chapter 11*).

1-1.2

Three classes of fire test exposure are described.

1-1.2.1 Class A. Class A tests shall be applicable to roof coverings that are effective against severe test exposure, afford a high degree of fire protection to the roof deck, do not slip from position, and do not present a flying brand hazard.

1-1.2.2 Class B. Class B tests shall be applicable to roof coverings that are effective against moderate test exposure, afford a moderate degree of fire protection to the roof deck, do not slip from position, and do not present a flying brand hazard.

1-1.2.3 Class C. Class C tests shall be applicable to roof coverings that are effective against light test exposure, afford a light degree of fire protection to the roof deck, do not slip from position, and do not present a flying brand hazard.

1-1.3

It is the intent of the tests to demonstrate the relative performance of materials under the test exposure involved. These tests shall not be construed as having determined suitability for use after fire exposure.

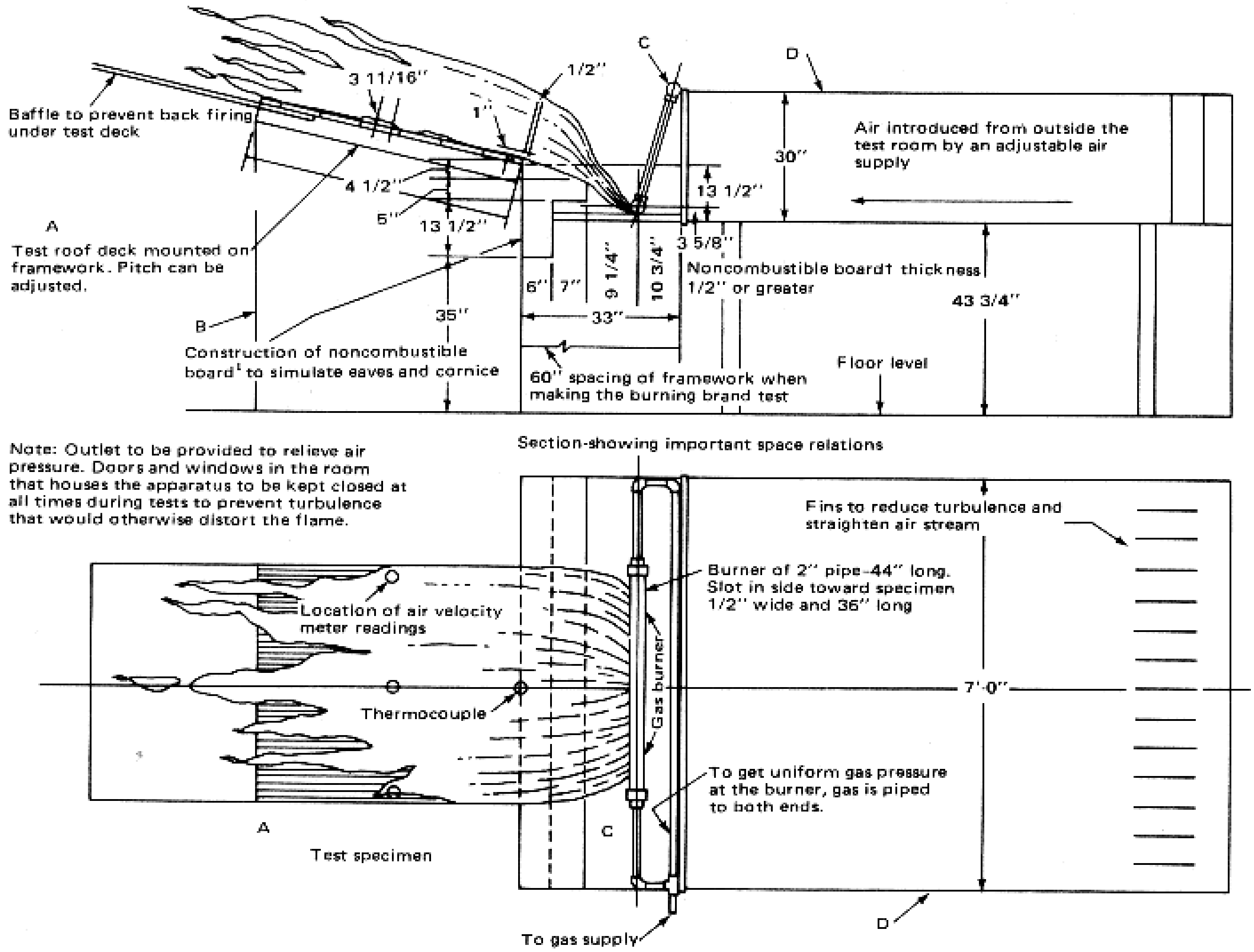
Chapter 2 Equipment and General Test Procedures

2-1 Apparatus.

2-1.1

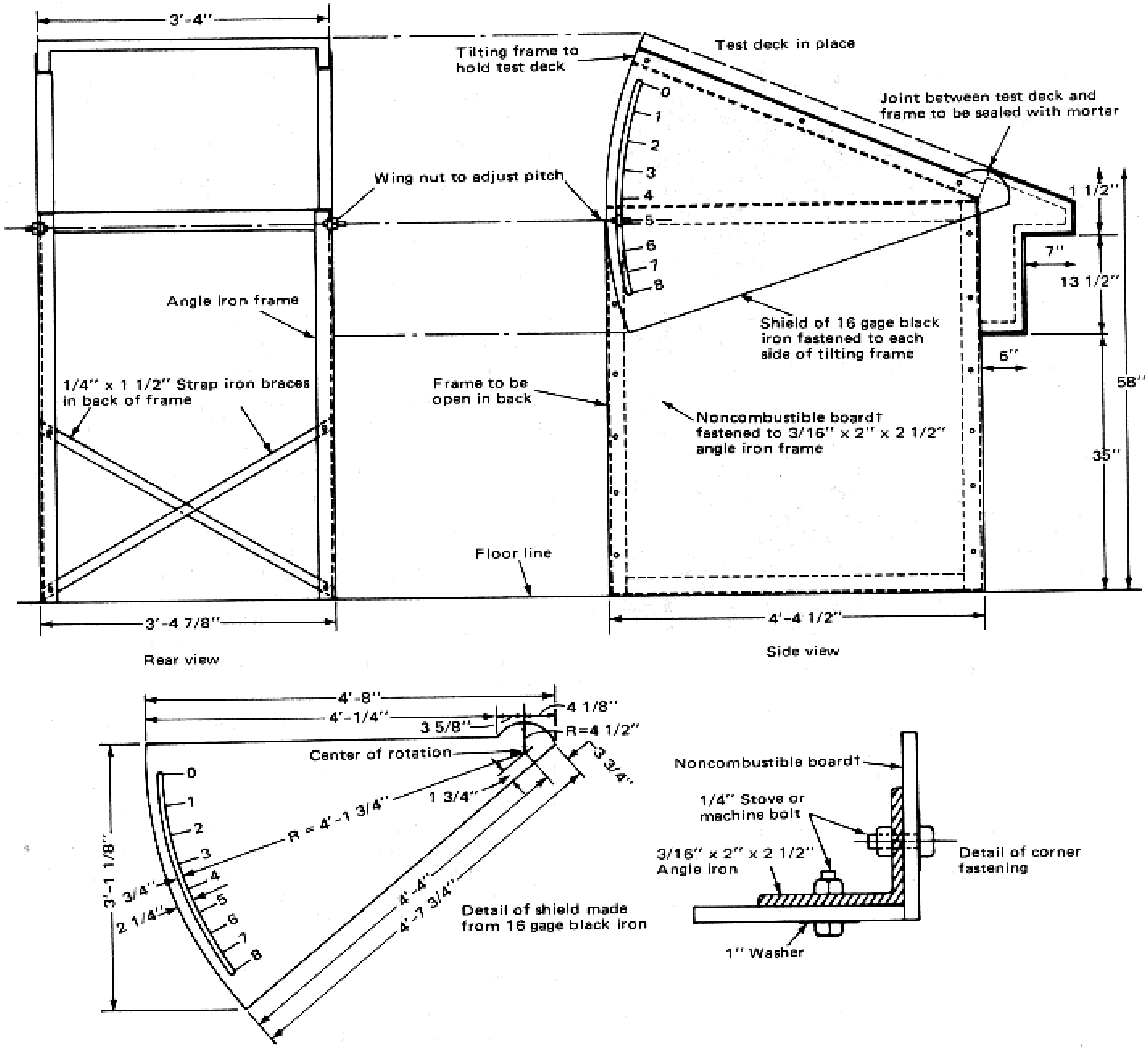
The essential elements of the fire test apparatus are illustrated in Figure 1. These shall include a test roof deck (A), an adjustable frame [*see (B) in Figure 2*] on which the test roof deck is mounted, a gas burner (C) as a source of flame, a wind tunnel (D), an air velocity meter[1], a gas pressure gauge, a control valve, and an adjustable air supply.

1Any direct reading instrument with a scale graduated in increments of not more than 20 ft/min (6 m/min) or any timed instrument with a scale graduated in increments of not more than 20 ft/min (6 m/min) for a timed interval of 1 min should be used



†Johns Manville Marinite or equivalent
For SI units: 1 in. = 25.4 mm, 1 ft = 0.305 m

Figure 1 Schematic drawing of fire test apparatus.



†Johns Manville Marinite or equivalent.
For SI units: 1 in. = 25.4 mm, 1 ft = 0.305 m

Figure 2 Detail of tilting frame to hold test roof deck.

2-1.2

Figure 3 illustrates the essential elements of the rain test apparatus.

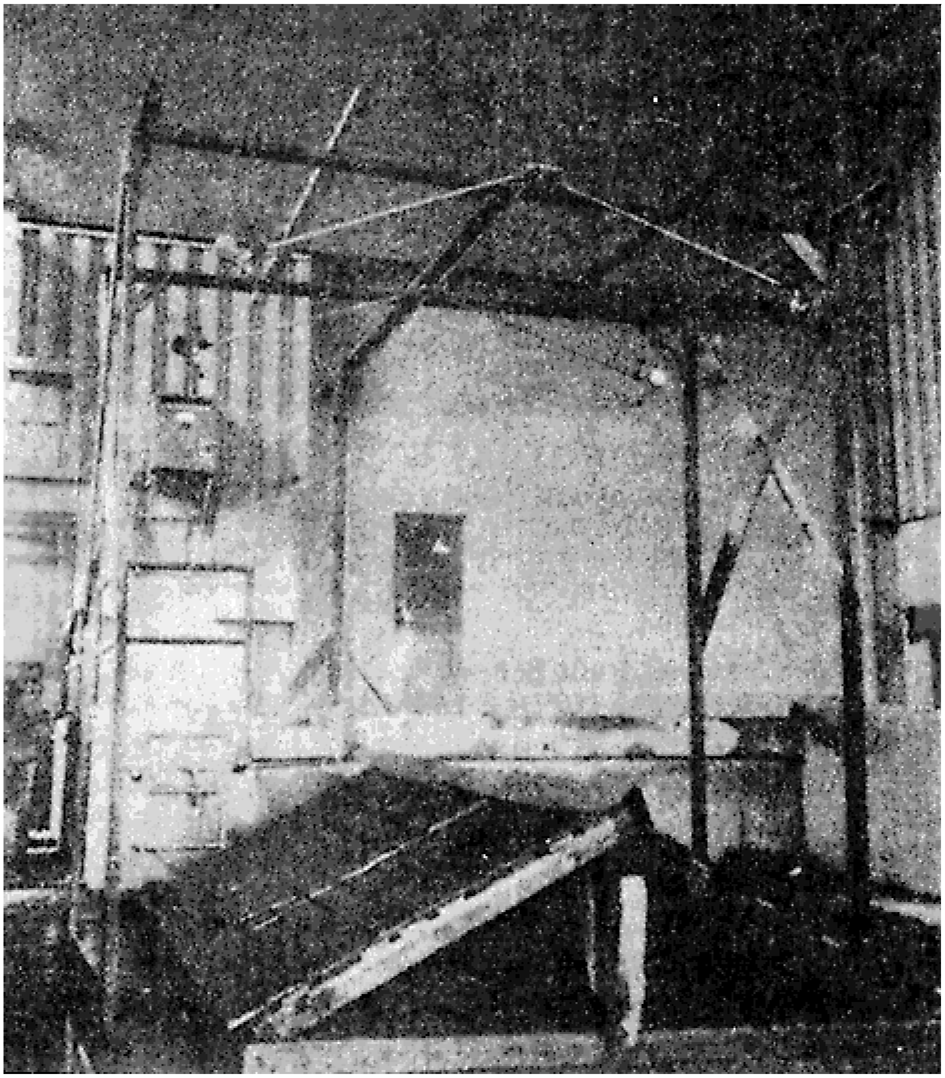


Figure 3 Rain test apparatus.

2-2 Test Flame.

Control of the shape and size of the flame depends on minimizing air turbulence in the immediate vicinity of the apparatus. To do this it is important that:

(a) Free outlet to outside air beyond and above the test apparatus so as to exhaust air introduced into the test room by the blower shall be provided, and

(b) All openings into the test room other than those mentioned in 2-1.1, such as doors and windows, shall be closed.

2-3 Supply Air.

The temperature of the room shall be between 50°F and 90°F (10°C and 32.2°C).

Chapter 3 Calibration

3-1 Air Current.

3-1.1

The test apparatus shall be set up for the intermittent flame test, and a smooth, noncombustible calibration deck 4 ft 4 in. (1320 mm) long shall be positioned on the framework at an incline of 0.416:1 [5 in. (127 mm) per horizontal ft (305 mm)].

3-1.2

The air velocity shall be measured midway up the slope of the calibration deck, at its center, and 3 in. (76 mm) from each edge.

3-1.3

The center of the air-measuring device shall be positioned $3^3/_4$ in. ± $^1/_8$ in. (95 mm ± 3 mm) above the surface. The airflow through and around the instrument shall be as free and undisturbed as possible.

3-1.4

The air supply system shall be adjusted to produce a 1-minute time average velocity of 1056 ft ± 44 ft/min (5.36 m ± 0.2 m/min) at each of the three locations detailed in 3-1.2.

3-2 Flame Temperature.

3-2.1

The test apparatus shall be set up for the intermittent flame test in accordance with 3-1.1, and the air velocity shall be adjusted in accordance with 3-1.4.

3-2.2

The temperature shall be measured with a No. 14 gauge (1.6 mm diameter) Type K wire thermocouple located 1 in. (25 mm) above the surface and $^1/_2$ in. (13 mm) toward the source of the flame from the lower front edge of the calibration deck.

3-2.3

The gas flow shall be adjusted to produce a 2-minute average flame temperature of 1400°F ± 50°F (760°C ± 28°C) for Class A and Class B and 1300°F ± 50°F (704°C ± 28°C) for Class C tests. The response of the thermocouple to the test flame shall be allowed to stabilize before the 2-minute average flame temperature is measured. The average shall be based on readings taken at 5-second intervals.

3-2.4

The top surface of the leading edge of the calibration deck shall be flush with the top edge of the simulated eave within a tolerance of 0 ± $^1/_2$ in. (0 ± 13 mm).

3-2.5

If the above conditions are satisfied, the flame shall be approximately the width of the deck at its bottom edge and the top surface of the calibration deck shall be uniformly bathed except for the two upper corners. The flame shall extend approximately to the upper edge of the calibration deck with licks of flame extending another 1 - 2 ft (300 -600 mm).

3-3 Rain Test.

3-3.1

The horizontal projected area over which each nozzle discharges water to the nearest sq ft (0.1 m^2) shall be measured. The discharge of water for each nozzle shall be measured for 1 minute.

3-3.2

The total water utilized during the test shall be monitored (a commercial water meter is suitable for the purpose). For a 7-day cycle, the water usage shall be 73 U.S. gal ± 1.7 U.S. gal/sq ft (2974 L ± 40 L/m^2) or 0.435 U.S. gal/sq ft/hr (17.7 L/m^2/hr).

3-4 Frequency of Calibration.

3-4.1

The apparatus shall be calibrated for air velocity and flame temperature prior to each day's use. The apparatus shall be calibrated for flame temperature when shifting from Class A or B to Class C tests or vice versa.

3-4.2

Any indication of off-limit condition, such as unusual flame appearance or flame contour, excess turbulence, unusual noise, etc., shall be cause for calibration prior to further use.

3-4.3

The water flow from each nozzle shall be visually checked for obvious water obstruction in the nozzle and uneven spray pattern each day during the water cycle, and adjustments shall be made when necessary.

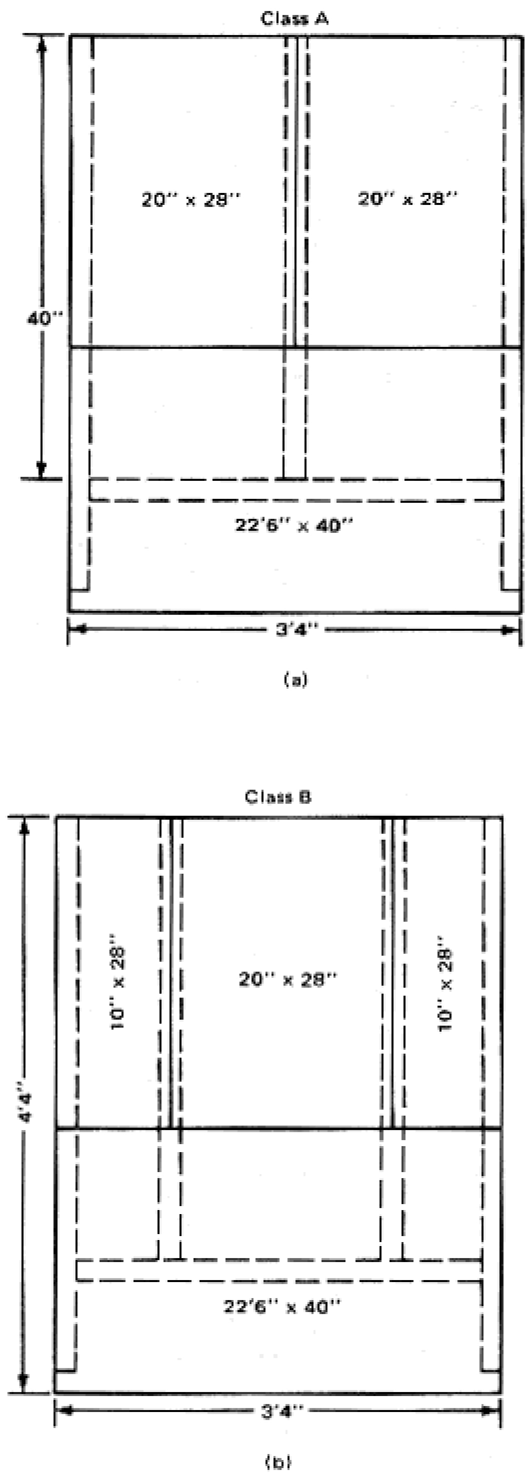
3-4.4

A review of the total water flow shall be made at the end of each day and at the end of each water cycle. The cause of any off-limit conditions shall be corrected.

Chapter 4 Preparation of Test Specimens

4-1 Construction of Test Decks.

[*Also see Figures 4(a), 4(b), 4(c), and 4(d)*.]



For SI units: 1 in. = 25.4 mm

Figures 4(a) (top) and 4(b) (bottom) Plywood—decks burning brand tests. Plywood overhangs 2 x 4s by 11/4

in. at leading edge. 2 x 4 supports are indicated by dotted lines. Plywood joint width - 1/8 in.

4-1.1

The test deck for the intermittent flame exposure, burning brand tests, flying brand test, rain test, and weathering test shall be 3 ft 4 in. × 4 ft 4 in. (1020 mm × 1320 mm) and shall be made of No. 1 white pine lumber having not less than 8 percent nor more than 12 percent moisture content.

Exception: As specified in 4-1.2 through 4-1.5.

4-1.1.1 The lumber shall be free of large or loose knots, sapwood, rot, or pitch pockets and shall contain no edge knots.

4-1.1.2 Individual deck boards shall be of nominal 1 in. × 8-in. (25 mm × 200-mm) lumber (S4S).

4-1.1.3 The boards shall be laid across the shorter dimension of the test deck spaced $^1/_4$ in. (6 mm) apart and shall be securely nailed to two nominal 2 in. × 4-in. (50 mm × 100-mm) wood battens located under and flush with the outer edges of the deck [*see Figure 4(d)]*.

4-1.1.4 Decks so constructed shall be even and uniform.

4-1.2

Where the roof covering is intended to be installed over other than solid deck, the test decks shall be constructed of nominal 1 in. × 4-in. (25 mm × 100-mm) lumber (S4S) spaced a minimum of 1$^5/_8$ in. (41 mm) apart and shall be securely nailed to two nominal 2 in. × 4-in. (50 mm × 100-mm) wood battens. The lumber shall be of the same quality as specified in 4-1.1.

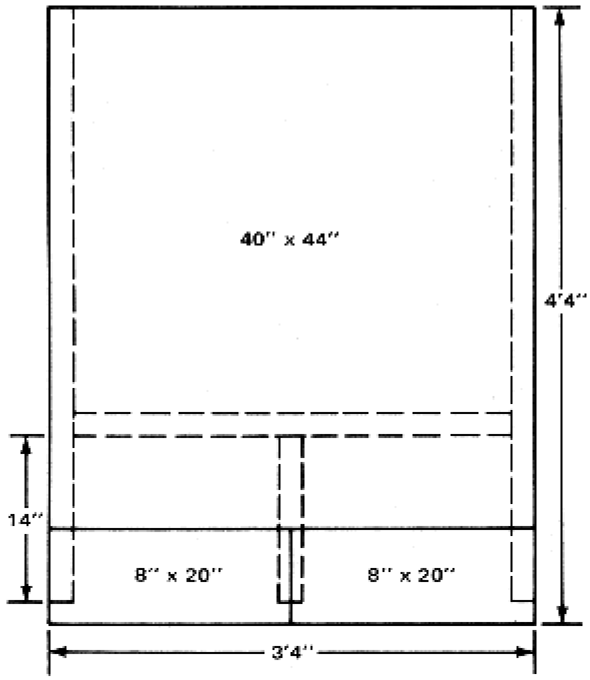
4-1.3

Roof coverings shall be permitted to be applied to panel-type test decks such as plywood, wafer board, particle board, or oriented strand board in the minimum thickness recommended by the manufacturer. *This deviation shall be noted in the report.*

4-1.3.1 Plywood, if used, shall be exterior Type C-C plugged or higher grade, conforming to PS1-83, *Construction and Industrial Plywood*.

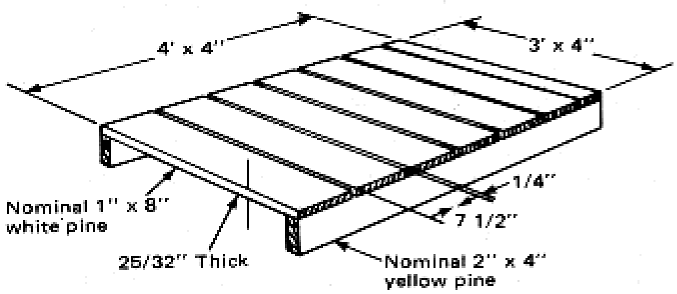
4-1.3.2 These decks shall have $^1/_8$-in. (3-mm) vertical and horizontal joints located as specified in 4-1.4 through 4-1.5.3 with all vertical joints centered on nominal 2 in. × 4-in. (50 mm × 100-mm) wood battens.

4-1.3.3 If wood battens or tongue and groove joints are specified for horizontal joints, it shall be so noted in reporting the tests.



For SI units: 1 in. = 25.4 mm

Figure 4(c) Plywood deck intermittent flame test, Class A or Class B. Plywood overhangs 2 x 4s by 11/4 in. at leading edge. 2 x 4 supports are indicated by dotted lines. Plywood joint width - 1/8 in.



For SI units: 1 in. = 25.4 mm

Figure 4(d) Construction of test deck for other than wood shingles and shakes.

4-1.4

Decks constructed of panel-type material for intermittent flame tests shall have a $^1/_8$-in. (3-mm) horizontal joint 8 in. (203 mm) from and parallel to the 3 ft 4-in. (1020-mm) long leading edge.

4-1.4.1 In addition, a $^1/_8$-in. (3-mm) vertical joint centered on the deck and extending from the leading edge of the deck to the $^1/_8$-in. (3-mm) horizontal joint shall be provided.

4-1.4.2 Since the lower $1^1/_2$ in. (38 mm) of this joint is not protected by the 2 in. × 4-in. (50 mm × 100-mm) batten, due to the mounting arrangement on the carriage, the underside of this joint shall be covered from the end of the 2 in. × 4 in. (50 mm × 100 mm) to the leading edge of the deck by a piece of sheet steel, nominally 2 in. (50 mm) in width.

4-1.5

For Class A and Class B burning brand tests on decks other than 1 in. × 8-in. (25 mm × 200-mm) nominal lumber, the $^1/_8$-in. (3-mm) horizontal joint shall be $22^1/_2$ in. (570 mm) from and parallel to the leading edge of the deck.

4-1.5.1 Class A test decks shall have a $^1/_8$-in. (3-mm) vertical joint centered on the deck that extends above the horizontal joint.

4-1.5.2 For Class B test decks, two $^1/_8$-in. (3-mm) vertical joints, extending above the horizontal joint with each vertical joint located 10 in. (250 mm) from and parallel to the edge of the deck, shall be provided.

4-1.5.3 For Class C burning brand test, five evenly spaced horizontal joints, with a minimum width of $^1/_8$ in. (3 mm) between joints in the plywood, shall be provided.

4-1.6

For the spread of flame tests, the deck shall be constructed in the same manner as specified for the intermittent flame test, except that (1) the vertical and horizontal joints need not be provided and (2) the length of the deck shall be as specified in 4-1.6.1.

4-1.6.1 The length of the test deck shall be 13 ft (4000 mm) for Class C tests, 9 ft (2700 mm) for Class B tests, and 8 ft (2400 mm) for Class A tests.

4-1.6.2 For tests of materials intended to be installed only over noncombustible decks, a noncombustible deck of the applicable length as specified in 4-1.6.1 shall be permitted to be used. This deviation shall be noted in the report.

4-2 Application of Roofing on Test Roof Deck.

4-2.1

Representative samples of roof covering materials shall be applied to test decks as specified in Table 1.

Table 1 Required Tests and Test Assemblies

	Minimum Required Number of Test Assemblies					
Material to Be Tested	**Intermittent Flame Test**	**Spread of Flame Test**	**Burning Brand Test**	**Flying-Brand Test**	**Rain Test**	**Weathering Test**
I. Other than wood shakes or shingles, for installation on:						

Combustible decks						
Class A	2	2	4	NA[a]	NA	NA
Class B	2	2	2	NA	NA	NA
Noncombustible decks only [b]	NA	2	NA	NA	NA	NA
II. Wood Shakes and shingles[c]:						
Class A	3 (2) [5]	3	6 (2) [5]	3 (2) [5]	6	15
Class B or Class C	3 (2) [5]	3	3 (2) [5]	3 (2) [5]	6	15

[a] NA - Test is not required.

[b]The flying brand, rain, and weathering tests may be required. (*See Sections 9-1, 10-1.1, and Section 11-1*.)

[c] Number in parentheses is number of samples from rain test to be tested. Number in brackets is number of samples from weathering test to be tested.

Note: Where roof covering materials exhibit variable performance, more than the minimum number of test decks may be required.

4-2.2

The roof covering materials under investigation shall be applied in accordance with the manufacturer's instructions and shall extend to and be flush with the edges of the deck.

Exception: A 1-in. (25-mm) overhang is permitted at the leading edge.

4-3 Storage and Conditioning of Test Roof Decks.

The completed test roof decks shall be stored indoors at a temperature of not lower than 60°F (16°C) nor more than 90°F (32°C). The completed test roof decks shall be conditioned to a constant mass. The moisture content of the sample immediately prior to the test shall be measured and recorded.

Chapter 5 General Conditions

5-1

The required tests, the applicable number of test decks, and the types of test assemblies are detailed in Table 1.

5-2

In the fire tests described below, mortar (cementitious mixture, lime, and water) shall be troweled into the joint formed by the leading edge of the roof covering material and the framework of the carriage. This is to prevent air or the test flame from traveling under the material being tested.

5-3

In these tests, all decks shall be subjected to an air current as calibrated in Chapter 3.

5-4

Prepared roof coverings shall be tested at a slope of 0.416:1 [5 in. (127 mm) per horizontal ft (305 mm)].

5-5

Built-up roof coverings shall be tested at the maximum slope recommended by the manufacturer but shall not exceed 0.416:1 [5 in. (127 mm) per horizontal ft (305 mm)].

5-6

The slope used shall be noted in the report.

Chapter 6 Intermittent Flame Exposure Test

6-1 General.

This test shall be performed on a minimum of two test decks.

NOTE: Where the roof covering materials exhibit a variable performance, more than two test decks shall be required.

6-2 Procedure.

6-2.1

A test deck 4 ft 4 in. (1320 mm) long shall be mounted on the framework at the required incline (*see Sections 5-4 through 5-6*), and the blower shall be adjusted to produce the specified air current.

6-2.2

The test deck shall be subjected to a luminous gas flame as calibrated in accordance with Section 3-2.

6-3 Application of Flame.

The flame shall be applied intermittently for the specified periods and specified time intervals between applications, as indicated below.

Method of Test	Flame On, minutes	Flame Off, minutes	No. of Test Cycles
Class A	2	2	15
Class B	2	2	8
Class C	1	2	3

6-4 Air Current.

The air current shall be maintained throughout the test and after the last application of flame until all evidence of flame, glow, and smoke has disappeared from both the exposed surface of the material being tested and the underside of the test deck, or until failure occurs. In no case shall the air current or test duration be maintained for more than 1 hour after the last flame cycle for a Class A or B test or $^1/_2$ hour after the last flame cycle for the Class C test.

6-5 Observations.

During and after the intermittent flame test, including "on" and "off" periods of flame application, observations shall be made for the appearance of sustained flaming on the underside of the test deck, production of flaming or glowing brands, displacement of portions of the test sample, and exposure or falling away of portions of the roof deck.

Chapter 7 Spread of Flame Test

7-1 General.

This test shall be performed on a minimum of two test decks.

NOTE: Where the roof covering materials exhibit a variable performance, more than two test decks shall be required.

7-2 Procedure.

A test deck, of a length as specified in 4-1.6.1 shall be mounted in the same manner, and shall use a luminous gas flame as described in Section 6-2 for the intermittent flame tests.

7-3 Application of Flame.

7-3.1

For Class A and Class B tests, the gas flame shall be applied continuously for 10 minutes or until the flame (actual flaming of the material being tested) permanently recedes from a point of maximum spread, whichever is shorter.

7-3.2

For Class C test the gas flame shall be applied for a period of 4 minutes, or until recession occurs, and then removed.

7-4 Observations.

During the application of the test flame, the test sample shall be observed for the distance to which flaming of the material has spread, production of flaming or glowing brands, and displacement of portions of the test sample.

Chapter 8 Burning Brand Test

8-1 General.

This test shall be performed on a minimum of four test decks for Class A fire test exposure and two test decks for Class B or Class C fire test exposure.

NOTE: Where the roof covering materials exhibit a variable performance, more than the minimum number of test decks shall be required.

8-2 Procedure.

A 4 ft 3-in. (1320-mm) long test deck shall be mounted in the same manner as specified in Section 6-2 for the intermittent flame test.

Exception: The framework shall be 60 in. (1520 mm) from the air duct outlet (see Figure 1), and the gas piping and burner shall be removed so as not to obstruct the airflow.

8-3 Size and Construction of Brands.

8-3.1 General.

The brands (*as shown in Figure 5*) shall be constructed as follows and shall be conditioned in an oven at 105°F-120°F 40.55°C-48.9°C) for at least 24 hours.

8-3.2 Class A Test Brand.

8-3.2.1 The Class A test brand shall consist of a grid 12 in. (305 mm) square and approximately $2^1/_4$ in. (57 mm) thick, made of dry Douglas fir lumber free of knots and pitch pockets.

8-3.2.2 Thirty-six, nominal 1 in. × 1 in. × 12-in. (25 mm × 25 mm × 305-mm) strips, dressed on all four sides to $^3/_4$ in. × $^3/_4$ in. (19 mm × 19 mm) and placed in three layers of 12 strips each, with strips spaced $^1/_4$ in. (6 mm) apart, shall be used.

8-3.2.3 These strips shall be placed at right angles to those in adjoining layers and shall be nailed at each end of each strip on one face and in a diagonal pattern (as shown in Figure 5) on the other face.

8-3.2.4 The dry weight of the finished brand shall be 2000 g ± 150 g at time of test.

8-3.3 Class B Test Brand.

8-3.3.1 The Class B brand shall consist of a grid 6 in. (150 mm) square and approximately $2^1/_4$ in. (57 mm) thick, made of dry Douglas fir lumber free from knots and pitch pockets.

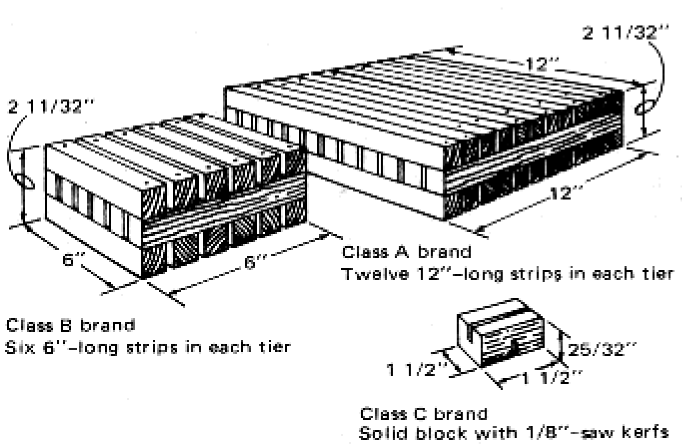


Figure 5 Brands for Class A, B, and C tests.

NOTE: Nails used in the construction of Class A and B brands should be No. 16, $1^1/_2$-in. (38-mm) long, bright, flat head, diamond point, wire nails. Sixty-eight nails weighing approximately 1.48 oz (42 g) should be used for Class A brand and 32 nails weighing approximately 0.74 oz (21 g) should be used for the Class B brand.

8-3.3.2 Eighteen, nominal 1 in. × 1 in. × 6-in. (25 mm × 25 mm × 150-mm) strips, dressed on all four faces to $^3/_4$ in. × $^3/_4$ in. (19 mm × 19 mm) and placed in three layers of six strips each, with strips placed $^1/_4$ in. (6 mm) apart, shall be used.

8-3.3.3 These strips shall be placed at right angles to those in adjoining layers and shall be nailed at each end of each strip on one face and in a diagonal pattern (as shown in Figure 5) on the other face.

8-3.4 Class C Test Brand.

8-3.4.1 The Class C test brand shall consist of a piece of dry, nonresinous, white pine lumber, free from knots and pitch pockets, $1^1/_2$ in. × $1^1/_2$ in. × $^{25}/_{32}$ in. (38 mm × 38 mm × 19 mm) thick, with a saw kerf $^1/_8$ in. (3 mm) wide, one half the thickness of the brand across the center of the top and bottom faces.

8-3.4.2 The saw kerf on opposite faces shall be at right angles to each other.

8-3.4.3 The dry weight of the finished brand shall be $9^1/_4$ g ± $1^1/_4$ g at time of test.

8-4 Ignition of Brands.

8-4.1

Before application to the test deck, the brands shall be ignited so as to burn freely in still air.

8-4.2

The brands shall be considered to be free burning after they have been subjected to the flame of a gas burner of such size that, during the process of ignition, the brands are nearly enveloped in the burner flame.

8-4.3

The flame temperature of the igniting flame shall be 1630°F ± 50°F (887°C ± 28°C) and shall be measured with a No. 14 gauge (1.6 mm diameter) Type K thermocouple $2^5/_{16}$ in. (59 mm) above the top of the burner, which shall be shielded from drafts.

8-4.4

The test brands shall be subjected to the required size of flame of the gas burner for the following periods of time:

(a) Class A test brands shall be exposed to the flame for 5 minutes, during which time they shall be rotated so as to expose each surface to the flame in the following manner and sequence:

Each 12 in. × 12-in. (305 mm × 305-mm) face for 30 seconds.

Each $2^1/_4$ in. × 12-in. (57 mm × 305-mm) face for 45 seconds.

Each 12 in. × 12-in. (305 mm × 305-mm) face again for 30 seconds.

(b) Class B test brands shall be exposed to the flame for 4 minutes, during which time they shall be rotated so as to expose each surface to the flame in the following manner and sequence:

Each 6 in. × 6-in. (150 mm × 150-mm) face for 30 seconds.

Each $2^1/_4$ in. × 6-in. (57 mm × 150-mm) face for 30 seconds.

Each 6 in. × 6-in. (150 mm × 150-mm) face again for 30 seconds.

(c) Class C test brands shall be exposed to the flame for 2 minutes, during which time they shall be rotated so as to expose each of the $1^1/_2$ in. × $1^1/_2$-in. (38 mm × 38-mm) faces to the flame for 1 minute.

8-5 Test Conditions.

8-5.1 Class A Tests.

8-5.1.1 A brand shall be placed on the surface of each test deck at the location considered most vulnerable (point of minimum coverage over deck joint) with respect to ignition of the deck, but in no case shall it be closer than 4 in. (100 mm) from either side or 12 in. (305 mm) from the top or bottom edge of the deck.

8-5.1.2 The brand shall be placed so that the strips in both the upper and lower layers are parallel to the direction of airflow, and the upper edge of the brand shall be located 3 in. (75 mm) above the horizontal joint in the test deck.

8-5.1.3 The brand shall be secured to the deck by a No. 18 (1.02 mm diameter) gauge soft iron wire.

8-5.1.4 If the roof covering is being tested as applied to plywood or other panel-type decks, the brand shall be placed so that it is centered laterally with respect to the vertical panel joint in the test deck, and the upper edge of the brand shall be located 3 in. (75 mm) above the horizontal panel joint in the test deck.

8-5.2 Class B Tests.

8-5.2.1 A brand shall be placed on the surface of the test deck at each of the two locations considered most vulnerable (point of minimum coverage over deck joint) with respect to ignition of the deck.

8-5.2.2 Each brand shall be positioned with its upper edge $1^1/_2$ in. (38 mm) above the selected joint in the deck boards, but in no case shall it be closer than 6 in. (150 mm) from each side or 12 in. (305 mm) from the top or bottom edge of the deck.

8-5.2.3 The brands shall be placed so that the strips in both the upper and lower layers are parallel to the direction of airflow.

8-5.2.4 The brands shall be secured to the deck by a No. 18 (1.02 mm diameter) gauge soft iron wire.

8-5.2.5 The second brand shall be applied 30 minutes after placing of the first brand or sooner if all burning resulting from the first brand has ceased.

8-5.2.6 If the roof covering is applied to plywood or other panel-type decks, the brands shall be placed so that they are centered laterally with respect to the vertical panel joints in the test deck, and the upper edge of the brands shall be located $1^1/_2$ in. (38 mm) above the horizontal panel joint in the test deck.

8-5.3 Class C Tests.

8-5.3.1 At 1- to 2-minute intervals, a brand shall be placed on the surface of the test deck at each of the 20 locations considered most vulnerable (points of minimum coverage over deck joints) with respect to ignition of the deck.

8-5.3.2 Each brand shall be positioned with its upper edge $^1/_2$ in. (13 mm) above the selected joint in the deck boards, but in no case shall it be closer than 6 in. (150 mm) from each side or 12 in. (305 mm) from the top or bottom edge of the deck.

8-5.3.3 No brand shall be placed closer than 4 in. (100 mm) from a point where a previous brand was located.

8-5.3.4 The brands shall be secured by a No. 18 (1.02 mm diameter) gauge soft iron wire stretched across the width of the deck and placed in the saw kerf of the brand. The saw kerf on the deck side of the brand shall be parallel to the direction of airflow.

8-5.3.5 In addition to the above requirements, where the roof covering is comprised of lapped courses, no brand shall be placed closer than $^1/_2$ in. (13 mm) from the bottom edge of the lapped course above nor shall it be closer than 2 in. (50 mm) from a joint in the roof covering material in the same course. Loose or unfastened portions of the roof covering that can be bent up to 90 degrees without injury to fastenings holding other portions of roof covering shall be cut away.

8-5.3.6 If the roof covering is applied to plywood or other panel-type decks, the brands shall be placed so that as many of the 20 brands as possible are centered over panel joints in the test deck.

8-5.3.7 For treated wood shingles, 20 ignited brands are to be placed on each deck at 1- or 2-minute intervals. For treated wood shakes, 20 ignited brands are to be distributed at 1- or 2-minute intervals on each pair of decks. Each brand is to be centered over the $^1/_4$-in. (6-mm) joint approximately $^1/_2$ in. (13 mm) below the butt of the shake or shingle in the course above. No brand is to be placed closer than 4 in. (100 mm) from the point where a previous brand was located. Positioning and securing of brands shall otherwise be in accordance with 8-5.3.1.

8-6 Duration of the Test.

Each individual test, whether Class A, Class B, or Class C, shall be continued until the brand is totally consumed and until all evidence of flame, glow, and smoke has disappeared from both the exposed surface of the material being tested and the underside of the test deck, or until failure occurs, but shall not be continued for more than $1^1/_2$ hours.

8-7 Test Results.

8-7.1

The results of tests in which the brands do not show progressive and substantially complete consumption after application to the test deck shall be disregarded.

8-7.2

If brands are replaced, they shall not be located in the same area as the disregarded brand.

8-8 Observations.

During and after the burning brand tests, observations for the appearance of sustained flaming on the underside of the test deck, production of flaming or glowing brands of roof covering material, displacement of the test sample, and the exposure or falling away of portions of the roof deck shall be made.

Chapter 9 Flying Brand Test

9-1 General.

This test shall be performed where there is a possibility that the roof covering will break into flaming particles that support combustion on the floor during the test exposure. (*See Table 1.*)

9-2 Procedure.

A test deck 4 ft 4 in. (1320 mm) long shall be mounted in the same manner, and a luminous gas flame shall be used as specified in Section 5-2 for the intermittent flame test.

9-3 Application of Flame.

9-3.1

The Class A and Class B test gas flame shall be applied continuously for 10 minutes.

9-3.2

The Class C test flame shall be applied continuously for 4 minutes.

9-4 Air Current.

Maintain the 12 mph (5.36 m/s) air current until all evidence of flame, glow, and smoke has disappeared from the exposed surface of the material being tested to determine if flying brands will develop. On treated wood shakes, the velocity of the air current shall be increased to 18.0 mph ± 0.75 mph (8.0 m/s ± 0.3 m/s) after the gas flame is extinguished.

Chapter 10 Rain Test[1]

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[1] This method referenced is described as Method A in ASTM D 2898-77, *Methods of Test for Durability of Fire Retardant Treatment of Wood***.**

10-1 General.

10-1.1

The rain test shall be conducted where the fire retardant characteristics of the roof covering may be adversely affected by water.

10-1.2

Asphalt shingles meeting ASTM D 225, *Standard Method for Steam Distillation of Bitominous Protective Coatings*, ASTM D 3018, *Standard Specification for Class A Asphalt Shingles Surfaced with Mineral Granules*, or UL55B, *Class C Asphalt Organic-Felt Sheet Roofing and Shingles*, slate, concrete, clay tile, and metal roofing that have been shown not to be adversely affected by prolonged exposure to the weather shall be exempt from the rain test.

10-1.3

This test shall be conducted on six test decks. (*See Table 1*.)

10-2 Procedure.

10-2.1

Test decks 4 ft 4 in. (1320 mm) long shall be mounted in a framework at a slope of 0.33:1 [4 in. (100 mm) per horizontal ft (300 mm)].

10-2.2

Approximately 7 ft (2130 mm) above the test decks, spray nozzles that deliver an average of 0.7 in. (17.8 mm) of water per hour at a temperature between 35°F - 60°F (2.0°C - 15.5°C) for the test deck area shall be mounted.

10-3 Application of Water.

10-3.1

The test decks shall be exposed to 12 one-week cycles.

10-3.2

Each cycle shall consist of 96 hours of water exposure and 72 hours of drying time at 140°F (60°C).

10-3.3

An alternative test cycle shall be permitted to be utilized, at the manufacturer's option, whereby two sets of six decks shall be alternately exposed to seven days (168 hours) of water exposure, followed by two days (48 hours) draining and five days (120 hours) drying at 140°F (60°C). This cycle shall be repeated seven times, with the exception that the seventh water exposure shall be reduced to six days (144 hours).

10-3.4

The final drying cycle shall be controlled so that the moisture content of the deck lumber is between 8 percent and 12 percent.

10-3.5

The intermittent flame, burning brand, and the flying brand tests shall then be repeated.

Chapter 11 Weathering Test

11-1 General.

This test shall apply to materials or constructions where the fire retardant characteristics of the roof covering may be adversely affected by weather. (*See Table 1*.) The test is to be conducted on 3 ft 4 in. × 4 ft 4 in. (1020 mm × 1320 mm) test decks, which are to be mounted outdoors at an incline of 0.416:1 [5 in. (127 mm) per horizontal ft (305 mm)], facing south. After one, two, three, five, and ten years of exposure, three test decks are to be brought indoors and conditioned until the deck lumber attains a moisture content between 8 percent and 12 percent. For plywood decks, the moisture content is to be not greater than 8 percent. These decks are then to be subjected to intermittent flame, burning brand, and flying brand tests. (*See Table 1*.)

Chapter 12 Conditions of Classification

12-1 Conditions to Be Met.

A roof covering material shall meet the conditions below when subjected to the particular class of fire tests.

12-1.1

At no time during or after the intermittent flame, spread of flame, or burning brand tests shall:

(a) Any portion of the roof covering material be blown off or fall off the test deck in the form of flaming or glowing brands that continue to glow after reaching the floor, or

(b) The roof deck be exposed, or

(c) Portions of the roof deck fall away in the form of particles that continue to glow after reaching the floor.

12-1.2

At no time during Class A, Class B, or Class C intermittent flame and burning brand tests shall there be sustained flaming of the underside of the deck. If flaming does occur, another series of tests shall be conducted during which no sustained flaming shall occurt

12-1.3

At the conclusion of the spread of flame tests, the flaming shall not have spread beyond 6 ft (1820 mm) for Class A, 8 ft (2.44 m) for Class B, or 13 ft (3960 mm) (the top of the deck) for Class C. There shall have been no significant lateral spread of flame from the path directly exposed to the test flame.

12-1.4

In the flying brand test, no flying, flaming brands, or particles that continue to glow after reaching the floor shall be produced.

12-1.5

For roof covering materials intended only for use on noncombustible decks, exposure of the roof deck during the spread of flame test shall not constitute failure.

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 ASTM Publications.

American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM D 225-1992, *Standard Method for Steam Distillation of Bitominous Protective Coatings*

ASTM D 2898-1981, *Methods of Test for Durability of Fire Retardant Treatment of Wood*

ASTM D 3018-1990, *Standard Specification for Class A Asphalt Shingles Surfaced with Mineral Granules*

13-1.2 UL Publication.

Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL55B-1983, *Class C Asphalt Organic-Felt Sheet Roofing and Shingles*

13-1.3 U.S. Government Publication.

United States Department of Commerce, National Institute of Standards and Technology, Gaithersburg, MD 20899.

PS1-1983, *Construction and Industrial Plywood*

NFPA 257

1996 Edition

Standard on Fire Test for Window and Glass Block Assemblies

1996 Edition

This edition of NFPA 257, *Standard on Fire Test for Window and Glass Block Assemblies*, 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 257 was approved as an American National Standard on February 2, 1996.

Origin and Development of NFPA 257

This standard was tentatively adopted by the NFPA in 1969 and officially adopted in 1970. Subsequent revisions were released in 1975, 1980, 1985, and 1990.

This 1996 edition of NFPA 257 is a complete rewrite that includes editorial and technical revisions. Many of the editorial and technical revisions were made to parallel those of NFPA 252, *Standard Methods of Fire Tests of Door Assemblies*. The technical revisions include modifications to the furnace pressure. The neutral pressure has been eliminated so that the test assembly can be tested to the pressure required by other code requirements (i.e., NFPA *101*®, *Life Safety Code*®, and the model building codes). In addition, the duration of the test method has been extended beyond the 45 minutes required in previous editions to allow for the testing of new glazing materials.

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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.

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 257

Standard on Fire Test for Window and Glass Block Assemblies

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 D.

Chapter 1 General

1-1 Scope.

This standard prescribes standardized fire and hose stream test procedures that apply to fire window assemblies including window, glass block, and other light-transmitting assemblies intended to be used in window openings to retard the spread of fire through such openings in fire-resistive walls.

1-2 Purpose.

The purpose of this standard is to prescribe specific fire and hose stream test procedures for fire window assemblies in order to standardize a method for determining the degree of fire protection provided by such assemblies in retarding the spread of fire (flame, heat, and hot gases) through window openings in fire-resistive walls. The degree of fire protection measured in units of time is not an absolute value, since all possible actual fire scenarios are not represented by the standard fire exposure described herein. This standard allows different fire window assemblies to be compared with each other in order to evaluate their relative performance as measured against a standard fire exposure.

1-3 Significance.

1-3.1

This standard is intended to evaluate the ability of a window, glass block, or other light-transmitting assembly to remain in a wall opening during a prescribed fire test exposure, which then is followed by the application of a prescribed hose stream.

1-3.2

Tests made in conformity with these standard test methods register performance during the test exposure and develop data that enable regulatory bodies to determine the suitability of fire window assemblies for use in wall openings where fire protection is required.

1-3.3

The tests described herein expose a specimen to a standard fire exposure that is controlled to achieve specified temperatures throughout a specified time period, which then is followed by the application of a specified standard hose stream. The fire exposure, however, is not necessarily representative of all fire conditions, due to the varying changes in the amount, nature, and distribution of fire loading, ventilation, compartment size and configuration, and the heat sink characteristics of the compartment. The fire exposure does, however, provide a relative measure of the fire performance of fire window assemblies under these specified fire exposure conditions. Similarly, the hose stream exposure is not necessarily representative of the application of an actual hose stream used by a fire department during fire suppression efforts.

1-3.4

Any variation from the construction or conditions that are tested can change the performance characteristics of the assembly substantially.

1-3.5

These tests shall not be construed as determining the suitability of fire window assemblies for continued use after exposure to real fires.

1-3.6

This standard does not provide the following:

(a) Full information regarding the performance of a specific fire window assembly where installed in walls constructed of materials other than those tested;

(b) Evaluation of the degree by which the fire window assembly contributes to the fire hazard by generation of smoke, toxic gases, or other products of combustion;

(c) Measurement of the ability of the fire window assembly to control or limit smoke or similar products of combustion that pass through the assembly.

1-3.7

Through-openings created by cracking, separation, or loss of glazing material shall be permitted by these test methods, provided such openings do not exceed specified limits.

1-4 Definitions.

Fire Window Assembly.* A window or glass block assembly for which a fire protection rating is determined in accordance with this standard and that is intended for installation in walls or partitions.

Glass Block Assembly. A light-transmitting assembly constructed of glass block held together with mortar or other suitable materials.

Glazed Light. A pane of glazing material that is separated by muntins and mullions from adjacent panes of glazing material in a fire window assembly.

Glazing Material.* A transparent or translucent material used in fire window assemblies.

Opening. For the purpose of Chapter 5, a through-hole in the fire window assembly that can be seen from the unexposed side while looking through the plane of the assembly from a perpendicular position.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Window Assembly.* An integral, fabricated unit containing a glazed light(s) placed in an opening in a wall and that is intended primarily for the transmission of light, or light and air, and not primarily for human entrance or exit.

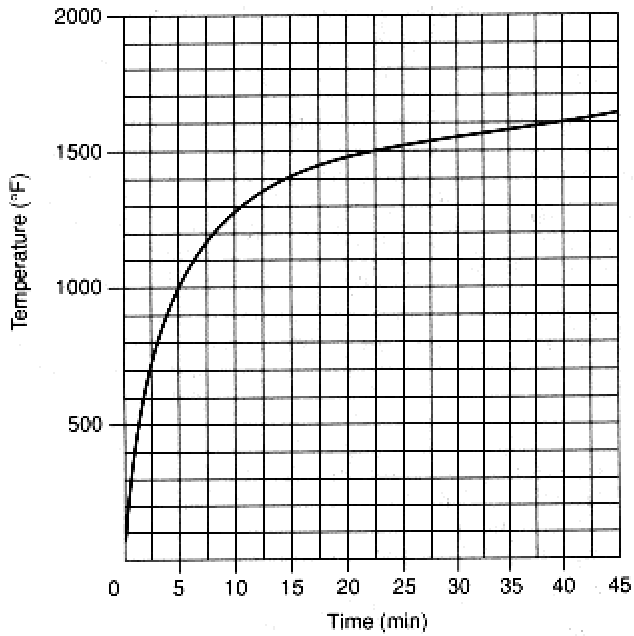
Chapter 2 Control of Fire Test

2-1 Temperature-Time Curve.

See Figure 2-1.1.

2-1.1

The temperature inside the furnace to which the test assemblies are exposed during the fire test shall be controlled to conform to the standard temperature-time curve shown in Figure 2-1.1. The points that determine the curve are specified immediately below Figure 2-1.1.



1000°F (583°C) .... at 5 minutes
1300°F (704°C) .... at 10 minutes
1399°F (760°C) .... at 15 minutes
1462°F (795°C) .... at 20 minutes
1510°F (821°C) .... at 25 minutes
1550°F (843°C) .... at 30 minutes
1584°F (868°C) .... at 35 minutes
1613°F (878°C) .... at 40 minutes
1638°F (892°C) .... at 45 minutes
1700°F (927°C) .... at 1 hour
1792°F (978°C) .... 1½ hours
1925°F (1052°C) .... at 3 hours

Figure 2-1.1 Temperature-time curve.

2-1.2

At the start of the test, the temperature inside the furnace shall be ambient.

2-2 Furnace Temperatures.

2-2.1

The temperature of the fire test furnace shall be determined by the average temperature obtained from the readings of not less than nine thermocouples symmetrically disposed and distributed to measure the temperature near all parts of the fire window assembly. The thermocouples shall be protected by sealed porcelain tubes having a $^{3}/_{4}$-in. (19-mm) outside diameter and a $^{1}/_{8}$-in. (3-mm) wall thickness, or, as an alternative in the case of base-metal thermocouples, they shall be protected by sealed $^{1}/_{2}$-in. (13-mm) nominal diameter wrought-steel or wrought-iron pipe of standard weight, or they shall be enclosed in protective tubes of such materials and dimensions that the time constant of the protected thermocouple assembly lies within a range of 5.0 minutes to 7.2 minutes. The exposed length of the thermocouple protection tube in the furnace chamber shall be not less than 12 in. (304.8 mm). The junction of the thermocouples shall be 6 in. (152.4 mm) from the exposed face of the test assembly, or from the wall in which the assembly is installed, during the entire test exposure.

2-2.2

The furnace temperature shall be measured and recorded at intervals not exceeding 1 minute.

2-2.3

The furnace temperature shall be controlled so that the area under the temperature-time curve obtained by averaging the results from the temperature readings is within 10 percent of the corresponding area under the standard temperature-time curve shown in Figure 2-1.1 for fire tests of 1 hour or less, within 7.5 percent for those tests longer than 1 hour but not longer than 2 hours, and within 5 percent for those tests longer than 2 hours.

2-3 Furnace Pressure.

2-3.1

The vertical pressure distribution within the fire test furnace shall be measured in accordance with 2-3.1.1 through 2-3.1.4.

2-3.1.1 The pressure within the furnace shall be measured by at least two pressure-sensing probes separated by a minimum vertical distance of 6 ft (1.8 m) inside the furnace.

2-3.1.2 The pressure-sensing probes shall be as shown in either Figure 2-3.1.2(a) or Figure 2-3.1.2(b).

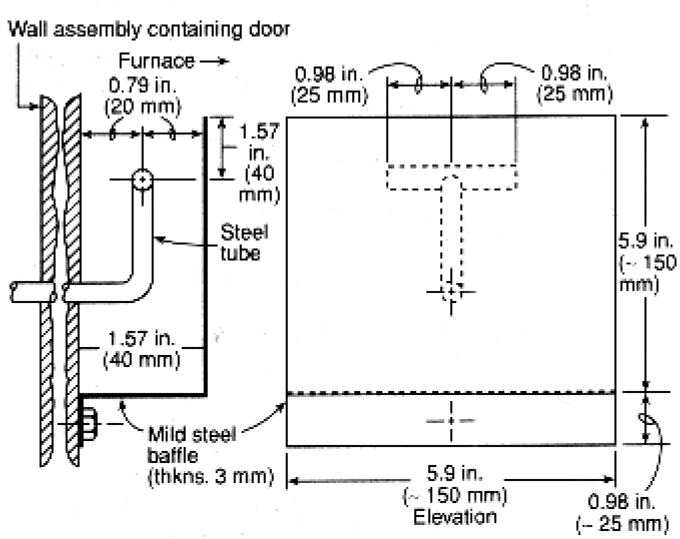


Figure 2-3.1.2(a) Static pressure-measuring device dimensions.

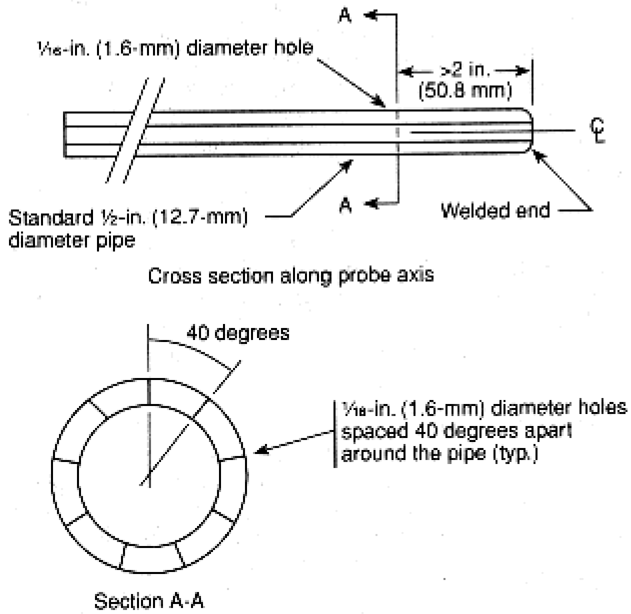


Figure 2-3.1.2(b) Pressure probe.

2-3.1.3 The pressure-sensing probes shall be located as near as practicable to the vertical centerline of the furnace opening.

2-3.1.4 The pressure at each location shall be measured using a differential pressure instrument capable of reading in increments no larger than 0.01 in. wg (2.5 Pa) with a precision of not more than ± 0.005 in. wg (± 1.25 Pa). The differential pressure measurement instrument shall be located to minimize stack effects caused by vertical runs of pressure tubing between the pressure-sensing probes and the differential pressure measurement instrument locations.

2-3.1.5 Based on the vertical separation and pressure differences between the two pressure-sensing probes, a calculation of the neutral plane [0 (zero) differential pressure] location shall be made.

2-3.2

Control of the furnace pressure shall be established beginning no later than 10 minutes after the start of the test and shall be maintained throughout the remainder of the test.

2-3.3 Pressure.

The differential pressures measured between the exposed and unexposed surfaces of the test assembly shall be controlled to within ± 20 percent of the intended pressures for the duration of the test (excluding the first 10 minutes).

2-3.4

The pressure shall be measured and recorded at least every 1 minute.

Chapter 3 Fire Window Assembly

3-1 Construction and Size.

3-1.1

The design, construction, material, workmanship, and hardware of the fire window assembly shall represent those for which a fire protection rating is desired. A record of materials and construction details to be used for the purpose of identification shall be kept.

3-1.2

The area of the fire window assembly shall be not less than 100 ft^2 (9.29 m^2), with no dimension less than 9 ft (2.75 m). If the conditions of use limit the construction to smaller dimensions, a proportionate reduction shall be permitted to be made in the dimensions of the fire window assembly for those tests used to qualify them for such restricted use.

3-2 Mounting.

The fire window assembly shall be installed in the wall or partition construction in the manner in which it is to be used. It shall be mounted so that the latches and fasteners, other than hinges, are on the unexposed side, and the mounting shall not prevent the free and easy operation of all operable components such as ventilators and sashes.

3-3 Strength.

The wall or partition in which the fire window assembly is tested shall have the strength and fire resistance to retain the assembly securely in position throughout the fire and hose stream tests. The wall or partition shall be constructed of materials representative of the wall or partition construction in which the fire window assembly is intended to be installed. Where used, wall anchors shall be suitable for the wall or partition in which the fire window assembly is installed.

Chapter 4 Conduct of Tests

4-1 Fire Test.

4-1.1 Duration.

The test shall be continued until the desired rating period is reached or until failure to meet the performance criteria of Chapter 6 occurs.

4-1.2 Furnace Heat Flux.

Procedures for measuring the total heat flux (convective and radiative) and the radiative heat flux within the furnace are provided in Appendix C.

4-1.3 Unexposed Surface Radiation.

Procedures for measuring the radiant heat flux from the unexposed face of the fire window assembly are provided in Appendix C.

4-2 Hose Stream Test.

4-2.1

Within the 2 minutes immediately following the fire endurance test, the fire-exposed side of the fire window assembly shall be subjected to the impact, erosion, and cooling effects of a standard hose stream.

4-2.2

The standard hose stream shall be delivered through a $2^1/_2$-in. (64-mm) hose discharging through a national standard play pipe in accordance with ANSI/UL 385, *Standard for Safety Play Pipes for Water Supply Testing in Fire-Protection Service*. The play pipe shall have an overall length of 30 in. (762 mm) and shall be equipped with a $1^1/_8$-in. (28.5-mm) discharge tip of the standard-taper, smoothbore pattern without shoulder at the orifice. The play pipe shall be fitted with a $2^1/_2$-in. (64-mm) inside diameter by 6-in. (153-mm) long nipple mounted between the hose and the base of the play pipe. The pressure tap for measuring the water pressure at the base of the nozzle shall be normal to the surface of the nipple, centered on its length, and shall not protrude into the water stream. The water pressure shall be measured with a suitable pressure gauge [minimum 0 psi to 50 psi (0 kPa to 345 kPa)] graduated in no more than 2-psi (13.8-kPa) increments.

4-2.3

The tip of the nozzle shall be located 20 ft (6.1 m) from the center of the fire window assembly. The lengthwise centerline of the nozzle shall be aligned parallel to the plane of the fire window assembly. The lengthwise centerline of the nozzle shall be aligned so that it deviates not more than 30 degrees from the line parallel to the center of the fire window assembly. Where the nozzle is so positioned with respect to this parallel line, the required distance from the tip of the nozzle to the center of the fire window assembly shall be reduced by 1 ft (0.31 m) for each 10 degrees of deviation from the parallel line.

4-2.4

The hose stream shall be directed around the periphery of the fire window assembly, starting upward from either bottom corner. When the hose stream has traversed around the periphery of the fire window assembly and is approximately 1 ft (0.31 m) from reaching the starting point, the hose stream shall be applied in vertical paths approximately 1 ft (0.31 m) apart until the entire width has been covered, and then in horizontal paths approximately 1 ft (0.31 m) apart until the entire height has been covered. If the required duration of the hose stream test has not been reached after this procedure has been performed, the procedure then shall be reversed and followed until the required duration has been met. Reversals in the direction of the hose stream shall be made within 1 ft (0.31 m) outside of the perimeter edge of the fire window assembly.

4-2.5

The minimum water pressure at the base of the nozzle shall be as specified in Table 4-2.6.

4-2.6

The hose stream shall be applied over the exposed area of the fire window assembly in accordance with the criteria specified in Table 4-2.6. The exposed area shall be calculated using the outside dimensions of the fire window assembly, including the frames.

Table 4-2.6 Water Pressure at Base of Nozzle and Duration of Application for Hose Stream

	Water Pressure at Base of Nozzle	Duration of Application of Exposed Area

Desired Rating	(psi)	(kPa)	(sec/ft^2)	(sec/m^2)
3 hours and over	45	310	3.0	32
$1^1/_2$ hours and over and less than 3 hours	30	207	1.5	16
1 hour and over and less than $1^1/_2$ hours	30	207	0.9	10
Less than 1 hour	30	207	0.6	6

NOTE: The exposed area shall be calculated using the outside dimensions of the test assembly, including the frames.

Chapter 5 Performance Criteria

5-1 Fire Test.

5-1.1 Window Assemblies.

During the fire test, a window assembly shall meet the performance criteria specified in 5-1.1.1 through 5-1.1.6.

5-1.1.1 The window assembly shall remain in the wall in which it is installed for the duration of the fire test.

5-1.1.2 No flaming shall occur on the unexposed surface of the assembly.

5-1.1.3 There shall be no separation of the glazing material edges from the glazing frame that creates openings.

5-1.1.4 At the perimeter of operable components, movement from the initial closed position shall not exceed the thickness of the frame member at any point.

5-1.1.5 The window assembly shall not move away from the wall to create an opening.

5-1.1.6 There shall be no openings in the window assembly.

5-1.2 Glass Block Assemblies.

During the fire test, a glass block assembly shall meet the performance criteria specified in 5-1.2.1 through 5-1.2.4.

5-1.2.1 The glass block assembly shall remain in the frame in which it is installed for the duration of the fire test.

5-1.2.2 No flaming shall occur on the unexposed surface of the assembly.

5-1.2.3 There shall be no openings in any of the individual glass blocks.

5-1.2.4 No openings shall be produced during the test in the joints between the individual glass blocks or between the glass blocks and the frame in which the glass block assembly is installed.

5-2 Hose Stream Test.

5-2.1 Window Assemblies.

During the hose stream test, a window assembly shall meet the performance criteria specified in 5-2.1.1 through 5-2.1.4.

5-2.1.1 The window assembly shall remain in the wall in which it is installed for the duration of the hose stream test.

5-2.1.2 At the perimeter of operable components, movement from the initial closed position shall not exceed the thickness of the frame member at any point.

5-2.1.3 Separation of the glazing material edges from the glazing frame due to movement away from the frame to create an opening shall not exceed 30 percent of each individual glazed light perimeter.

5-2.1.4 Openings created by glazing material breakage in the central area of each individual glazed light shall not exceed 5 percent of the area of the glazed light.

5-2.2 Glass Block Assemblies.

During the hose stream test, a glass block assembly shall meet the performance criteria specified in 5-2.2.1 and 5-2.2.2.

5-2.2.1 The glass block assembly shall remain in the frame in which it is installed for the fire test.

5-2.2.2 At least 70 percent of the glass blocks shall not develop openings.

Chapter 6 Report

6-1 Report Results.

Results shall be reported in accordance with the performance of the fire window assembly subjected to the tests as prescribed in these test methods. The report shall include, but shall not be limited to, the information specified in 6-1(a) through (l) as follows:

(a) A description of the construction details and materials used to construct the wall or partition in which the assembly is mounted for testing;

(b) The temperature measurements of the furnace plotted on a comparative graph showing the standard temperature-time curve;

(c) All observations of the reactions of the fire window assembly that have an influence on its performance during both the fire and hose stream tests;

(d) A description of the fire window assembly, including fasteners and attachments, as they appear after both the fire and hose stream tests;

(e) The amount and nature of the movement of any operable components from the initial closed position;

(f) For fire window assemblies, the condition of the individual glazed lights, including movement of the edges, and the percentage and location of glazing material fragments dislodged during the tests;

(g) For glass block assemblies, any loosening of the blocks in the frame and any through-openings, including their location;

(h) The materials and construction of the fire window assembly, details of installation, including frames, latches, hinges, and fasteners used for mounting, and the size of the glazed area in order to ensure positive identification or duplication of the fire window assembly in all respects;

(i) Pressure differential measurements made between the furnace and the unexposed side of the fire window assembly [in. wg (Pa)] and the calculation that determines the position of the neutral plane with respect to the top of the fire window assembly during the fire test [ft (m)];

(j) The actual duration of the fire test as described in Section 4-1. The fire protection rating of the fire window assembly as determined in accordance with this standard also shall be reported. One of the following fire protection ratings shall be assigned:

1. 20 minutes;
2. 30 minutes;
3. $^3/_4$ hour;
4. 1 hour;
5. $1^1/_2$ hours;
6. 2 hours;
7. 3 hours; or
8. Hourly increments for ratings over 3 hours.

(k) Where the fire protection rating is 30 minutes or longer, a correction shall be applied for variation of the furnace exposure time from that prescribed in those cases where it affects the fire protection rating. This shall be done by multiplying the indicated duration by $^2/_3$ of the difference in area between the curve of the average furnace temperature and the standard temperature-time curve for the first $^3/_4$ of the test duration and then dividing the product by the difference in area between the standard temperature-time curve and a baseline of 68°F (20°C) for the same portion of the test, increasing the latter area by 54°F/hr (30°C/hr) [3240°F/min (1800°C/min)], to compensate for the thermal lag of the furnace thermocouples during the first part of the test. For fire exposure in the test higher than the standard temperature-time curve, the indicated fire protection rating shall be increased by the amount of the correction and shall be decreased similarly for fire exposure below the standard temperature-time curve.

The correction shall be expressed by the following formula:

$$C = \frac{2I(A - A_s)}{3(A_s + L)}$$

where:

C = correction in the same units as I

I = indicated fire protection rating

A = area under the curve of the indicated average furnace temperature for the first $^{3}/_{4}$ of the indicated rating period

A_s = area under the standard temperature-time curve for the same part of the indicated fire protection rating

L = lag correction in the same units as A and A_s [54°F/hr (30°C/hr)] [3240°F/min (1800°C/min)].

(l) The results of the hose stream test.

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 ANSI/UL Publication.

Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

ANSI/UL 385, *Standard for Safety Play Pipes for Water Supply Testing in Fire-Protection Service*, 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-1-4 Fire Window Assembly.

For further information, see NFPA 80, *Standard for Fire Doors and Fire Windows*.

A-1-4 Glazing Material.

For further information, see NFPA 80, *Standard for Fire Doors and Fire Windows*.

A-1-4 Window Assembly.

For further information, see NFPA 80, *Standard for Fire Doors and Fire Windows*.

Appendix B Commentary — Background and Development

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

B-1 Introduction.

This commentary provides the user of NFPA 257 with background information on the development of the standard and its application in the fire protection of buildings. It also provides guidance in the planning and performance of fire tests and in the reporting of results.

No attempt has been made to incorporate all the available information on fire testing in this commentary. The serious student of fire testing should review the referenced documents for a better appreciation of the intricate problems associated with testing and with the interpretation of test results.

B-2 Major Revisions.

The 1996 edition of this standard incorporates significant revisions to the earlier editions in an effort to update the standard and to provide additional performance information useful for fire protection engineering purposes and building code requirements for the use and application of fire window assemblies. Based on international standards, it has been determined that additional useful information can be obtained readily during the fire test of fire window assemblies. This information can be used by building codes to determine acceptable levels of performance and can be applied by fire protection engineers and other design professionals to achieve a more cost-effective level of fire and life safety where using fire window assemblies.

The requirements for the duration of the fire test have been left open, whereas, in previous editions, it was limited to 45 minutes. With the advent of new glazing materials that can provide various levels of fire protection, this edition of the standard responds to the needs of the industry and the fire protection community to establish various fire protection ratings that are both longer and shorter than the 45-minute specification in past editions. The 45-minute limit was based on the ability of standard wired glass to perform satisfactorily in accordance with earlier editions of this fire test standard.

To parallel the criteria in NFPA 252, *Standard Methods of Fire Tests of Door Assemblies*, the hose stream test duration and application pressure have been modified to reflect the increased duration of the fire test.

This standard also has been clarified with regard to the amount of glass or glass block that may be permitted to be broken or otherwise dislodged during the fire test and the hose stream test.

Criteria also have been established for limiting flaming on the unexposed face of the fire window assembly.

A test procedure for measuring the radiant heat flux from the unexposed face of the window assembly has been added to Appendix B. Its purpose is to provide a standardized protocol for making such measurements so that the information developed can be used for fire protection engineering purposes and fire modeling where it is desirable to control the radiant heat transfer through a fire window or glass block assembly.

B-3 Application.

Openings in the exterior walls of buildings have contributed to the spread of fire. Fire protection standards and building codes recognize the hazard associated with exterior wall openings that are created by inadequate spatial separation between buildings. Where the spatial separation is inadequate and the expected fire exposure is moderate or light, these regulations permit window openings protected with fire windows. This protection can be provided by properly designed windows and glass block assemblies. Where sustained severe exposures are possible, the openings should be protected with fire door assemblies.

To protect paths of egress from interior fires, fire window assemblies can be specified for openings abutting exterior stairs and fire escapes and in corridors where wall openings are used to provide natural lighting of the corridor from adjacent rooms.

B-4 Scope and Significance.

NFPA 257 provides a method for evaluating the effectiveness of light-transmitting opening protectives.

The fire window assembly is exposed to predetermined fire conditions for a desired fire protection rating period and then, at the option of the test sponsor, is subjected to a standard hose stream impact test. NFPA 257 also measures heat transmission and radiation through the assembly (*see Appendix C*). NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*, should be consulted for information on exterior fire exposure problems, and NFPA 80, *Standard for Fire Doors and Fire Windows*, should be referenced for information on radiant heat transfer.

Openings in walls, even where protected, provide a lower fire protection rating than that of the wall, and the designed protection cannot be expected if combustibles are located directly in front of or behind the protectives. Therefore, clear spaces should be provided on both sides of openings in fire-rated walls and partitions.

B-5 Furnace.

The method provides details on the operating characteristics and temperature measurement requirements of the test furnace. The walls of the furnace typically should be of furnace refractory materials and should be sufficiently rugged to maintain the overall integrity of the furnace during the fire exposure period.

The thermocouples in the furnace are located 6 in. (152 mm) from the face of the wall in which the fire window assembly is installed. Otherwise, no furnace depth is specified. A minimum depth of 18 in. (457 mm) is necessary to meet the 12-in. (304-mm) minimum exposed length of the thermocouple protection tube. Reference documents should be consulted for a more comprehensive review of furnace design and performance.

B-6 Temperature-Time Curve.

A specified temperature-time relationship for the test fire is defined in the standard. The actual recorded temperature-time condition achieved in the furnace during the test as measured by the area under the temperature-time curve is required to be within the specified percentages of those of the standard curve. The number and type of temperature-measuring devices are outlined in the standard. Specific standard practices for location and use of these temperature-measuring devices also are outlined in the standard.

The standard temperature-time curve represents a relatively severe building fire. The curve was adopted in 1918 as a result of several conferences by 11 technical organizations, including testing laboratories, insurance underwriters, fire protection associations, and technical societies. It should be recognized that the temperature-time relationship of this test method represents only one actual fire situation. However, it is used in other fire test methods such as NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*; NFPA 252, *Standard Methods of Fire Tests of Door Assemblies*; and ASTM E 814, *Standard Test Method for Fire Tests of Through-Penetration Fire Stops*.

Although the temperature-time curve is specified for standard thermocouples located within the furnace, measurement of the temperature-time curve in this manner does not establish a standard incident heat flux on the tested specimen. Incident heat flux that occurs in an actual fire can vary significantly from that developed by tests conducted by this standard test method. Similarly, this standard provides for a standard temperature-time relationship to be followed by all furnaces using this standard method. However, the internal heat flux developed in various test furnaces can vary.

B-7 Furnace Control.

The standard contains specific instructions for measuring temperatures in the furnace and for the selection of required thermocouples. Thermocouples of the design specified are sufficiently rugged to retain accuracy throughout anticipated test periods. However, their massive construction results in a significant time delay in response to temperature change, causing actual temperatures that exceed the indicated temperatures during the early stages of the test period, when the temperature rises rapidly. The iron or porcelain tubes surrounding the junction and leads of the thermocouple provide a shield against degradation of the junction and increase the thermal inertia. Depending on the type of thermocouple used and its method of protection, some laboratories replace furnace thermocouples after accumulating 3 or 4 hours of use.

B-8 Test Assemblies.

Fire window assemblies are tested in relatively large sizes compared with most side-hinged swinging fire doors [e.g., 100 ft^2 (9.3 m^2) for windows versus 20 ft^2 to 40 ft^2 (6.1 m^2 to 12.2 m^2) for doors]. The size of individual panes of glazing material is determined by the designer. Fire window assemblies as large as 150 ft^2 (13.9 m^2) have been tested. Where assemblies are less than 100 ft^2 (9.3 m^2), this fact should be reported.

B-9 Conduct of the Tests.

The test frame or wall in which a fire window assembly is installed should be rugged enough to endure the fire exposure during the test period without affecting the window assembly. Traditionally, this wall has been of masonry construction. Today, fire windows are installed in walls of other than masonry construction and have been tested in such walls as well.

B-10 Furnace Pressures.

A fire in a building compartment creates both negative and positive pressures on window assemblies, depending on atmospheric conditions, height above the ground, wind conditions, and ventilation of the compartment at the beginning of the fire and during the fire.

A furnace pressure that is slightly higher than the ambient pressure outside of the furnace could have significant impact on the performance of fire barrier assemblies. Operating a test furnace at a negative pressure differential has the effect of drawing any hot gases or flames back into the furnace chamber so that the ability to observe flaming around any openings on the unexposed surface is minimized. Furthermore, the draft induced by the negative pressure differential reduces any heating that might occur along the edges of any openings and, in fact, provides some degree of cooling of surfaces. Positive compartment pressures in actual fires have the opposite effect.

In previous editions, NFPA 257 specified that the pressure in the furnace should be maintained as nearly equal to atmospheric as possible. This method of test generally resulted in the test assembly being subjected to a negative pressure during the test, since most laboratories set the neutral plane in the furnace at or above the top of the assembly. As revised, the standard now permits tests to be conducted under any pressure situation, depending on the needs/requirements of the manufacturer, test laboratory, or the authority having jurisdiction. The pressure in the furnace is required to be measured and reported.

The differential pressure employed is intended to be that pressure that is necessary to evaluate the fire window assembly with respect to its field installation. The differential pressure should be determined by one of the following:

(a) Code requirements;

(b) The design pressure that can occur in the type of installation for which the test is proposed;

(c) The test sponsor; or

(d) Other circumstances.

B-11 Hose Stream Test.

Immediately following the fire test, the test assembly is removed from the furnace and the fire window assembly is subjected to the impact, erosion, and cooling effects of a stream of water from a $2^1/_2$-in. (63.5-mm) hose discharging through a standard play pipe equipped with a $1^1/_8$-in. (28.5-mm) tip under a specified pressure for a specified duration based on the length of the fire test and the area of the fire window assembly. The application of water produces stresses in the assembly and provides a measure of its structural capabilities. Weights have been used in Europe to provide a measure of the ability of the assembly to withstand impact. The hose stream is considered to be an improvement over the weights in both uniformity and accuracy.

Just as the standard fire exposure is not intended to be representative of any or all actual fire conditions, the standard hose stream exposure is not intended to be representative of any actual fire-fighting or fire suppression activity. The fire exposure test and the hose stream test provide a relative measure of the performance of constructions and assemblies under specified standard exposure conditions.

The hose stream test provides a method for evaluating the integrity of constructions and assemblies and for eliminating inadequate materials or constructions. The cooling, impact, and erosion effects of the hose stream provide important tests of the integrity of the specimen being evaluated.

The rapid cooling and thermal shock imposed by the hose stream test following the fire exposure test eliminate materials that are subject to failure under such conditions. The orthogonal load imposed by the hose stream subjects vertical specimens to a load in a direction perpendicular to the normal dead load on the specimen. This effect eliminates constructions or assemblies with marginal factors of safety for withstanding lateral forces.

The hose stream test provides a real and measurable lateral impact load on the specimen. Testing by Ingberg at the National Bureau of Standards established that the standard hose stream test produced a 57.7-lb (256.6-N) force on the specimen.

The combined effects of the hose stream test provide a method of screening the integrity of a specimen that cannot be provided by any other means.

B-12 Performance Criteria.

During the fire and hose stream tests, the fire window assembly should remain in place and not become loosened from the test frame. During the hose stream test, fire window assemblies are permitted to have glazing material dislodged from the central portion, provided the amount dislodged does not exceed 5 percent of the area of each individual glazed light. During the hose stream test, separation of the glazing material edges from the frame by movement away from the frame to create an opening (*see definition in Section 1-4*) is limited to 30 percent of the perimeter of each individual glazed light. At least 70 percent of the glass blocks should not develop openings.

Appendix C Radiant and Total Heat Flux

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

C-1 Fire Test.

Where it is desirable to obtain information and data on the transmission and reradiation of radiant heat through and by a fire window or glass block assembly, the following procedures should be followed. These procedures are intended to standardize the test methodology in order to develop comparative test results that can be used to establish a basis for incorporating mandatory procedures into this standard.

C-2 Furnace Heat Flux.

Prior to performing measurements of thermal radiant heat transfer through window assemblies, a furnace calibration should be performed to determine baseline incident heat fluxes on the fire window assembly and to assess furnace heat flux uniformity. This should be performed in accordance with C-2.1 through C-2.5.

C-2.1

The calibration procedure should be performed for a minimum duration of 3 hours with the furnace operating at temperatures corresponding to the standard temperature-time curve specified in Section 2-1.

C-2.2

The furnace should initially be calibrated prior to measuring the unexposed surface radiation of any fire window assemblies. After the initial furnace calibration, it is not necessary to recalibrate the furnace unless there is a significant modification made to the furnace or the furnace fuel that could have more than a nominal effect on the heat flux characteristics of the furnace.

C-2.3

The total (convective and radiative) heat flux produced in the furnace should be measured by three total heat flux transducers having a 180-degree view angle. The transducers should be installed on the exposed face of a calibration wall and located at the upper $^1/_4$, middle, and lower $^1/_4$ of the calibration wall along its vertical centerline. The calibration wall should have the same dimensions as the furnace opening that receives the test assembly. The calibration wall should be constructed of noncombustible materials and should have a solid backing. The face of the calibration wall to be installed in the furnace opening facing the burners should be covered with a single layer of low density ceramic fiber batts or blankets having a minimum thickness of 1 in. (25.4 mm). The calibration wall should be installed in the furnace opening prior to the start of the calibration procedure.

C-2.4

The radiant heat flux produced by the furnace should be measured by three radiant heat transducers having a 150-degree view angle that are located adjacent to each of the total heat flux transducers. The view angles are specified to provide for a view of the entire furnace back wall opposite the calibration wall. The heat flux transducers should be equipped with a window to limit the transducer measurement to radiant heat flux only over the appropriate radiation spectrum. Sapphire or calcium fluoride windows have been found satisfactory for the anticipated wavelength range.

C-2.5

The total heat flux transducers and the radiant heat flux transducers should be calibrated to indicate incident heat flux with a range of 0 kW/m^2 to 230 kW/m^2. Water-cooled Gardon-type transducers with an accuracy of ± 3 percent and a maximum nonlinearity of ± 2 percent of full range have been found to be suitable. The transducers initially should be calibrated traceable to NIST and not less than annually thereafter. The calibration schedule shall be verified and documented before the heat flux transducers are used.

C-3 Unexposed Surface Radiation.

Thermal radiation from the unexposed surface of the fire window assembly should be measured in accordance with C-3.1 and C-3.3.

C-3.1

A minimum of two total heat flux transducers should be used.

C-3.2

The heat flux transducers should be located 6 ft ± 1 in. (1.83 m ± 0.3 mm) from the unexposed surface of the fire window assembly where measured along an axis perpendicular to the face of the test assembly. One transducer should be centered on the upper half of the fire window assembly, and one should be centered on the lower half. The transducers should be aligned to allow viewing of the corresponding area of the fire window assembly with the aid of a laser pointer. The field of view of the transducers should include only the unexposed surface of the fire window assembly to prevent the fluxmeter from sensing radiation from surfaces other than the fire window assembly. This can be accomplished by using a radiant heat shield with an unglazed opening of the appropriate size placed between the fire window assembly and the heat flux transducers. Radiation from the unexposed face of the fire window assembly should not pass through any glazing or light-transmitting material and should not otherwise be obstructed before reaching the target of the transducers. If it is not practicable to locate the transducers at the prescribed distance of 6 ft (1.83 m), they should be permitted to be located at a greater distance, but not more than 12 ft (3.66 m), along the axis perpendicular to the face of the fire window assembly. The radiant heat flux corresponding to a distance of 6 ft (1.83 m) should be calculated based on the ratio of the corresponding radiation configuration factors of the 6-ft (1.83-m) distance and the greater distance used.

C-3.3

The heat flux transducers should be calibrated to indicate incident heat flux and to have a range of 0 kW/m^2 to 50 kW/m^2. Water-cooled Gardon-type or Schmidt-Boelter-type transducers with an accuracy of ± 3 percent and a maximum nonlinearity of ± 2 percent of full range have been found to be suitable. The transducers initially should be calibrated traceable to NIST and not less than annually thereafter. The calibration schedule should be verified and documented before the heat flux transducers are used.

C-4 Report.

The results of the heat flux measurements performed in accordance with this test procedure should be reported. The report should include, but should not be limited to, the following information:

(a) The total heat flux and the radiant heat flux measured inside the furnace (kW/m^2);

(b) The radiant heat flux (kW/m^2) measured on the unexposed face side of the fire window assembly, the position of the transducers (in ft), and the calculated radiant heat flux (kW/m^2) corresponding to a distance 6 ft (1.83 m) from the fire window assembly where the transducers are located more than 6 ft (1.83 m) from the test assembly.

Appendix D Referenced Publications

D-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.

D-1.1 NFPA Publications.

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

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 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*, 1995 edition.

NFPA 252, *Standard Methods of Tests of Door Assemblies*, 1995 edition.

D-1.2 Other Publications.

D-1.2.1 ASTM Publication. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM E 814, *Standard Test Method for Fire Tests of Through-Penetration Fire Stops*, 1994.

D-1.2.2 "Thermal Radiation from Marine Fire Boundaries: Evaluation and Analysis of A-60, A-30, A-15, and A-0 Bulkhead Assemblies," Report No. CG-D-01-94, LeMoyne Boyer, SwRI, San Antonio, TX, July 1993.

NFPA 258

1994 Edition

Standard Research Test Method for Determining Smoke Generation of Solid Materials

1994 Edition

This edition of NFPA 258, *Standard Research Test Method for Determining Smoke Generation of Solid Materials*, was prepared by the Technical Committee on Fire Tests 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 258

The smoke problem that develops during unwanted fires has been recognized for years. There is continuing recognition of the major role of combustion products in the majority of fire fatalities. Fire fighters are faced with the smoke problem daily in their work.

The many ways in which fire gases influence a hazard to life have, to date, precluded their exact technical assessment. A test method, such as the one described in this standard, has obvious merit as a measurement tool for assisting in research, development, and production quality control of materials and products. Use of this test method for rough analysis of the smoke production during an actual fire is informative in demonstrating the magnitude of the smoke problem.

The smoke density chamber provides a means for characterizing smoke production with an accuracy far in excess of any application requirements. It also provides a means for reporting rate of smoke production and time at which specific smoke levels are reached under the test conditions applied.

The concept of specific optical density, while outdated in terms of photometric practice, was first introduced for measuring smoke as part of the smoke density chamber test method. It is based on Bouguer's law and permits reporting smoke developed in terms that recognize the area of the specimen involved, the volume of the box, and the optical path length of the photometer.

The test method was developed at the National Bureau of Standards and first described publicly in 1967. Since then, there have been numerous publications reporting on its application and on studies of the correlation of results of interlaboratory tests through its use.

This standard was tentatively adopted by the NFPA as a standard in 1974. A revised edition was adopted as a standard in 1976 and reconfirmed at the NFPA 1981 and 1986 Fall Meetings. The 1989 edition reflected a minor revision to the scope statements of the standard.

This 1994 edition is a reconfirmation of the 1989 edition with minor editorial changes and updating of the references within the document.

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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.

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 where such documents are not available. The Committee shall 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; and act in a liaison capacity between NFPA and the committees of other organizations writing fire test standards. The Committee shall not be responsible for fire tests that are used to evaluate extinguishing agents, devices, or systems.

NFPA 258
Standard Research Test Method for Determining Smoke Generation of Solid Materials

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 Appendix E.

Chapter 1 General

1-1 Scope.

1-1.1

This method of test provides a procedure for measuring the total smoke generated in a closed chamber from solid materials and assemblies in thicknesses up to and including 1 in. (25.4 mm) where subjected to specific test conditions.

1-1.2

Measurement is made of the attenuation of a light beam by the suspended solid or liquid particles (smoke) accumulated within a closed chamber. The smoke is due to either nonflaming pyrolytic decomposition or flaming combustion of a relatively small sample of material.

1-1.3*

Results of the test shall be expressed in terms of specific optical density, which is a dimensionless value derived from the measured light transmission and geometric measurements of the chamber and the specimen.

1-1.4

This test shall be used only as a research and development tool. It shall not be used as a basis for determining ratings for building code or other regulatory purposes.

1-1.5

This standard is intended to measure and describe the properties of materials, products, or assemblies in response to heat and flame under controlled laboratory conditions and is not intended to describe or appraise the fire hazard or fire risk of materials, products, or assemblies under actual fire conditions.

1-2 Significance.

1-2.1*

This test method shall provide a means for comparing the specific optical density of the smoke generated by materials and assemblies in the form and thickness tested, and under the specified exposure conditions.

1-2.2

Values determined by this test are specific to the specimen or assembly material in the form and thickness tested and shall not be considered inherent, fundamental properties of a given material.

1-2.3

The values stated in U.S. customary units shall be regarded as the standard. The metric equivalent of U.S. customary units given in the standard are approximate.

1-2.4

No basis is provided for predicting the density of smoke that can be generated by materials upon exposure to heat and flame under other fire conditions or in other atmospheres.

1-2.5

Values determined by this test are specific with respect to the effect of attenuation of light transmission within the chamber of the smoke generated by the material in the form, thickness, and quantity tested where subjected to the energy sources specified. These values by themselves do not provide a basis for predicting material performance in actual fires.

1-3 Summary of Method.

1-3.1

This method for measuring the smoke generated by materials employs an electrically heated radiant energy source mounted within an insulated ceramic tube and positioned to produce an irradiance level of 2.2 Btu/sec•ft^2 (2.5 W/cm^2) averaged over the central $1^1/_2$ in. (38.1 mm) diameter area of a vertically mounted specimen facing the radiant heater. The nominal 3 in. × 3 in. (76.2 mm × 76.2 mm) specimen shall be mounted within a holder that exposes an area measuring $2^9/_{16}$ in. × $2^9/_{16}$ in. (65.1 mm × 65.1 mm). The holder can accommodate specimens up to 1 in. (25.4 mm) thick. This exposure provides the nonflaming condition of the test.

1-3.2

For the flaming condition, a six-tube burner shall be used to apply a row of equidistant premixed (air-propane) flamelets across the lower edge of the exposed specimen area and into the specimen holder trough. This application of flame, in addition to the specified irradiance level from the heating element, shall constitute the flaming combustion exposure.

1-3.3

The test specimens shall be exposed to the flaming and nonflaming conditions within a closed 18-ft^3 (0.51-m^3) chamber. A photometric system with a 36-in. (914-mm) vertical light path measures the continuous decrease in light transmission as smoke accumulates. Exposure shall be continued for 20 minutes or until minimum light transmission is reached, whichever occurs first.

1-3.4

Calibration procedures for the test equipment, such as those described in B-2, shall be followed.

1-3.5*

The light transmittance measurements shall be used to express the smoke generated by the test materials in terms of the specific optical density during the time necessary to reach the maximum value.

Chapter 2 Test Apparatus

2-1* Test Apparatus.

The apparatus shall be essentially as shown in Figures 2-1(a) and (b). The apparatus shall include that given in Sections 2-2 through 2-11.

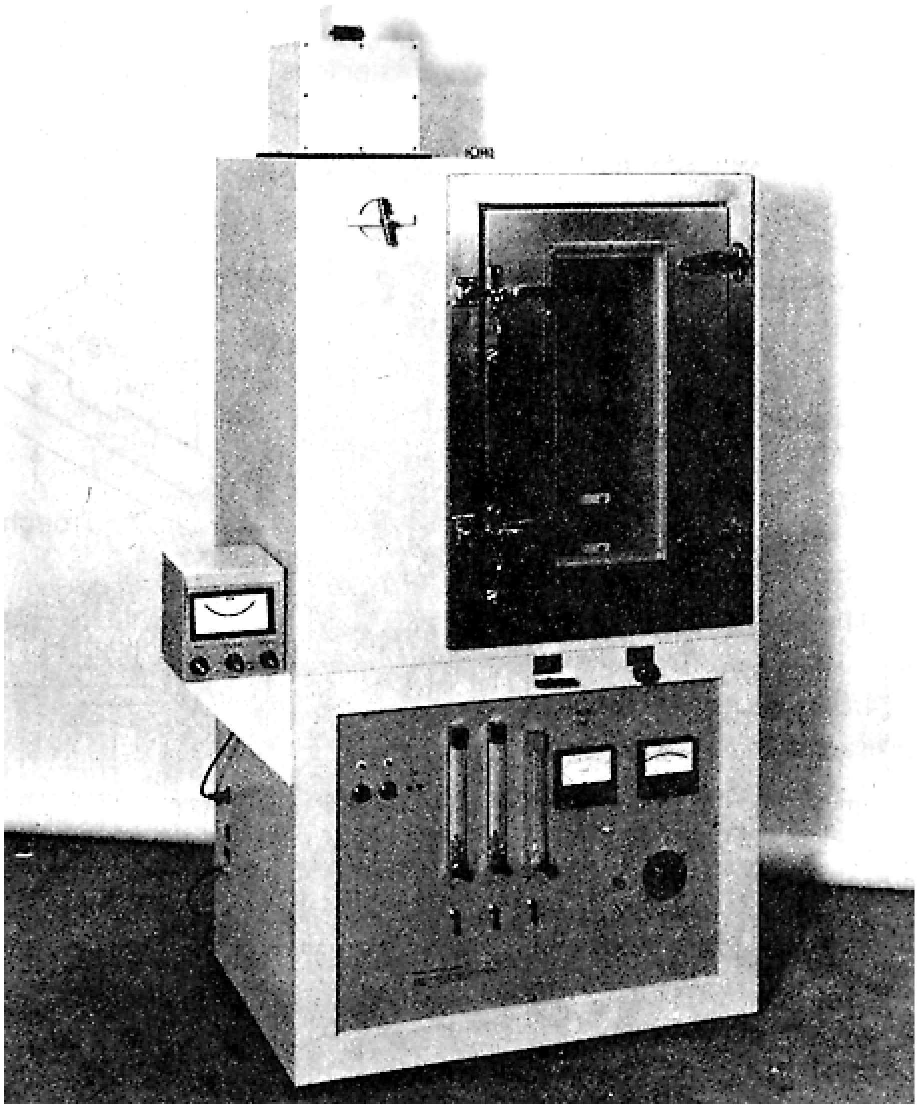
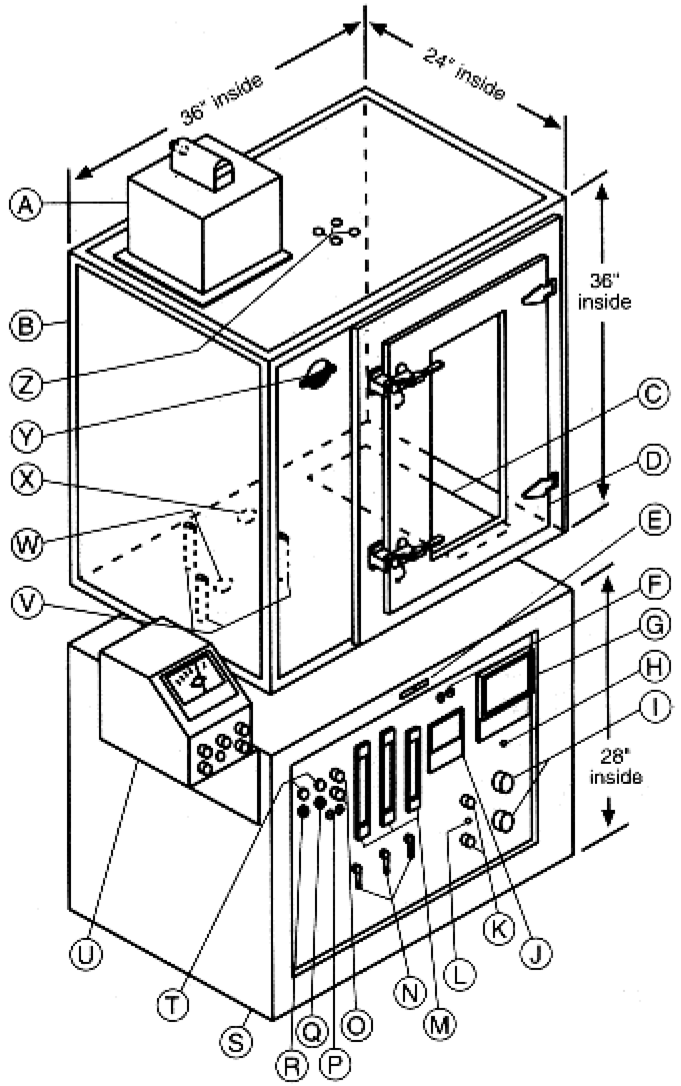


Figure 2-1(a) Smoke density chamber.



A — Phototube enclosure
B — Chamber
C — Blowout panel
D — Hinged door with window
E — Exhaust vent control
F — Radiometer output jack
G — Temperature (wall) indicator
H — Temperature indicator switch
I — Autotransformers
J — Voltmeter (furnace)
K — Fuse holders
L — Furnace heater switch
M — Gas & air flowmeters
N — Gas & air shutoff valves
O — Light intensity controls
P — Light voltage measuring jack
Q — Light source switch
R — Line switch
S — Support frame
T — Indicating lamps
U — Photometer readout
V — Rods
W — Glass window
X — Exhaust vent
Y — Inlet vent
Z — Access ports

For SI units: 1 in. = 25.4 mm.

Figure 2-1(b) Smoke density chamber assembly.

2-2 Test Chamber.

2-2.1

As shown in Figure 2-1(b), the test chamber shall be fabricated from laminated panels to provide inside dimensions of 36 in. × 24 in. × 36. in. ± $^1/_8$ in. (914 mm × 610 mm × 914 mm ± 3 mm) for width, depth, and height, respectively.

2-2.2*

The interior surfaces shall consist of porcelain-enameled metal or equivalent coated metal that is resistant to chemical attack and corrosion and suitable for periodic cleaning.

2-2.3

Sealed openings shall be provided to accommodate a vertical photometer, power and signal connectors, air and gas supply tubes, exhaust blower, inlet and exhaust vents, pressure and gas sampling taps, a pressure relief valve, a rod for remote positioning of the specimen holder, an aluminum foil [0.0010 in. (approx. 0.025 mm) or less in thickness] safety blowout panel at least 125 in.^{2} (806 cm^2) in area, and a hinged front-mounted door with an observation port or window.

2-2.4

All openings shall be located on the floor of the chamber.

Exception: The gas sampling taps, the positioning rod, and an inlet vent.

2-2.5

Where all openings are closed, the chamber shall be capable of developing and maintaining positive pressure during test periods, in accordance with Section 2-10.

2-3 Radiant Heat Furnace.

2-3.1

An electric furnace, as shown in Figure 2-3, with a 3-in. (76.2-mm) diameter opening shall be used to provide a constant irradiance on the specimen surface.

2-3.2

The furnace shall be located along the centerline, equidistant between the front and back of the chamber, with the opening facing toward and about 12 in. (305 mm) from the right wall.

2-3.3

The centerline of the furnace shall be about 7$^3/_4$ in. (195 mm) above the chamber floor.

2-3.4 Furnace Control System.

2-3.4.1 The furnace control system shall maintain the required irradiance level under steady-state conditions, with the chamber door closed to within ± 0.04 Btu/sec•ft^2 (± 0.05 W/cm^2) for 20 minutes.

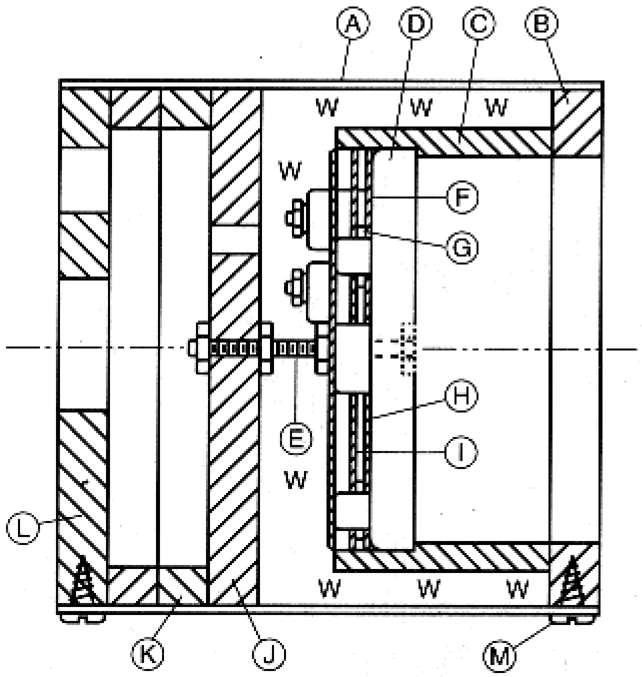
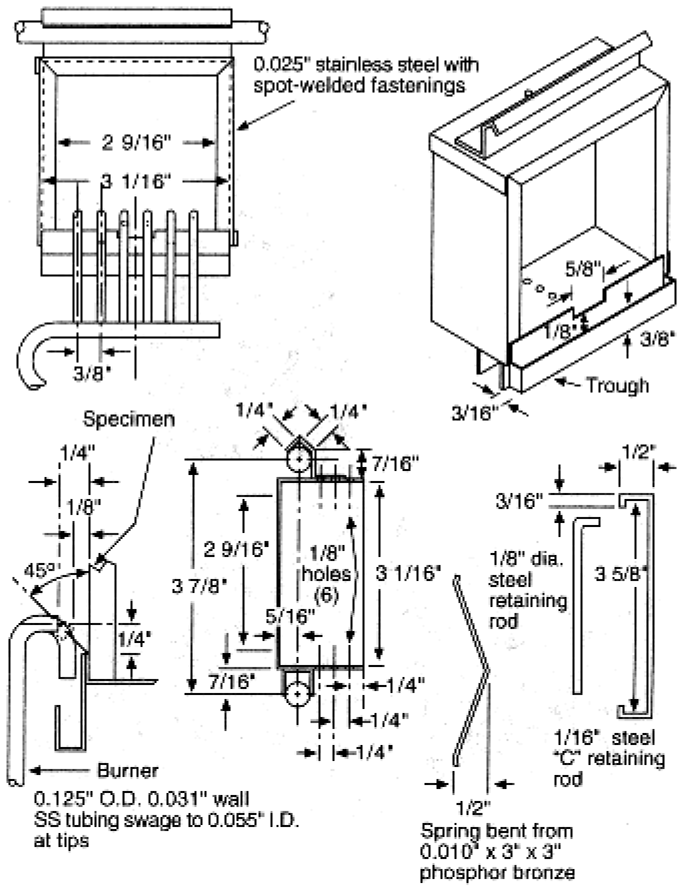


Figure 2-3 Furnace section.

2-3.4.2* The control system shall consist of an autotransformer or alternate control device and a voltmeter or other means for monitoring the electrical output.

2-4 Specimen Holder.

Specimen holders shall conform in shape and dimension to that shown in Figure 2-4, and shall be fabricated to expose a $2^9/_{16}$ in. × $2^9/_{16}$ in. (65.1 mm × 65.1 mm) specimen area. Also shown in Figure 2-4 are the spring and rods for retaining the specimen within the holders.

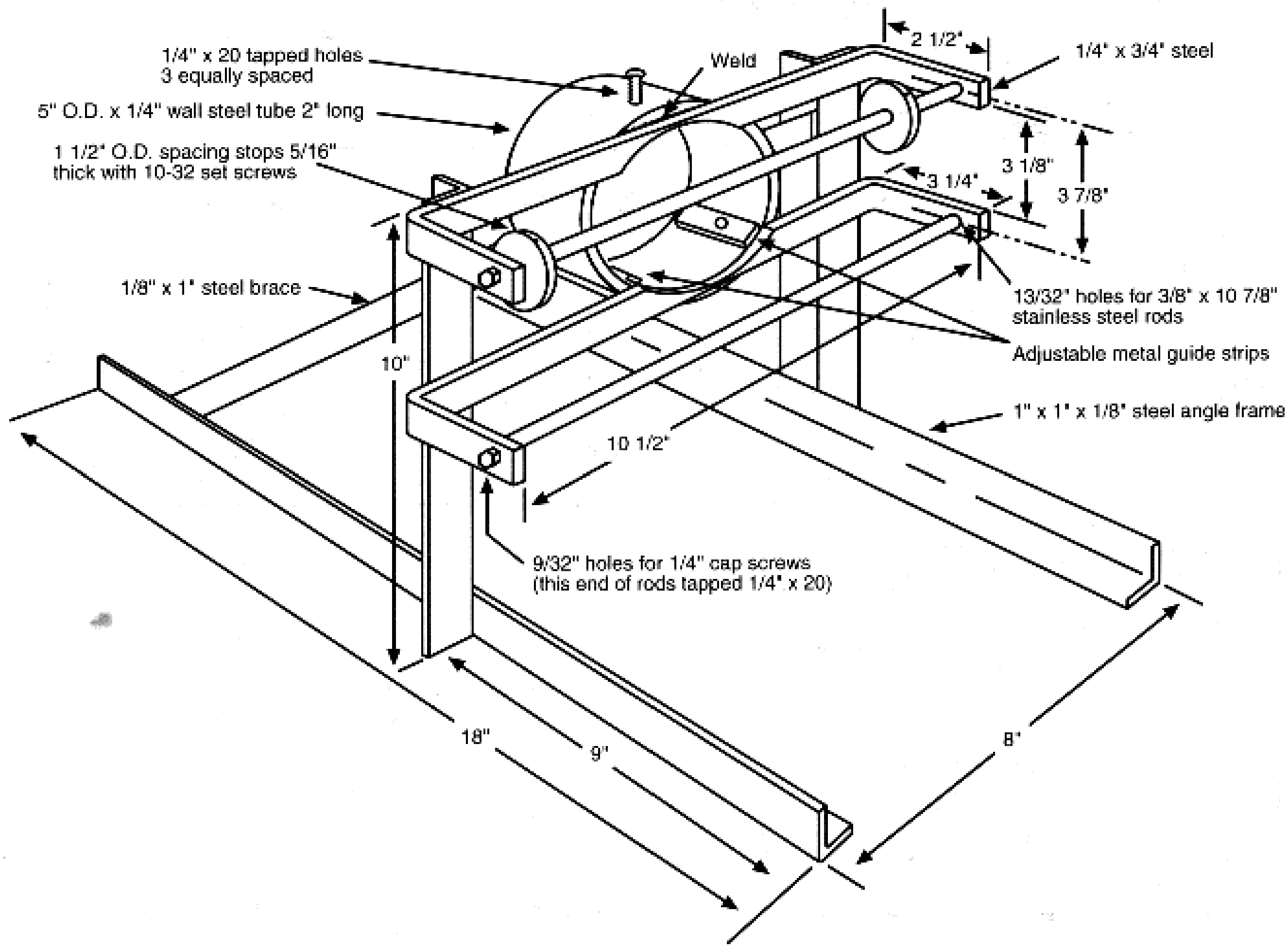


For SI units: 1 in. = 25.4 mm.

Figure 2-4 Details of specimen holder and pilot burner.

2-5 Framework for Support of the Furnace and Specimen Holder.

The framework for support of the furnace and specimen holder shall be constructed in accordance with Figure 2-5.



For SI units: 1 in. = 25.4 mm.

Figure 2-5 Furnace support.

2-6 Photometric System.

2-6.1

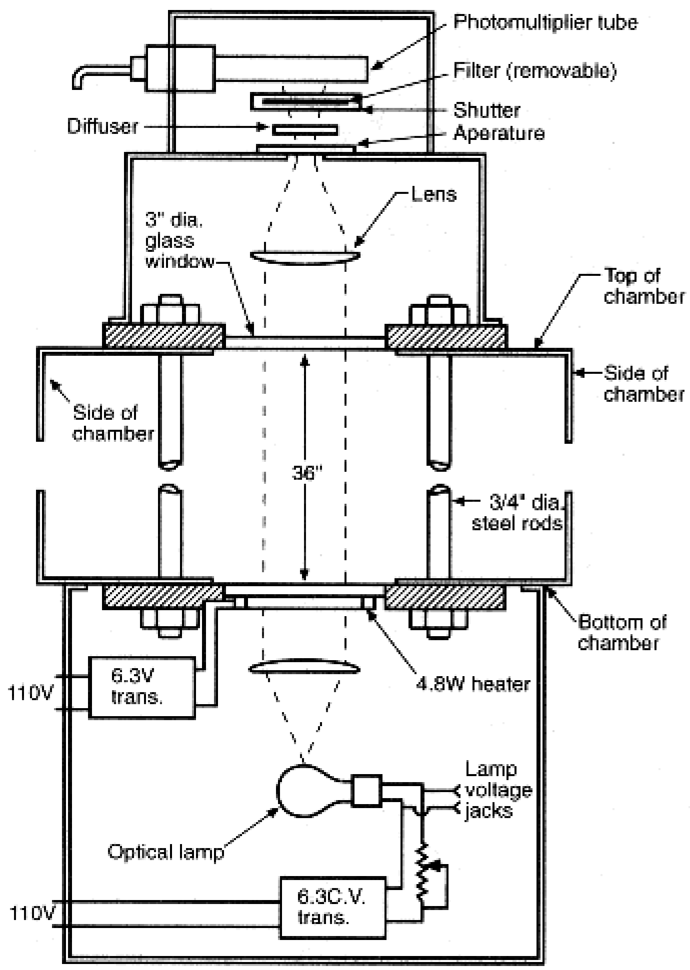
The photometric system shall consist of a light source and photodetector, oriented vertically to reduce variations in measurement brought about by stratification of the smoke generated by materials under test.

2-6.2

The system shall be as shown in Figures 2-6.2(a) and (b) and shall include the following:

(a) The *light source* shall be an incandescent lamp operated at a fixed voltage in a circuit powered by a voltage-regulating transformer. The light source shall be mounted in a sealed and light-tight box located below the chamber. This box shall contain the necessary optics to provide a collimated light beam passing vertically through the chamber.

(b) The *photodetector* shall be a photomultiplier tube with an S-4 spectral sensitivity response and a dark current less than 10A. A sealed box located directly opposite the light source shall be provided to house the photodetector and the focusing optics. A glass window shall be used to isolate the photodetector and its optics from the interior of the chamber.



For SI units: 1 in. = 25.4 mm.

Figure 2-6.2(a) Photometer details.

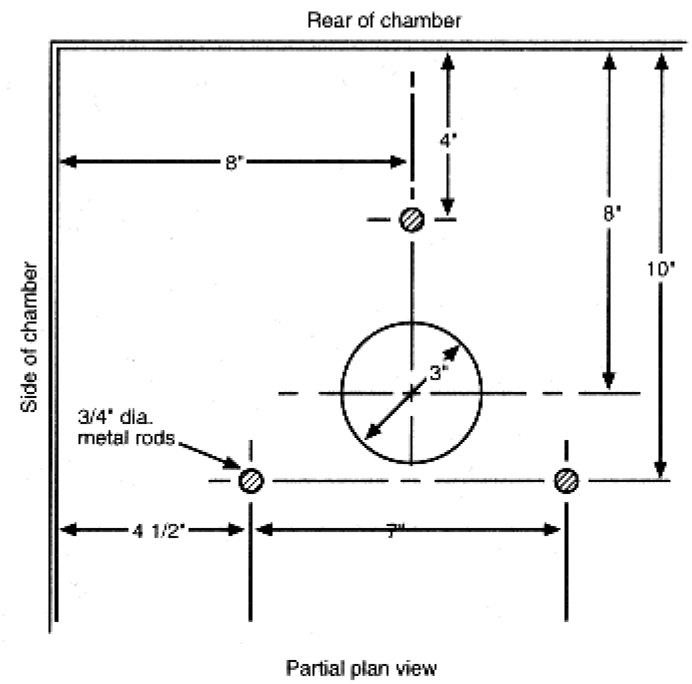


Figure 2-6.2(b) Photometer location.

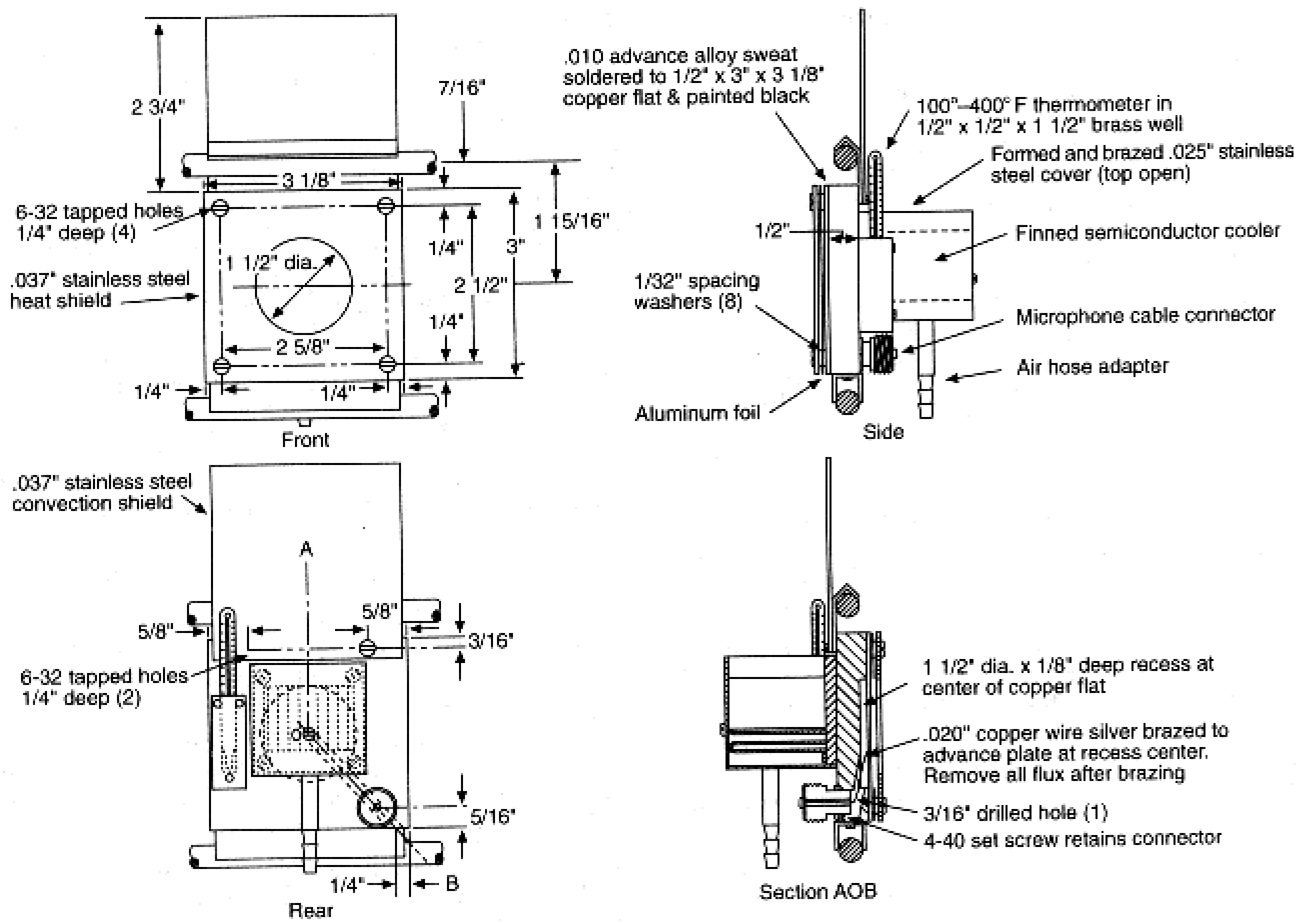
2-7 Radiometer.

2-7.1*

The radiometer for standardizing the output of the radiant heat furnace shall be of the circular foil type.

2-7.2

The construction of the radiometer shall be as shown in Figure 2-7.2.



For SI units: 1 in. = 25.4 mm.

Figure 2-7.2 Radiometer detail.

2-7.3

The radiometer shall have a stainless steel reflective heat shield with a $1^1/_2$-in. (38.1-mm) aperture on the front and a finned cooler supplied with compressed air mounted on the rear to maintain a constant body temperature of 200°F ± 5°F (93°C ± 3°C).

2-8 Thermocouples for Determining Chamber Wall Temperature.

A thermocouple shall be provided for determining the chamber wall temperature prior to testing.

2-9 Portable Recorder or Readout Meter.

2-9.1

The outputs of the radiometer and the thermocouples shall be monitored by a suitable recorder or readout meter.

2-9.2

The photodetector output shall be recorded or monitored with a potentiometer or other suitable instrument capable of measurement over a range of 5 decades or more. (*See B-1.4*.)

2-10 Manometer for Chamber Pressure Measurements.

2-10.1

A simple water manometer with a range of up to 6 in. (152 mm) of water shall be provided to monitor chamber pressure and leakage. (*See B-2.3*.)

2-10.2

The pressure measurement point shall be through a gas sampling hole at the top of the chamber.

2-10.3

A simple water column or relief valve shall be provided to permit control of chamber pressure. (*See B-1.8*.)

2-11 Multiple Flamelet Burner with Premixed Air-Propane Fuel.

2-11.1

For a flaming exposure test, a six-tube burner, with construction details as shown in Figure 2-4, shall be used.

2-11.2

The burner shall be centered in front of and parallel to the specimen holder.

2-11.3

The tips of the two horizontal tubes shall be centered $^1/_4$ in. ± $^1/_{16}$ in. (6.4 mm ± 1.6 mm) above the holder edge and $^1/_4$ in. ± $^1/_{16}$ in. (6.4 mm ± 1.6 mm) away from the specimen surface.

2-11.4

Provision shall be made to rotate or move the burner out of position during nonflaming exposures.

2-11.5

A premixed air and propane (95 percent purity or better) test gas shall be used.

2-11.6

The air and propane shall be metered by calibrated flow meters and needle valves at 500 cm^3/min for air and 50 cm^3/min for propane.

Chapter 3 Test Specimens

3-1 Specimen Description.

3-1.1 Size.

3-1.1.1 The test specimens shall be 3 in. × 3 in. ± 0.03 in. (76.2 mm × 76.2 mm ± 0.7 mm) and shall have an intended installation thickness up to and including 1 in. (25.4 mm).

3-1.1.2 Specimens provided in thicknesses in excess of 1 in. (25.4 mm) shall be sliced to 1 in. (25.4 mm) thickness and the original (uncut) surface shall be tested.

3-1.1.3 Multilayer materials greater than 1 in. (25.4 mm) thick that consist of a core material with surface facings of different materials shall be sliced to 1 in. (25.4 mm) thickness, and each original (uncut) surface shall be tested separately if required under 3-1.3.

3-1.2 Specimen Orientation.

3-1.2.1 If visual inspection of the specimen indicates a pronounced grain pattern, process-induced surface orientation, or other nonisotropic property, the specimen shall be tested in two or more orientations.

3-1.2.2 The highest smoke density value and the test orientation shall be stated.

3-1.3 Specimen Assembly.

3-1.3.1* The specimen shall be representative of the material or composite and shall be prepared in accordance with recommended application procedures.

Exception: Flat sections of the same thickness and composition shall be permitted to be supplied and tested in place of curved, molded, or specialty parts.

3-1.3.2 Where an adhesive is intended for field application of a finish material to a substrate, the prescribed type of adhesive and its spreading rate shall be noted and used for the test.

3-1.3.3* Where supplementary tests are necessitated by delamination, cracking, peeling, or other separations affecting smoke generation, the manner of performing such supplementary tests, and the test results, shall be included in the report with the conventional test.

3-1.3.4 For comparative tests of finish materials without a normal substrate or core and for screening purposes only, the following procedures shall be employed:

(a) Rigid or semirigid sheet materials shall be tested by the standard procedure, regardless of thickness.

(b) Liquid films (paints, adhesives, etc.), intended for application to combustible base materials, shall be appliedto the smooth face of $^1/_4$-in. (6.4-mm) thick tempered hardboard, with a nominal density of 50 lb/ft^3 to 60 lb/ft^3 (0.8 g/cm^3 to 0.97 g/cm^3), using recommended (or practical) application techniques and coverage rates. Tests also shall be conducted on the hardboard substrate alone, and these values shall be recorded as supplemental to the measured values for the composite specimen.

(c) Liquid films (paints, adhesives, etc.), intended for application to noncombustible substrate materials, shall be applied to the smooth face of $^1/_4$-in. (6.4-mm) thick asbestos-cement board, with nominal density of 120 lb/ft^3 (1.9 g/cm^3), using recommended (or practical) application techniques and coverage rates.

3-2 Number of Test Specimens.

Three tests under flaming exposure and three tests under nonflaming exposure shall be conducted on each material (a total of six specimens) in accordance with the conditions of this standard.

3-3 Specimen Conditioning.

Specimens shall be predried for 24 hours at 140°F ± 5°F (60°C ± 3°C), then conditioned to equilibrium (constant weight) with an ambient temperature of 73°F ± 5°F (23°C ± 3°C) and a relative humidity of 50 percent ± 5 percent.

3-4 Specimen Mounting.

3-4.1

All specimens shall be covered across the back, along the edges, and over the front surface periphery with a single sheet of aluminum foil [0.0015 in. ± 0.0005 in. (approximately 0.04 mm) thick].

3-4.2

Care shall be taken not to puncture the foil or to introduce unnecessary wrinkles during the wrapping operation.

3-4.3

Foil shall be folded in a way that minimizes loss of melted material at the bottom of the holder.

3-4.4*

Excess foil along the front edges shall be trimmed off after mounting. A flap of foil shall be cut and bent forward at the spout to permit flow from melting specimens.

3-4.5

All specimens shall be backed with a sheet of asbestos millboard. (*See Section 2-4.*)

3-4.6

The specimen and its backing shall be secured with a spring and retaining rod. A modified C-shape retaining rod shall be used with specimens from $^5/_8$ in. to 1 in. (15.9 mm to 25.4 mm) thick.

3-4.7

Flexible specimens shall not be compressed below their normal thickness.

3-4.8

It is the intent of this test method to maintain the prescribed exposure conditions on the specimen for the test duration. If under either the flaming or nonflaming exposure there is an excess of melted material that overflows the trough, the specimen area shall be reduced; e.g., if the area is reduced to $1^1/_2$ in. wide × 3 in. high (38.1 mm wide × 76.2 mm high) centrally located, the appropriate area shall be used in calculating D_s. *(See Section 5-1.)*

Chapter 4 Test Procedure

4-1 Test Room.

All tests shall be conducted in a room or enclosed space having an ambient temperature of 73°F ± 5°F (23°C ± 3°C) and relative humidity of 50 percent ± 20 percent at the time of test. Precautions shall be taken to provide a means for removing potentially hazardous gases from the area of operation.

4-2 Equipment Cleaning.

4-2.1*

The chamber walls shall be cleaned whenever periodic visual inspection indicates the need.

4-2.2*

The exposed surfaces of the glass windows separating the photodetector and light source housing from the interior of the chamber shall be cleaned before each test.

4-3 Warm-up of Furnace.

4-3.1

During the warm-up period all electric systems (furnace, light source, photometer readout, etc.) shall be on, the exhaust vent and chamber door shall be closed, and the inlet vent shall be open.

4-3.2*

When the temperature on the center surface of the back wall reaches a steady-state value in the range of 95°F ± 4°F (35°C ± 2°C), the chamber is ready for furnace calibration or testing.

4-3.3*

The furnace output irradiance shall be calibrated, without the burner in place, at periodic intervals according to test experience.

4-3.4

A "blank" specimen holder, with the asbestos millboard exposed, shall always be directly in front of the furnace.

Exception: Where displaced to the side by (1) the specimen holder during a test or (2) the radiometer during calibration.

The specimen holder shall be returned immediately to the above position when testing or calibration is completed.

4-3.5

During calibration, the radiometer shall be placed on the horizontal rods of the furnace support framework and accurately positioned in front of the furnace opening by sliding and displacing the "blank" specimen holder against the prepositioned stop. The furnace support framework, stop, and "blank" specimen holder shall provide for the horizontal and vertical centering within ± $^{1}/_{16}$ in. (1.6 mm) of the furnace opening of the radiometer during calibration and of the loaded specimen holder during test.

4-3.6

With the chamber door closed and the inlet vent opened, the compressed air supply to the radiometer cooler shall be adjusted to maintain its body temperature at 200°F ± 5°F (93°C ± 3°C).

4-3.7

The autotransformer setting shall be adjusted to obtain the calibrated millivolt output of the radiometer corresponding to a steady-state irradiance of 2.2 Btu/sec•ft^2 ± 0.04 Btu/sec•ft^2 (2.5 W/cm^2 ± 0.05 W/cm^2) averaged over the central $1^1/_2$-in. (38.1-mm) diameter area.

4-3.8

The recorder or meter described in Section 2-9 shall be used to monitor the radiometer output. After the prescribed irradiance level has reached steady-state, the radiometer shall be removed from the chamber and replaced with the "blank" specimen holder.

4-3.9

After the system has reached steady-state conditions, the meter or recorder zero, or both, shall be adjusted.

4-3.10

The amplifier sensitivity shall be adjusted to obtain a full-scale reading of the photodetector (100 percent transmittance) on the recorder or readout meter.

4-3.11

The "dark current" (zero percent transmittance) on the maximum sensitivity range of the readout meter shall be determined by blocking the light, and the "dark current" reading shall be adjusted to zero.

4-4 Burner Positioning.

For nonflaming exposures, the multiple flamelet burner shall be removed. For flaming exposures, the burner shall be positioned across the lower edge of the specimen as described in Section 2-11. The burner distance relative to the "blank" specimen shall be checked before fuel adjustment and ignition.

4-5 Procedures.

Before positioning the test specimen, the chamber shall be flushed for about 2 minutes with the door and exhaust and inlet vents open, and the starting temperature of the chamber shall be verified using the procedure described in 4-3.1 and 4-3.2.

4-5.1

The exhaust vent and blower then shall be closed.

4-5.2

The loaded specimen holder shall be placed on the bar support and shall be pushed into position in front of the furnace (with burner in position for flaming exposure) by displacing the "blank" holder.

4-5.3

The chamber door shall be closed quickly and the timer or recorder chart drive, or both, shall be simultaneously started. The inlet vent shall be closed completely only when the photometer indicates smoke.

4-5.4

Light transmittance and the corresponding time shall be recorded, either as a continuous plot with a multirange recorder or at sufficient time intervals with a multirange meter readout. The necessary full-scale range changes in decade steps shall be observed and noted.

4-5.5

The increase in chamber pressure shall be observed with the manometer described in Section 2-10. A regulator (*see B-1.8*) shall be used to maintain the pressure in the range of 4 in. ± 2 in. (100 mm ± 50 mm) of water during most of the test. If negative pressure develops after very intense specimen flaming, the inlet vent shall be opened slightly to equalize the pressure. As a result of pressure rise, the fuel and air valves shall be adjusted during the flaming test to maintain a constant flow rate.

4-5.6

Any observations pertinent to the burning and smoke-generating properties of the material under test shall be recorded in accordance with Chapter 6.

4-5.7

The test shall continue for 20 minutes or until a minimum light transmittance value is reached, whichever occurs first. If the minimum light transmittance does not occur within the 20-minute exposure period, this shall be noted in reporting the results.

4-5.8

If transmittance falls below 0.01 percent, the chamber window shall be covered with an opaque screen to avoid possible light-scattering effects from room light. Also, any supplementary optical filter in the photometer system shall be removed or displaced in order to extend the measuring range. If extraneous light can reflect into the photometer during removal of the filter, the high voltage shall be turned off or the scale shall be adjusted to minimize sensitivity. The filter shall be replaced before exhausting smoke from the chamber.

4-5.9*

The burner on flaming exposures shall be extinguished, and exhausting of the chamber shall be initiated within 1 minute after reaching minimum transmittance. The specimen shall be displaced from the front of the furnace by pushing the “blank” specimen holder with the positioning rod. Exhausting shall continue with the inlet vent open until maximum transmittance is reached. This transmittance value shall be recorded as the T_c, “the clear beam” reading, which shall be used to correct for deposits on the photometer windows.

Chapter 5 Calculations

5-1 Specific Optical Density.

Specific optical density, D_s, from the percent light transmittance, T, caused by the smoke generated from an exposed specimen area, A, in the closed chamber of volume, V, and over a light path, L, shall be calculated as follows:

$$D_s = \frac{V}{AL}\left[\log_{10}\left(\frac{100}{T}\right)\right] = G\left[\log_{10}\left(\frac{100}{T}\right)\right]$$

where G represents the geometrical factor associated with the dimensions of the chamber and specimen. Corrections for the volume of the furnace assembly and the volume included in the door recess are generally less than 1 percent and shall be permitted to be disregarded.

Where it is necessary to remove the neutral density filter to measure low levels of light transmittance (*see B-1.4*), the specific optical density appropriate for the filter shall be added. The value to be added shall be equal to the known optical density of the filter multiplied by G. (*See B-2.1.3*.)

5-2 Maximum Specific Optical Density.

The maximum specific optical density, D_m, shall be calculated using the formula in Section 5-1, with a light transmittance corresponding to the minimum level reached during the test. All maximum specific optical density values shall be corrected by subtracting the specific optical density equivalent for soot and other deposits on the photometer windows. The “clear beam” transmittance reading, T_c, shall be used to calculate a specific optical density equivalent, D_c, using the same formula but with different subscript. A corrected maximum specific optical density calculation shall be expressed as follows:

$$D_m \text{ (corr.)} = D_m - D_c$$

5-3 Light Transmittance.

For systems without “dark current” cancellation, a correction shall be made for any percent light transmittance reading, T, approaching the dark current value, T_d. The corrected percent light transmittance, T`, shall be obtained from the following equation:

$$T' = 100\left[1 - \frac{100 - T}{100 - T_d}\right] = 100\left[\frac{T - T_d}{100 - T_d}\right]$$

and shall be used for the specific optical density calculations described in Sections 5-1 and 5-2.

Chapter 6 Report

6-1

The report (*see Appendix C*) shall include the following:

(a) A complete description of the specimen tested, including type, manufacturer, shape, thickness, and other appropriate dimensions, weight or density, and coloring.

(b) A complete description of the test specimens, including substrate or core, special preparation, and mounting.

(c) The test specimen conditioning procedure.

(d) The number of specimens tested.

(e) The test conditions: Type of exposures, type of holder used, exposure period.

(f) Observations of the burning or smoldering characteristics of the specimens during test exposure, such as delamination, sagging, shrinkage, melting, and collapse.

(g)* Observations of the smoke-generating properties of the specimens during exposure, such as color of the smoke and nature of the settled particulate matter.

(h) A record of the geometrical factor, G, as calculated from measured values of chamber volume, V; photometer light path length, L; and exposed specimen area, A. (*See Chapter 5*.)

(i)* Test results calculated as described in Chapter 5, including the average and range on each set of specimens for D_m (corr.) and D_c.

6-2

If the test is terminated on the basis of a 20-minute exposure limitation, this fact shall be noted when reporting measurements observed at that time.

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

A commentary describing the significance of specific optical density and appropriate considerations for application of test results is included in Appendix D.

A-1-2.1

Attempts are now underway to relate the results of this test to the measurement of smoke generated under large-scale test conditions. Other test methods for measuring smoke have been reviewed and summarized in “The Control of Smoke in Building Fires — A State-of-the-Art Review.”

A-1-3.5

Additional parameters, such as the maximum rate of smoke accumulation, the time to a fixed optical density level, or a smoke obscuration index, might be more appropriate in particular situations.

A-2-1

A more detailed description of the suggested apparatus is given in B-1.

A-2-2.2

Commercially available panels of porcelain-enamel steel (interior surface) permanently laminated to asbestos-cement board and backed with galvanized steel (exterior surface), with a total thickness $^3/_{16}$ in. (4.76 mm), have been found suitable.

A-2-3.4.2 Where line voltage fluctuations are present, a constant-voltage transformer might be needed to maintain the prescribed irradiance level.

A-2-7.1

The operation of a circular foil-type radiometer is described by Gardon. (*For further* *information see R. Gardon, "An Instrument for the Direct Measurement of Intense Thermal Radiation*.")

A-3-1.3.1 Substrate or core materials for the test specimens should be the same as those for the intended application. Where a material or assembly might be exposed to a potential fire on either side, both sides should be tested.

A-3-1.3.3 Finish materials, including sheet laminates, tiles, fabrics, and others secured to a substrate materialwith adhesive, and composite materials not attached to a substrate, can be subject to delamination, cracking, peeling, or other separations affecting their smoke generation. To evaluate these effects, supplementary tests, performed on a scored (slit), exposed surface or on interior layers or surfaces, might be necessary.

A-3-4.4

Problems associated with interpretation of experimental results when unburned molten drips occur are discussed in Appendix D.

A-4-2.1

Charred residues on the specimen holder and horizontal rods should be removed to avoid contamination. An ammoniated spray detergent and soft scouring pads have been found effective.

A-4-2.2

Ethyl alcohol has been found to be generally effective for cleaning the surfaces of the glass windows.

A-4-3.2

To increase chamber wall surface temperature to the stated level under adverse conditions, an auxiliary heater can be used. Conversely, to decrease this temperature, the exhaust blower can be used to introduce cooler air from the laboratory.

A-4-3.3

Periodic intervals have been shown by test experience normally to consist of two calibrations per test day.

A-4-5.9

In some cases, the transmittance can somewhat increase and subsequently decrease to the ultimate minimum transmittance.

A-6-1(g) Although not specifically required as part of the method, products of combustion can be drawn from the chamber at various times during the test for analysis. The physical properties of the smoke can be investigated by electrostatic or impact collection and various methods of particle analysis. The presence and concentrations of various toxic and irritating gaseous products can be determined using colorimetric gas detector tubes, gas chromatography methods, ion-selective electrodes, or other techniques.

A-6-1(i) Sufficient test results should result in the development of a smooth curve of D_s versus time.

Appendix B Apparatus Construction and Calibration

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

B-1 Construction Details.

B-1.1 Radiant Heat Furnace.

(*See Section 2-3.*) The furnace consists of a coiled wire or other suitable electrical heating element (525 W or greater) mounted vertically in a horizontal ceramic tube 3 in. (76.2 mm) inside diameter × $3^3/_8$ in. (85.7 mm) outside diameter × $1^5/_8$ in. (41.3 mm) long. The tube is bored out at one end to $3^1/_{32}$ in. (77.0 mm) inside diameter and to a depth of $^5/_8$ in. (15.9 mm) to accommodate the heating element. A $^1/_{16}$-in. (1.6-mm) asbestos paper gasket and three stainless steel reflectors are mounted behind the heating element. A $^3/_8$-in. (9.5-mm) asbestos millboard disc, provided with ventilation and lead wire holes, is positioned behind the heating element and used to center the assembly with respect to the front of the $^3/_8$-in. (9.5-mm) asbestos millboard ring by means of a 6-32 stainless steel screw. The adjustment nuts on the end of the centering screw provide proper spacing of the furnace components. The cavities adjacent to the heating element assembly should be packed with glass wool. The furnace assembly is housed in a 4-in. (102-mm) outside diameter, 0.083-in. (2.1-mm) wall, $4^1/_8$-in. (105-mm) long stainless steel tube. Two additional $^3/_8$-in. (9.5-mm) asbestos board spacing rings and a rear cover of $^3/_8$-in. (9.5-mm) asbestos board complete the furnace. The furnace should be located centrally along the long axis of the chamber with the opening facing toward and about 12 in. (305 mm) from the right wall. The centerline of the furnace should be about $7^3/_4$ in. (195 mm) above the chamber floor.

B-1.2 Specimen Holder.

(*See Section 2-4.*) The specimen holder should conform in shape and dimension to Figure 2-4 and should be fabricated by bending and brazing (or spot welding) 0.025-in. (0.6-mm) thick stainless steel to provide a $1^1/_2$-in. (38.1-mm) depth, and to expose a $2^9/_{16}$ in. × $2^9/_{16}$ in. (65.1 mm × 65.1 mm) specimen area. As described in Section 2-5, the holder should have top and bottom guides to permit accurate centering of the exposed specimen area in relation to the furnace opening. A 3 in. × 3 in. (76.2 mm × 76.2 mm) sheet of $^1/_2$ in. (12.7 mm) asbestos millboard, having a nominal density of 50 lb/ft^3 ± 10 lb/ft^3 (0.85 g/cm^3 ± 0.17 g/cm^3), should be used to back the specimen. A spring bent from 0.010-in. (approximately 0.25-mm) thick phosphor bronze sheet should be used with a steel retaining rod to hold the specimen and millboard backing securely in position during testing.

B-1.3 Support of Furnace and Specimen Holder.

(*See Section 2-5.*) The framework as shown in Figure 2-5 has welded to it a 5-in. (127-mm) outside diameter, $^1/_4$-in. (6.4-mm) wall, 2-in. (50.8-mm) long, horizontally oriented steel tube to support the radiant heat furnace described in Section 2-3. This support tube should have provision to align the furnace opening accurately so that it is (1) $1^1/_2$ in. ± $^1/_{16}$ in. (38.1 mm ± 1.6 mm) away from, (2) parallel to, and (3) centered horizontally and vertically to within ± $^1/_{16}$ in. (1.6 mm) of the exposed specimen area. Three tapped holes with screws equidistantly positioned around the furnace support tube, or one screw at the top of the support in conjunction with two adjustable (vertically along the support tube) metal guide strips mounted horizontally inside the tube, are to provide for adequate alignment.

The framework should have two $^3/_8$-in. (9.5-mm) diameter transverse rods of stainless steel to accept the guides of the specimen holder described in B-1.2. The rods should support the holder so that the exposed specimen area is parallel to the furnace opening. Spacing stops should be mounted at both ends of each rod to permit quick and accurate lateral positioning of the specimen holder.

B-1.4 Photometric System.

(*See Section 2-6*.) The photometric system should consist of a tungsten-filament light source (Type 1630 6.5 volt lamp, maintained at 4 V ± 0.2 V) and a photodetector with an S-4 spectral sensitivity response. The photometer should be oriented vertically to reduce variations in measurement brought about by stratification of the smoke generated by the specimens under test. This system is shown in Figures 2-6.2(a) and (b). The window in the chamber floor through which the light beam passes is provided with an electric heater to maintain a temperature of at least 125°F (52°C) to minimize smoke condensation. The collimated beam inside the chamber should have a path length of 36 in. ± $^1/_8$ in. (914 mm ± 3 mm). The approximately circular light “spot” is centered entirely within the sensing area of the detector. A typical photomultiplier photometer system will require a high-voltage dc power supply and a neutral density filter of sufficient optical density to produce a convenient signal level for the indicator or recorder. The photometer system used should be capable of permitting the recording of reliable optical densities of at least 6.0, corresponding to transmittance values of 0.0001 percent of the incident light. (*See B-2.1.1*.)

The two optical platforms and their housings should be kept in alignment with three metal rods, $^1/_2$ in. (12.7 mm) in diameter and fastened securely into $^5/_{16}$-in. (7.9-mm) thick externally mounted top and bottom plates, and should be symmetrically arranged about the collimated light beam.

B-1.5 Radiometer.

(*See Section 2-7*.) The body temperature of the radiometer should be monitored with a 100°F to 220°F (38°C to 100°C) thermometer in a $^1/_2$ in. × $^1/_2$ in. × $1^1/_2$ in. (12.7 mm × 12.7 mm × 38.1 mm) brass well drilled to accept the thermometer with a close fit. Silicone grease can be used to provide good thermal contact.

The circular receiving surface of the radiometer should be spray-coated with an infrared-absorbing black paint containing a silicone vehicle. The radiometer should be calibrated calorimetrically in accordance with the procedure summarized in B-2.2.

B-1.6 Chamber Wall Thermocouple.

(*See Section 2-8*.) A thermocouple is mounted with its junction secured to the geometric center of the inner rear wall panel of the chamber using a $^1/_4$-in. (6.4-mm) thick polystyrene foam disk cover and epoxy cement.

B-1.7 Burner.

(*See Section 2-11*.) The multiple flamelet burner is a six-tube burner, with construction details as shown in Figure 2-4.

The vertical tubes of the six-tube burner are made from $^1/_8$-in. (3.2-mm) outside diameter, 0.031-in. (0.8-mm) wall stainless steel tubing (two tubes are bent 180 degrees into the trough, two tubes are bent 135 degrees from the vertical, and two tubes are bent 90 degrees from the vertical).

All tubes should be crimped at the tip to reduce the opening diameter to 0.055 in. (1.4 mm). The horizontal manifold section of the burner consists of $^1/_4$-in. (6.4-mm) outside diameter, 0.035-in. (0.9-mm) wall stainless steel tubing. The other end is attached to a fitting in the chamber floor.

B-1.8 Chamber Pressure Regulator.

A simple pressure regulator consists of an open, water-filled bottle and a length of flexible tubing, one end of which is connected to a sampling port on the top of the chamber. The other end of the tubing is inserted 4 in. (102 mm) below the water surface. The bottle is located at the same level as the floor of the chamber.

B-2 Calibration of Test Equipment.

B-2.1 Photometric System.

B-2.1.1 When first assembled and as necessary following use or when suspicious of a malfunction, calibration of the photometer should be checked by interrupting the light beam with calibrated neutral density filters. The filters should cover the full range of the instrument. Optical density values measured by the photometer should be within ± 3 percent of the calibrated values.

B-2.1.2 Shifts in dark current levels between tests, excessive zero shifts during test, or lack of calibration indicate the need for inspection of the photometer system.

B-2.1.3 The optical density of a supplementary filter used to extend the measuring range of the photometer should be known to an accuracy of ± 3 percent.

B-2.2 Radiometer.

Calibration of the radiometer is accomplished by placing it at suitable distances from a radiant energy source, while maintaining its body temperature at 200°F ± 5°F (93°C ± 3°C) with controlled airflow through the rear-mounted cooler, and measuring its electrical output as a function of the irradiance level. The irradiance level is determined calorimetrically by measuring the rate of temperature rise of a blackened thin copper disk of known weight, area [$1^1/_2$-in. (38.1-mm) diameter], specific heat, and absorptivity in place of the radiometer. The measured millivolt output of the radiometer, at a body temperature of 200°F (93°C), corresponding to an irradiance level of 2.2 Btu/sec•ft^2 ± 0.04 Btu/sec•ft^2 (2.5 W/cm^2 ± 0.05 W/cm^2) is used to establish the furnace control settings discussed in 4-3.2.

B-2.3 Chamber Pressure Manometer — Leak Rate Test.

For purposes of standardization, a leakage rate test should be periodically conducted using the manometer and tubing described in Section 2-10. The chamber is pressurized to 3 in. (76 mm) of water by introducing compressed air through a gas sampling hole in the top. The decrease in pressure from 3 in. to 2 in. (76 mm to 50 mm) of water is timed with a stopwatch. This time should not be less than 5.0 minutes.

B-2.4 Standard Smoke-Generating Materials.

For checking operational and procedural details of the equipment and method described in this standard, two standard materials can be used. Under nonflaming conditions, a single layer of alpha-cellulose (cotton linters) paper, and, under flaming conditions, plastic sheet, should provide repeatable maximum specific optical density values in two portions of the measuring range. Use of these standard materials does not obviate the need for following the calibration and standardization procedure outlined in this standard.

NOTE: These reference materials, designated SRM 1006 and SRM 1007, can be purchased from the Office of Standard Reference Materials, National Institute of Standards and Technology, Gaithersburg, MD 20899.

Appendix C Suggested Report Form — Smoke Density Chamber

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

Suggested Report Form — Smoke Density Char

Sample Code ______________________ **Test No.** __________

Lab Code ______________________ **Operator** __________

Recorded Data or Curve

Operating Conditi

Time (min) % Trans. (D_s)

Radiometer Rea

Irradiance ______

Furnace Voltage

Burner Fuel ______

Thermal Exposu

Chamber Pressu

Chamber Wall T

Chamber Surfac

Burner: Stand

Sample

Description ______

Manufacturer ______

Preconditioning:

Duration hr ______

Conditioning: Te

RH ______

kness: ______

or lb/ft³

Initial Wt. ______

% Loss ______

Appendix D Commentary

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

D-1 Introduction.

The smoke density chamber test was developed at the National Bureau of Standards and was first described in an ASTM research symposium in 1967.[1,9] Since that time, there have been numerous publications reporting on its application and on studies of the correlation of results of interlaboratory tests through its use.[2]

D-1.1

The method is somewhat like the box-type test developed by Rohm and Haas.[9,10] However, it provides certain modifications in the nature of specimen exposure and the capability for quantitative measurement of the smoke produced. Advantages provided by use of this test method include: (1) the smoke collection chamber is essentially sealed so all smoke produced during a test is retained; (2) only one surface of a test specimen is exposed to fire or radiant heating, thus providing a measure of effectiveness of surface treatment assisting in control of smoke release; (3) a vertical photometer is used as a means for avoiding measurement errors resulting from smoke stratification; (4) provision is included for reporting the result of smoke measurements in terms of specific optical density, which is a measurement of the amount of smoke produced and therefore is useful for comparing one composition of a material against another.

D-1.2

Measurements made with the test relate to light transmission through smoke.

D-2 Features of Test Method.

D-2.1

Two exposure conditions can be simulated by the test: (1) radiant heating in the absence of ignition, and (2) an open-flame combustion of the specimen in the presence of supporting radiation. These two conditions were selected as representative of two types of fire involvement. The irradiance level of 2.2 Btu/sec•ft^2 (2.5 W/cm^2) was selected as the highest for which most cellulosics would pyrolize without self-ignition. This irradiance level is much lower than that which would exist in a compartment after flashover. It more nearly simulates conditions in the initial stages of a fire.

D-2.1.1 From a scientific viewpoint, it would be desirable to have constant irradiance over all portions of the specimen. From a practical point of view, this is not feasible because size and heat input of the furnace would have to be greatly increased. It was considered, therefore, more practical to accept a modest nonuniformity of irradiance across the surface of the specimen. This is not defined in terms of radiance units, but rather by specifying the dimensions of the furnace geometry and the specimen spacing. Thus, radiant configuration geometry was selected as a means of specifying the variability of surface irradiance. The average irradiance specified in the test method is that measured by the radiometer described in the standard, an instrument sensitive only to the $1^1/_2$-in. (38.1-mm) diameter central area of the specimen holder.

D-2.2

Figure D-1 shows the result of one survey of irradiance across the specimen diagonal. This suggests that the overall average effective flux level during nonflaming pyrolysis is probably about 2.0 Btu/sec•ft^2 (2.3 W/cm^2). While this degree of nonuniformity is short of technical perfection, it is accepted as a practical compromise, considering the use for which the test method is intended.

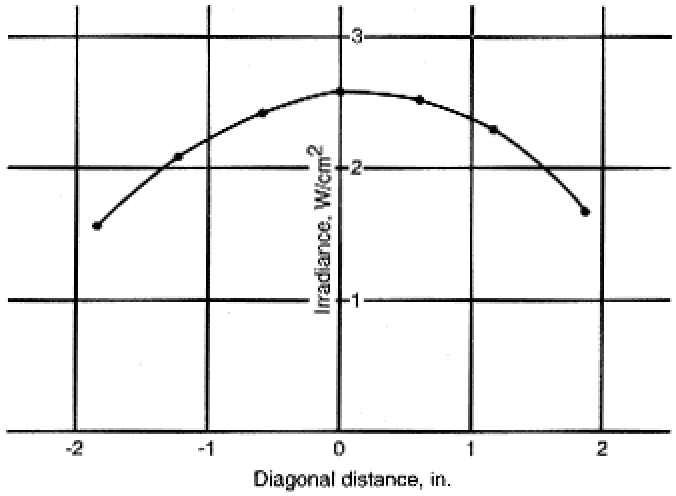


Figure D-1 Diagonal survey of irradiance at specimen during operation at nominal 2.2 Btu/sec·ft^2(2.5 W/cm2).

D-2.2.1 The primary measurement made during the conduct of the test is of the amount of light transmitted as a fraction or percentage of the initial light transmitted by the optical system. The minimum percent light transmitted value is, in turn, used to calculate the maximum specific optical density, D_m, value, in accordance with Chapter 5. There is some advantage to using specific optical density as a value by which to evaluate results as compared to using percent light transmittance.

D-2.2.2 The use of this unit of smoke measurement is based on Bouguer's law of light attenuation, which is expressed as follows:

$$T = T_o e^{-\sigma L}$$

where:

T = % flux transmittance.

T_o = 100, the initial transmitted flux.

σ = attenuation coefficient.

L = length of the optional path.

e = 2.7183.

D-2.2.3 While the smoke produced from fire usually does not meet the requirement of a monodispersed aerosol, it has been found to behave in a photometric manner such that, for the purposes intended, optical density can be considered to be roughly proportional to the smoke particulates produced. The measurement unit, specific optical density, Ds, has been introduced to provide a conveniently factored rating scale as follows:

D_s = (V/AL)d = (V/AL) log (100/T) where (V/AL) = 132.

Previous draft versions of this test method have proposed that, in the situation where the smoke produced exceeded the measurement capability of the apparatus, or if only small specimens were available, specimens of less than standard size could be tested and the results extrapolated to the standard specimen size. This procedure should not be used for several reasons, one of which involves the nonuniformity of irradiance and pilot flame exposure.

D-2.2.3.1 Certain other test methods report smoke simply in terms of light transmission. The problem with such a procedure is that one unfamiliar with the characteristics of smoke aerosols might assume that the percent light transmittance is a reciprocal, linear function of the quantity of smoke produced, thus concluding that as the quantity of smoke produced is doubled, the percent light transmittance is cut in half. This is not true.

D-2.2.4 The concept of specific optical density, while old in terms of chemical photometric practice, was first introduced for measuring smoke as part of the smoke density chamber test method. It is based on Bouguer's law and permits reporting smoke development in terms that recognize the area of the specimen involved, the volume of the box, and the optical path length of the photometer. Specific optical density is without dimension. Its value should, however, be recognized as relating to the specimen only in the thickness tested. In theory, it has the unique advantage of providing a basis for estimating the smoke optical density or light-obscuring properties of smoke that can be developed by the same assumption of uniform smoke-air mixing and under similar fire exposure conditions.[11] At the present time, techniques for using this theoretical approach have not been developed to a practical stage because of (1) variations in types of fire exposure, (2) the rate of involvement of a material in a fire, (3) the ventilation characteristics of the compartment, and (4) the degree of stratification of the accumulated smoke. These are, in most instances, undetermined variables that greatly influence light transmission through smoke resulting from a fire.

D-3 Factors Influencing the Test.

During development of the test method, many factors were considered that could influence the measurements. Some of the more important of these are mentioned and briefly outlined in the following paragraphs.

D-3.1

It was observed that, in spite of significant thermal convection mixing, smoke near the top of the cabinet was obviously more dense. This fact was verified by experimental measurements. As a result, it was apparent that a vertical photometer would yield a much more representative measurement of smoke accumulation than would be provided by a horizontal unit at one position in the chamber.

D-3.2

Experiments showed that the optical density of the accumulated smoke was sensitive to the spacing between the specimen face and the plane of the furnace opening. The experiments seem to suggest that the sensitivity was caused by two effects: (a) close spacing caused more smoke to enter the furnace and become consumed there; (b) reduced air circulation moving past the specimen, which inhibited open-flame combustion. As a result, the separation called for in B-1.3 of $1^1/_2$ in. ± $^1/_{16}$ in. (38.1 mm ± 1.6 mm) was selected as a fair compromise for the purpose of standardization. If this spacing is not held, a small systematic change should be expected in smoke measurement. Similarly, it is necessary to maintain the specified spacing of 3.0 in. ± $^1/_{32}$ in. (76.2 mm ± 0.8 mm) between the heater face and the specimen surface.

D-3.3

The use of aluminum foil to wrap the back and edges of the specimen was introduced to provide better standardization, because it was found that if smoke was allowed to leak out the back and edges of the specimen holder, the various ways in which this could occur introduced an undesirable variability in the measurements.

D-3.4

The question of how to assess, in an equitable fashion, the smoke production of thermoplastics has been a vexing one since early development of the test. The decision to use a vertical specimen orientation was based on knowledge that fire behavior and thus smoke production differ in vertical and horizontal arrangement positions. Since the method was considered most likely to be used for experimental evaluation of interior wall finished products, the vertical specimen position was selected as most relevant. Obviously, the thermoplastic problem remained. Portions of such materials were found to melt and drip in varying degrees to the floor of the chamber. Thus, the smoke resulting from such materials is less than would be expected if all the material remained in the flux field. Whether such materials should be penalized or credited for such behavior has not been validated by definitive experimental and theoretical studies. In spite of this uncertainty, during the latter development stages of the test methods, a decision was reached to provide a trough on the specimen holder to collect and permit consumption of some of the molten residue. In processing this standard, questions were raised as to the usefulness of the trough, since the thermal exposure to the material within it is less severe than that to material that remains in the normal specimen position. A small-scale study was conducted. It showed that thermoplastic materials differed widely. Whereas appreciable smoke developed from one material placed in the trough, only a small quantity of smoke developed when another material was placed in the trough. This did not seem, however, to be too different from the performance that might be expected from the same materials in another fire exposure; thus, there does not seem to be any reason to ban thermoplastic materials that melt or drip into the trough from the test.

D-4 Precision.

D-4.1

In any method, one of the important considerations is the degree to which a method, when applied to a given material, will yield constant results. Since this test results in destruction of the specimen, the results of any test to determine precision are affected not only by the random errors that might be inherent in the procedure but also by any variation in the properties of the replicate specimens. Thus, in studying the degree to which experimental results can be repeated within a given laboratory, it is desirable to use a material from which specimens of uniform composition and dimensional characteristics can be prepared.

This fact was recognized in planning the large interlaboratory study of the precision of the measurement method. In spite of this, some of the experimental variability observed was undoubtedly related to variations in the replicate specimens. In at least one instance, variation in thickness as great as 20 percent was observed. To assist in identifying variability resulting from this cause, requirements for weighing specimens have now been included as a part of the test procedure.

D-4.2

Various changes were made in the test method description as adopted, as compared to the description used to advise for the round-robin test conducted. These included (1) running additional samples when the results of three specimens are highly variable, (2) maintenance of pilot burner, (3) deletion of data that are inconsistent with the equipment, and (4) improved calibration and alignment procedures. These changes are such that the precision data given should be assumed to be conservative as they relate to the test method adopted. Better precision might result if another laboratory round-robin test is conducted.

D-4.2.1 When studying the results reported by the various laboratories participating in the round-robin study, it was realized that the test method draft given to the laboratories to follow failed to contain a section describing conditions under which data obtained from the test should be excluded. For instance, certain materials were found to ignite under the nonflaming exposure condition. Obviously, these were not nonflaming results. Another cause for such questioning of data involved results that exceeded the measurement capability of the photometer.

D-5 Reporting of Results.

One of the obvious needs with a test method of this type is to consider ways in which the experimental data should be reported. Early draft versions of this standard contained a recommendation that a correction factor be applied to the measured D_m (corr.). The reporting of D_m as a preferred measurement result is based on the following fact:

The deposit remaining following a test represents a part of the smoke produced. Thus, it seems irrational to subtract this value unless it can be shown that the deposit results from late accumulation following a peak smoke reading. The procedures of the test method seem to make this unlikely.

D-5.1

Experience has shown that the determination of the value of T used eventually to calculate D_m (corr.) is subject to variations in operator technique during the chamber venting procedure.

D-5.2

The introduction of the correction factor, while not in itself a significant technical problem, suggests a technical sophistication that simply is not justified on the basis of the intended use of the data. The effect of these facts was noticed during analysis of the round-robin experimental data. The results were found to be more consistent for the uncorrected data (D_m).

D-6 Limitations on Application of Smoke Measurement Data.

D-6.1

The smoke problems that develop during unwanted fires have been recognized for many years. Fire fighters are faced with them daily in their work. However, three problems have tended to prevent application of standards limiting the acceptability of materials or products on the basis of smoke production:

(a) The extent to which the smoke measurement assesses the smoke hazard;[12,13]

(b) The lack of a well-defined measurement method that could be shown to provide a technically valid means for smoke characterization;

(c) The fact that most materials or products, when burning, release large quantities of smoke, and there are only limited ways of reducing smoke production.

(1) The first problem still exists.

(2) The second problem has been partially alleviated with the development of the smoke chamber. However, it must be recognized that only two of a wide range of fire exposure conditions are simulated by the test method. Thus, any rank ordering of materials by the test should be recognized as based only on the fire exposure conditions applied, and, in fact, the test method develops different rankings depending on whether a ranking is based on the nonflaming exposure or the flaming exposure. All of the parameters that affect fire behavior will influence the amount of smoke produced. Thus, it is unrealistic to place great confidence in the smoke measurement as a unique and absolute measure of smoke production during building fires.

(3) The third problem also remains. If significant changes in smoke levels are to be expected when fire occurs, it seems necessary to require large changes in D_s. To limit the type and size of fire that could develop, very severe limitations would have to be placed on smoke production of both the building finish material and the occupancy items, and comprehensive fire prevention and protection measures would have to be continually maintained.

D-6.2

It is important to remember that, for any given thermal exposure condition, the smoke produced when a fire occurs is related to the thickness and density of the material involved. The importance of specimen thickness is illustrated in Figure D-2. The indication deviations from a linear relationship of D_m with specimen thickness result from the decreasing pyrolysis rate of the specimen as the burning layer progresses into the specimen and, also, from the increasing rate of smoke dropout and condensation as high smoke concentration develops.

D-6.3

The smoke density chamber provides a means for characterizing smoke production for research and development only. It provides a means for reporting an experimental rate of smoke production and a time at which specific smoke levels are reached under the test conditions applied.

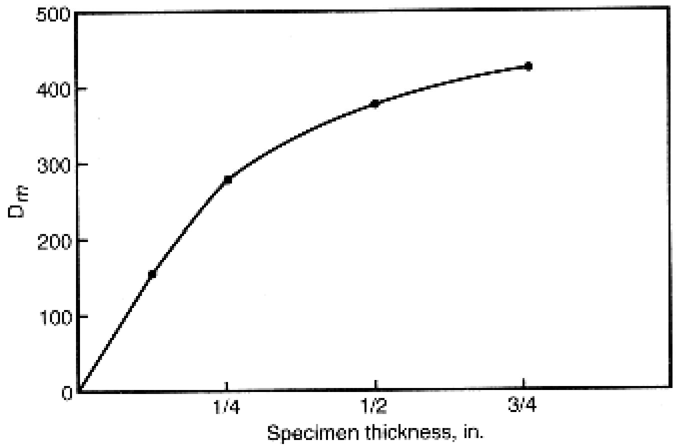


Figure D-2 D_m for spruce as a function of specimen thickness under nonflaming conditions.

Footnotes to Appendix D

[1] Gross, D., Loftus, J. J., and Robertson, A. F., Measuring Smoke from Burning Materials,” *Symposium on Fire Test Methods — Restraint and Smoke* (1966), ASTM STP422, American Society for Testing and Materials, 1967, p. 166.

[2] Gross, D., Loftus, J. J., Lee, T. G., and Gray, V. E., “Smoke and Gases Produced by Burning Aircraft Interior Materials,” *NBS Bldg. Sci. Series*, BSS 18 (February 1969), U.S. Government Printing Office, Washington, DC.

[3] Brenden, J. J., “Usefulness of a New Method for Smoke Yield from Species and Panel Products,” *Forest Products Journal*, FPJOA, Vol. 21 (1971), pp. 23-28.

[4] Lee, T. G., “Interlaboratory Evaluation of Smoke Density Chamber,” *NBS Tech. Note 708* (December 1971).

[5] Lee, T. G., “The Smoke Density Chamber Method for Evaluating the Potential Smoke Generation of Materials,” *NBS Tech. Note 757* (January 1973).

[6] ASTM Committee E05.2, “Interlaboratory Test Data for the Smoke Chamber Test Method,” RRE-5-1002 (1976).

[7] Gaskill, J. R., “Smoke Development in Polymers During Pyrolysis or Combustion,” *Journal of Fire and Flammability*, JFFLA (July 1970), pp. 183-216.

[8] Chien, W. P. and Seader, J. D., “Prediction of Specific Optical Density for a Smoke Obscuration in an NBS Smoke Density Chamber,” *Fire Technology*, FITCA, Vol. 11, No. 3 (August 1975), pp. 206-217.

[9] Bartosic, A. J. and Rarig, F. J., “Evaluation of the XP2 Smoke Density Chamber,” *Symposium on Fire Test Methods — Restraint and Smoke* (1966), ASTM STP422, American Society for Testing and Materials, 1967, p. 106.

[10] ASTM D2843, *Standard Test Method for Density of Smoke from the Burning or Decomposition of Plastics* (1977, Rev. 1988), Annual Book of ASTM Standards.

[11] Robertson, A. F., "Estimating Smoke Production During Building Fires," *Fire Technology*, FITCA, Vol. 11, No. 2 (May 1975), pp. 80-94.

[12] Yuill, C. H. et al., "The Control of Smoke in Building Fires — A State-of-the-Art Review," *Materials Research and Standards*, Vol. II, No. 4 (1971), pp. 16-24.

[13] Committee E-5, "A Report on Smoke Test Methods," *Standardization News* (August 1976), pp. 18-26.

Appendix E Selected Papers for Further Study

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

E-1 General.

The following list of papers has been selected as an introduction to a much broader list of documents relating to smoke problems during building fires. In selecting these references, emphasis has been placed on U.S. and Canadian work. There is a considerable body of foreign language publications of great merit, but, with one or two exceptions, these have not been included.

E-1.1 Review Papers.

Autian, J., "Toxicology Aspects of Flammability and Combustion of Polymeric Materials," *Fire and Flam*. (July 1970), pp. 239-268.

Galbreath, M., "Fire in High Buildings," National Research Council of Canada, *Fire Study*, Vol. 21, NRC No. 10081 (Ottawa, April 1968).

Little, Arthur D., "Fire Gas Research Report," *NFPA Quarterly*, Vol. 45, No. 3 (January 1952), pp. 280-306.

Wood, P. G., "The Behavior of People in Fire," Joint Fire Res. Org., *Fire Research Note No. 953* (November 1972), p. 113.

E-1.2 Fire Gas and Smoke Hazard.

Bono, J. A. and Breed, B. K., "Smoke Ratings in Relation to Visual Observations," *Fire Technology*, Vol. 2, No. 2 (May 1966), pp. 146-158.

Fiorca, V., Higging, E. A., Thomas, A. A., and Davis, H. V., "Acute Toxicity of Brief Exposures to HF, HCl, NO_2 and HCN with and without CO," *Fire Technology*, Vol. 8, No. 2 (May 1972), pp. 120-129.

Fristrom, R., *Annual Summary Report* (July 1972 to 30 June 1973), App. Phys. Lab., Johns Hopkins Univ., Rept. No. FPP A73 (August 1973).

Jin, T., "Visibility through Fire Smoke (Part 2, Visibility of Monochromatic Signs through Fire Smoke)," *Report of Fire Res. Inst. of Japan*, No. 33 (1971), pp. 31-48.

Shern, J. H., "Smoke Contribution Factor in Fire Hazard Classification of Building Materials," *Symposium on Fire Test Methods — Restraint and Smoke* (1966), ASTM STP422, American Society for Testing and Materials, 1967.

Smith, E. E., “Evaluation of the Fire Hazard of Duct Materials,” *Fire Technology*, Vol. 9, No. 3 (August 1973), pp. 157-170.

Tsuchiya, Y. and Sumi, K., “Combined Lethal Effect of Temperature CO, CO_2 and O_2 of Simulated Fire Gases,” *Fire and Flam*., Vol. 4 (April 1973), pp. 132-140.

Tsuchiya, Y. and Sumi, K., “Evaluation of the Toxicity of Combustion Products,” *Fire and Flam*., Vol. 3 (January 1972), pp. 46-50.

Yuill, C. H., “The Life Hazard of Bedding Fires,” *Fire and Flam.*, Vol. 1 (October 1970), pp. 312-323.

E-1.3 Smoke Test Methods.

ASTM D2843, *Standard Test Method for Density of Smoke from the Burning or Decomposition of Plastics* (1977, Rev. 1988), Annual Book of ASTM Standards.

ASTM E162, *Standard Method of Test for Surface Flammability of Materials Using a Radiant Heat Energy Source* (1990), Annual Book of ASTM Standards.

Bartosic, A. J. and Rarig, F. J., “Evaluation of the XP2 Smoke Density Chamber,” *Symposium on Fire Test Methods — Restraint and Smoke* (1966), ASTM STP422, American Society for Testing and Materials, 1967.

Brenden, J. J., “Usefulness of a New Method for Smoke Yield from Species and Panel Products,” *Forest Prod. J*., Vol. 21 (1971), pp. 23-28.

Christian, W. J. and Waterman, T. E., “Ability of Small-Scale Tests to Predict Full-Scale Smoke Production,” *Fire Technology*, Vol. 7, No. 4 (November 1971), pp. 332-344.

Comeford, J. J. and Birky, M., “A Method for the Measurement of Smoke and HCl Evolution from Poly(vinyl chloride),” *Fire Technology*, Vol. 8, No. 2 (May 1972), pp. 85-90.

Gardon, R., “An Instrument for the Direct Measurement of Intense Thermal Radiation,” *Review of Scientific Instruments*, Vol. 24 (1953), pp. 366-370.

Gross, D., Loftus, J. J., and Robertson, A. F., “Method for Measuring Smoke from Burning Materials,” *Symposium on Fire Test Methods — Restraint and Smoke* (1966), ASTM STP422, American Society for Testing and Materials, 1967.

Lee, T. G., “Interlaboratory Evaluation of Smoke Density Chamber,” *NBS Tech. Note 708* (December 1971).

Lee, T. G., “The Smoke Density Chamber Method for Evaluating the Potential Smoke Generation of Materials,” *NBS Tech. Note 757* (January 1973).

NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, 1990 edition.

Rasbash, D. J., “Smoke and Toxic Products Produced at Fires,” *Trans. J. Plastics Inst*. (January 1967), pp. 55-61.

Silversides, R. G., “Measurement and Control of Smoke in Building Fires,” *Symposium on Fire Test Methods — Restraint and Smoke* (1966), ASTM STP422, American Society for Testing and Materials, 1967.

Smith, E. E., “Measuring Rate of Heat, Smoke, and Toxic Gas Release,” *Fire Technology*, Vol. 8, No. 3 (August 1972), pp. 237-245.

E-1.4 Smoke Behavior During Fires.

Bell, D. and Lieberman, P., “Smoke and Fire Propagation in Compartment Spaces,” *Fire Technology*, Vol. 9, No. 2 (May 1973), pp. 91-100.

Carhart, H., Hazlett, R. N., Johnson, E., and Stone, J. P., “The Transport of Hydrogen Chloride by Soot from Burning Polyvinylchloride,” *Fire and Flam*., Vol. 4 (January 1973), pp. 42-51.

“The Control of Smoke in Building Fires — A State-of-the-Art Review,” *Mtls. Res. and Stds*., Vol. 11, No. 4 (April 1971), pp. 16-24.

Fackler, J. B., “Fire and Smoke Invasion of Apartments,” *Symposium on Fire Test Methods — Restraint and Smoke* (1966), ASTM STP422, American Society for Testing and Materials, 1967.

Heselden, A. and Hinkley, P., “Smoke Travel in Shopping Malls — Experiments in Cooperation with Glasgow Fire Brigade,” Part I, Joint Fire Res. Org., *Fire Research Note 832* (July 1970). See also *Fire Research Abstracts and Reviews*, Vol.12, No. 3 (1970), p. 234.

Hinkley, P. L., “The Flow of Hot Gases Along an Enclosed Shopping Mall — A Tentative Theory,” Joint Fire Res. Org., *Fire Research Note 807* (March 1970). See also *Fire Research Abstracts and Reviews*, Vol. 12, No. 3 (1970), p. 235.

“Movement of Smoke on Escape Routes in Buildings” (Proceedings of the Symposium held at Watford College of Technology) Joint Fire Res. Org., Her Majesty’s Stationery Office, London (1971).

Shorter, G. W. et al.,“The St. Lawrence Burns,” *NFPA Quarterly*, Vol. 53, No. 4 (April 1960), pp. 300-316.

E-1.5 Smoke Management During Fires.

“Explanatory Paper on Control of Smoke Movement in High Buildings,” *National Building Code of Canada*, Nat. Res. Council, Canada, NRC, No. 11413.

Haggerty, J. R., “A New Look at Smoke Stop Partitions,” *Fire Technology*, Vol. 6, No. 2 (May 1970), pp. 111-122.

McGuire, Tamura, and Wilson, “Factors in Controlling Smoke in High Buildings,” ASHRAE Symposium, *Fire Hazards in Buildings* (January 1970), pp. 8-13.

Shaw, C. and Tamura, G., “Basis for the Design of Smoke Shafts,” *Fire Technology*, Vol. 9, No. 3 (August 1973), pp. 209-222.

Shern, J. H., “Smokeproof Towers in Center Core Structures,” *Fire Technology*, Vol. 2, No. 4 (November 1966), pp. 303-307.

Shorter, G. W. and Wilson, A. G., “Fire and High Buildings,” *Fire Technology*, Vol. 6, No. 4 (November 1970), pp. 292-304.

E-1.6 Chemical Analysis of Fire Gases.

DiPietro, J. and Stepniczka, H., “A Study of Smoke Density and Oxygen Index of Polystyrene ABS and Polyester Systems,” *Fire and Flam*., Vol. 2 (January 1971), pp. 36-53.

Gaskill, “Smoke Development in Polymers During Pyrolysis of Combustion,” *Fire and Flam*., Vol.1 (1970), pp. 183-216.

Hilado, C., “The Effect of Chemical and Physical Factors on Smoke Evaluation from Polymers,” *Fire and Flam*., Vol. 1 (July 1970), pp. 217-238.

Hilado, C. J., “Smoke from Cellular Polymers,” *Fire Technology*, Vol. 5, No. 2 (May 1969), pp. 130-139.

Wagner, J. P., “Survey of Toxic Species in the Pyrolysis of Combustion of Polymers,” *Fire Research Abstracts and Reviews*, Vol. 14, No. 1 (1972), pp. 1-23.

Woolley, W. D. and Wadley, Ann I., “The Thermal Decomposition Products of Phenol-Formaldehyde Laminates, Part 2. The Production of Carbon Monoxide and Carbon Dioxide,” Joint Fire Res. Org., *Fire Research Note 852* (December 1970).

E-1.7 Smoke Production Measurements.

Gaskill J. R., and Veith, C. R., “Smoke Opacity from Certain Woods and Plastics,” *Fire Technology*, Vol. 4, No. 3 (August 1968), pp. 185-195.

Gross, D., Loftus, J. J., Lee, T. G., and Gray, V. E., “Smoke and Gases Produced by Burning Aircraft Interior Materials,” *NBS Bldg. Sci. Series*, BSS 18 (February 1969), U.S. Government Printing Office, Washington, DC.

Robertson, A. F., “Tests Indicate Venting Increases Smoke Production from Some Polymerics,” *Fire Engineering*, Vol. 126, No. 9 (September 1973), pp. 97-98.

NFPA 259

1993 Edition

Standard Test Method for Potential Heat of Building Materials

1993 Edition

This edition of NFPA 259, *Standard Test Method for Potential Heat of Building Materials*, 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 259

This standard is based on a test method developed at the National Bureau of Standards in 1961. Consideration of the test method by the NFPA was begun in 1973 culminating in the standard that was adopted in 1976, reconfirmed in 1981, and revised at the 1986 Fall Meeting. The 1993 edition is a reconfirmation of the 1987 edition.

Technical Committee on Fire Tests

Jesse J. Beitel, *Chairman*
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Peter J. Barbadoro, Westinghouse Savannah River Co., SC

April L. Berkol, ITT Sheraton Corp., MA
Rep. American Hotel & Motel Assn.

John A. Blair, E. I. du Pont de Nemours & Co., DE
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Delbert F. Boring, Jr., American Iron & Steel Inst., OH

Philip J. DiNenno, Hughes Assoc., Inc., MD

Gerard R. Dufresne, U.S. Testing Co Inc., NJ

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Jeffrey E. Gould, Factory Mutual Research Corp., MA

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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 259
Standard Test Method for Potential Heat of Building Materials

1993 Edition

NOTICE: Information on referenced publications can be found in Chapter 7 and Appendix B.

Chapter 1 General

1-1 Scope.

This method of test provides a means of determining, under controlled laboratory conditions, the total potential release of heat of materials under defined fire exposure conditions. Determinations may be made on individual homogeneous or individual composite materials, from which a representative sample can be taken. It is essential that the information on application of potential heat data in Appendix A be consulted prior to applying test results.

1-2 Significance.

The potential heat test method yields a property-type measurement of the total heat release possible from building materials when exposed to oxidizing conditions at 750°C (1382°F).

Except for very low heat materials such as steel, results are reported in terms of heat release per unit mass (Btu/lb).

1-3 Definition.

Potential heat of a material as determined by this method is the difference between the heat of combustion of a representative specimen of the material and the heat of combustion of any residue remaining after exposure to a defined fire condition, using combustion calorimetric techniques.

1-4 General.

One of two specimens removed from the material to be tested is pulverized, pelleted, and burned in a high-pressure oxygen atmosphere. This determines the gross heat of combustion of the material. The second specimen is heated in air for two hours at a temperature of 750°C (1382°F). A portion of the resulting residue of this specimen, if any, corresponding to a predetermined weight of original material, is ground or pulverized, mixed with a combustion promoter, and pelleted for burning as was the first specimen. After correcting for the heat produced by the combustion promoter, the difference in heating values of the two specimens is the potential heat as defined in Section 1-3. The test procedure is illustrated schematically in Figure 1-4.

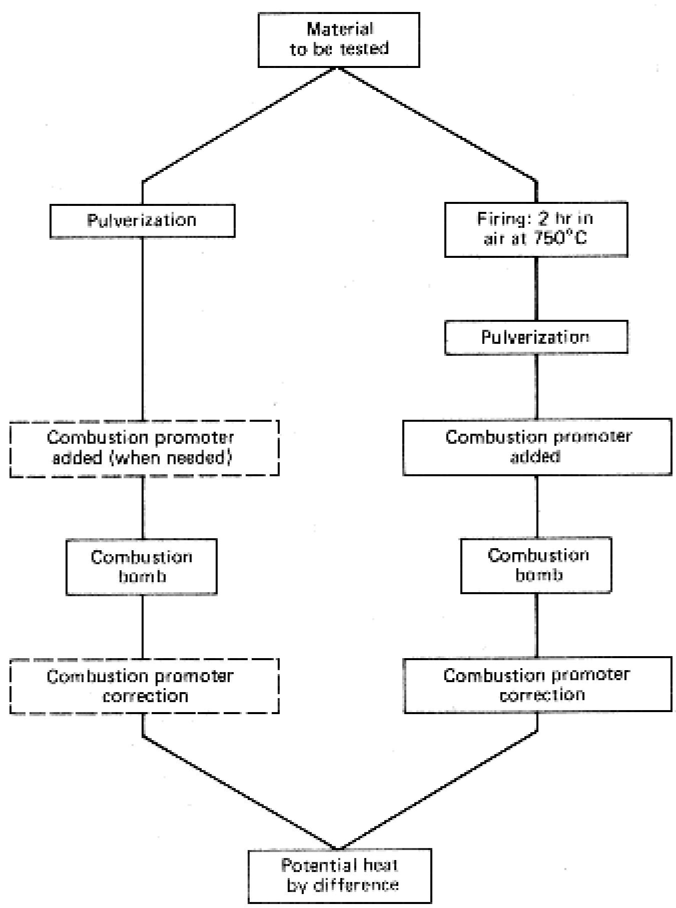


Figure 1-4 Schematic diagram of test procedure for potential heat measurements.

Chapter 2 Test Apparatus and Materials

2-1 Oxygen Bomb Calorimeter.

This device shall be used to determine the gross heat of combustion of the test specimen. The apparatus shall include the firing circuit and fuse wire.

NOTE: Either the isothermal-jacket bomb calorimeter (ASTM D3286) or the adiabatic bomb calorimeter (ASTM D2015) may be used.

2-2 Electric Muffle Furnace.

This apparatus shall be used to fire the test specimen. A small opening or port shall be provided for passage of an air-supply tube. Auxiliary apparatus includes:

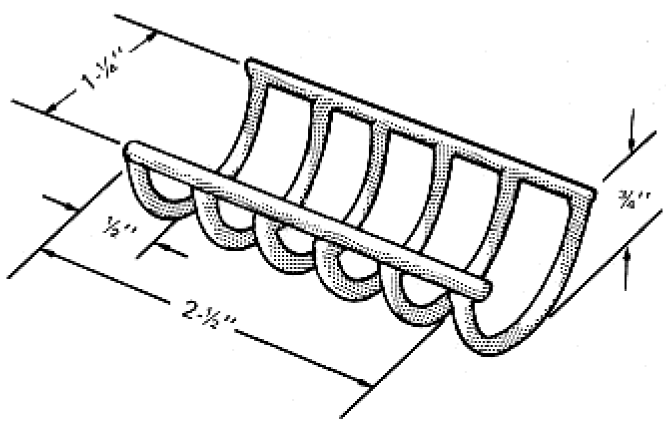
(a) *Specimen Container.* This shall be a fused silica or ceramic container, 1$^{1}/_{4}$ in. (31.8 mm) inside diameter by 4 in. (101.6 mm) long.

(b) *Container Cap.* This shall be of material similar to the specimen container (a) and shall be snug fitting. An opening shall be provided for insertion of the air tube (c), sized to allow a loose fit.

(c) *Air Supply Tube.* This tube shall be of porcelain, fused silica, or corrosion-resistant metal. Inside diameter shall be $^{3}/_{16}$ in. (4.8 mm) minimum; length shall be sufficient to extend beyond the opening in the container cap (b).

(d) *Wire Specimen Holder* [*see Figure 2-2(d)*]. This shall be formed to hold the test specimen away from the walls of the specimen container (a), thus allowing free airflow around the specimen. Corrosion-resistant wire shall be used.

(e) *Specimen Container Support.* This shall be of fire brick or similar material, shaped to hold the specimen container (a) and cap (b) in alignment with the port of the muffle furnace, thus allowing the air supply tube (c) to be inserted through the port and into the specimen container (a).



For SI Units: 1 in. = 25.4 mm.

Figure 2-2(d) Wire specimen holder for muffle furnace firing.

2-3 Mill.

This shall be either the hand mill or the ball mill type. It shall be used to pulverize test specimens.

2-4 Pelleting Press.

This press shall be used for compressing the pulverized test specimen into a pellet shape suitable for the bomb calorimetry procedure. The press shall be a type normally used for bomb calorimetry.

2-5 Microbalance.

This balance shall be a type normally used for chemical analysis, weighting to 0.1 mg.

2-6 Oxygen Cylinder and Accessory Equipment.

This cylinder and its accessories shall be suitable for use with the bomb calorimeter.

2-7 Compressed Air Supply.

This shall be a suitable laboratory air supply for use with the muffle furnace.

2-8 Standard Alkali Solution.

This shall be the standard alkali titrating solution, as specified in ASTM D3286, *Test Method for Gross Calorific Value of Solid Fuel by the Isothermal-Jacket Bomb Calorimeter*, or ASTM D2015, *Test Method for Gross Calorific Value of Solid Fuel by the Adiabatic Bomb Calorimeter*.

2-9 Combustion Promoter.

This shall be the National Institute of Standards and Technology standard material for calorimetric determinations, benzoic acid (SRM 39i).

Chapter 3 Test Specimens

3-1 Specimens.

Two air-dry representative specimens shall be required for each determination, one for each test procedure.

3-1.1

A specimen shall be considered air dry when it has reached constant weight in an environment maintained at 73 ± 2°F (23 ± 1°C) and 50 ± 5 percent relative humidity.

3-1.2

If the test subject is a composite or heterogeneous material, the various elements of the subject shall be contained in the test specimen in the same proportions as in the material.

Chapter 4 Direct Bomb Test

4-1 Specimen Preparation.

4-1.1

One test specimen shall be pulverized in the hand or ball mill so as to pass through a 60-mesh screen. Enough of the specimen shall be pulverized so as to provide no less than 10 g of powder.

NOTE: While many materials may be suitably reduced using a clean carbide double bastard file or mortar and pestle or both, it may sometimes be useful to (dry-ice) freeze materials containing asphaltic, mastic, or plastic components prior to filing, or to use mechanical blenders, ball or hammer mills, grinders, milling or lathe cutters, etc. For laminated materials, it may be preferable to separate into component layers and to grind, file, or pulverize each component separately. The powdered components then may be mixed intimately in proportion to their original weight fractions and the mixture tested, or, alternately, each component may be tested separately and the contributions of heat combined in proportion to their original weight fraction.

4-1.1.1 The specimen that is pulverized shall not be smaller than $^1/_2$ in. × 3 in. (12.7 mm × 76.2 mm) in the thickness supplied.

4-1.1.2 Particular care shall be taken to avoid segregation or separation of components. For grossly heterogeneous materials, a representative specimen shall be obtained by combining samples of material from different units (or sheets) and from different locations on each unit.

4-1.2

A pellet, weighing approximately 1 g, shall be prepared from an intimate mixture of the powder.

4-1.2.1 All weight measurements shall be to the nearest 0.1 mg.

4-1.2.2 Pellets shall be made in accordance with the method for the particular pelleting press in use and of a size convenient for the specimen cup. The pellets shall be no harder than is necessary to prevent their disintegration during preparation for firing. Excessively hard pellets may fracture and result in incomplete combustion when fired.

4-2 Test Procedure.

4-2.1

The pellet shall be placed in the crucible and tested in accordance with ASTM D3286, *Test Method for Gross Calorific Value of Solid Fuel by the Isothermal-Jacket Bomb Calorimeter*, or ASTM D2015, *Test Method for Gross Calorific Value of Solid Fuel by the Adiabatic Bomb Calorimeter*.

Caution: For tests on specimens that are predominantly metallic, the use of a silica or quartz crucible is recommended. The water equivalent of the calorimeter using the appropriate crucible should be measured and used.

4-2.2

If, after being fired in the oxygen bomb, the pellet is found to have burned completely, or to have left residue or ash that weighs less than 1 percent of the original pellet weight, the heat of combustion shall be computed on an air-dry basis. In this case, procedures set forth in 4-2.3 shall be ignored.

4-2.3

If the pellet does not burn, or a residue or ash that weighs 1 percent or more of the original pellet weight remains after the firing, another 1-g pellet shall be prepared using approximately $^1/_2$-g portions of the powdered specimen and a standard specimen of benzoic acid combustion promoter. (*See Section 4-1.*)

4-2.3.1 Each portion shall be weighed accurately to 0.1 mg prior to pelletizing.

4-2.3.2 The pellet shall be weighed accurately to 0.1 mg.

4-2.3.3 Any loss in weight after mixing and pelletizing shall be subtracted from the specimen and the combustion promoter in proportion to their original weight fractions, and the corrected weights shall be used in the heat of combustion calculations.

4-2.3.4 The pellet prepared with the benzoic acid shall be tested in accordance with 4-2.1.

4-2.4

In calculating the heat of combustion, as determined in 4-2.3, a correction for the heat of combustion of the benzoic acid present in the pellet shall be applied to the measured heat released by the specimen. The gross heat of combustion of the specimen material, on an air-dry basis, shall then be computed.

Chapter 5 Muffle Furnace and Bomb Test

5-1 Specimen Preparation.

An air-dry specimen of the test material selected in accordance with Chapter 3 shall be cut in the form of a rectangular prism $^1/_2$ in. ± $^1/_8$ in. × $^3/_4$ in. ± $^1/_8$ in. × $2^1/_2$ in. ± $^1/_2$ in. (12.7 mm ± 3.2 mm × 190 mm ± 3.2 mm × 63.5 mm ± 12.7 mm). Sheet materials shall be layered to these dimensions.

5-2 Muffle Furnace Procedure.

5-2.1

The muffle furnace shall be preheated to 750 ± 10°C (1382 ± 18°F).

5-2.2

The specimen shall be weighed and placed on the wire support in the specimen container. The container shall be closed with its cap and placed in the fire-brick base.

5-2.3

When the furnace has been preheated, the fire-brick base, with the specimen and its container, shall be placed in the muffle furnace so as to align the muffle furnace port and the opening in the specimen container cap. The external air supply tube shall be passed through the port into the container in proximity to the specimen.

5-2.4

The test specimen shall be fired for two hours with a regulated airflow supplied to the specimen of 0.1 cfm (47.2 cm^3/sec), referenced to 60°F (15.6°C) and 30 in. Hg (101,000 N/m^2).

5-2.4.1 If ignition should occur immediately upon placing the specimen in the furnace, application of air shall be delayed until the initial flaming has stopped.

5-2.5

Upon completion of the two-hour firing cycle, the container with the specimen shall be cooled in a desiccator, and the weight of the residue shall be determined.

5-2.6

If the residue from the muffle firing procedure is less than 5 percent of the initial weight of the specimen, the provisions of 5-2.7 and 5-2.8 shall be omitted and the heat of combustion previously determined under the direct bomb test, described in Chapter 4, shall be reported as the potential heat of the material.

5-2.7

If the residue after muffle firing is in excess of 5 percent of the original specimen weight, the residue shall be pulverized into a homogeneous powder. A $^{1}/_{2}$-g sample of residue shall be mixed with an equal weight of benzoic acid and formed into a 1-g pellet. The pellet is then treated as specified in the procedure for direct bomb test to determine the heat of combustion of the residue.

5-2.8

The heat of combustion of the residue per unit weight of original specimen shall be computed by multiplying the heat of combustion determined in 5-2.7 by the ratio of residue weight in 5-2.5 to the original specimen weight.

Chapter 6 Calculating Potential Heat

6-1 Calculations with Less than 5 Percent Residue.

The potential heat for test specimens yielding a residue from the muffle test procedure of less than 5 percent of the specimen's initial weight shall be equivalent to the specimen's heat of combustion, as determined by the direct bomb test, described in Chapter 4.

6-2 Calculations with More than 5 Percent Residue.

For test specimens that yield a residue from the muffle test procedure of 5 percent or more of initial specimen weight and, therefore, require direct bomb calorimetry of the residue, the potential heat shall be determined as follows:

6-2.1

The heat of combustion of the residue shall be subtracted from the heat of combustion determined via the direct bomb test. The potential heat shall thus be a measure of the heat released by a material in the muffle furnace firing.

6-2.2

Potential heat shall be reported as quantity of heat per unit weight.

Exception: Where appropriate, potential heat shall be reported as quantity of heat per unit volume or surface area. For material such as metals where the combustion process is relatively slow, and is a function of surface area, potential heat shall be reported appropriately on a surface area basis only.

6-2.3

One determination of the potential heat of a material is normally adequate, provided there is not significant variability to the material and the testing laboratory has established good confidence in its procedures.

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 ASTM Publications.

American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103.

ASTM D2015-78, *Test Method for Gross Calorific Value of Solid Fuel by the Adiabatic Bomb Calorimeter*

ASTM D3286-82, *Test Method for Gross Calorific Value of Solid Fuel by the Isothermal-Jacket Bomb Calorimeter*

Appendix A Application of Potential Heat Data

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

A-1 Application of Potential Heat Data.

The potential heat test provides an assessment of one property of a material — the total heat release possible with muffle exposure of the specimen, under oxidizing conditions, at 750°C (1382°F). The appropriate use of this procedure must recognize its nature as a property type-test. (*See A. F. Robertson in ASTM Standardization News*.) In many applications, additional supporting test data by other fire test methods may be required for qualifying materials for various fire safe applications. As an example, it should be recognized that under actual fire conditions some materials release all or most of their heat very rapidly. Other materials release heat very slowly and depending on thickness and fire conditions may never release all the heat possible. The use of the material and additional supporting data are usually required for classifying the materials.

A-2 The Test Method.

The potential heat test method (*see ASTM Proceedings*) makes use of oxygen bomb calorimetric measurement methods. It measures the difference between the heat of combustion of a product sample and that of the residue remaining after exposure of another specimen to a standardized intense thermal exposure. Results of the test are usually reported in terms of heat release per unit mass of the specimen involved.

The test procedure is based on as complete combustion of the specimen as is possible within a two-hour exposure period in a muffle furnace at 750°C (1382°F).

The bomb calorimetry techniques used involve very small specimens of about 1-g mass. Because of this, the sampling and specimen preparation procedures used become of considerable importance, especially with heterogeneous or composite materials. Two procedures are available to the investigator: One involves pulverizing a representative section of the complete composite and then testing the resultant mixture in the form of a small pellet. Another involves measuring the potential heat of the individual components of the material and then, on the basis of computations, deriving an overall value for the composite. The selection of a specimen for thermal exposure in the muffle furnace will, of course, depend on which of the preparation procedures is to be used.

The fact that the muffle exposure is a severe one, involving combustion of most of the oxidizable fuel at 750°C (1382°F), is essential for its consideration as a property type-test method. This must be carefully considered when applying potential heat data as a basis of code or regulatory procedures for building or other fire safety purposes. This is especially true when life safety is of prime concern. Thus the potential heat of two wall components may be identical, and yet in one wall the combustible component may be placed on the exposed wall surface while in the other it may be deeply buried, for example, beneath an exposed masonry construction. Obviously, these walls represent two possible extremes in the hazard presented by the wall to building occupants in the event of a fire. Thus, simple consideration of the potential heat of the wall materials yields little information on the relative fire participation hazard of the two walls. This problem is characteristic of property-type fire tests. It emphasizes the need for discretion in the use of the test methods and in the application of resulting test data.

A-3 Auxiliary Tests.

As indicated above, property-type fire tests are seldom comprehensive enough to form the sole basis of acceptance of materials or products. Additional tests are usually required. Examples of other types of tests that might be of value in evaluating materials as to their fire hazard include the adiabatic furnace, a smoldering test, heat release rate calorimeter, and flame spread tests. (*See J. Res. NBS, Vol. 61, ASTM STP 502, ASTM E 906, ASTM E 162, and NFPA 255.*) Only the flame spread and heat release rate tests have received recognition by national standards organizations. The smoldering and adiabatic furnace test have not yet received recognition as standards, although numerous ad hoc tests of this type have been conducted as the need for them became obvious.

A-4 Precision of the Potential Heat Test.

The original paper on this test method (*see ASTM Proceedings, Vol. 61*) discussed the precision level possible within a single laboratory. It was concluded that with technicians skilled in the procedure involved, the standard deviation of differences between duplicate determinations of potential heat would be equal to about 94 Btu/lb (219 kJ/kg). This prediction, based on early work at NBS, was later confirmed for three of the five materials tested in the interlaboratory study. (*See ASTM STP 464.*) In this reference a figure of 92 Btu/lb (214 kJ/kg) was reported. These values correspond to expected repeatability between duplicates of 200 Btu/lb (465 kJ/kg) with a 95 percent confidence level.

In the original paper it was stated that this order of repeatability was independent of the potential heat measured. Figure A-4 provides a graphical indication of the basis of this claim. This figure presents a plot of the difference between duplicate determinations of potential heat as a function of the average. Because of the precision, most of the recent measurements of potential heat have involved a single determination and thus are not useful for this plot. The materials represented by the data comprise a widely varied group. They include materials of laminated, homogeneous, and heterogeneous characteristics. Both very low and high values of potential heat are shown. Different symbols are used as a means for identification of slightly different procedures used for deriving the data. Thus, all the data above 8000 Btu/lb (18,600 kJ/kg) represent a single calorimetric determination as permitted by the test procedure when negligible ash remains following specimen exposure in the muffle furnace. The data reproduced as dots are based on two direct bomb calorimetric determinations and one measurement of the heat of combustion of the ash from a muffle exposed specimen. All remaining data are based on duplicate determinations of both the direct specimen and muffle exposed specimen. It should be noted that all the NBS data derived in connection with the interlaboratory study (*see ASTM STP 464*) are included in this figure. Thus the figure tends to confirm the predictions made with regard to reproducibility in that study.

Actually the test procedure has been slightly modified from that used in the last interlaboratory test, with the objective of improving the precision on those materials that proved most difficult in the study. These changes have included more detailed instructions on the preparation of specimens from laminated materials or those of heterogeneous character. Because of this and the fact that four of the eleven laboratories participating in the interlaboratory study were successful in producing data for all materials that were within the 200 Btu/lb (465 kJ/kg), repeatability and reproducibility values reported, based on three of the materials, would also be applicable to the full range of materials likely to be tested in the future. These precision levels involve a repeatability within a laboratory of 200 Btu/lb (465 kJ/kg) and a reproducibility between laboratories of 500 Btu/lb (1160 kJ/kg) based on duplicate tests. Thus, the procedure appears to provide adequate precision when skilled laboratory technical work is available.

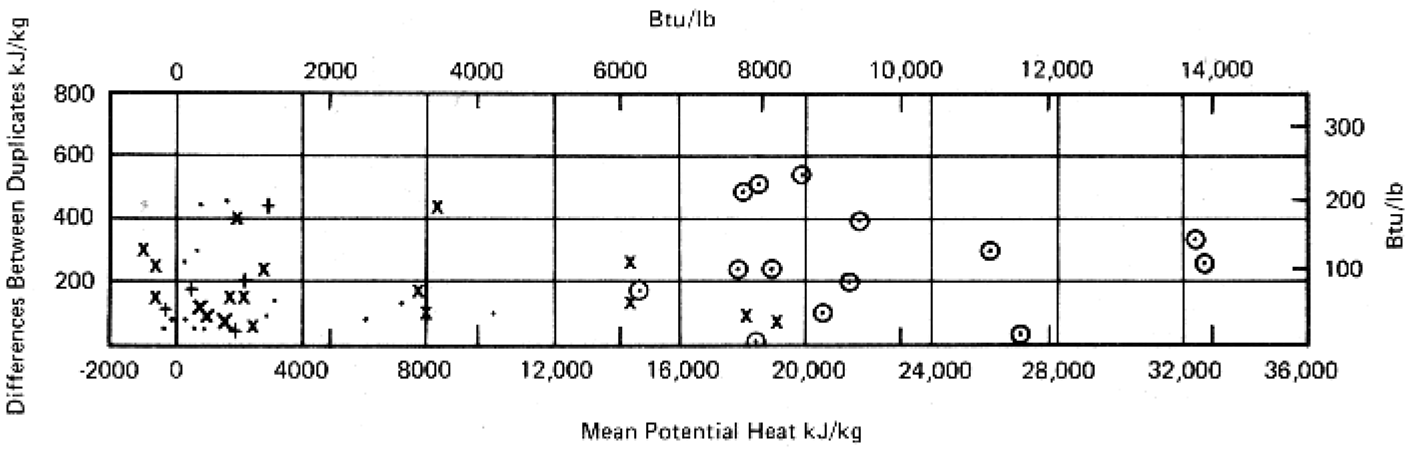


Chart represents deviation between duplicates as a function of average potential heat for a wide range of materials. Data points represent: × - specified procedure, two determinations on both material and muffled specimen, + - specified procedure NBS data from round robin study (see ASTM STP 464), • - specified procedure but only one test of muffled specimen, and ⊙ specified procedure for materials of low ash content, no test on muffled specimen.

Figure A-4 NBS data difference between duplicate potential heat measurements, as a function of the average.

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 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, 1990 edition

B-1.2 ASTM Publications.

American Society of Testing and Materials, 1916 Race St., Philadelphia, PA 19103.

ASTM, E 162-83-1984, *Standard Method of Test for Surface Flammability of Materials Using a Radiant Heat Energy Source*

ASTM E 906-83-1984, *Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products*

ASTM STP 464-1970, *Interlaboratory Comparison of the Potential Heat Test Method*, Gross, D. and Natrella, M. G., pp. 127-152

ASTM STP 502-1972, *Ignition, Heat Release and Noncombustibility of Materials*, Parker W. J. and Long, M. E., "Development of a Heat Release Rate Calorimeter at NBS." pp. 135-151

Proc. ASTM, Vol. 61, 1961, Loftus, J. J., Gross, D., and Robertson, A. F., "Potential Heat, A Method for Measuring the Heat Release of Materials in Building Fires," pp. 1336-1348

ASTM Standardization News, Nov. 1975, A. F. Robertson, "Test Method Categorization and Fire Hazard Standards," pp. 18-20

B-1.3 NIST Publication.

National Institute of Standards and Technology (formerly National Bureau of Standards), Gaithersburg, MD 20899.

Gross, D. and Robertson, A. F., "Self-Ignition Temperatures of Materials from Kinetic Reaction Data," *J. Res. NBS* V 61, n5, pp. 413-417, Nov. 1958

NFPA 260

1994 Edition

Standard Methods of Tests and Classification System for

Cigarette Ignition Resistance of Components of Upholstered

1994 Edition

This edition of NFPA 260, *Standard Methods of Tests and Classification System for Cigarette Ignition Resistance of Components of Upholstered Furniture*, 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 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 260

Regulation of the manufacture of furniture has been a subject of research and debate since 1967, when the Flammable Fabrics Act was amended by Congress to include products in addition to wearing apparel and home textiles that might constitute an unreasonable flammability risk. The National Bureau of Standards (NBS) began funding laboratory research on the subject in 1968. With its formation in 1973, the U. S. Consumer Product Safety Commission (CPSC) became the government agency responsible for administration of the Flammable Fabrics Act, including the adoption of any program or standard regulating upholstered furniture. NBS retained responsibility for designing test methods related to flammable fabrics.

In 1976, NBS submitted a draft to the CPSC for a proposed cigarette ignition resistance standard for upholstered furniture. Shortly thereafter, however, the CPSC was reorganized into separate program areas, followed by nearly a year’s worth of study on its children’s sleepwear standards, which was prompted by findings that a chemical used in sleepwear to make it flame-retardant might be carcinogenic. In November 1978, the CPSC staff, after modifying the originally proposed NBS standard on upholstered furniture, recommended to the CPSC commissioners that they publish the proposed standard.

In December 1978, at an informal meeting during which the CPSC asked that comments be submitted before publishing the final version of the standard, the upholstered furniture industry proposed its own voluntary program, the Upholstered Furniture Action Council (UFAC) Voluntary Action Program.

The UFAC voluntary program was adopted in April 1979. The 1983 edition of this standard (then NFPA 260A) was developed subsequent to that date by the Technical Committee on Fire Tests and drew heavily on the UFAC test method for components of upholstered furniture. The

1986 edition brought the document into substantial agreement with the UFAC test method. The 1989 edition was renumbered as NFPA 260 and included refinements for further agreement with the UFAC test method.

The 1994 edition of this standard provides further refinements that reflect minor changes and editorial clarification. These changes involve current definitions and technology used within the upholstered furniture industry.

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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.

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. The Committee also shall 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; and act as liaison between NFPA and the committees of other organizations developing fire test standards. The Committee is not responsible for fire tests that are used to evaluate extinguishing agents, devices, or systems.

NFPA 260
Standard Methods of Tests and Classification System for Cigarette Ignition Resistance of Components of Upholstered Furniture

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 C.

Chapter 1 General

1-1 Purpose.

These test methods are designed to evaluate ignition resistance of upholstered furniture when exposed to smoldering cigarettes under specified conditions.

1-1.2

It is the intent of this standard to provide tests to determine whether covered upholstered furniture components such as cover fabrics, welt cords, decking materials, interior fabrics, and filling/padding materials are relatively resistant to ignition by smoldering cigarettes.

1-1.3*

This standard establishes a classification system for determining the resistance of upholstered furniture components to cigarette ignition.

1-2 Scope.

1-2.1

These tests apply to upholstered furniture components that are tested in a standard, defined composite.

1-2.2

These tests apply to cover fabrics, interior fabrics, welt cords, decking materials, barrier materials, and filling/padding materials including, but not limited to, battings of natural or man-made fibers, foamed or cellular filling materials, resilient pads of natural or man-made fibers, and loose particulate filling materials (such as shredded polyurethane or feathers and down).

1-3 Significance.

1-3.1

Tests specified by this standard are intended to measure the performance of upholstered furniture components under conditions of exposure to a smoldering cigarette.

1-3.2

Tests specified by this standard are not intended to measure the performance of upholstered furniture under conditions of open flame exposure and do not indicate whether the furniture will resist the propagation of flame under severe fire exposure or when tested in a manner that differs substantially from the test standard.

1-3.3

The test results obtained with a material component tested in a given mock-up, in accordance with this standard, do not necessarily indicate the performance of the same material component in the form of other geometric configurations, such as full-size furniture.

1-3.4

Tests specified by this standard measure and describe the response of materials, products, or assemblies to a smoldering cigarette under controlled laboratory conditions and do not necessarily describe or appraise the fire hazard or fire risk of materials, products, or furniture assemblies under actual fire conditions.

1-3.5

This standard is intended to assist in component selection and composite design for upholstered furniture in order to achieve a high level of resistance to cigarette ignition.

1-3.6

The effects of aging on components and composites made from components have not been studied. As a result, the test methods contained in this standard might not predict changes caused by aging or contamination during normal use.

1-4 Test Selection.

1-4.1

All outer cover fabrics shall be subjected to the fabric test.

1-4.2

All interior fabrics used in intimate contact with outer fabrics shall be subjected to the interior fabric test.

1-4.3

All welt cord shall be subjected to the welt cord test.

1-4.4

All material used under the cover fabric in seats or within inside vertical walls (inside arms and inside backs) shall be subjected to the filling/padding test.

1-4.5

Any material used in the deck under loose cushions shall be subjected to the decking test.

1-4.6

Any material intended to serve as a barrier between Class II cover fabrics and conventional polyurethane foam in a seat shall be subjected to the barrier test.

1-5 Definitions.

Barrier/Barrier Fabric. The fabric or other material placed directly under the cover fabric when Class II cover fabric is used. All barrier materials used in cigarette-resistant furniture construction shall be classified as Class I barrier fabric using the test method described in Section 4-6.

Char. Carbonaceous material formed by pyrolysis or incomplete combustion.

Fill/Filling Direction. The filling direction of a woven fabric is that direction perpendicular to the warp direction. The term “fill” often is used to describe the yarns used in the filling direction.

Ignition. Continuous, self-sustaining, smoldering combustion of upholstered furniture substrates after exposure to burning cigarettes.

Machine Direction. In the case of nonwoven or film-type materials, the machine direction is that direction parallel to the longest dimension of the roll goods. Where rolls or sheets are cut into small pieces, the machine direction can become impossible to distinguish unless the samples are identified individually prior to cutting.

Obvious Ignition. Pronounced, continuous, and self-sustaining combustion of the test system. This is a matter of operator judgment based upon experience in this type of operation.

Sample. Material being tested.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Selvedge. The selvedge of a fabric is the outermost edge of the narrowest width of the fabric. In upholstery fabrics, the selvedge is the edge at the 1373 mm (54 in.) dimension, and in most upholstery fabrics, the selvedge is woven in such a manner that it cannot be used as upholstery fabric.

Specimen. Individual pieces of a sample used in a single test assembly.

Warp/Warp Direction. In woven textiles, the warp direction is that direction on the roll of fabric that is parallel to the selvedges. Thus, yarns or patterns that run in the warp direction run parallel to the selvedges. Yarns running in the warp direction of woven fabrics are called warp yarns.

Welt. The cord or piping sewn into the seam or border edge of a cushion, pillow, arm, or back of a furniture item.

Chapter 2 Test Apparatus

2-1 Mini-Mock-Up Tester.

(*See Figure 2-1*.)

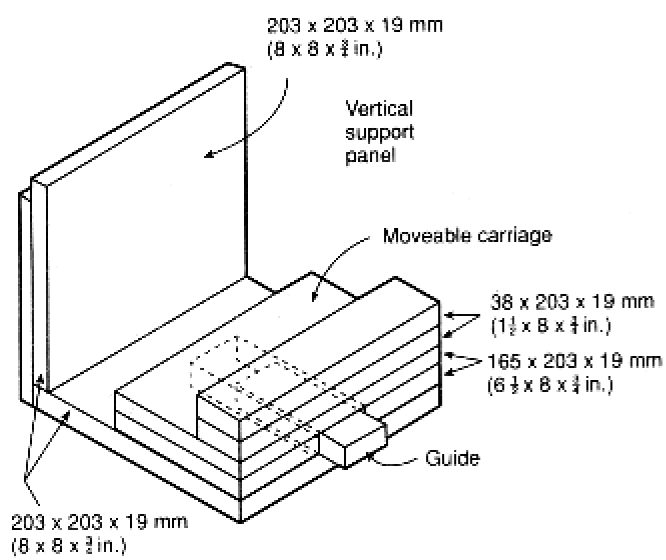

Figure 2-1 Mini-mock-up tester.

2-1.1

The mini-mock-up tester consists of a base with a centrally located guide and a stationary vertical panel, a movable horizontal carriage, and a removable vertical support panel.

2-1.2

The base consists of two wooden panels, each nominally 203 mm × 203 mm (8 in. × 8 in.) with nominal 19-mm (0.75-in.) thickness, joined together at one edge. The carriage has a 125 mm × 203 mm (5 in. × 8 in.) platform to support a horizontal specimen. The platform is 38 mm (1.5 in.) above the floor of the base and has a 38-mm (1.5-in.) lip at the front edge. The carriage is grooved to fit over a guide provided on the floor of the base. The removable vertical support panel consists of a wooden panel of nominal 203 mm × 203 mm (8 in. × 8 in.) area and nominal 19-mm (0.75-in.) thickness, which stands against the vertical wall of the base.

2-2 Decking Materials Tester.

The decking materials tester consists of a plywood base and a plywood retainer ring. The base measures 533 mm × 343 mm × 13 mm (21 in. × 13.5 in. × 0.5 in.). The retainer ring measures 533 mm × 343 mm × 13 mm (21 in. × 13.5 in. × 0.5 in.) with an opening measuring 406 mm × 216 mm (16 in. × 8.5 in.). (*See Figure 2-2.*)

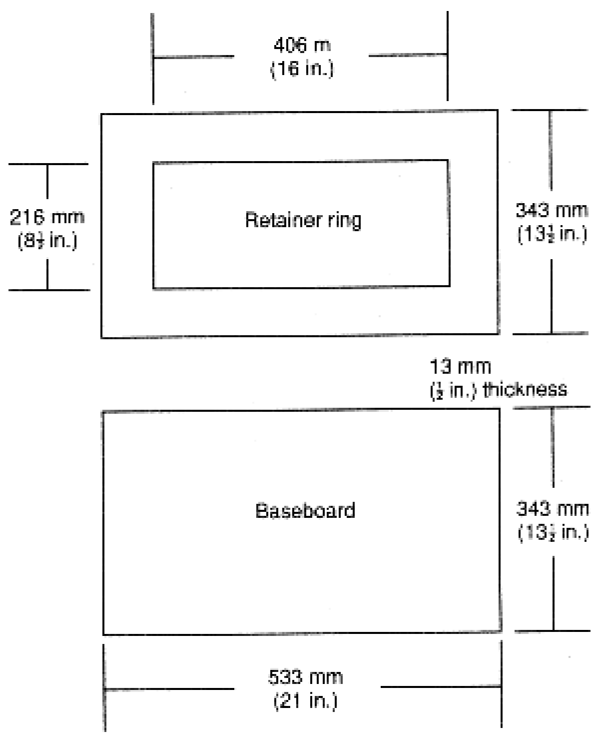

Figure 2-2 Decking materials tester.

2-3 Ignition Source.

The ignition source for the test shall be natural tobacco cigarettes without filter tips, 85 mm ± 2 mm (3.4 in. ± 0.1 in.) long, with a packing density of 0.270 g/cm^3 ± 0.020 g/cm^3 (0.156 oz/in.^{3} ± 0.012 oz/in.^{3}), and a total weight of 1.1 g ± 0.1 g (0.039 oz ± 0.004 oz) (Pall Mall or equivalent).

2-4 Standard Type I Cover Fabric.

Standard Type I cover fabric shall be 100 percent cotton mattress ticking conforming to

Federal Specification CCC-C-436- *Cloth, Ticking, Twill, Cotton*, Type I. It shall be laundered and tumble-dried once before use.

2-5* Standard Type II Cover Fabric.

Standard Type II cover fabric shall be UFAC Type II, 100 percent bright, regular rayon, scoured, 20/2, ring-spun, of basket-weave construction, 125 g/m^2 ± 12 g/m^2 (3.7 oz/yd^2 ± 0.8 oz/yd^2), and white in color and shall not be treated with any flame-retardant finishes, whiteners, or back coating.

2-6 Sheeting Material.

Sheeting material shall be cotton bed sheeting weighing 125 g/m^2 ± 28 g/m^2 (3.7 oz/yd^2 ± 0.8 oz/yd^2) and white in color and shall not be treated with flame retardants. For testing, the fabric shall be cut into squares of 127 mm × 127 mm (5 in. × 5 in.). If 100 percent cotton sheeting is unavailable, a 50/50 blend of cotton/polyester conforming to the other specifications (weight, color, and untreated) shall be permitted to be used.

2-7 Polyurethane Foam Substrate.

The polyurethane foam substrate shall be an open-celled, polyether-type, urethane UFAC foam having a density of 20 kg/m^3 to 25 kg/m^3 (1.3 lb/ft^3 to 1.6 lb/ft^3) and containing no inorganic fillers and shall not be treated with flame retardant.

2-8 Miscellaneous.

Other apparatus needed to carry out the testing include straight pins, a staple gun, a knife or scissors, tongs, and a linear scale graduated in millimeters or tenths of an inch.

2-9* Air Velocity.

The air velocity across the test assemblies shall be maintained below 15.2 m/min (50 ft/min) (which is virtually the velocity of natural convection created by the burning cigarette) in order to minimize localized effects from draft superheating of cigarette embers. The smoke plume from the burning cigarette shall be visibly vertical and shall be a minimum of 152 mm (6 in.) in height.

NOTE: A fume hood with air curtains drawn across the face and zero air velocity at the test locations is recommended.

2-10 Extinguishing Equipment.

A pressurized water fire extinguisher or other suitable fire extinguishing equipment shall be immediately available. A water bottle fitted with a spray nozzle shall be provided to extinguish any ignited portions of the test specimen. A bucket of water shall be provided for immersing smoldering or burning materials removed from the tester. Tongs for handling smoldering materials prior to immersion, gloves, and breathing apparatus shall be provided.

2-11 Draft Enclosure.

An open draft preventive enclosure shall be provided and used to restrict airflow to convection only. (*See Figure 2-11*.)

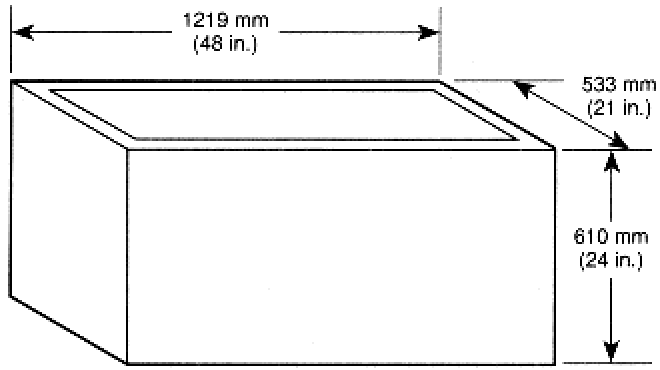

Figure 2-11 Draft enclosure.

Chapter 3 Test Specimens

3-1 Specimen Conditioning.

All test upholstery fabrics and test materials (including cigarettes and sheeting material) shall be conditioned at a temperature of 21°C ± 2.8°C (70°F ± 5°F) and a relative humidity of less than 65 percent for at least four hours prior to testing. If the test room does not meet these specifications for conditioning, the testing shall be initiated within ten minutes after the specimens are removed from the conditioning room.

3-2 Cover Fabric Test.

3-2.1

Three 203 mm × 203 mm (8 in. × 8 in.) specimens shall be cut from the material to be tested for horizontal panels, and three 203 mm × 381 mm (8 in. × 15 in.) specimens shall be cut for vertical panels.

3-2.2

Each specimen shall have its long dimension cut in the direction of the warp and assembled for testing in a warp-to-warp orientation, such that the major areas of weave variation lie in the crevice of the assembled test apparatus.

3-2.3

For fabrics with complex weaves, specimens shall be cut such that portions of the three largest areas of weave complexity are contacted by the cigarettes placed on the test assemblies. For dyed or printed fabrics, or both, color shall not constitute a variation relative to cigarette ignition resistance in this test.

3-3 Interior Fabric Test.

Three 203 mm × 203 mm (8 in. × 8 in.) specimens shall be cut from the material to be tested.

3-4 Welt Cord Test.

Three 203-mm (8-in.) specimens shall be cut from the welt cord to be tested.

3-5 Filling/Padding Component Test.

3-5.1

Three 203 mm × 127 mm × 51 mm (8 in. × 5 in. × 2 in.) specimens shall be cut for the horizontal panels, and three 203 mm × 203 mm × 51 mm (8 in. × 8 in. × 2 in.) specimens shall be cut for the vertical panels.

3-5.2*

For loose or particulate materials (shredded polyurethane, down, etc.), bags (sometimes referred to as “ticking”) used to contain the loose or particulate material shall be sewn as follows:

“Knife edge”-type bags measuring 254 mm × 254 mm (10 in. × 10 in.) inside seam to inside seam. The bags shall be made of the same material used to manufacture the upholstered furniture, and the loose or particulate material shall be the same as that used to manufacture the upholstered furniture. The bags, sewn on three sides, then shall be filled with 40 g ± 2 g (1.4 oz ± 0.07 oz) of the loose or particulate material, and the fourth side shall be sewn closed. The composite of the bag material and the loose or particulate material shall be tested using the filling-padding test and shall pass the minimum Class I criteria for the filling and padding test when tested in the vertical wall of the mini-mock-up.

3-6 Decking Materials Test.

One specimen measuring 533 mm × 343 mm (21 in. × 13.5 in.) and at least 25 mm (1 in.) thick shall be cut from the decking material to be tested. If sample thickness is less than 25 mm (1 in.), multiple layers shall be used in this test to achieve the required thickness.

3-7 Barrier Materials Test.

Three 203 mm × 203 mm (8 in. × 8 in.) specimens shall be cut for horizontal panels from the material to be tested, and three 203 mm × 381 mm (8 in. × 15 in.) specimens shall be cut for vertical panels.

Chapter 4 Test Procedures

4-1 Cover Fabric Test.

4-1.1

For horizontal panels, the 203 mm × 203 mm (8 in. × 8 in.) cover fabric specimen shall be placed on a 203 mm × 127 mm × 51 mm (8 in. × 5 in. × 2 in.) polyurethane substrate as shown in Figure 4-1.1, using pins in the ends of the fabric specimen to hold it in place.

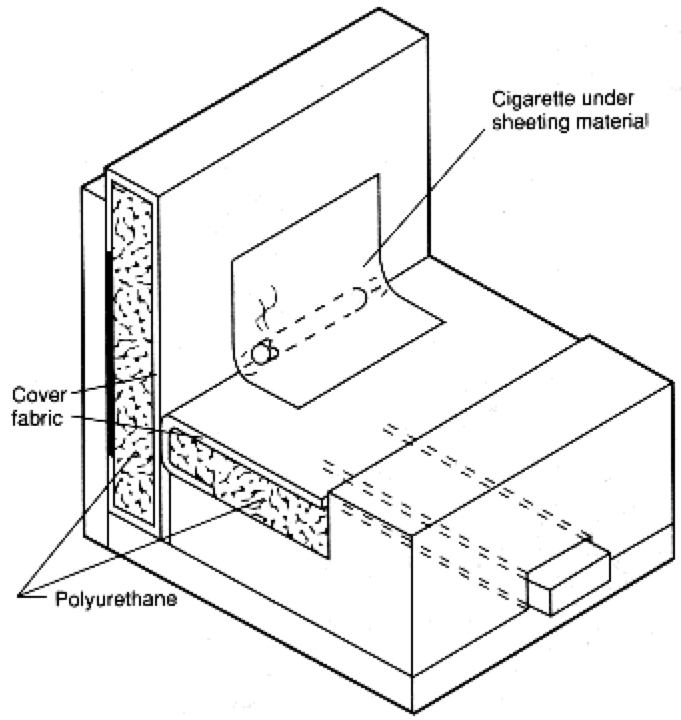

Figure 4-1.1 Cover fabric test method.

4-1.2

For vertical panels, the 203 mm × 381 mm (8 in. × 15 in.) fabric specimen shall be placed on a 203 mm × 203 mm × 51 mm (8 in. × 8 in. × 2 in.) polyurethane substrate as shown in Figure 4-1.1. The fabric shall overlap the top and bottom of the substrate and be pinned into place on the corners. The warp or machine direction of the fabric shall run from front to back on the test assembly.

4-1.3

Each assembled vertical and horizontal panel shall be placed in a mini-mock-up tester as shown in Figure 4-1.1.

4-1.4

The position of the crevice shall be marked on the sides of the vertical substrate.

4-1.5

Three cigarettes shall be lighted, and a lighted cigarette shall be placed on each of the three test assemblies such that the cigarette lies in the crevice and against the vertical panel with each cigarette end equidistant from its respective side of the assembly.

4-1.6

A piece of sheeting material shall be placed over each cigarette and shall be smoothed over the cigarette to ensure intimate contact. The sheeting shall be pinned to the vertical panel approximately 63 mm (2.5 in.) above the crevice.

NOTE: Proper fabric-to-cigarette contact is ensured by running a finger over the covered cigarettes.

4-1.7

Each cigarette shall be allowed to burn its full length unless an obvious ignition of the polyurethane substrate occurs. If a cigarette extinguishes before burning its entire length, a fresh cigarette shall be placed on a fresh area of the test assembly and covered with sheeting fabric until one of the following occurs:

(a) Three cigarettes have burned their entire lengths on three individual test specimens, or

(b) Three cigarettes have self-extinguished on the sample.

4-1.8

If an obvious ignition occurs on any of the three specimens, the smoldering materials shall be extinguished and the sample shall be recorded as a Class II cover fabric by the results of this test.

4-1.9

If no obvious ignition occurs, the char on the vertical panel measured from the original crevice position to the highest part of the destroyed or degraded fabric shall be recorded to the nearest 2.5 mm (0.1 in.). The original crevice position can be determined by laying a straightedge or ruler between the two marks required by 4-1.4 on the edges of the vertical panel. The highest point of destroyed or degraded fabric shall be defined as the highest point at which any of the fabric is charred from front to back.

4-2 Interior Fabric Test.

4-2.1

For horizontal panels, the 203 mm × 203 mm (8 in. × 8 in.) piece of interior fabric and the 203 mm × 203 mm (8 in. × 8 in.) standard Type I cover fabric shall be placed with the interior fabric against the polyurethane substrate as shown in Figure 4-2.1, using pins in the ends of the fabric specimens to hold them in place.

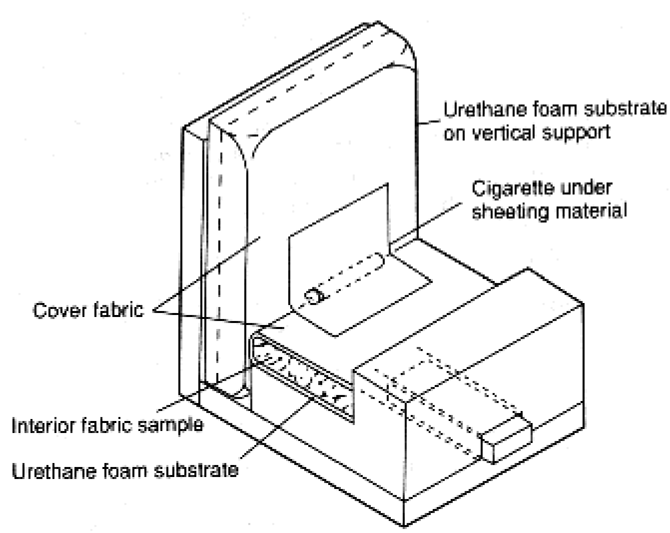

Figure 4-2.1 Interior fabric test method.

4-2.2

For vertical panels, 203 mm × 381 mm (8 in. × 15 in.) standard Type I cover fabric shall be placed on a 203 mm × 203 mm × 51 mm (8 in. × 8 in. × 2 in.) polyurethane substrate as shown in Figure 4-2.1. The fabric shall overlap the top and bottom of the substrate and be pinned into place at the corners.

4-2.3

Each assembled vertical and horizontal panel shall be placed in a mini-mock-up tester as shown in Figure 4-2.1.

4-2.4

The position of the crevice shall be marked on the sides of the vertical polyurethane substrate.

4-2.5

Three cigarettes shall be lighted, and a lighted cigarette shall be placed on each of the three test assemblies such that the cigarette lies in the crevice and against the vertical panel with each cigarette end equidistant from its respective side of the assembly.

4-2.6

A piece of sheeting material shall be placed over each cigarette and shall be smoothed over the cigarette to ensure intimate contact. The sheeting shall be pinned to the vertical panel approximately 63 mm (2.5 in.) above the crevice.

NOTE: Proper fabric-to-cigarette contact is ensured by running a finger over the covered cigarettes.

4-2.7

Each cigarette shall be allowed to burn its full length unless an obvious ignition of the polyurethane substrate occurs. If a cigarette extinguishes before burning its entire length, a fresh cigarette shall be placed on a new test assembly and covered with sheeting fabric until one of the following occurs:

(a) Three cigarettes have burned their entire length on three individual test specimens, or

(b) Three cigarettes have self-extinguished on the sample.

4-2.8

If an obvious ignition occurs on any of the three specimens, the smoldering materials shall be extinguished and the sample shall be recorded as a Class II interior fabric by the results of this test.

4-2.9

If no obvious ignition occurs, the char on the vertical panel measured from the original crevice position to the highest part of the destroyed or degraded interior fabric shall be recorded to the nearest 2.5 mm (0.1 in.). The original crevice position can be determined by laying a straightedge or ruler between the two marks required by 4-2.4 on the vertical panel. The highest point of destroyed or degraded fabric shall be defined as the highest point at which any of the fabric is charred from front to back.

4-3 Welt Cord Test.

4-3.1

Three specimens of standard Type II cover fabric shall be cut for each of the sizes specified, as follows:

(a) 203 mm × 203 mm (8 in. × 8 in.) for horizontal panels

(b) 203 mm × 381 mm (8 in. × 15 in.) for vertical panels

(c) 203 mm × 25 mm (8 in. × 1 in.), folded for unsewn welts.

The width of the welt can be adjusted to the size of the welt cord.

4-3.1.1 For horizontal panels, the 203 mm × 203 mm (8 in. × 8 in.) Type II cover fabric shall be placed on a 203 mm × 127 mm × 51 mm (8 in. × 5 in. × 2 in.) polyurethane substrate as shown in Figure 4-3.1.1, using pins in the ends of the fabric specimens to hold them in place.

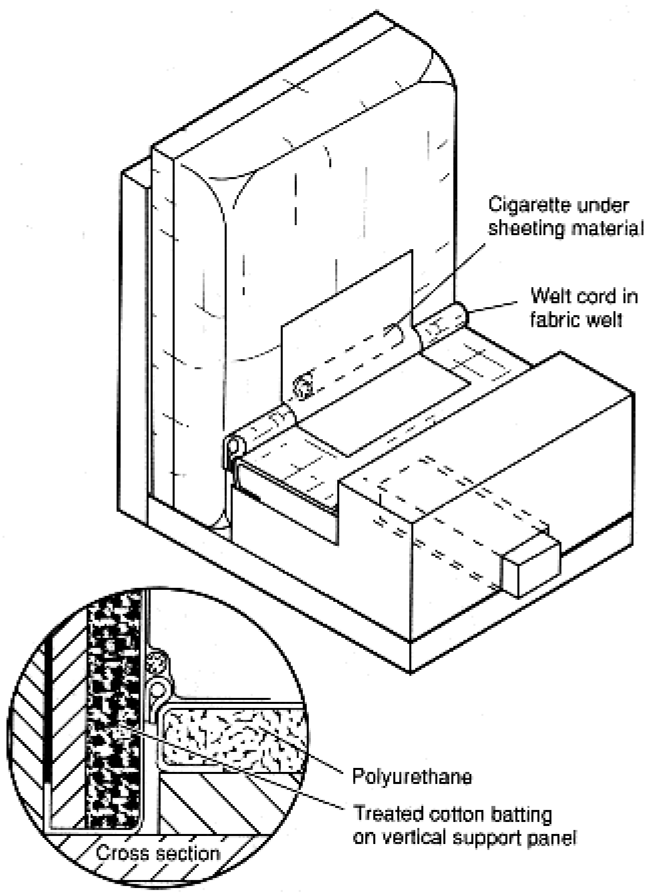

Figure 4-3.1.1 Welt cord test method.

4-3.1.2 For vertical panels, the 203 mm × 381 mm (8 in. × 15 in.) Type II cover fabric shall be placed on a 203 mm × 203 mm × 51 mm (8 in. × 8 in. × 2 in.) polyurethane substrate as shown in Figure 4-3.1.1. The fabric shall overlap the top and bottom of the substrate and be pinned into place at the corners.

4-3.2

Each assembled vertical and horizontal panel shall be placed in a mini-mock-up tester as shown in Figure 2-1.

4-3.3

A welt cord specimen shall be placed into the center of a folded strip of standard Type II cover fabric to form an unsewn welt. An unsewn welt shall be placed in each test assembly such that the fabric edges are located between the horizontal and vertical panels and are held tightly in place by the panels. (*See Figure 4-3.1.1*.)

4-3.4

The position of the top of the welt shall be marked on the sides of the vertical polyurethane substrate.

4-3.5

Three cigarettes shall be lighted, and a lighted cigarette shall be placed on each of the three test assemblies such that the cigarette lies on the welt and against the vertical panel with each cigarette end equidistant from its respective side of the assembly.

4-3.6

A piece of sheeting material shall be placed over each cigarette and shall be smoothed over the cigarette to ensure intimate contact. The sheeting shall be pinned to the vertical panel approximately 63 mm (2.5 in.) above the crevice.

NOTE: Proper fabric-to-cigarette contact is ensured by running a finger over the covered cigarettes.

4-3.7

Each cigarette shall be allowed to burn its full length unless an obvious ignition of the polyurethane substrate occurs. If a cigarette extinguishes before burning its entire length, a fresh cigarette shall be placed on a new test assembly and covered with sheeting fabric until one of the following occurs:

(a) Three cigarettes have burned their entire lengths on three individual specimens, or

(b) Three cigarettes have self-extinguished on the sample.

4-3.8

If an obvious ignition occurs on any of the three specimens, the smoldering materials shall be extinguished and the sample shall be recorded as a Class II welt cord by the results of this test.

4-3.9

If no obvious ignition occurs, the char on the vertical panel measured from the top of the original welt position to the highest part of the destroyed or degraded fabric shall be recorded. The top of the original welt position can be determined by laying a straightedge or ruler between the two marks required by 4-3.4 on the edges of the vertical panel. The highest point of destroyed or degraded fabric shall be defined as the highest point at which any of the fabric is charred from front to back.

4-4 Filling/Padding Component Test.

4-4.1

Three 203 mm × 203 mm (8 in. × 8 in.) specimens shall be cut from standard Type I cover fabric for the horizontal panels, and three 203 mm × 305 mm (8 in. × 12 in.) specimens shall be cut for the vertical panels.

4-4.1.1 Three horizontal panels shall be constructed by wrapping each panel with Type I cover fabric such that the top surface is completely covered and the long direction of the fabric continues over the crevice edge and partially covers the bottom surface. The cover fabric shall be pinned in place, top and bottom. (*See Figure 4-4.1.1.*)

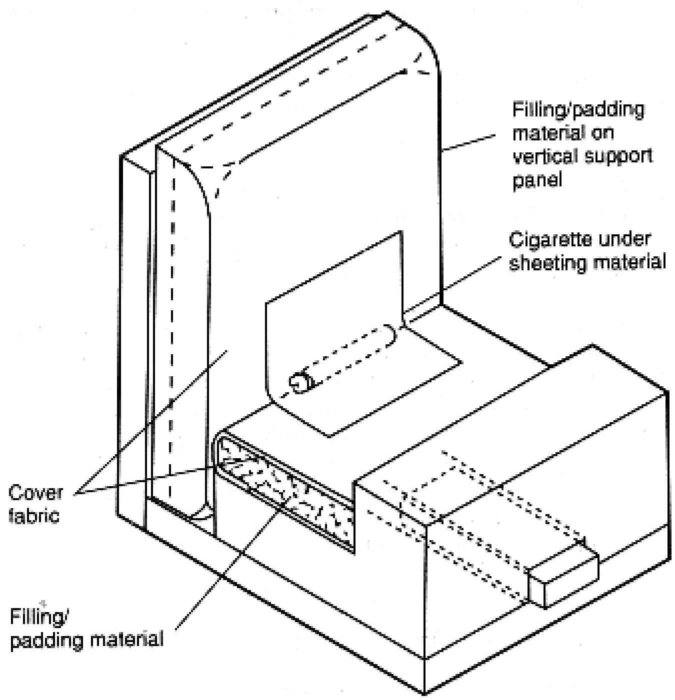

Figure 4-4.1.1 Filling/padding component test method.

4-4.1.2 Three vertical panels shall be constructed by covering one surface of a removable vertical support panel with a vertical pad of the test specimen material topped by the Type I cover fabric. The Type I cover fabric shall be pulled around the top and bottom of the removable vertical support panel and stapled to the back side.

4-4.2

Each assembled vertical and horizontal panel shall be placed in a mini-mock-up tester, as shown in Figure 4-4.1.1, such that a snug fit is created between the two panels.

4-4.3

The position of the crevice shall be marked on the edges of the cover fabric.

4-4.4

Three cigarettes shall be lighted, and a lighted cigarette shall be placed on each of the three test assemblies such that the cigarette lies in the crevice and against the vertical panel with each cigarette end equidistant from its respective side of the assembly.

4-4.5

A piece of sheeting material shall be placed over each cigarette and shall be smoothed over the cigarette to ensure intimate contact. The sheeting shall be pinned to the vertical panel approximately 63 mm (2.5 in.) above the crevice.

NOTE: Proper fabric-to-cigarette contact is ensured by running a finger over the covered cigarettes.

4-4.6

Each cigarette shall be allowed to burn its full length unless an obvious ignition of the substrate occurs. If a cigarette extinguishes before burning its entire length, a fresh cigarette shall be placed on a new test assembly and covered with sheeting fabric until one of the following occurs:

(a) Three cigarettes have burned their entire lengths on three individual test specimens, or

(b) Three cigarettes have self-extinguished on the sample.

4-4.7

If an obvious ignition occurs on any of the three specimens, the smoldering materials shall be extinguished and the sample shall be recorded as a Class II filling/padding material by the results of this test.

4-4.8

If no obvious ignition occurs, the char on the vertical panel measured from the original crevice position to the highest part of the destroyed or degraded fabric shall be recorded. The original crevice position can be determined by laying a straightedge or ruler between the two marks required by 4-4.3 on the edges of the vertical panel.

4-5 Decking Materials Test.

4-5.1

One 533 mm × 343 mm (21 in. × 13.5 in.) specimen shall be cut from standard Type II fabric.

4-5.2

The decking material specimen shall be placed on the plywood base of the decking materials tester and covered with the standard Type II fabric. The plywood retainer ring shall be placed on top of the cover fabric as shown in Figure 4-5.2.

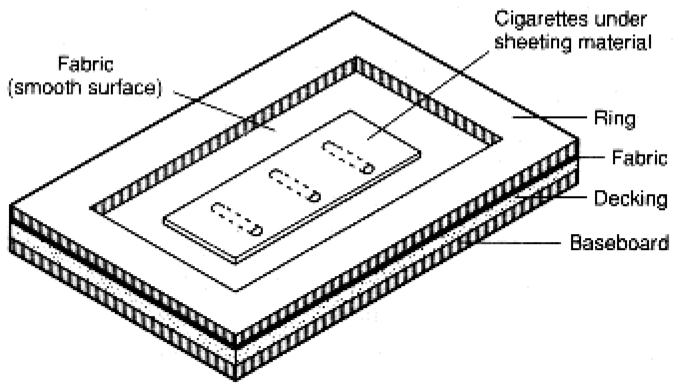

Figure 4-5.2 Decking materials test method.

4-5.3

Three cigarettes shall be lighted and placed on the surface of the standard Type II fabric so that they are equally spaced from each other and from the edges of the retainer ring.

4-5.4

A piece of sheeting material shall be placed over each of the cigarettes and shall be smoothed over the cigarette to ensure intimate contact.

4-5.5

Each cigarette shall be allowed to burn its full length. If a cigarette extinguishes before burning its entire length, another cigarette shall be placed on a fresh area of the cover fabric until one of the following occurs:

(a) Three cigarettes have burned their entire lengths, or

(b) Three cigarettes have self-extinguished.

4-5.6

If an obvious ignition occurs at any of the cigarette locations, the smoldering material shall be extinguished and the sample shall be recorded as a Class II decking material by the results of this test.

4-5.7

If no obvious ignition occurs, the maximum length of char shall be measured from the original cigarette position and recorded to the nearest 2.5 mm (0.1 in.).

4-6 Barrier Materials Test.

4-6.1

Three 203 mm × 203 mm (8 in. × 8 in.) specimens shall be cut from standard Type II cover fabric for horizontal panels and three 203 mm × 381 mm (8 in. × 15 in.) specimens shall be cut for vertical panels.

4-6.1.1 For horizontal panels, a barrier specimen shall be placed on a 203 mm × 127 mm × 51 mm (8 in. × 5 in. × 2 in.) polyurethane substrate. The barrier shall be folded around and under the polyurethane as shown in Figure 4-6.1.1 and fastened in place with pins. The 203 mm × 203 mm (8 in. × 8 in.) cover fabric shall be placed over each barrier and fastened in place with pins.

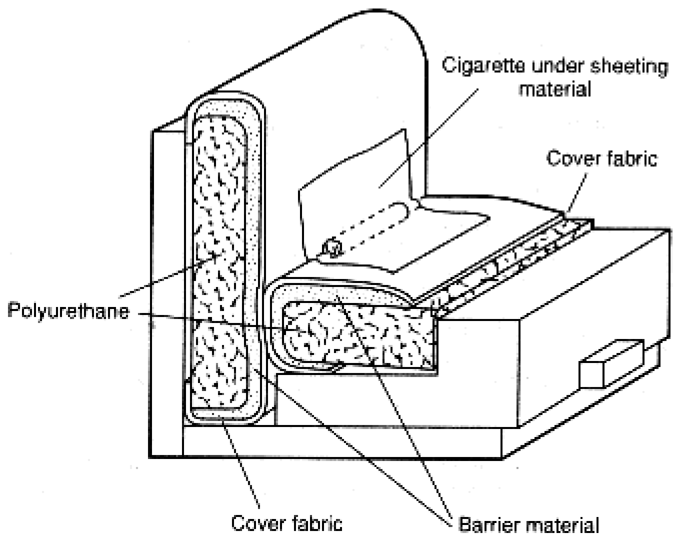

Figure 4-6.1.1 Barrier materials test method.

4-6.1.2 For vertical panels, a barrier specimen shall be placed on a 203 mm × 203 mm × 51 mm (8 in. × 8 in. × 2 in.) polyurethane substrate. The 203 mm × 381 mm (8 in. × 15 in.) cover fabric specimen shall be placed over each vertical panel and fastened in place with pins as shown in Figure 4-6.1.1.

4-6.2

Each assembled horizontal panel and vertical panel shall be arranged in the test assembly such that a firm contact is achieved across the entire crevice formed by vertical and horizontal panels.

4-6.3

The position of the crevice shall be marked on the sides of the vertical polyurethane substrate.

4-6.4

Three cigarettes shall be lighted, and a lighted cigarette shall be placed on each of the three test assemblies such that the cigarette lies in the crevice and against the vertical panel with each cigarette end equidistant from its respective side of the assembly.

4-6.5

A piece of sheeting material shall be placed over each cigarette and shall be smoothed over the cigarette to ensure intimate contact The sheeting shall be pinned to the vertical panel approximately 63 mm (2.5 in.) above the crevice.

NOTE: Proper fabric-to-cigarette contact is ensured by running a finger over the covered cigarettes.

4-6.6

Each cigarette shall be allowed to burn its full length unless an obvious ignition of the substrate occurs. If a cigarette extinguishes before burning its entire length, a fresh cigarette shall be placed on a fresh area of the test assembly and covered with sheeting fabric until one of the following occurs:

(a) Three cigarettes have burned their entire lengths on three individual test specimens, or

(b) Three cigarettes have self-extinguished on the sample.

4-6.7

If an obvious ignition occurs on any of the three specimens, the smoldering materials shall be extinguished and the sample shall be recorded as a Class II barrier material by the results of this test.

4-6.8

If no obvious ignition occurs, the char on the vertical panel measured from the original crevice position to the highest part of the destroyed or degraded fabric shall be recorded to the nearest 2.5 mm (0.1 in.). The original crevice position can be determined by laying a straightedge or ruler between the two marks required by 4-6.3 on the edges of the vertical panel. The highest point of destroyed or degraded fabric shall be defined as the highest point at which any of the fabric is charred from front to back.

Chapter 5 Cigarette Resistance Classifications

5-1 General.

Furniture components shall be classified as Class I or Class II in accordance with Sections 5-2 through 5-7. An upholstered furniture component shall meet the requirements of Class I to be considered resistant to cigarette ignition.

5-2 Cover Fabric Classification.

5-2.1 Class I.

Class I cover fabric shall meet the criteria of 5-2.1.1 and 5-2.1.2.

5-2.1.1 When subjected to the cover fabric test, a specimen shall show no evidence of ignition of any test assembly.

5-2.1.2 The vertical char on any of the three specimens shall not exceed 45 mm (1.75 in.).

5-2.2 Class II.

Cover fabrics that do not meet Class I criteria shall be designated as Class II.

5-3 Interior Fabric Classification.

5-3.1 Class I.

Class I interior fabric shall meet the criteria of 5-3.1.1 and 5-3.1.2.

5-3.1.1 When subjected to the interior fabric test, a specimen shall show no evidence of ignition of any test assembly.

5-3.1.2 The vertical char on the cover fabric of any of the three specimens shall not exceed 38 mm (1.5 in.).

5-3.2 Class II.

Interior fabrics that do not meet Class I criteria shall be designated as Class II.

5-4 Welt Cord Classification.

5-4.1 Class I.

Class I welt cord shall meet the criteria of 5-4.1.1 and 5-4.1.2.

5-4.1.1 When subjected to the welt cord test, a specimen shall show no evidence of ignition of any test assembly.

5-4.1.2 When measured from the top of the original welt position, the vertical char on the cover fabric shall not exceed 38 mm (1.5 in.) for any of three replicated tests.

5-4.2 Class II.

Welt cord that does not meet Class I criteria shall be designated as Class II.

5-5 Filling/Padding Components Classification.

5-5.1 Class I.

Class I components shall meet the criteria of 5-5.1.1 and 5-5.1.2.

5-5.1.1 When subjected to the filling/padding test, a specimen shall show no evidence of ignition of any test assembly.

5-5.1.2 When measured from the original crevice position, the vertical char length on the cover fabric shall not exceed 38 mm (1.5 in.) for any of three replicated tests.

5-5.2 Class II.

Components that do not meet Class I criteria shall be designated as Class II.

5-6 Decking Materials Classification.

5-6.1 Class I.

Class I decking materials shall meet the criteria of 5-6.1.1 and 5-6.1.2.

5-6.1.1 When subjected to the decking test, a specimen shall show no evidence of ignition at any cigarette location.

5-6.1.2 When measured from the original cigarette position, the char length on the cover fabric shall not exceed 38 mm (1.5 in.) at any of three cigarette locations.

5-6.2 Class II.

Decking materials that do not meet Class I criteria shall be designated as Class II.

5-7 Barrier Materials Classification.

5-7.1 Class I.

Class I barriers shall meet the criteria of 5-7.1.1 and 5-7.1.2.

5-7.1.1 When subjected to the barrier test, a specimen shall show no evidence of ignition of any test assembly.

5-7.1.2 When measured from the original crevice position, the vertical char length on the cover fabric shall not exceed 51 mm (2.0 in.) for any of three replicated tests.

5-7.2 Class II.

Barriers that do not meet Class I criteria shall be designated as Class II.

Chapter 6 Safety Precautions

6-1 CAUTION:

Even under the most carefully observed conditions, smoldering combustion can progress to a point where it cannot be extinguished readily. Any test shall be discontinued as soon as continuing combustion occurs. The exposed area shall be wet immediately with a water spray from the water bottle, and the charred or burned material shall be removed and immersed in a bucket of water. The test area then shall be ventilated.

6-2 Exposure.

Products of combustion can cause irritation and be dangerous to test personnel. Test personnel shall avoid exposure to smoke and gases produced during testing as much as possible. A large hood with a low air velocity shall be permitted to be in operation during testing to remove products of combustion.

Chapter 7 Precision and Accuracy

7-1 Statement.

A precision and accuracy statement is under study and will be provided for later inclusion in the test method. For preliminary data, see Appendix B.

Chapter 8 Referenced Publications

8-1

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 this reference is the current edition as of the date of the NFPA issuance of this document.

Federal Specification CCC-C-436-E, *Cloth, Ticking Twill, Cotton*, February 14, 1986. General Services Administration, Specification Unit (3 FPB-W), Suite 8100, 470 E. L'enfant S.W., Washington, DC 20407.

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

Cover fabrics determined to be Class II by this test should not be used without a Class I-type barrier in the manufacture of furniture intended to be resistant to cigarette ignition. Barrier materials also are classified by this test. Any other components determined to be Class II by this test should not be used in the manufacture of furniture intended to be resistant to cigarette ignition.

A-2-5

UFAC refers to the Upholstered Furniture Action Council. Standard Type II cover fabric can be obtained from TESTFABRICS, Inc, P.O. Box 420, Middlesex, NJ 08846-0420.

A-2-9

It is recommended that the properly loaded mini-mock-up tester and/or the decking materials tester be placed in a draft enclosure (*see Section 2-11*), and then the draft enclosure should be placed into a fume hood having air curtains or a door across the hood face and containing virtually zero air velocity.

A-3-5.2

Composites of loose/particulate materials and bag materials that are not classified as Class I should not be used in upholstered furniture that is expected to be resistant to cigarette ignition.

Appendix B Commentary

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

B-1 Introduction.

B-1.1

In April 1979, the Upholstered Furniture Action Council (UFAC) adopted a voluntary program designed to reduce the cigarette ignition propensity of upholstered furniture. The UFAC program is based on the six test methods described in this standard and consists of the following four elements:

(a) Classification of cover fabrics,

(b) Construction criteria for use of complying materials,

(c) A labeling plan to inform the consumer of the safer product,

(d) A compliance verification program to ensure that furniture manufacturers and their suppliers utilize materials and methods of construction as required by the voluntary program.

B-1.2

The UFAC construction criteria are intended to:

(a) Eliminate ignition-prone welt cords and to substitute smolder-resistant welt cords that meet the requirements of the UFAC welt cord test.

(b) Eliminate untreated cotton batting as a substrate in immediate contact with decking fabrics and to substitute materials that meet the requirements of the UFAC decking material test.

(c) Eliminate untreated cotton batting in immediate contact with the covering of the inside vertical walls and to substitute materials that meet the requirements of the UFAC filling/padding test.

(d) Eliminate intimate contact between Class II fabrics and the horizontal seating surfaces of conventional polyurethane foam cushions. Where Class II fabrics are used with conventional polyurethane foam cushions, a barrier meeting the requirements of the UFAC barrier test should be used.

B-2 Nature of Tests.

B-2.1

The six test methods outlined in this standard define the performance of welt cord, filling materials, decking substrates, barriers, interior fabrics, and cover fabrics. All are composite tests of individual components in combination with actual materials used by the upholstery industry. Certain standard materials have been selected for use in these tests. Performance of each component is evaluated in an assembly in which all other materials are standard. Thus, individual performance can be measured. The test methods are essentially similar. They are varied only as necessary to measure the performance of different components.

B-2.2

In the UFAC program, only those welt cords, filling materials, decking substrates, and barrier materials that meet the requirements for Class I performance may be permitted to be used. Class I cover fabrics may be permitted to be used in contact with other Class I materials. Class II cover fabrics may be permitted to be used only in conjunction with Class I barrier materials.

B-3 Experimental Study.

The significance of the UFAC program was validated by a series of chair tests in July 1979. These tests demonstrated that the UFAC program yielded a significant reduction in cigarette ignition propensity of upholstered furniture components compared to components not meeting UFAC criteria. An improvement of 89 percent was achieved by application of the UFAC criteria. In furniture manufactured before implementation of the UFAC program, 41 percent of all test cigarettes caused ignition of the filling materials. In furniture manufactured by UFAC methods, only 4.5 percent of the cigarettes caused ignitions.

NOTE: For further information, see UFAC Voluntary Action Program Chair Tests, July 26, 27, and 28, 1979.

B-4 Further Experimental Study.

A sound and sensible method(s) for developing statistically significant precision and bias statements for tests such as are contained in this standard has yet to be discovered. However, reproducibility within a laboratory and from laboratory to laboratory has been studied. The percentage of reproducibility when testing the same component in these two laboratory situations is specified in Tables B-4(a) and B-4(b):

Table B-4(a) Reproducibility within the Same Laboratory

Test Method	% Reproducibility[1]
Cover Fabric Classification	94

Interior Fabric Classification	94
Filling/Padding Classification:	
Slab and Garnetted F/P	89
Loose and Particulate F/P	89
Welt Cord Classification	94
Decking Material Classification	95
Barrier Material Classification	96

[1]The percent of reproducibility equals the percentage of replicates tested that produced the same result. For example, for welt cord classification, 94 percent of the replicate tests produced the same pass/fail or classification results.

Table B-4(b) Reproducibility from Laboratory to Laboratory

Test Method	% Reproducibility[1]
Cover Fabric Classification	89
Interior Fabric Classification	91
Filling/Padding Classification:	
Slab and Garnetted F/P	86
Loose and Particulate F/P	85
Welt Cord Classification	91
Decking Material Classification	94
Barrier Material Classification	96

[1]The percent of reproducibility equals the percentage of laboratories that obtained the same pass/fail or the same classification result. For example, for the filling/padding classification for slab and garnetted materials, the testing laboratories obtained the same results 86 percent of the time.

NOTE: For further information, see UFAC Voluntary Action Program Interlab Tests, 1981—1991, and Schnadig Corporation Test Data.

B-5 General Comments.

B-5.1

Cover fabrics determined to be Class II by these test methods may be permitted to be used where a Class I barrier is provided.

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.

C-1.1 UFAC Publications.

Upholstered Furniture Action Council, P.O. Box 2436, High Point, NC 27261.

UFAC Voluntary Action Program Chair Tests, July 26, 27, and 28, 1979.

UFAC Voluntary Action Program Interlab Tests, 1981–1991.

C-1.2 Other References.

Schnadig Corporation Test Data; Schnadig Corporation, Engineering and Technical Services, Belmont, MS 38827.

TESTFABRICS, Inc., P.O. Box 420, Middlesex, NJ, 08846-0420.

NFPA 261

1994 Edition

Standard Method of Test for Determining Resistance of

Mock-Up Upholstered Furniture Material Assemblies to

Ignition by Smoldering Cigarettes

1994 Edition

This edition of NFPA 261, *Standard Method of Test for Determining Resistance of Mock-Up Upholstered Furniture Material Assemblies to Ignition by Smoldering Cigarettes*, 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 15-18, 1993 in Phoenix, Arizona. 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.

Origin and Development of NFPA 261

Regulation of the manufacture of furniture has been a subject of research and debate since 1967, when the Flammable Fabrics Act was amended by Congress to include products in addition to wearing apparel and home textiles that might constitute an unreasonable flammability risk. The National Bureau of Standards (NBS) began funding laboratory research on the subject in 1968. With its formation in 1973, the U.S. Consumer Product Safety Commission (CPSC) became the government agency responsible for administration of the Flammable Fabrics Act, including the adoption of any program or standard regulating upholstered furniture. NBS retained responsibility for designing test methods related to flammable fabrics.

In 1976, NBS submitted a draft to the CPSC for a proposed cigarette-ignition resistance standard for upholstered furniture. Shortly thereafter, however, CPSC was reorganized into separate program areas, which was followed by nearly a year's worth of work on its children's sleepwear standards due to findings that a chemical added to sleepwear to make it flame-retardant might be carcinogenic. In November 1978, the CPSC staff, after modifying the original standard on upholstered furniture proposed by NBS, recommended to the CPSC commissioners that they publish the standard.

This standard was developed subsequent to the CPSC actions of 1978-79 by the Technical Committee on Fire Tests and drew heavily on the NBS research and proposed test methodology. The first edition, published in 1983, was identified as NFPA 260B. The 1989 edition was a reconfirmation of the first edition and was renumbered as NFPA 261.

The 1994 edition represents a reconfirmation of the 1989 edition with minor editorial clarifications.

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Rep. American Textile Manufacturers Inst. Inc.

James A. Milke, University of Maryland, MD

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Sivon C. Reznikoff, Arizona State University, AZ

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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.

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. The Committee is not responsible for fire tests that are used to evaluate extinguishing agents, devices, or systems.

NFPA 261 Standard Method of Test for Determining Resistance of Mock-Up Upholstered Furniture Material Assemblies to Ignition by Smoldering Cigarettes

1994 Edition

NOTICE: Information on referenced publications can be found in Appendix B.

Chapter 1 General

1-1 Purpose.

This method is designed to evaluate the ignition resistance of upholstered furniture when exposed to smoldering cigarettes under specified conditions.

1-2 Scope.

This method is recommended for upholstered furniture.

1-2.1

This test shall apply to upholstered furniture mock-ups.

1-2.2

Mock-up testing is useful in assessing the relative resistance to continuing combustion of individual materials used in furniture, such as cover fabrics, filling materials, welt tape, etc., in realistic combinations and in an ideal geometric arrangement of the seat cushions, back, and arms of furniture items.

1-3 Summary of Method.

1-3.1

The test uses lighted cigarettes (covered with a piece of sheeting material) to determine the ignition resistance of upholstered furniture items reproduced in mock-up.

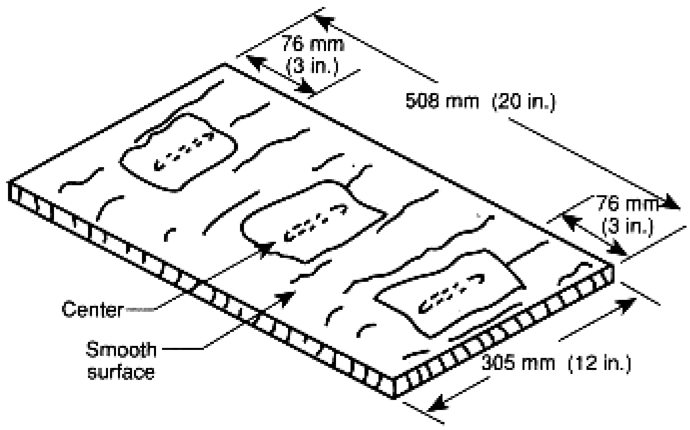

Figure 1-3.2(a) Upholstered furniture mock-up test: armrest, top of back, and seat support system.

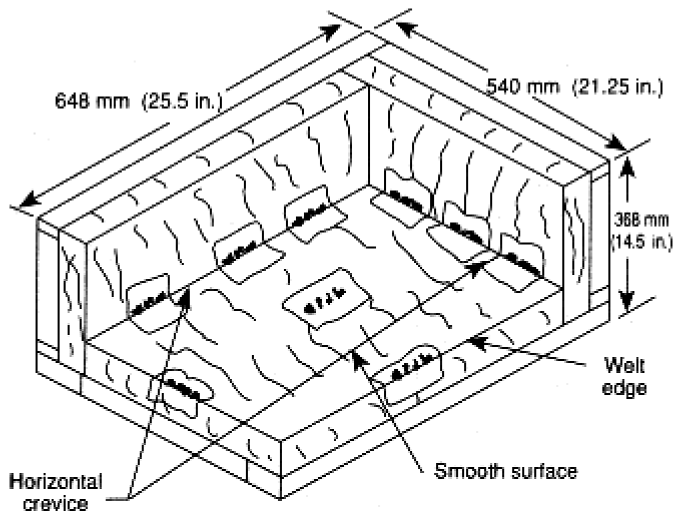

Figure 1-3.2(b) Upholstered furniture mock-up test: seat cushion, side, and back.

1-3.2

Locations to be tested include horizontal crevices formed where seat cushions and vertical test panels meet; seat cushion surfaces including smooth surface, quilt, tuft, and welt edges; and top surfaces of armrests, backs, and loose seat support systems. [*See Figures 1-3.2(a) and (b).*]

1-3.3

Obvious ignitions or char length measurements shall be used to determine if a particular combination of upholstering materials meets test criteria.

1-4 Significance.

1-4.1

This method is intended to measure the performance of upholstered furniture under conditions of exposure to a smoldering cigarette. This is accomplished by testing furniture mock-ups.

1-4.2

This method is not intended to measure the performance of upholstered furniture under conditions of open flame exposure and does not indicate whether the furniture will resist the propagation of flame under severe fire exposure or when tested in a manner that differs substantially from the test standard.

1-4.3

The results obtained with a material assembly tested in mock-up using this method shall not necessarily indicate the performance of the same material assembly in other geometric configurations.

1-5 Definitions.

Bolsters. Pillows or similarly shaped units containing upholstery material covered by upholstery cover material, which might or might not be attached to the upholstered furniture item but are sold and delivered with it.

Char. Carbonaceous material formed by pyrolysis or incomplete combustion.

Deck. The upholstered support under the seat cushion in a loose seat construction.

Furniture Mock-Up. A representation of production furniture that uses the same upholstery cover material and upholstery material, assembled in the same manner as in production furniture but with straight, vertical sides.

Quilted. Fused or stitched with thread through the upholstery cover material and one or more layers of upholstery material.

Shall. Indicates a mandatory requirement.

Should. Indicates recommendations or that which is advised but not required.

Tufted. Buttoned or laced through the upholstery cover material and upholstery material.

Upholstered Furniture. For the purpose of this test method, a unit of interior furnishing that (1) has any surface covered, in whole or in part, with a fabric or related upholstery cover material, (2) contains upholstery material, and (3) is intended or promoted for sitting or reclining.

Upholstery Cover Material. The outermost layer of fabric or related material used to enclose the main support system or upholstery materials, or both, used in a furniture item.

Upholstery Material. The padding, stuffing, or filling material used in a furniture item, which can be either loose or attached, enclosed by an upholstery cover material, or located between the upholstery cover material and support system, if present. (This definition includes, but is not limited to, material such as foam, cotton batting, polyester fiberfill, bonded cellulose, or down.)

Welt. The seam or border edge of a cushion, pillow, arm, or the back of an item.

Chapter 2 Test Apparatus

2-1 Mock-Ups.

Mock-up elements for the mock-up test jigs are illustrated in Figures 2-1(a), (b), and (c). Figures 1-3.2(a) and (b) show the completed mock-up assemblies.

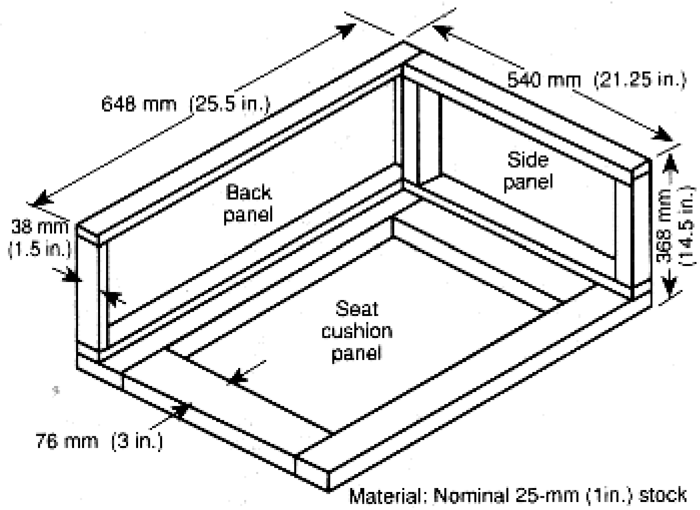

Figure 2-1(a) Frame for upholstered furniture mock-up test.

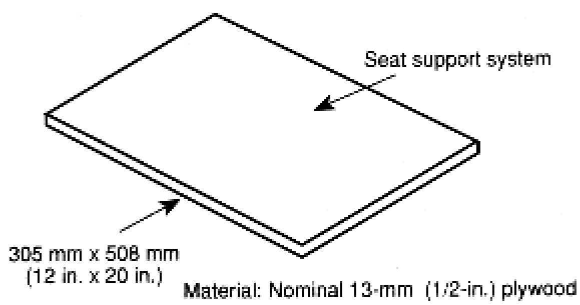

Figure 2-1(b) Armrest and top of back mock-up test.

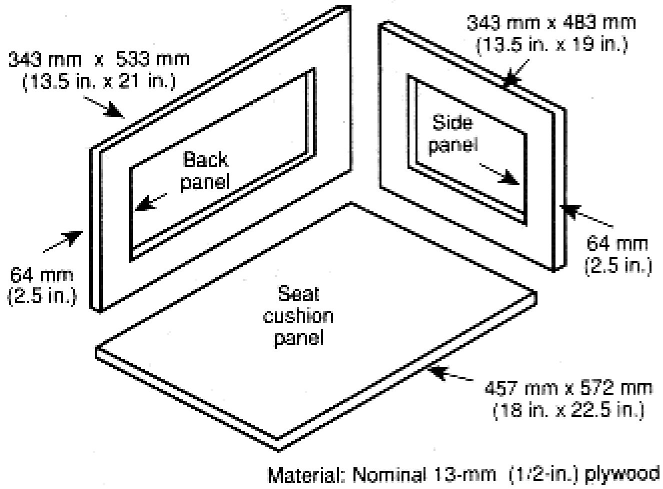

Figure 2-1(c) Panels for upholstered furniture mock-up test.

2-2 Ignition Sources.

The ignition source for the test shall be cigarettes without filter tips, made from natural tobacco, 85 mm ± 2 mm (3.4 in. ± 0.1 in.) long with a packing density of 0.270 g/cm3 ± 0.020 g/cm3 (0.156 oz/in.3 ± 0.012 oz/in.3) and a total weight of 1.1 g ± 0.1 g (0.039 oz ± 0.004 oz). The smoldering rate of this cigarette shall be 0.10 mm/sec ± 0.01 mm/sec (0.236 in./min. ± 0.024 in./min) when the cigarette is allowed to burn downward in a draft-protected area.

NOTE: With the cigarette supported at the bottom in a vertical position, the burning rate is determined in the region of 10 mm to 50 mm (0.39 in. to 1.97 in.), measured from the top.

2-3 Sheeting Material.

The sheeting material used to cover the test cigarettes shall be 50 percent cotton/50 percent polyester or 100 percent cotton bed sheeting material, and shall weigh 125 g/m^2 ± 28 g/m^2 (3.7 oz/yd^2 ± 0.8 oz/yd^2). The material shall be laundered in an automatic home clothes washing machine and dried in a tumble drier at least once before use. For testing, the sheeting material shall be cut into pieces approximately 12.5 cm × 12.5 cm (5 in. × 5 in.).

2-4 Test Area.

The test room shall be draft-protected and equipped with a suitable system for exhausting smoke and noxious gases produced during testing.

2-5 Extinguishing Equipment.

A pressurized water fire extinguisher or other suitable fire extinguishing equipment shall be immediately available. A water bottle fitted with a spray nozzle shall be provided to extinguish any ignited portions of the mock-up. A bucket of water shall be provided for immersing smoldering or burning materials removed from the mock-up.

2-6 Miscellaneous.

Other apparatus required to carry out the testing include: straight pins, a knife or scissors, tongs, and a linear scale at least 15 cm (6 in.) long and graduated in millimeters or in $^1/_{10}$-in. or $^1/_{16}$-in. divisions.

Chapter 3 Conditioning

3-1 General.

Test samples, cigarettes, and sheeting material shall be conditioned at a temperature of 23°C ± 5°C (73.4°F ± 9°F) and a relative humidity of 50 percent ± 5 percent for at least 48 hours immediately prior to testing. If the test room conditions do not meet the above specifications, then testing shall be initiated within 10 minutes after the materials are removed from the conditioned room. The mock-up assembly shall be constructed in the conditioned area.

Chapter 4 Test Specimens

4-1 General.

Furniture mock-ups shall be created by arranging upholstery cover material and upholstery materials in the same sequence in which they are used in production furniture.

The various parts of the mock-up shall be constructed as described in Sections 4-2 through 4-6. In all cases, the arrangement and thickness of upholstery material in the mock-up shall reproduce the construction details of production furniture.

4-2 Loose Seat Cushions.

4-2.1

Seat cushions shall be made in the same size and manner and with the same material as production furniture.

Exception: Cushions 68 cm x 55 cm (25 in. x 22 in.) shall be permitted to be used if production furniture cushion dimensions exceed these values.

4-2.2

The cushion thickness shall be a maximum of 13 cm (5 in.).

4-3 Decks.

Decks shall be prepared (if they are part of the furniture item) by attaching to the horizontal panel [*see Figure 2-1(b)*] of the test apparatus the same materials in the same thickness as used in actual furniture construction. The decking or upholstery cover material shall be stretched over the upholstery materials and securely fastened to the underside of the wood panel.

4-4 Tight Seat.

If a furniture item is constructed with tight seats only, then the seat shall be duplicated for test in mock-up. Tight seat cushions shall be made 45 cm ± 5 cm × 55 cm ± 5 cm (18 in. ± 2 in. × 22 in. ± 2 in.) and with the same fabric and the same thickness used in production furniture. The cushion assembly shall be attached to the horizontal panel of the test apparatus [*see Figure 2-1(c)*] by extending the upholstery cover material around the panel edges and fastening the cover material to the underside of the wood panel.

4-5 Side and Back Panels.

Furniture sides and backs shall be mocked-up if, in the type of furniture to be represented by the mock-up, they are located within 2.5 cm (1 in.) of a seat cushion. Mock-ups shall be made by upholstering one surface of the vertical test panel [*see Figure 2-1(c)*] with the same upholstery material and upholstery cover material used in production furniture. The upholstery cover material shall be stretched over the upholstery material and fastened to the back side of the framework. All edges of the panels shall be covered with upholstery cover material. If the side panel and back panel constructions of the furniture item are the same, only one vertical panel shall be required to be assembled and tested.

4-6 Bolsters.

Bolsters resting on the seat cushion or suspended above it tend to confine the heat from the cigarette and often create a spatial arrangement that differs from the crevice space found in production furniture. In such cases, a mock-up bolster shall be prepared, with dimensions that fit into the mock-up and create the same spatial arrangement for the cigarette as in production furniture.

4-7 Armrests and Tops of Backs.

Tops of armrests and backs shall be tested if (1) they present a surface large enough and so oriented as to support a cigarette and (2) if the construction differs in any way from the side panel and back panel constructions. Tops of armrests and backs shall be made by upholstering a piece of 1.3-cm (0.5-in.) thick plywood, approximately 30 cm × 50 cm (12 in. × 20 in.), with the same materials used in the furniture item. The mock-up shall reproduce significant details of the construction of full-size furniture.

Chapter 5 Testing Procedures

5-1 Mock-up Test Sample.

A mock-up test sample shall be assembled by attaching the side or back panel, or both, to the mock-up frame and placing a seat cushion (either loose or tight seat construction) against the panels, as shown in Figure 1-3.2(b). The assembly shall be permitted to be placed on a table or platform in the test area and shall be under an exhaust hood or other suitable means for exhausting the products of combustion from testing. The decks for loose cushion items, tops of armrests, and backs shall be tested separately. The test to evaluate upholstered furniture material assemblies for cigarette ignition resistance might require two vertical panels, one seat cushion (loose or tight), one bolster, one deck, one top of armrest, and one top of back.

5-2 Cigarette Locations.

At least three cigarettes shall be burned on each surface location [*see Figures 1-3.2(a) and (b)*]. These locations include the crevice(s) where seat cushion and vertical panels meet, seat cushion surfaces (including welt and smooth, quilted, or tufted areas), top of upholstered armrest, and tops of upholstered back and deck.

5-3 Crevice Location.

For crevice locations, the two cigarettes on either side of the center cigarette shall be placed in the crevice so that their butt ends burn out at least 7.5 cm (3 in.) from the outermost edge of the side of the back panel. The cigarettes shall be placed horizontally. Two of the three cigarettes shall be placed so that their entire length burns out against the welt cord and the vertical panel surface. The third cigarette shall be placed so that its entire length burns out against the welt cord and a horizontal surface of the seat cushion.

5-4 Test Cigarette.

Each test cigarette shall be well-lighted and burned not more than 4 mm (0.16 in.) when placed at a specific test location. After placement, each cigarette shall be covered with a piece of sheeting material. For crevice tests, one end of the sheeting material shall be pinned to the vertical panels [approximately 5 cm (2 in.) above the cigarette] and the remaining material dropped to completely cover the test cigarette. For all tests, proper sheeting material-to-cigarette contact shall be ensured by running a finger across the full length of the covered cigarette.

5-5 Seat Cushion.

5-5.1

For the test of a seat cushion (either loose or tight), three covered cigarettes shall be burned on each different surface location encountered.

5-5.2

For the purposes of this test, smooth surfaces, welt edges, fused or threaded portions of quilts, and tuft depressions shall be considered different surface locations on a seat cushion. Test cigarettes shall be arranged so that the butt ends burn out on the threads of a quilt or in tuft depressions. The smooth surface of a quilted or tufted cushion shall not be required to be tested. For smooth surface cushions, the test cigarettes shall be burned in the center of the cushion.

5-6 Test Cigarette.

Three test cigarettes shall be burned on each horizontal mock-up test panel duplicating armrests, tops of backs, and seat cushion support systems. One cigarette shall be burned at the center of the panel, and the other two shall be burned at least 7.5 cm (3 in.) from the edges of the test panel. Refer to Figure 1-3.2(a) for the location of the cigarettes on the test panels.

5-7 Test Acceptance.

A test at any location is considered complete if any of the following occurs:

(a) Three cigarettes in a given location have burned their full lengths without sustained ignition.

(b) Three cigarettes in a given location have self-extinguished before burning their full lengths.

(c) Three cigarettes in a given location sustained ignition.

5-8 Ignition.

If continuing ignition occurs (i.e., fabric and filling materials are ignited and are smoldering and generating smoke at a rapid rate), it is not a requirement to wait until a cigarette has burned its full length; the test shall be stopped and the burning material extinguished. The test room shall be ventilated and an ignition recorded for the cigarette test location.

5-9 Char Length Measurement.

5-9.1

If the cigarette burns to completion at a test location, the maximum char length in any direction of any material, from the point nearest to the original location of the cigarette shall be measured.

5-9.2

The char length measurement for each cigarette shall be recorded, except when the cigarette has extinguished without burning to completion or where continuous combustion occurs. If the char from one cigarette runs into that from another, the results of the test are invalid and the test shall be repeated, burning one cigarette at a time.

All mock-ups shall be disassembled. When disassembling the apparatus, if it is shown that smoldering is still in progress, the test is invalid and shall be repeated.

5-10 Testing Environment.

The test shall be carried out in a draft-protected area. The maximum airflow across the sample face shall be less than 15.2 m/min (50 ft/min).

Chapter 6 Safety Precautions

6-1 CAUTION:

Even under the most carefully observed conditions, smoldering combustion can progress to a point where it cannot be readily extinguished. A test shall be stopped as soon as continuing combustion has definitely occurred. Immediately wet the exposed area with a water spray from the water bottle, remove the charred or burned material, and immerse the material in a bucket of water. Ventilate the test area.

6-2 Exposure.

Products of combustion can be physically irritating and dangerous to test personnel. Test personnel shall avoid exposure to smoke and gases produced during testing as much as possible. A large hood with a low air velocity shall be permitted to be in operation during testing to remove products of combustion.

Chapter 7 Report

7-1 Reporting.

The maximum char distance measured to the nearest 0.5 cm (0.2 in.) from the center of the original location of the test cigarette shall be recorded for each cigarette location, except when a continuing combustion occurs. In this case, an ignition shall be recorded for the test location.

Appendix A Commentary

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

A-1 Introduction.

The test for determining the smoldering cigarette ignition resistance of mock-up furniture material assemblies was developed by the National Bureau of Standards with the cooperation of various industry groups and individuals. The work was done in response to data indicating that cigarette ignition of upholstered furniture is a major cause of life loss due to fire in the United States.

A-2 Nature of Test.

A-2.1

Upholstered furniture consists of upholstery cover fabric and interior components (filling/padding), such as foam, polyester, or cotton batting. Often a welt cord is attached to the pillow and other edges of the upholstery. These materials are arranged in complex geometrical forms, including flat, tufted, convex, concave, and horizontal and vertical surfaces. Both the combination of fabric and filling/padding materials and their geometrical arrangement affect their propensity to ignite when exposed to burning cigarettes.

A-2.2

Originally, an attempt was made to develop separate tests for each of the component materials: fabric, filling/padding, and welt cord. It soon became obvious that there was considerable interaction among these components, and it was decided that they would have to be tested in the combination in which they would be used in actual furniture. However, to avoid the cost and effort required to build prototype furniture for each combination of materials, the test is limited to a simple mock-up of the seating surface and vertical members, with the fabric, filling/padding, and welt cord arranged as in the proposed construction of actual furniture.

A-3 Experimental Studies.

In a controlled study, the relationship between the results of the mock-up test and the performance of actual furniture was shown to be very close.

Thirty-eight locations in both mock-up and full-size chairs were tested in each of 3 laboratories for a total of 114 tests. Fourteen test locations out of 114 provided different results for the mock-up than for the actual item of furniture. There was 87 percent agreement.

A-4 Agreement Between Laboratories.

In a controlled study, the percentage of agreement between laboratories was high.

More than 2,200 tests were conducted on mock-ups in 38 laboratories. One hundred twenty-six test results differed from the majority. There was 94 percent agreement. For additional information, see NBSIR 78-1438, PFF6-76, June 1978, Loftus, NBS.

Appendix B Referenced Publication

B-1

The following document or portions thereof are referenced within this standard for informational purposes only and thus is not considered part of the requirements of this document.

NBSIR, Back-Up Report for the Proposed Standard for the Flammability (Cigarette Ignition Resistance) of Upholstered Furniture, PFF6-76, Joseph J. Loftus, Final Report, June 1978.

NFPA 262

1994 Edition

Standard Method of Test for Fire and Smoke Characteristics of Wires and Cables

1994 Edition

This edition of NFPA 262, *Standard Method of Test for Fire and Smoke Characteristics of Wires and Cables*, was prepared by the Technical Committee on Fire Tests 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 262

The test procedure covered by this standard was originally developed by Underwriters Laboratories Inc. and published as UL 910, *Standard for Safety Test for Flame-Propagation and Smoke- Density Values for Electrical and Optical- Fiber Cables Used in Spaces Transporting Environmental Air*. It is an adaptation of the Steiner tunnel test (NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, UL 723, *Tests for Surface Burning Characteristics of Building Materials*), which was designed to provide information for evaluating the potential for fire spread along cables and wires housed in a plenum or other environmental space. The original 1985 edition was reconfirmed in 1990. The 1994 edition contains minor editorial changes.

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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.

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 where such documents are not available. The Committee shall 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; and act in a liaison capacity between NFPA and the committees of other organizations writing fire test standards. The Committee shall not be responsible for fire tests that are used to evaluate extinguishing agents, devices, or systems.

NFPA 262
Standard Method of Test for Fire and Smoke Characteristics of Wires and Cables

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 General

1-1 Scope.

This test method is for determining values of flame spread distance and smoke density for insulated, jacketed, or both, electrical wires and cables and optical fiber cables that are to be installed in plenums and other spaces used for environmental air without the wires and cables being enclosed in raceways, in accordance with the applicable provisions of Sections 725-2, 760-2, 770-2, 800-49, and 820-49 of NFPA 70, *National Electrical Code*.®

1-2 Significance.

This test is designed to provide comparative test data on wiring or cable intended for use in plenums or other environmental air handling spaces. Such data are used to evaluate the potential for the spread of fire along electrical cables or wires or along optical fiber cables and the potential for the development of high smoke levels in these spaces if the wires and cables are exposed to fire. The test method has been correlated with the results of tests on wiring exposed to fires in simulated plenums.

1-3 Purpose.

1-3.1

The purpose of the test is to measure and record the fire and smoke characteristics of wiring or cable by measuring the flame spread distance along the test specimens, and the light transmittance of the smoke developed, when exposed to the test fire.

1-3.2

Smoke density as well as flame spread shall be recorded in this test. However, there is not necessarily a relationship between these measurements.

1-3.3

This test method does not investigate circuit integrity characteristics or other such functionality performances during or after the fire test.

1-4* Summary of Test Method.

This test method shall use an apparatus similar to that specified in NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*. A special specimen holder shall be used to expose the test specimens; the holder, 11.25 in. (286 mm) wide and approximately 4.25 in. (108 mm) down from the ceiling of the test chamber, shall be filled with one layer of test specimens. The specimens shall be exposed to a 300,000 Btu/hr (87.9 kW) fire, 4.5 ft (1.4 m) long, for a period of 20 minutes, with an initial draft of 240 ft/min (73 m/min) through the chamber. The travel distance of the flame along the specimen and the light transmittance at the end of the chamber shall be reported. The light transmittance shall be converted to a peak and average optical density.

Chapter 2 Test Equipment

2-1 Fire-Test Chamber.

2-1.1*

The fire-test chamber shall consist of a horizontal duct having the shape and size shown in Figures 2-1.1(a), (b), and (c). The sides and base of the duct shall be lined with insulating masonry faced with a row of refractory fire brick, as illustrated in Figure 2-1.1(b). One side shall be provided with a row of double-pane [inside pane mounted flush with inner wall — see Figure 2-1.1(b)], pressure-tight observation windows (as described in Sections 4-2 and 4-3) located so that the entire length of the specimen being tested can be observed from outside the fire-test chamber.

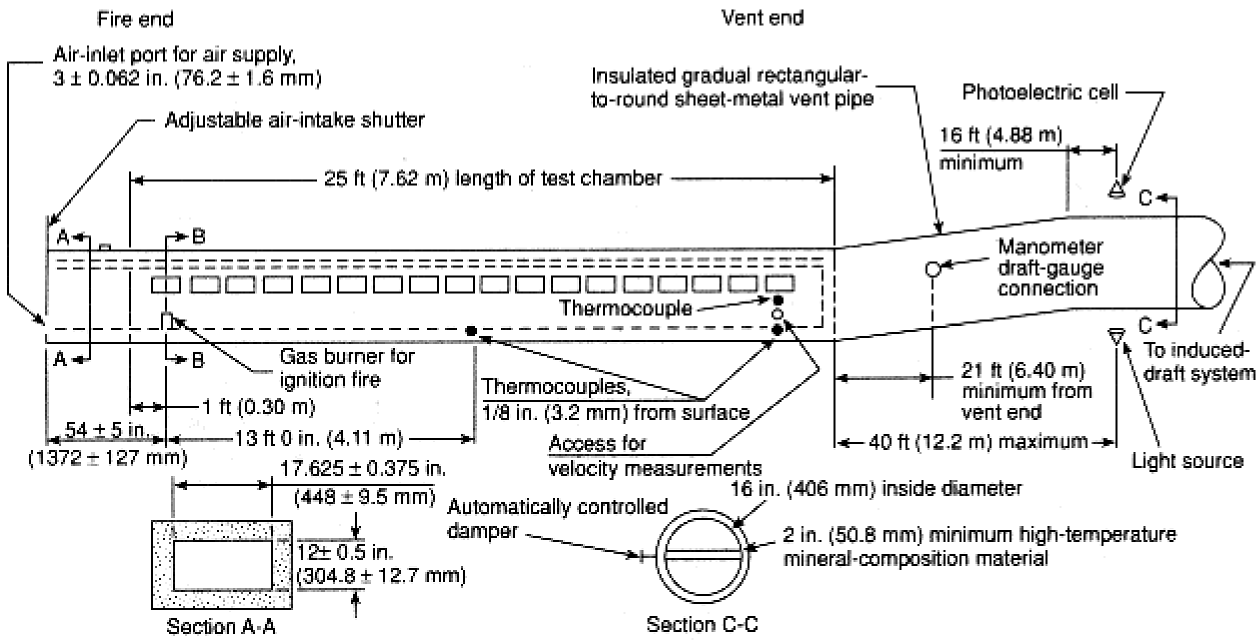

Figure 2-1.1(a) Details of fire-test chamber Sections A-A and C-C.

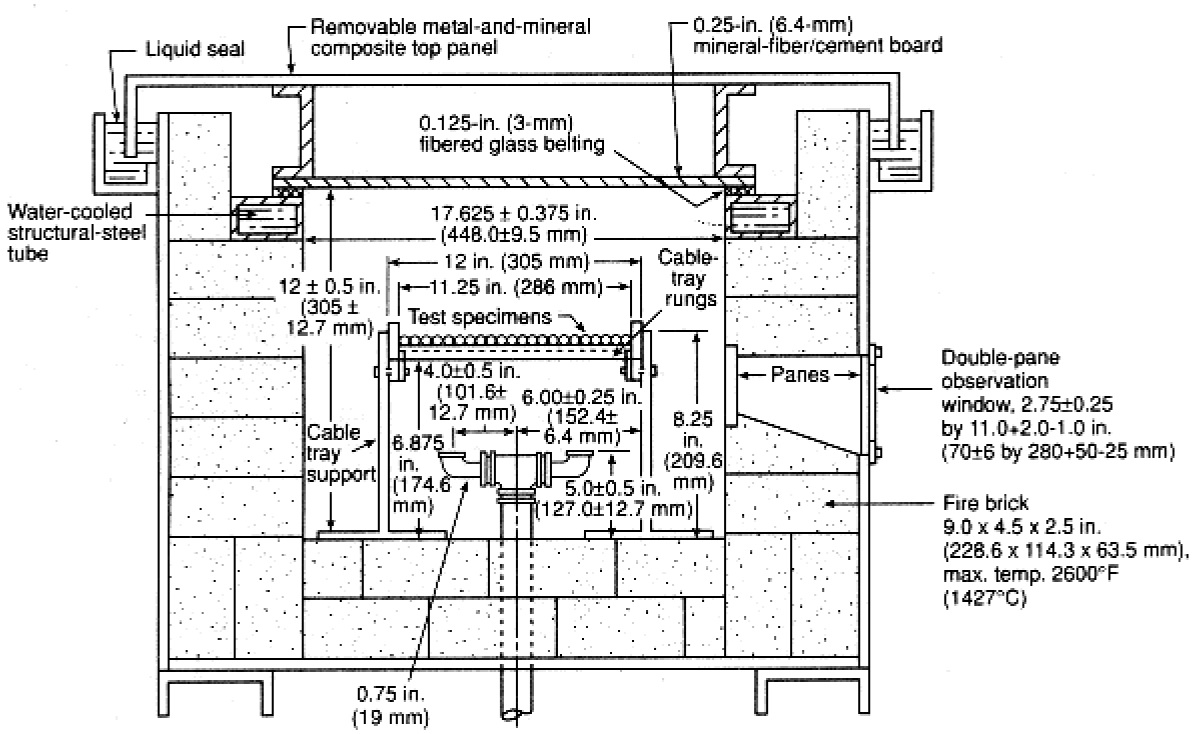

Figure 2-1.1(b) Details of fire-test chamber Section B-B.

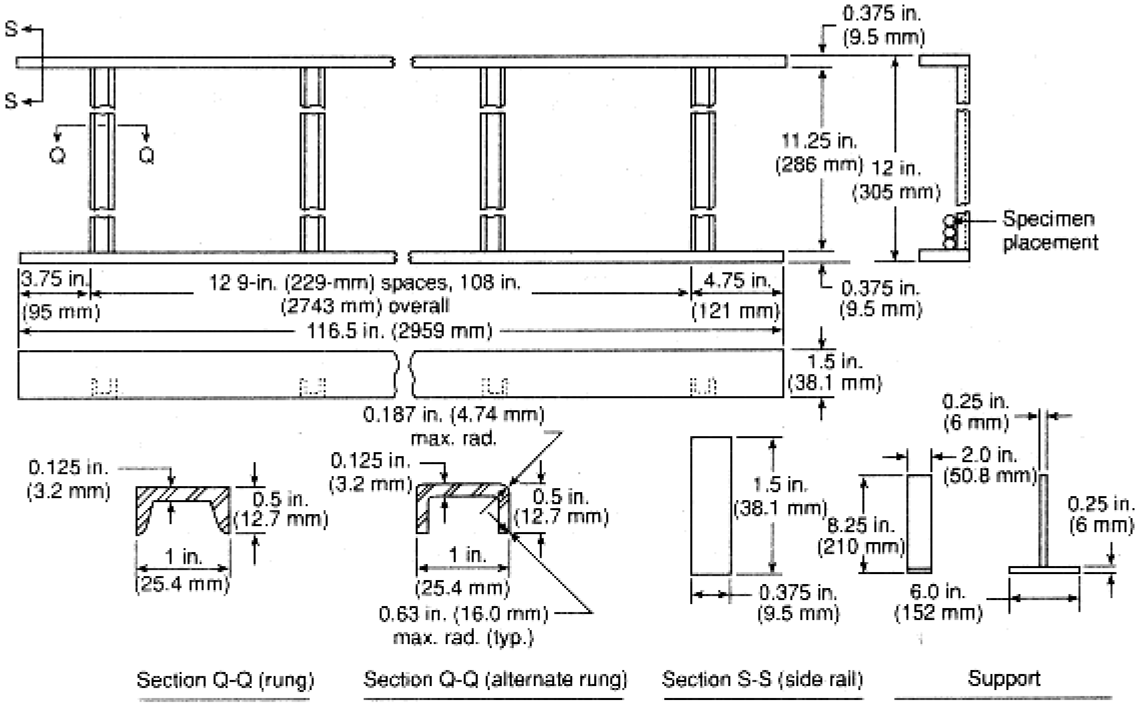

Figure 2-1.1(c) Details of steel cable tray and supports.

2-1.2*

The ledges shall be fabricated of structural metal.

2-1.3*

To provide air turbulence for combustion, turbulence-inducing baffling shall be provided by positioning six refractory fire bricks [long dimension vertical and 4.5-in. (114-mm) dimension parallel to the wall] along the side walls of the chamber at distances of 7.0, 12.0, and 20.0 ft ± 0.5 ft (2.1, 3.6, and 6.1 m ± 0.2 m) on the window side and 4.5, 9.5, and 16.0 ft ± 0.5 ft (1.4, 2.9, and 4.9 m ± 0.2 m) on the opposite side.

2-1.4

The top shall consist of a removable metal-and-mineral insulation composite unit with insulation consisting of nominal 2.0-in. (50.8-mm) thick mineral-composition material. The top unit, shown in Figure 2-1.1(b), shall completely cover the fire-test chamber. The mineral-composition material shall have physical characteristics comparable to the following:

Maximum effective use temperature of at least	1200°F (650°C)
Bulk density	21 lb/ft^3 (336 kg/m^3)

Thermal conductivity at	0.50 - 0.71 Btu · in/h · ft^2 ·°F
300°F to 700°F (149°C to 371°C)	(0.072–0.102 W/m^2 · K)
KpC product*	1 to 4 Btu^2 · in/ft^5 · h · $°F^2$
	(1 × 10^4 to 4 × 10^4 W^2 · s/m^4 · K)

*KpC is equal to the thermal conductivity times the density times the specific heat.

The entire top-panel unit shall be protected with flat sections of high-density [nominally 110 lb/ft^3 (1760 kg/m^3)] 0.25-in. (6-mm) mineral-fiber/cement board maintained in an unwarped and uncracked condition through continued replacement. While in place, the top panel shall be completely sealed against the leakage of air into the fire-test chamber during the test.

2-1.5

The ladder-type cable tray used to support the test specimens is shown in Figures 2-1.1(b) and (c). The tray is fabricated from cold-rolled steel having 50,000 psi (350 MPa) minimum tensile strength. The solid-bar-stock side rails are as shown in Section S-S in Figure 2-1.1(c). The C-shaped channel rungs are as shown in Section Q-Q in Figure 2-1.1(c). Each rung is 11.25 in. (286 mm) long. The rungs are welded to the side rails 9.0 in. (229 mm) on centers along the tray length. The tray, which shall be permitted to consist of several sections, shall have a total assembled length of 23.9 ft (7.29 m) and shall be supported with 16 supports equally spaced along the length of the tray. The supports [*see Figure 2-1.1(c)*] are fabricated from bar steel.

2-1.6

One end of the test chamber, designated as the fire end in Figure 2-1.1(a), is provided with two gas burners delivering flames upward that engulf the cross section of the test specimens midway between two rungs of the cable tray. As shown in Figure 2-1.1(b), the burners are positioned transversely to each side of the centerline of the furnace so that the flame is evenly distributed over the width of the specimens.

2-1.7

The controls used to maintain a constant flow of gas to the burners are to consist of a pressure regulator, a gas meter calibrated to read in increments of not more than 0.1 ft^3 (2.8 dm^3), a gauge to indicate gas pressure in inches of water column (Pa), a quick-acting gas shutoff valve, a gas-metering valve, and an orifice plate in combination with a manometer to assist in maintaining uniform gas flow conditions. An air intake fitted with a vertically sliding shutter extending the entire width of the test chamber shall be provided at the fire end. The shutter shall be positioned to provide an air-inlet port as shown in Figure 2-1.1(a). A draft gauge manometer to indicate static pressure shall be connected approximately midway in the section between the air intake and the burners, as shown in Figure 2-1.1(a).

2-1.8

The other end of the test chamber, designated as the vent end in Figure 2-1.1(a), shall be fitted with a rectangular-to-round transition piece, which is in turn to be fitted to a round flue pipe. The movement of air shall be by induced draft. The draft-inducing system shall have a total draft capacity of at least 0.15 in. of water column (37 Pa) with the specimens in place, with the shutter at the fire end open to its normal position, and with the damper [*see Section C-C in Figure 2-1.1(a)*] in the fully open position.

2-1.9

The damper shall be installed in the vent pipe downstream of the smoke-indicating attachment described in 2-2.1.

2-1.10

An automatic draft-regulator controller shall be permitted to be mounted in the vent pipe downstream of the manual damper. Other manual, automatic, or special draft-regulation devices shall be permitted to be incorporated to maintain airflow control throughout each test run.

2-1.11

The room in which the test chamber is located shall have provision for a free inflow of air to maintain the room at atmospheric pressure throughout each test run.

2-2 Smoke Measurement.

2-2.1*

A light source shall be mounted on a horizontal section of the vent pipe (*see Figure 2-2.1*) at a point at which (a) it is preceded by a straight run of round pipe at least 12 diameters or 16 ft (4.88 m) from the vent end of the rectangular-to-round transition section, and (b) it is not affected by flame from the test chamber. The light beam shall be directed upward along the vertical axis of the vent pipe. The vent pipe shall be insulated with high-temperature mineral-composition material from the vent end of the chamber to the photometer location. A photoelectric cell having an output directly proportional to the amount of light received shall be mounted over the light source with an overall light-to-cell path length of 36.0 in. ± 2.0 in. (914 mm ± 51 mm). The light source and photocell shall be located such that they are open to the environment of the test room. The cylindrical light beam shall pass through 3-in. (76-mm) diameter openings at the top and bottom of the 16-in. (406-mm) diameter duct, with the resultant light beam centered on the photocell. The cell shall be connected to recording devices for indicating changes in the attenuation of incident light by passing smoke, by particulate matter, and by other effluents.

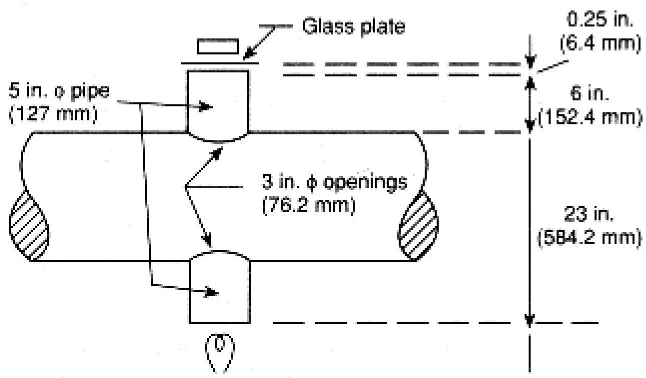

Figure 2-2.1 Light source mounting.

2-2.2

The output of the photoelectric cell shall be connected to a recording device having an accuracy within ± 1 percent of full scale to process the signal into a continuous record of smoke obscuration.

2-2.3

Linearity of the photometer system shall be verified periodically by interrupting the light beam with calibrated neutral density filters. The filters shall cover the full range of the recording instrument. Transmittance values measured by the photometer, using neutral density filters, shall be within ± 3 percent of the calibrated value for each filter.

2-3 Temperature Measurement.

2-3.1

A No. 18 AWG thermocouple [nominal wire cross section of 1620 CM (0.823 mm^2)] with 0.375 in. ± 0.125 in. (10 mm ± 3 mm) of the junction exposed in the fire-chamber air shall be inserted through the floor of the test chamber so that the tip is 1.000 in. ± 0.031 in. (25 mm ± 1 mm) below the top surface of the gasketing tape and within 12 in. (300 mm) of the vent end of the test chamber at the center of the width of the chamber.

2-3.2

A No. 18 AWG thermocouple [nominal wire cross section of 1620 CM (0.823 mm^2)] embedded 0.125 in. (3 mm) below the floor surface of the test chamber shall be mounted in refractory or portland cement (carefully dried to keep it from cracking) at distances of 13.5 ft (4.11 m) and 24.0 ft (7.32 in.) from the fire end of the test chamber.

Chapter 3 Test Specimens

3-1 Specimen.

Cable specimens in 24.0-ft (7.32-m) lengths shall be installed in a single layer across the bottom of the cable tray as shown in Figure 2-1.1(b). The specimens shall lie in the tray in parallel and in straight rows without any space between adjacent specimens other than that needed for the cable fasteners described in Section 3-2. The number of cable specimens shall equal the measured inside width of the rack divided by the cable diameter rounded to the nearest lower whole number of specimens that fit considering the presence of cable fasteners.

3-2 Securing.

Bare copper or soft steel tie wires not larger than No. 18 AWG [nominal wire cross section of 1620 CM (0.823 mm^2)] shall be permitted to be used to fasten the cable specimens to the rungs of the cable tray wherever a tie is necessary to keep the cable in contact with the rung straight and parallel with all of the other cable specimens and to minimize movement during the test. A tie shall not be used in any manner that alters the ability of the cable to transmit gases or vapors, or both, longitudinally through the core of the cable.

3-3 Identification.

Properties applicable to identification of the cable specimens shall be determined and recorded.

Chapter 4 Calibration of Test Equipment

4-1 Chamber.

One 0.25-in. (6.4-mm) mineral-fiber/cement board shall be placed on the ledge of the furnace chamber as shown in Figure 2-1.1(b). The removable top of the test chamber shall be placed in position.

4-2 Leakage Test.

With the board in position and with the removable top in place, the draft shall be established to produce a 0.15-in. water column reading (37 Pa) on the draft manometer with the fire-end shutter open 3 in. ± 0.063 in. (76 mm ± 2 mm) and with the manual damper in the fully open position. Then, the fire-end shutter shall be closed and sealed. The manometer reading shall increase to at least a 0.375-in. water column (93 Pa), indicating that no excessive air leakage exists.

4-3 Supplemental Leakage Test.

In addition, a supplemental leakage test shall be conducted periodically by activating a smoke bomb in the fire chamber while the fire shutter and exhaust duct beyond the differential manometer tube are sealed. The bomb shall be ignited and the chamber shall be pressurized to a 0.375-in. ± 0.150 in. water column (93 Pa ± 37 Pa). All points of leakage observed in the form of escaping smoke particles shall be sealed.

4-4 Draft.

A draft reading shall be established within a range of 0.055 in. to 0.085 in. water column (13 Pa to 21 Pa). The required draft-gauge reading shall be maintained by regulating the manual damper. The air velocity at each of seven points, each located 12 in. (300 mm) from the vent end, shall be recorded. These points shall be determined by dividing the width of the tunnel into seven equal sections and recording the velocity at the geometric center of each sec- tion. The average velocity shall be 240 ft/min ± 5 ft/min (73.2 m/min ± 1.5 m/min).

4-5 Air Supply.

The air supply shall be maintained at 70.0°F ± 5.0°F (21.0°C ± 2.8°C), and the relative humidity shall be kept at 50 percent ± 5 percent.

4-6 Test Fire.

The test fire that produces approximately 300,000 Btu (thermochemical)/hr (87.9 kW) shall be fueled with bottled methane gas of uniform quality and with a heating value of approximately 1000 Btu (thermochemical)/ft^3 (37.3 MJ/m^3). The gas supply shall be initially adjusted to approximately 5000 Btu (thermochemical)/min (87.9 kW). The gas pressure, the pressure differential across the orifice plate, and the volume of gas used shall be recorded in each test. A length of coiled copper tubing shall be inserted into the gas line between the supply and the metering connection to compensate for possible errors in the indicated flow because of reductions in the gas temperature associated with the pressure drop and expansion across the regulator. Other applicable means of correction shall be permitted to be used. With the draft and the gas supplies adjusted as indicated in Section 4-4 and in this section, the test flame shall extend downstream to a distance of 4.5 ft (1.4 m) over the specimens, with negligible upstream coverage.

4-7 Preheat.

The test chamber shall be preheated with the mineral-fiber/cement board and the removable top in place and with the fuel supply adjusted to the required flow. The preheating shall be continued until the temperature indicated by the floor thermocouple at 24.0 ft (7.32 m) reaches 150°F ± 5°F (66°C ± 3°C). During the preheat test, the temperatures indicated by the thermocouple at the vent end of the test chamber shall be recorded at 15-second intervals and shall be compared to the preheat temperatures taken at the same intervals from the representative curve of temperature as a function of time shown in Figure 4-7. The preheating is for the purpose of establishing the conditions that exist following successive tests and to indicate the control of the heat input into the test chamber. If appreciable variation from the temperatures shown in the representative preheat curve occurs because of variations in the characteristics of the gas used, adjustments in the fuel supply shall be made before proceeding with the red oak calibration tests.

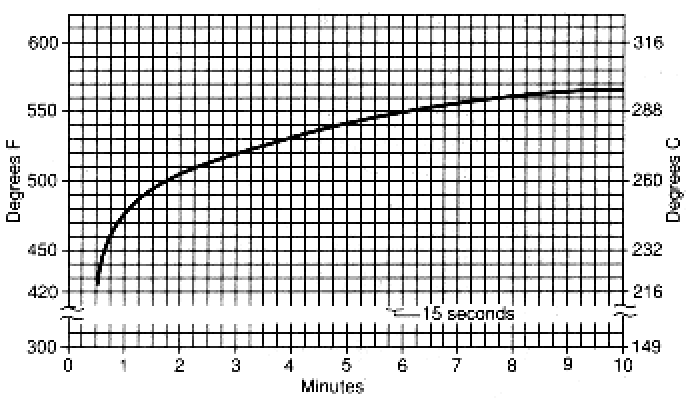

Figure 4-7 Representative preheat curve.

4-8 Testing.

The furnace shall cool after each test. As soon as the floor thermocouple at 14 ft (4.2 m) shows a temperature of 105°F ± 5°F (41°C ± 3°C), the next set of specimens shall be placed in position for test.

4-9 Calibration Test.

With the test equipment adjusted and conditioned as described in Sections 4-2, 4-4, 4-5, and 4-7, a test or series of tests shall be made using nominally $^{25}/_{32}$-in. (19.8-mm) select-grade red oak flooring in place of the mineral-fiber/cement board specified in Section 4-1. Prior to the testing, the wood shall be conditioned to a moisture content of 6 to 8 percent as determined by the 221°F (105°C) oven method (Method A) described in ASTM D4442, *Test Methods for Direct Moisture Content Measurement of Wood and Wood-Base Materials*. Observations shall be made continually, and the time shall be recorded when the flame reaches the end of the specimen [that is, 19.5 ft (5.94 m) from the end of the ignition fire]. The end of the ignition fire shall be considered as being 4.5 ft (1.4 m) from the burners. The flame shall reach the end point in 5.5 minutes ± 15 seconds. The flame shall be judged to have reached the end point when the vent end thermocouple registers a temperature of 980°F (527°C). The temperature measured by the thermocouple near the vent end shall be recorded at least every 30 seconds. The photoelectric cell output shall be recorded immediately before the test and at least every 15 seconds during the test.

4-10 Calibration Time.

Calibration tests shall be conducted for 10 minutes.

4-11 Recording.

The temperature and changes in photoelectric cell readings shall be recorded electronically or plotted separately on coordinate paper. Figures 4-11(a), (b), and (c) are representative curves for red oak for the flame spread, the thermocouple temperature at the 24.0-ft (7.32-m) location, and the optical density.

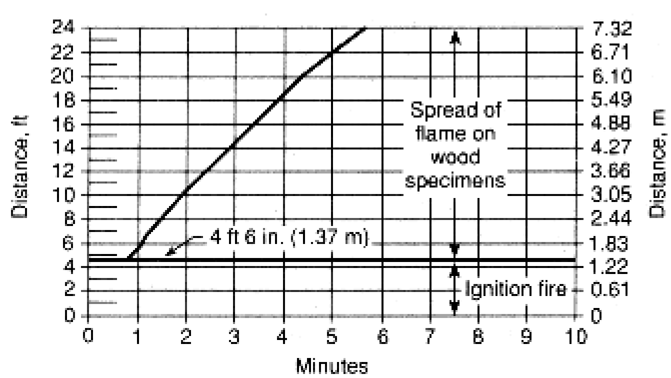

Figure 4-11(a) Representative curve of flame spread for red oak.

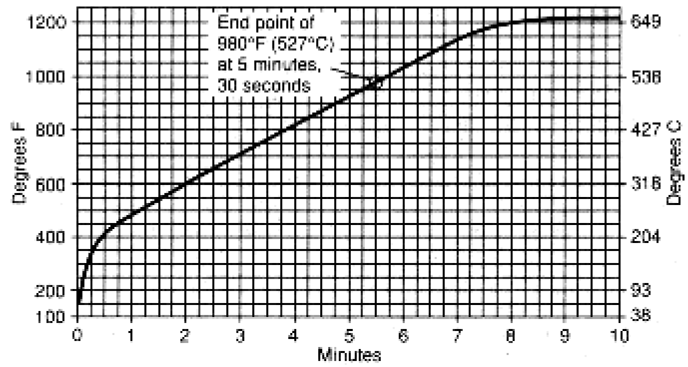

Figure 4-11(b) Representative curve of temperature at the 24.0-ft (7.32-m) location for red oak specimen.

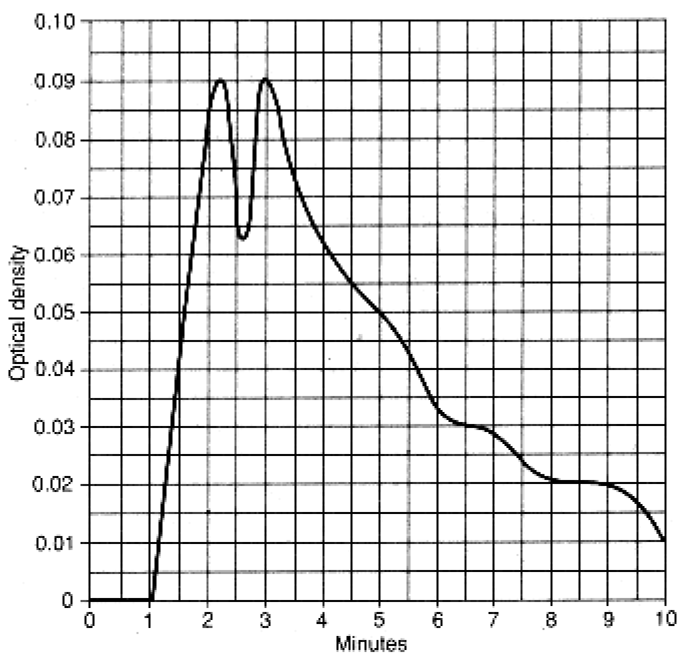

Figure 4-11(c) Representative curve of optical density for red oak.

4-12 Specimen Testing.

Following the calibration test(s) for red oak, a similar test or tests shall be conducted on specimens of 0.25-in. (6-mm) mineral-fiber/cement board. The temperature readings shall be plotted separately on coordinate paper. Figure 4-12 is a representative curve for mineral-fiber/cement board for the temperature recorded by the thermocouple at the 24.0-ft (7.32-m) location.

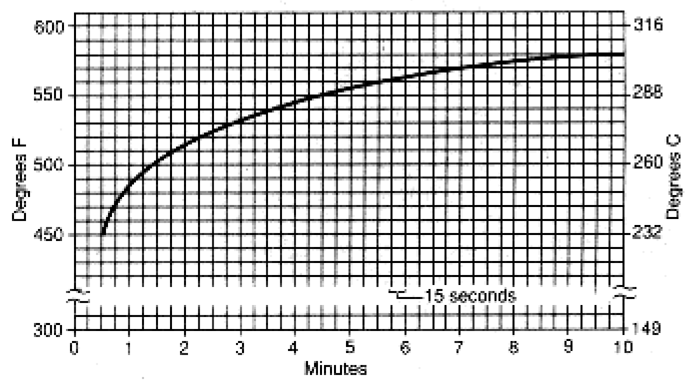

Figure 4-12 Representative curve of temperature at the 24.0-ft (7.32-m) location for mineral-fiber/cement board.

Chapter 5 Test Procedure

5-1 Procedure.

5-1.1

The cable tray and supports shall be placed in the test chamber as shown in Figure 2-1.1(b) and described in 2-1.5 and 2-1.6 with the end 1.0 in. (25 mm) downstream from the centerline of the burners.

5-1.2

The furnace shall be preheated as described in Section 4-7.

5-1.3

The furnace shall be cooled as described in Section 4-8.

5-1.4

The specimens shall be installed as described in Section 3-1.

5-1.5

The removable test chamber top shall be placed in position on top of the furnace side ledge.

5-1.6

The test equipment shall be adjusted and conditioned as described in Sections 4-2, 4-4, 4-5, and 4-7 (with the open-cable test specimens in place).

5-1.7

The test gas flame shall be ignited. The distance and time of maximum flame front shall be observed and recorded. The test shall be continued for 20 minutes.

5-1.8

The photoelectric cell output shall be recorded immediately prior to the test and continuously during the test.

5-1.9

The gas pressure, the pressure differential across the orifice plate, and the volume of gas used shall be recorded for the duration of the test.

5-1.10

After the gas supply to the ignition flame is shut off, smoldering and other conditions within the furnace shall be observed and recorded, and the specimens then shall be removed for examination.

Chapter 6 Report

6-1 Report Layout.

The report shall include all of the following for each test:

(a) A detailed description of the open-cable specimens tested;

(b) The number of lengths used as specimens for the test;

(c) The graph of flame distance beyond 4.5 ft (1.4 m) versus time for the duration of the test. Figure 6-1(a) is a representative flame spread curve. The graph shall also show the representative flame spread curve of red oak [*see Figure 4-11(a)*];

(d) The graph of the optical density of the smoke generated during the test versus time for the duration of the test:

$$\text{Optical density} = \log_{10} T_0/T$$

where T_0 is the initial light transmission and T is the light transmission during the test, which varies with the amount of smoke. Figure 6-1(b) is a representative smoke curve. The graph shall also show the representative optical density curve of red oak [*see Figure 4-11(c)*];

(e) The peak and average optical density measured and calculated for the entire test period;

(f) Observations of the condition of the test specimens after completion of the test; and

(g) The weight (mass) of nonmetallic components normalized to a figure based on 1000 ft (300 m) of tray length. For example, if the weight (mass) of a 1-ft (0.3-m) length of specimen cable, minus the metallic-component weight, is 0.016 lb (0.0073 kg), and there are 15 cables in the tray, the normalized value is $0.016 \times 15 \times 1000 = 240$ lb per 1000 ft of tray (32.85 kg per 300 m of tray).

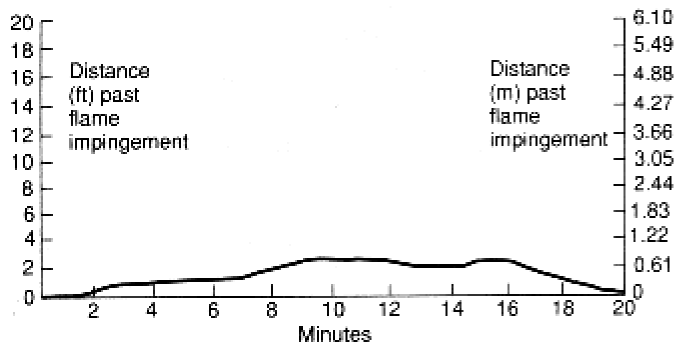

Figure 6-1(a) Representative flame spread curve of test specimen.

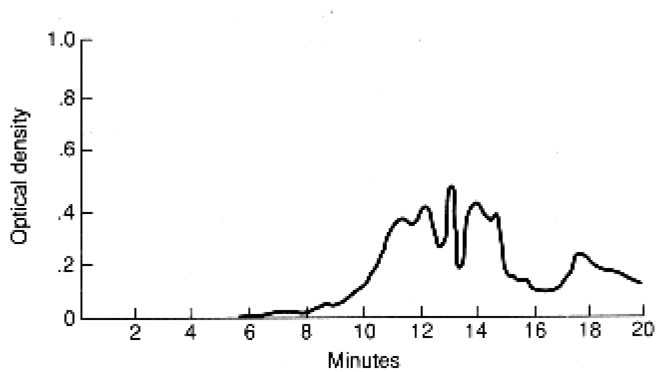

Figure 6-1(b) Representative optical density curve of test specimen.

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 70, *National Electrical Code,* 1993 edition.

NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, 1990 edition.

7-1.2 Other Publication.

7-1.2.1 ASTM Publication. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187.

ASTM D4442, *Test Methods for Direct Moisture Content Measurement of Wood and Wood-Base Materials*, 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-1-4

For procedures for determining the fire-resistive performance of building construction assemblies incorporating electrical wiring and cables, see NFPA 251, *Standard Methods of Fire Tests of Building Construction and Materials*.

A-2-1.1

The operation and calibration of this equipment is based on the use of A. P. Green G-26 refractories. A glass acceptable for the double-pane, pressure-tight observation windows is Vycor 100-percent silica glass, nominally 0.25 in. (6 mm) thick, or an equivalent.

A-2-1.2

Water-cooled structural-steel tubing may be permitted to be used for this purpose.

A-2-1.3

The operation and calibration of the equipment is based on the use of A. P. Green G-26 refractories.

A-2-2.1

An acceptable light source is a General Electric Model 4405 12-V sealed-beam clear auto spot lamp. A meter that may be permitted to be used for a photoelectric cell is a Weston Instruments No. 856BB photronic cell with an overall light-to-cell path length of 36.0 in. ± 2.0 in. (914 mm ± 51 mm).

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 251, *Standard Methods of Fire Tests of Building Construction and Materials*, 1990 edition.

NFPA 263

1994 Edition

Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products

1994 Edition

This edition of NFPA 263, *Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products*, was prepared by the Technical Committee on Fire Tests 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 263

NFPA 263 was developed originally in 1986. The 1994 edition reflects some minor changes that were made for clarity and updating of certain testing procedures. These changes involve the method of securing the specimen, control of the air supply and pilot burner, and calibration of the burner.

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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.

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 where such documents are not available. The Committee shall 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; and act in a liaison capacity between NFPA and the committees of other organizations writing fire test standards. The Committee shall not be responsible for fire tests that are used to evaluate extinguishing agents, devices, or systems.

NFPA 263
Standard Method of Test for
Heat and Visible Smoke Release Rates
for Materials and Products

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 G.

NOTE: Unless otherwise noted, distances in all figures are given in mm.

Chapter 1 General

1-1 Scope.

1-1.1*

This test method shall be used to determine the release rates of heat and visible smoke from materials and products when exposed to different levels of radiant heat using the test apparatus, specimen configuration, and procedures described by this test method.

1-1.2

The method provides for radiant thermal exposure of a specimen both with and without a pilot. Piloted ignition is permitted to be effected by direct flame impingement on the specimen (piloted point ignition) or by placing the pilot to ignite gases evolved by pyrolysis of the specimen.

1-1.3

Heat and smoke release are measured from the moment the specimen is injected into a controlled exposure chamber. The measurements are continued during the period of ignition (and progressive flame involvement of the surface in the case of point ignition) and to such a time that the test is terminated.

1-1.4

The method tests materials and products under a constant, imposed, external heat flux that shall be permitted to be varied from zero to 100 kW/m^2 (9.3 kW/ft^2).

1-1.5

This standard is intended to measure and describe the properties of materials, products, or assemblies in response to heat and flame under controlled laboratory conditions and shall not be used to describe or appraise the fire hazard or fire risk of materials, products, or assemblies under actual fire conditions. However, results of this test shall be permitted to be used as elements of a fire risk assessment that takes into account all of the factors that are pertinent to an assessment of the fire hazard of a particular end use.

1-2 Significance.

1-2.1

The test method provides a description of the behavior of material and product specimens under a specified fire exposure, in terms of the release rate of heat and visible smoke. The change in behavior of materials and products with change in heat-flux exposure shall be permitted to be determined by testing specimens in a series of exposures that covers a range of heat fluxes.

1-2.2

The data obtained for a specific test describe the rate of heat and smoke release of the specimen when exposed to the specific environmental conditions and procedures used in performing that test.

1-2.3

The entire exposed surface of the specimen will not be burning during the progressive involvement phase when piloted point-ignition (impingement) procedures are used. During the period of progressive surface involvement, release rates of heat and smoke are “per m^2 of original exposed surface area,” not “per m^2 of flame-involved surface.”

1-2.4

The rates of both heat and smoke release are calculated per m^2 of original surface area exposed. If a specimen swells, sags, delaminates, or otherwise deforms so that the exposed surface area changes, calculated release rates shall correspond to the original area, not to the new surface area.

1-2.5

Heat release values depend on the mode of ignition. Gas-phase ignition gives a more dimensionally consistent measure of release rate when very rapid or immediate flame involvement of the specimen’s surface occurs. However, piloted point ignition allows release-rate information to be obtained at external heat flux from zero up to that required for satisfactory gas-phase ignition, usually over 20 kW/m^2 (1.85 kW/ft^2) external exposure. No correlation between the two modes of piloted ignition has been established.

1-2.6

Release rates depend on many factors, some of which cannot be controlled. Samples that produce a surface char, a layer of adherent ash, or those that are composites or laminates sometimes will not attain a steady-state release rate. Thermally thin specimens (i.e., specimens whose unexposed surface changes temperature during period of test) will not attain a steady-state release rate. Therefore, release rates for a given material will depend on how the material is used, its thickness, and method of mounting, for example.

1-2.7

Heat release values are for the specific specimen size (exposed area) tested. Results are not able to be scaled directly to different exposed surface areas for some products.

1-2.8

The method is limited to specimen sizes of materials described in Section 4-1 and to products from which a test specimen can be taken that is representative of the product in actual use. The test is limited to exposure of one surface; the exposed surface can be either vertical or horizontal. A heat release rate of 8 kW, which is equivalent to 355 kW/m^2 (33 kW/ft^2) for 150 mm × 150 mm (5.9 in. × 5.9 in.) vertical specimens, or 533 kW/m^2 (49.5 kW/ft^2) for 100 mm × 150 mm (3.9 in. × 5.9 in.) horizontal specimens, shall not be exceeded. Combustion can occur above the stack at burning rates greater than these.

1-2.9

No general relationship between release rate values obtained from horizontally and vertically oriented specimens has been established. Specimens shall be tested in the orientation of the material in its end use condition. To provide additional information, specimens that melt and drip in vertical orientation also shall be tested horizontally.

1-2.10

Release rate measurements provide useful information for product development by giving a quantitative measure of specific changes in fire performance caused by product modifications.

1-3 Summary of Method.

The specimen to be tested is injected into an environmental chamber through which a constant flow of air passes. The specimen's exposure is determined by a radiant heat source adjusted to produce the desired total heat flux on the specimen. The specimen shall be permitted to be tested so that the exposed surface is horizontal or vertical. Combustion can be initiated by non-piloted ignition, piloted ignition of evolved gases, or point ignition of the surface. The changes in temperature and optical density of the gas leaving the chamber are monitored, from which data the release rates of heat and visible smoke, as defined in Sections 6-1 and 6-2, are calculated.

1-4 Definitions and Terms.

Gas-Phase Ignition. Ignition of pyrolysis products leaving a heated surface by a pilot flame or other ignition source that does not impinge on, nor significantly affect (e.g., by re-radiation), the heated surface.

Shall. Indicates a mandatory requirement.

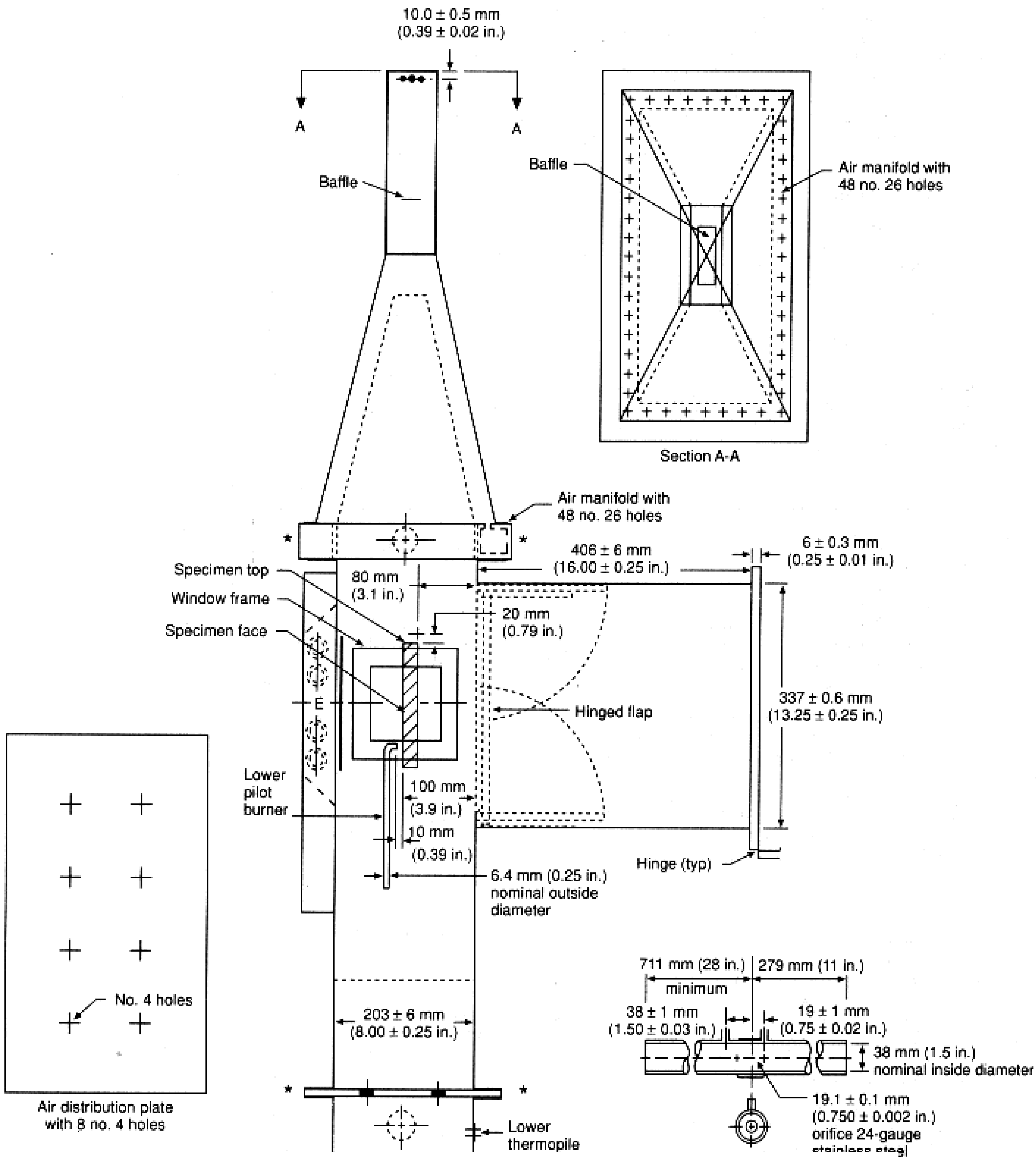
Should. Indicates a recommendation or that which is advised but not required.

SMOKE Unit. The concentration of smoke particulates in a cubic meter of air that reduces the percent transmission of light through a 1-meter path of 10 percent. SMOKE = Standard Metric Optical Kinetic Emission.

Chapter 2 Test Apparatus

2-1* Test Apparatus.

A release rate apparatus used to determine release rates of heat and smoke by this test method is shown in Figures 2-1 and 2-2. All exterior surfaces of the apparatus, except the holding chamber, shall be insulated with 25-mm (0.98-in.) thick, low density, high temperature, fiberglass board insulation. A gasketed door through which the sample injection rod slides forms an airtight closure on the specimen hold chamber.

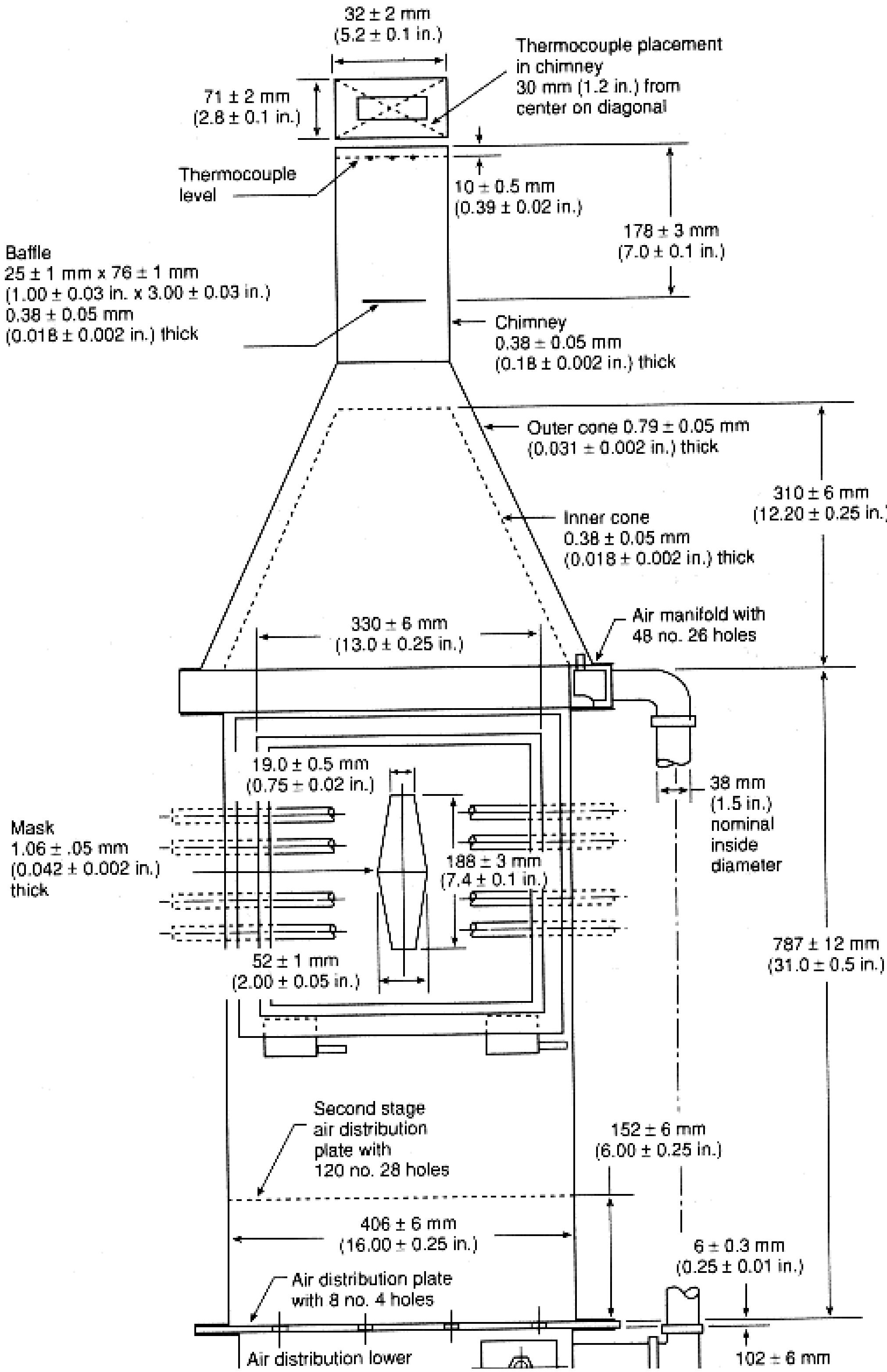


with bolts or clamps.

Figure 2-1 Rate of heat release apparatus.

2-2 Thermopile.

The temperature difference between the air entering the environmental chamber and that leaving shall be monitored by a thermopile having five hot and five cold, 24-gauge, chromel-alumel junctions. None of the thermocouple junctions shall be encased in any heat-conductive material. The thermocouple wires shall be stripped 15 mm (0.59 in.) so as to be free of any insulation. The stripped wires shall not touch except at the weld. There shall be no copper-chromel or copper-alumel junctions in the circuit. The loop to be formed by the thermocouple junction shall be 1.3 mm ± 0.3 mm (0.51 in. ± 0.01 in.) in diameter. The cold junctions shall be located in the pan below the air distribution plate. The hot junctions shall be located 10 mm (0.39 in.) below the top of the chimney. One of the hot junctions shall be placed at the center of the chimney's cross section, and the other four shall be placed on the chimney diagonals 0.30 mm (0.01 in.) from the center thermocouple.


32 ± 2 mm
(5.2 ± 0.1 in.)
Thermocouple placement
in chimney
30 mm (1.2 in.) from
center on diagonal
71 ± 2 mm
(2.8 ± 0.1 in.)
Thermocouple
level
10 ± 0.5 mm
(0.39 ± 0.02 in.)
178 ± 3 mm
(7.0 ± 0.1 in.)
Baffle
25 ± 1 mm x 76 ± 1 mm
(1.00 ± 0.03 in. x 3.00 ± 0.03 in.)
0.38 ± 0.05 mm
(0.018 ± 0.002 in.) thick
Chimney
0.38 ± 0.05 mm
(0.18 ± 0.002 in.) thick
Outer cone 0.79 ± 0.05 mm
(0.031 ± 0.002 in.) thick
310 ± 6 mm
(12.20 ± 0.25 in.)
Inner cone
0.38 ± 0.05 mm
(0.018 ± 0.002 in.) thick
330 ± 6 mm
(13.0 ± 0.25 in.)
Air manifold with
48 no. 26 holes
19.0 ± 0.5 mm
(0.75 ± 0.02 in.)
38 mm
(1.5 in.)
nominal
inside
diameter
Mask
1.06 ± .05 mm
(0.042 ± 0.002 in.)
thick
188 ± 3 mm
(7.4 ± 0.1 in.)
787 ± 12 mm
(31.0 ± 0.5 in.)
52 ± 1 mm
(2.00 ± 0.05 in.)
Second stage
air distribution
plate with
120 no. 28 holes
152 ± 6 mm
(6.00 ± 0.25 in.)
406 ± 6 mm
(16.00 ± 0.25 in.)
6 ± 0.3 mm
(0.25 ± 0.01 in.)
Air distribution plate
with 8 no. 4 holes
Air distribution lower
102 ± 6 mm

Thermopile
Airflow

Figure 2-2 Rate of heat release apparatus.

2-3 Thermal Inertia Compensator.

2-3.1

A compensator tab shall be made from 0.55-mm (0.21-in.) stainless steel sheet, 10 mm × 20 mm (0.39 in. × 0.79 in.). An 800-mm (31.5-in.) length of 24-gauge chromel-alumel, glass-insulated, duplex thermocouple wire shall be welded or silver soldered to the tab as shown in Figure 2-3.1 and the wire bent back so that it is flush against the metal surface.

2-3.2*

The compensator tab shall be mounted on the exhaust stack as shown in Figure 2-3.2(a) using a 6-32 round head machine screw, 12 mm (0.47 in.) long. Small [approximately 4.5 mm (0.18 in.) inside diameter, 9 mm (0.35 in.) outside diameter] washers between the head of the machine screw and the compensator tab shall be permitted to be added to give the best response to a square wave input. The “sharpness” of the square wave can be increased by changing the ratio of the output from the thermopile and compensator thermocouple, which is fed to the recorder. The ratio is changed by adjusting the 1 K ohm variable resistor (R_1) of the thermopile bleeder shown in Figure 2-3.2(b). When adjusting compensation, R_1 shall be maintained at as small a value as possible. Adjustment of the compensator shall be made during calibration.

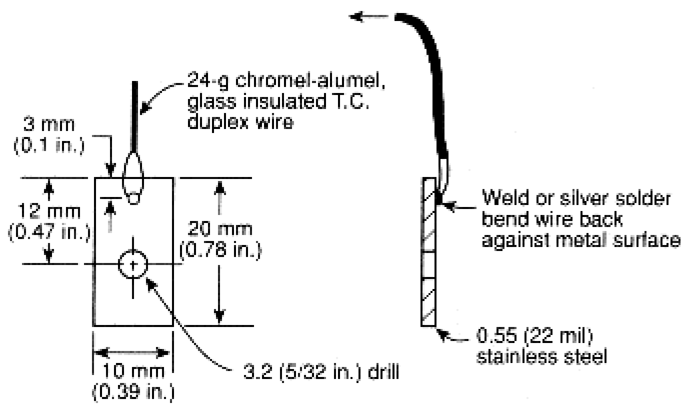


Figure 2-3.1 Compensator tab.

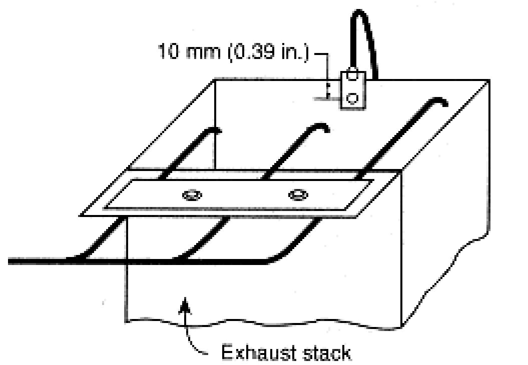


Figure 2-3.2(a) Compensator tab mount.

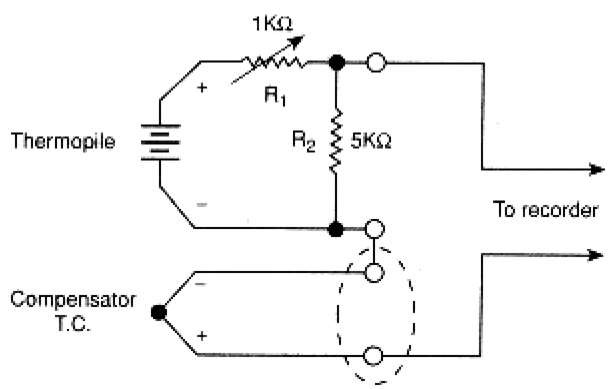
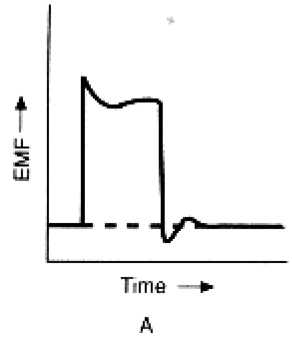
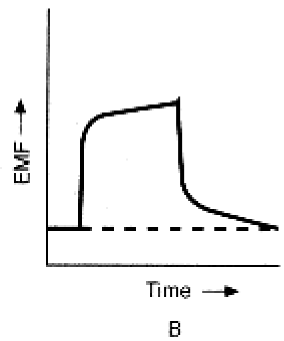


Figure 2-3.2(b) Wiring diagram.

2-3.3

Washers and variable resistor (R_1) shall be adjusted so that 90 percent full-scale response is obtained in 8 to 10 seconds. There shall be no overshoot, as shown in Figure 2-3.3(a). If an insufficient number of washers is added, or R_1 is too small, the output with square wave input will look like Figure 2-3.3(b); if too many washers are added and R_1 is too large, the output will look like Figure 2-3.3(a).





Figures 2-3.3(a) and 2-3.3(b) Square wave responses.

2-3.4

The output of the compensator shall be subtracted from the thermopile. The junctions enclosed in the dotted circle of Figure 2-3.2(b) shall be kept at the same constant temperature by electrically insulating the junctions and placing them on the pipe carrying air to the manifold, then covering them and the pipe with thermal insulation.

2-4 Smoke Monitor.

2-4.1*

A photometer [*see Figure 2-4.1(a)*] measures the percent of light transmitted through the gases leaving the apparatus. A photocell and circuitry shown in Figure 2-4.1(b) shall be used and calibrated as described in Section 3-2. The light source shall be a No. 82 miniature incandescent lamp operated at its recommended current (1.0 ampere).

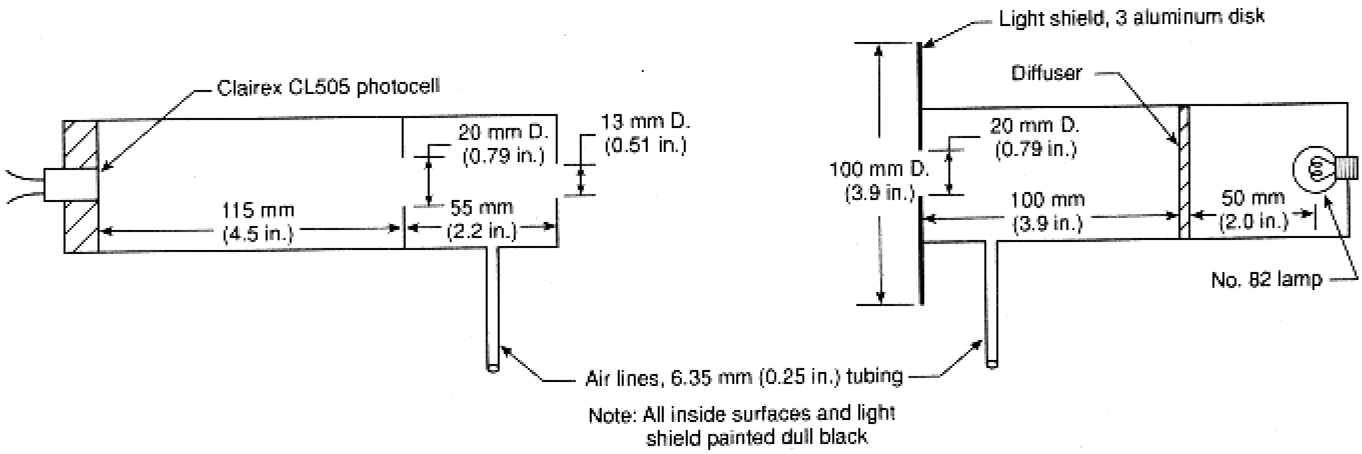


Figure 2-4.1(a) Smoke monitor.

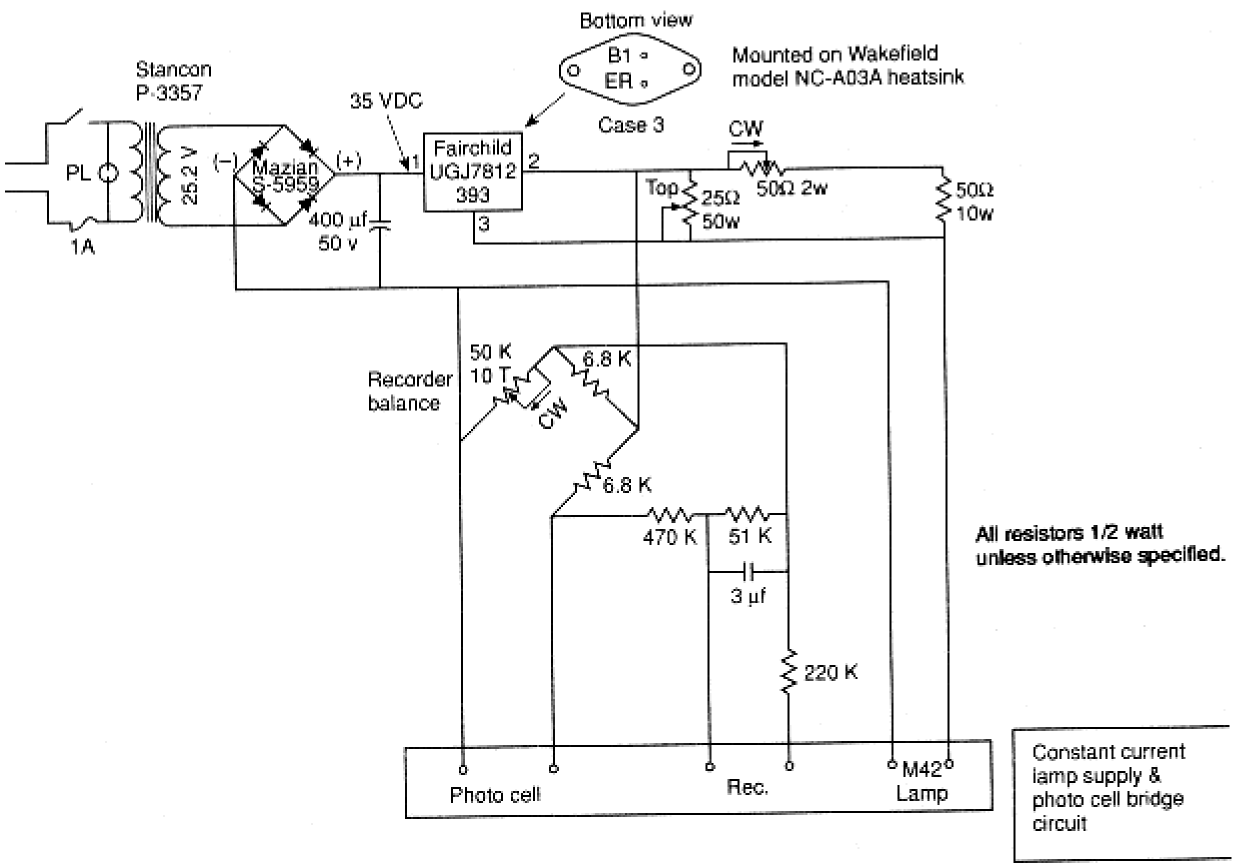


Figure 2-4.1(b) Constant current lamp supply and photocell bridge circuit.

2-4.2

The smoke monitor apparatus shall be mounted with the centerline 25 mm (0.98 in.) above the exhaust stack and centered parallel to the length of the opening. The two parts of the optical system bulb and photometer shall be 130 mm (5.1 in.) apart. A continuous flow of constant temperature air, approximately 0.004 m^3/min (0.013 ft^3/min), shall be maintained to the air lines to prevent smoke from entering the smoke monitor. The photometer shall be encased either in a black plastic tube or a white translucent plastic covered with black tape.

2-5* Radiation Source.

A radiant heat source for generating a flux up to 100 kW/m^2 (9.3 kW/ft^2), using four silicon carbide elements [Type LL, 508 mm × 15 mm (20 in. × 0.59 in.), nominal resistance 1.4 ohms] is shown in Figures 2-1, 2-2, and 2-5. The silicon carbide elements shall be mounted in the stainless steel panel box by inserting them through 16-mm (0.63-in.) holes in 1-mm (0.04-in.) thick ceramic fiber board. Location of the holes in the pads and stainless steel cover plates are shown in Figure 2-5. The truncated diamond-shaped mask of 1.07-mm ± 0.05 mm (0.04-in. ± 0.002 in.) stainless steel is added to provide uniform heat flux over the area occupied by the 150 mm × 150 mm (5.9 in. × 5.9 in.) vertical sample. A power supply of 12.5 kVA, adjustable from 0 to 270 volts, shall be required. The heat flux density over the specimen surface when set at 3.5 W/cm^2 (22.6 W/$in.^2$) shall be uniform within 5 percent, and shall be checked periodically and after each heating element change. Uniformity of heat flux density shall be determined by calorimeter measurements at the center and at the four corners of the specimen surface.

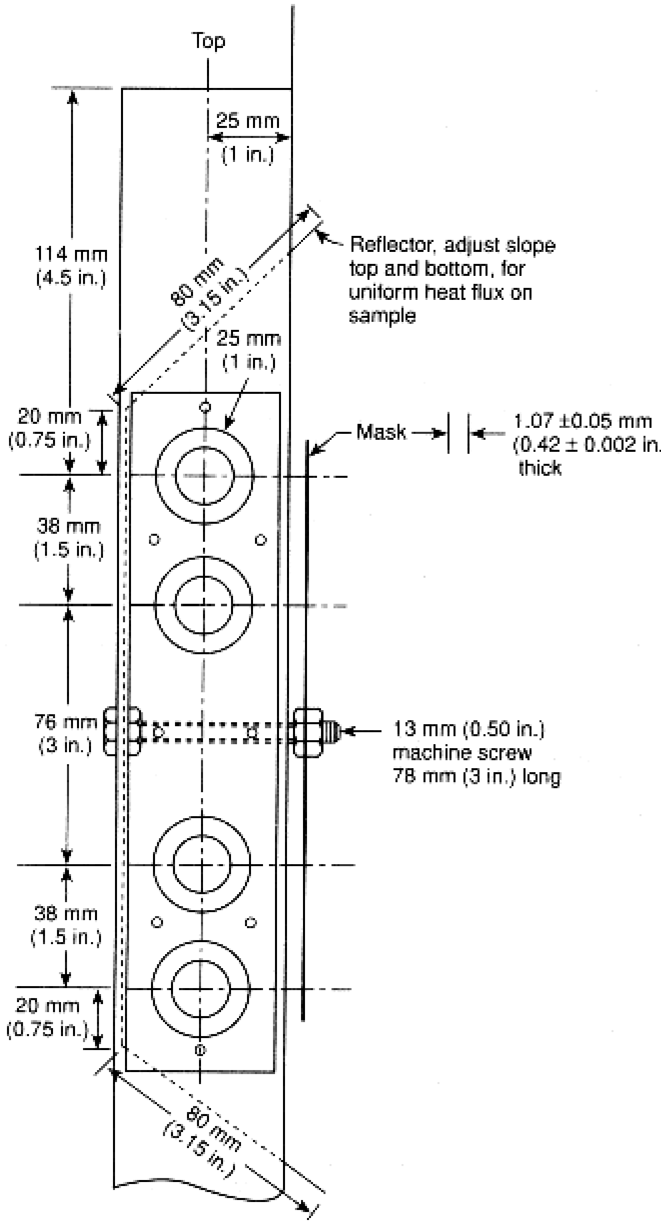


Figure 2-5 Side view—global radiant heat panel.

2-6 Air Distribution System.

2-6.1

The air entering the apparatus shall be 21°C to 24°C (70°F to 75°F) and set at approximately 0.04 m^3/sec (1.4 ft^3/sec) using an orifice meter. The orifice meter shall be comprised of a square-edged circular plate orifice 0.5 mm (0.02 in.) thick, located in a circular pipe with a diameter of 38 mm (1.5 in.), with two pressure-measuring points located 38 mm (1.5 in.) above and 20 mm (0.79 in.) below the orifice and connected to a mercury manometer. The inlet pipe shall remain 38 mm (1.5 in.) in diameter. (*See Figure 2-1*.)

2-6.2

The air entering the environmental chamber shall be distributed by a 6.3-mm (0.25-in.) thick aluminum plate having eight No. 4 drill holes, 51 mm (2 in.) from the sides on 102-mm (4-in.) centers, mounted at the base of the environmental chamber. A second plate of 18-gauge steel having 120 evenly spaced No. 28 drill holes shall be mounted 150 mm (5.9 mm) above the aluminum plate. A well-regulated supply of air at ambient temperature, 23°C ± 5°C (73.4°F ± 9°F) shall be required. The air supply shall be regulated by either a rotometer or an orifice plate placed properly in the air line and capable of operating from 0.03 m^3/sec to 0.05 m^3/sec (1.05 ft^3/sec to 1.77 ft^3/sec). (*See Figure 2-2*.)

2-6.3

The air supply manifold at the base of the pyramidal section shall have 48 evenly spaced No. 26 drill holes 10 mm (0.39 in.) from the inner edge of the manifold so that 0.03 m^3/sec (1.05 ft^3/sec) of air flows between the pyramidal sections and 0.01 m^3/sec (0.35 ft^3/sec) flows through the environmental chamber when total airflow to the apparatus is controlled at 0.04 m^3/sec (1.4 ft^3/sec).

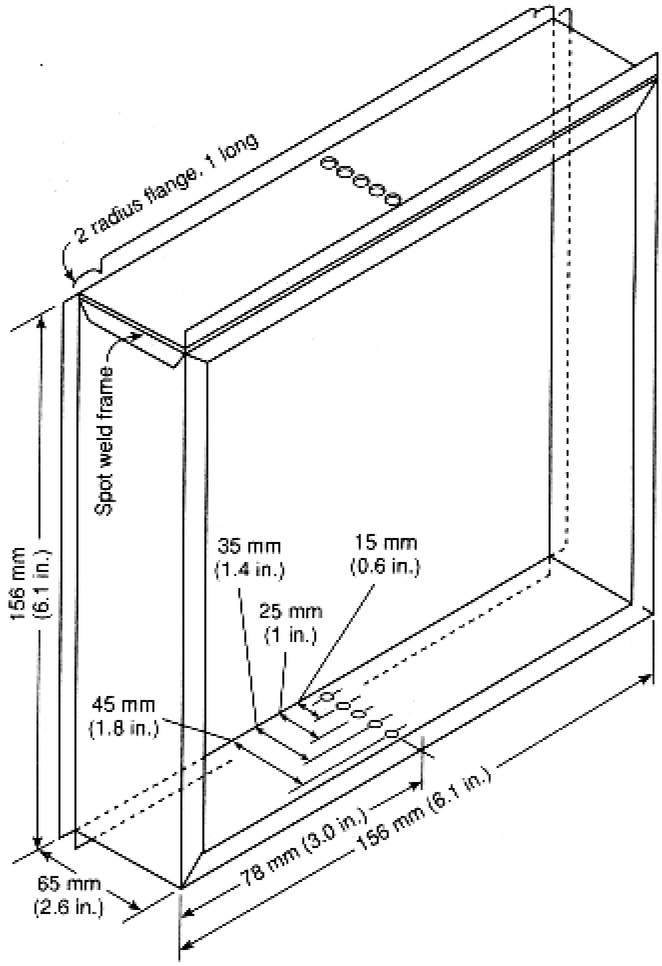
2-7 Exhaust Stack.

An exhaust stack, 133 mm × 70 mm (5.2 in. × 2.7 in.) in cross section and 254 mm (10 in.) long, fabricated from stainless steel, shall be mounted on the outlet of the pyramidal section. See Figures 2-1 and 2-2. A 25 mm × 76 mm (1 in. × 3 in.) plate of 0.5 mm ± 0.05 mm (0.02 in. ± 0.002 in.) gauge stainless steel shall be centered inside the stack, perpendicular to the airflow, 75 mm (3 in.) above the base of the stack.

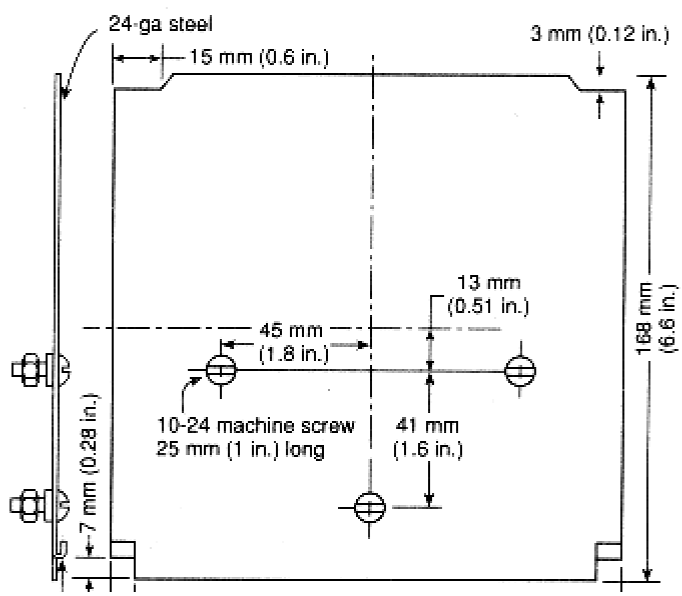
2-8 Specimen Holder.

2-8.1*

Vertical specimen holders shall be attached to the injection rod using the vertical support shown in Figure 2-8.1(a). Two different types of specimen holders shall be provided, one for 150 mm × 150 mm (5.9 in. × 5.9 in.) specimens to be tested in vertical orientation [*see Figure 2-8.1(a)*] and the other for 110 mm × 150 mm (5 in. × 5.9 in.) specimens in horizontal orientation [*see Figure 2-8.1(b)*]. Each holder shall be provided with a V-shaped spring pressure plate and a 12.7-mm (0.5-in.) backing plate of rigid insulation board having a density of 320 kg/m^3 ± 80 kg/m^3 and thermal conductivity of 0.08 W/m ± 0.01 W/m, °K. The position of the spring pressure plate shall be permitted to be changed to accommodate different specimen thicknesses by inserting a retaining rod in different holes of the specimen holder frame. Each holder shall also have two wires attached to the front of the holder to secure the face of the specimen in the holder.



2 radius flange, 1 long
Spot weld frame
156 mm
(6.1 in.)
35 mm
(1.4 in.)
15 mm
(0.6 in.)
25 mm
(1 in.)
45 mm
(1.8 in.)
65 mm
(2.6 in.)
78 mm (3.0 in.)
156 mm (6.1 in.)



24-ga steel
15 mm (0.6 in.)
3 mm (0.12 in.)
13 mm
(0.51 in.)
45 mm
(1.8 in.)
168 mm
(6.6 in.)
10-24 machine screw
25 mm (1 in.) long
41 mm
(1.6 in.)
7 mm (0.28 in.)

Figure 2-8.1(a) Vertical specimen holder.

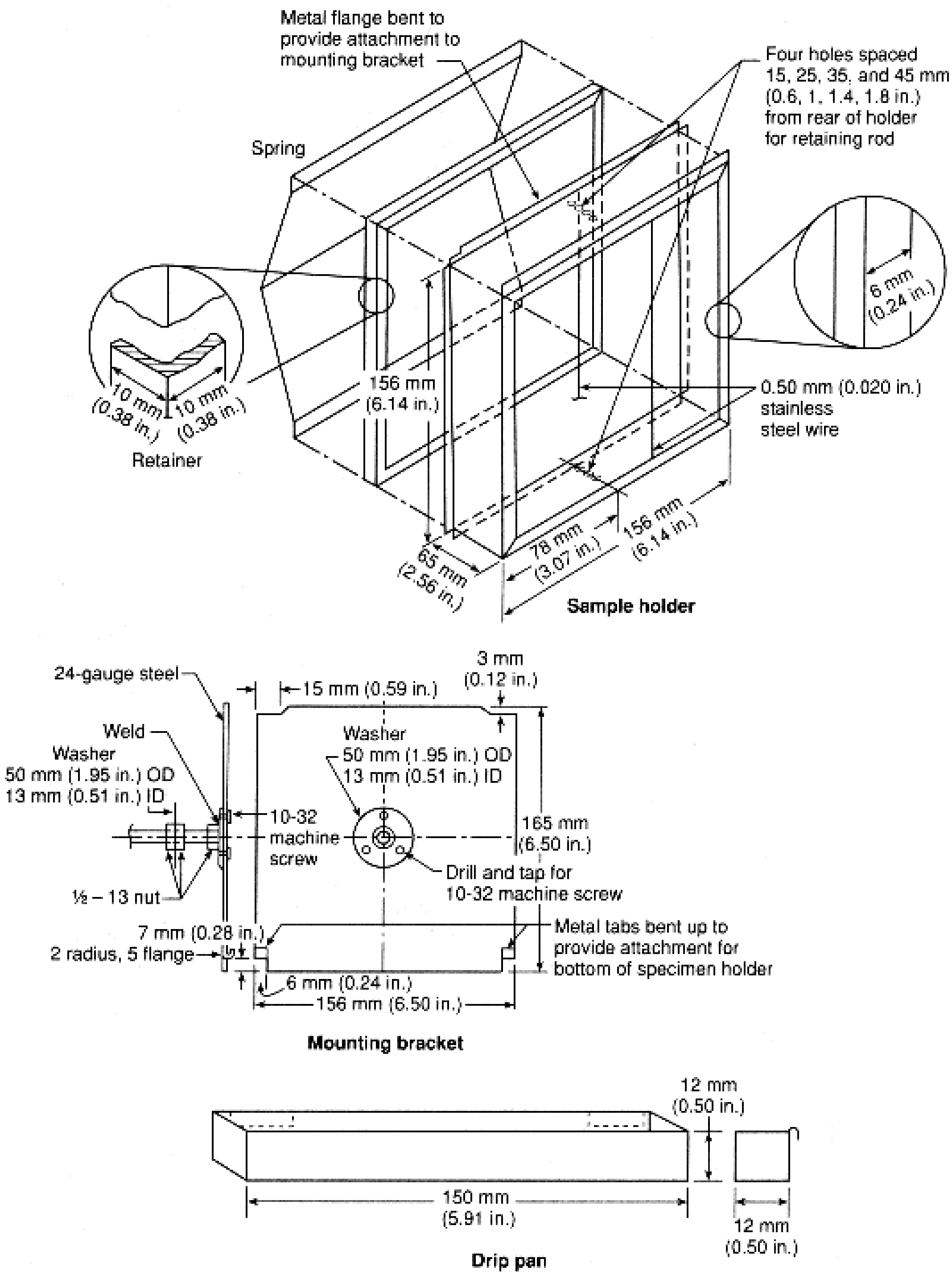


Figure 2-8.1(b) Heat release specimen holder, mounting bracket, and drip pan.

2-8.2 Drip Pan.

A drip pan shall be fabricated of stainless steel sheet 0.43 mm ± 0.05 mm (0.017 in. ± 0.002 in.) thick, as shown in Figure 2-8.1(b), and be attached to the specimen holder using the flanges shown in Figure 2-8.1(b). Drip pans shall be permitted to be used to prevent melting specimens from dripping into the lower pilot burner. Foil shall be permitted to be used to line the drop pan to facilitate cleaning after use.

2-9* Calorimeter.

A water-cooled, total heat flux density, foil-type gardon gauge calorimeter shall be used to measure the total heat flux for both horizontal and vertical specimens at the point where the center of the specimen's surface is located at the start of the test. The total-flux meters shall have view angles of 180 degrees and be calibrated for incident flux. When positioned to measure flux, the sensing surface of the flux meter for vertical specimens shall extend beyond any solid supporting device so that air heated by such a support does not contact the sensing surface of the flux meter.

2-10 Pilot Burners.

2-10.1 Lower Pilot Burner.

Pilot flame tubing shall be 6.3-mm (0.25-in.) outside diameter, 0.8-mm (0.03-in.) wall, stainless steel tubing. A methane-air mixture, 120 cm^3/min (304.8 $in.^3$/min) gas and 850 cm^3/min (2159 $in.^3$/min) air, shall be the fuel mixture fed to the lower pilot-flame burner. For the pilot flame described in 2-11.3, no air shall be used.

2-10.2 Spark Igniter.

A spark igniter shall be permitted to be installed to ensure that the lower pilot burner remains burning. A test is invalidated if the lower pilot burner becomes extinguished for any period that exceeds 3 seconds. A circuit for a satisfactory device is shown in Figure 2-10.

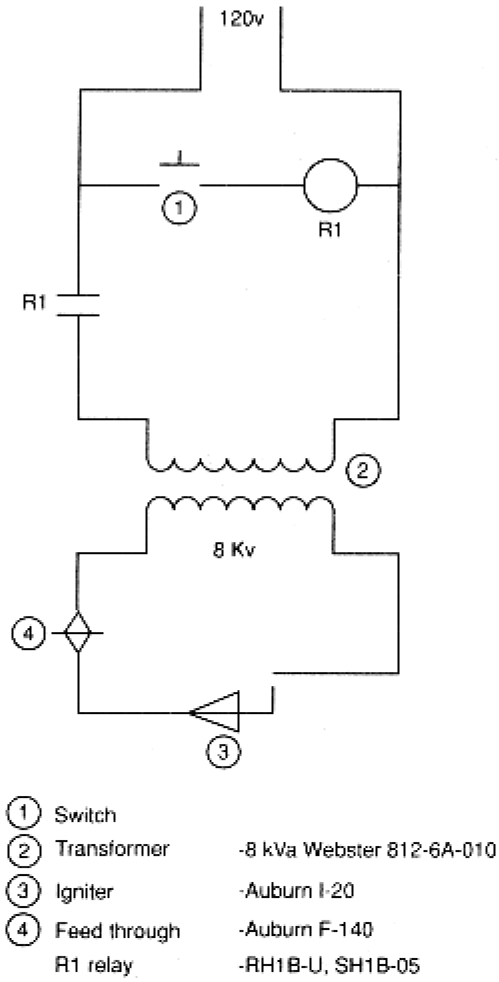


Figure 2-10 Lower pilot burner igniter schematic.

2-10.3 Pilot Burner for Vertical Impinging Flame.

The pilot burner shall be a straight length of 6.3-mm (0.25-in.) outside diameter, 0.8-mm (0.03-in.) wall, stainless steel tubing 360 mm (14.2 in.) long. One end of the tubing shall be closed, and there shall be three No. 40 drill holes, 60 mm (2.4 in.) apart, drilled into the tubing for gas ports, all radiating in the same direction. The first hole shall be 5 mm (0.2 in.) from the closed end of the tubing.

2-11 Pilot Flame Positions.

2-11.1

In addition to piloted and non-piloted mode of operation, pilot ignition of a specimen shall be permitted to be accomplished by locating the pilot flame at different positions relative to the sample surface so that the flame might or might not impinge on the specimen's surface. The location chosen depends on the nature of ignition to be simulated by the test. In all piloted ignitions, the lower pilot flame size shall be that described in 2-10.1. Pilot positions are described in 2-11.2 through 2-11.4. Pilot ignition by an impinging flame shall be required when release rate information is needed at a heat flux below that at which the pyrolysis rate of the specimen can maintain a combustible gas phase. At heat fluxes above that producing a combustible gas mixture over the surface of the sample, either piloted point ignition or gas-phase ignition shall be permitted to be used. In gas-phase ignition, surface involvement is usually very rapid, eliminating the progressive-involvement phase of the release rate curve. If the rate of surface involvement at a given flux is to be observed, piloted point ignition shall be used.

2-11.2 Pilot Ignition — Vertical Specimen with Impinging Flame.

The position of the end of the pilot burner tubing shall be 10 mm (0.39 in.) from and perpendicular to the exposed vertical surface of the specimen. The centerline at the outlet of the burner tubing shall intersect the vertical centerline of the sample 5 mm (0.2 in.) above the lower edge of the specimen. An upper, non-impinging pilot burner also shall be used.

2-11.3 Piloted Ignition — Vertical Specimen without Impinging Flame.

The pilot burner shall be a straight length of 6.3-mm (0.25-in.) outside diameter, 0.8-mm (0.03-in.) wall, stainless steel tubing 360 mm (14.2 in.) long. One end of the tubing shall be closed, and there shall be three No. 40 drill holes, 60 mm (2.4 in.) apart, drilled into the tubing for gas ports, all radiating in the same direction. The first hole shall be 5 mm (0.2 in.) from the closed end of the tubing. The tube shall be inserted into the environmental chamber through a 6.6-mm (0.26-in.) hole drilled 10 mm (0.39 in.) above the upper edge of the window frame. The tube shall be supported and positioned by an adjustable Z-shaped support mounted outside the environmental chamber, above the viewing window. The tube shall be positioned above and 20 mm (0.79 in.) behind the exposed upper edge of the specimen. The middle hole shall be in the vertical plane perpendicular to the exposed surface of the specimen, which passes through its vertical centerline, and shall be pointed toward the radiation source. Fuel gas to the burner shall be methane or natural gas with at least 90 percent methane. Flow of fuel gas shall be adjusted to produce flame lengths of 25 mm (1 in.). An air-gas mixture shall not be used for this pilot burner.

2-11.4 Piloted Ignition — Horizontal Specimen with Impinging Flame.

Normal position of the end of the burner tubing is 10 mm (0.39 in.) above and perpendicular to the exposed horizontal surface of the specimen. The centerline at the outlet of the burner intersects the center of the specimen.

Chapter 3 Calibration of Equipment

3-1 Calibration.

3-1.1 Calibration Burner.

A calibration burner, as shown in Figure 3-1.1, shall be provided that fits over the end of the pilot flame tubing with a gastight connection.

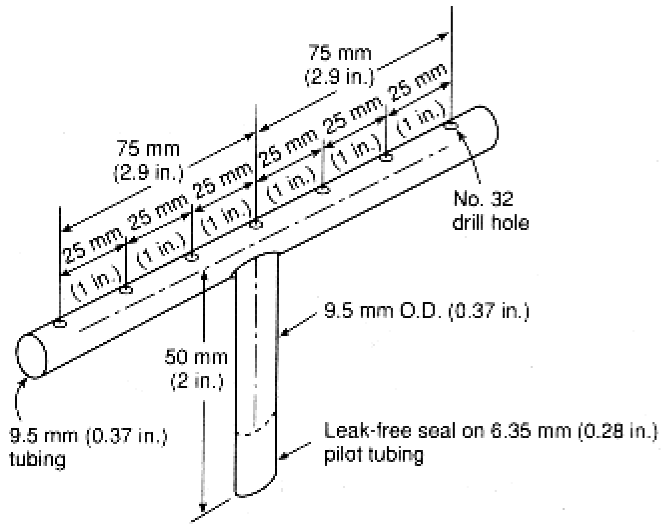


Figure 3-1.1 Calibration burner.

3-1.2 Calibration Gas.

Methane of at least 99 percent purity shall be used for calibration purposes.

3-1.3 Wet Test Meter.

A wet test meter accurate to 0.2 L/min (0.007 ft^3/min) shall be provided to measure the gas flow rate to the calibration burner. Prior to usage, the wet test meter shall be leveled and filled with distilled water to the tip of the internal pointer.

3-1.4 Calibration Gas Manifold.

3-1.4.1 A manifold shall be provided upstream of the wet test meter to control calibration gas flow. The manifold shall have four flow orifices controlled by needle valves that are preset to provide calibration gas at approximate (uncorrected for the presence of water vapor) flow rates of 1, 4, 6, and 8 L/min (0.035, 0.140, 0.210, and 0.280 ft^3/min) as indicated by revolution rate (measured by a stopwatch accurate to 1 second) of the wet test meter. Output from each of the four flow orifices shall be controlled by a toggle on/off valve and be plumbed into a single flow line so that the calibration gas flow rate to the calibration burner can be set at either 1, 4, 6, or 8 L/min (0.035, 0.140, 0.210, or 0.280 ft^3/min).

3-1.4.2 The actual corrected value, F, of each of the flow rates shall be determined to an accuracy of 0.2 L/min (0.007 ft^3/min), and these corrected values shall be used for calibration calculations.

3-1.5 Calibration Procedure.

3-1.5.1 The lower pilot burner shall be replaced with the calibration burner.

3-1.5.2 A wet test meter shall be installed. It shall be ensured that the test meter is leveled and filled with distilled water. The ambient temperature and pressure of the water shall be based on the internal wet test meter temperature.

3-1.5.3 The air distribution system shall be turned on.

3-1.5.4 The radiant heat source shall be turned on, and it shall be ensured that the heat flux density is 3.50 W/cm^2 ± 0.05 W/cm^2.

3-1.5.5 Using the calibration gas manifold, the baseline flow rate of 1 L/min (0.035 ft^3/min) of methane shall be set for the calibration burner, and the burner shall be lighted. The thermopile baseline voltage shall be measured.

3-1.5.6 Immediately prior to recording the thermopile outputs in 3-1.5.7, the chamber shall be preconditioned at a methane flow rate of 8 L/min (0.280 ft^3/min). The thermopile output for this step shall not be recorded, as it is part of the calibration.

3-1.5.7 The gas flow to the burner shall be increased to a higher flow rate and then decreased to the baseline flow rate. After 2 minutes of burning at each rate, the thermopile output (millivolts) shall be monitored for a 10-second period, the average reading shall be recorded, and the flow rate shall be decreased to the baseline flow of 1 L/min (0.035 ft^3/min). This sequence of increasing and decreasing the methane flow rate shall be as follows: 1-4-1-6-1-8-1-6-1-4 L/min (0.035–0.0140–0.035–0.210–0.035–0.0280–0.035–0.0210–0.140 ft^3/min).

3-1.6

The calibration factor shall be computed for each upward rate step (i.e., 1-4-1-6-1-8-1-6-1-4 L/min (0.035–0.0140–0.035–0.210–0.035–0.0280–0.035–0.0210–0.140 ft^3/min) according to the following formula:

$$k_h = 23.5 \times T_a \times \frac{273}{760} \times \frac{(P - P_v)}{(V_1 - V_o)} \quad \frac{(F - F_o)}{\text{kW/m}^2 - \text{mv}}$$

NOTE: The constant used in the above equation is derived as follows: 23.5 = (Heat content of methane @ STP, 31.176 Btu•L) × (conversion factor of 0.0176 kW•min/Btu)/(area of a specimen, 0.02323 m^2).

where:

F = Corrected upper flow rate of calibration gas [L/min (either 4, 6, or 8)].

F_o = Corrected baseline flow rate of methane [L/min (approx. 1 L/min)].

P = Ambient atmospheric pressure (mm Hg).

P_v = Water vapor pressure of wet test meter water temperature (mm Hg).

T_a = Ambient temperature (°K).

V_1 = Thermopile voltage at upper flow rate (mv).

V_o = Thermopile voltage at baseline flow rate (mv).

3-1.7

The five results shall be averaged and the percent relative standard deviation shall be computed. If the percent relative standard deviation is greater than 5 percent, the determination shall be repeated. If it is less than 5 percent, the average shall be used as the calibration factor.

3-2 Smoke Photometer.

3-2.1

Four neutral-density filters having accurately known optical densities of approximately 0.1, 0.2, 0.4, and 1.0 shall be used to calibrate the smoke photometer. The output of the photometer circuit shall be “zeroed” with no filter or smoke in the light path (zero absorbance). Each of the filters described above then shall be alternately placed in the light path, and, finally, the light path shall be completely obscured (zero percent transmission). A plot of percent transmission (% *T*) versus recorder output shall be made. For the photometer in Section 2-4, this will not be a straight line. Using the relationship, optical density = log (100/% *T*), a curve of values of optical density (absorbance) versus recorder output shall be constructed.

3-2.2

The optical density of the neutral density filters shall be determined at a wavelength of 580 mm (22.6 in.).

3-2.3

After the optical density versus recorder output relationship has been determined, minor variations due to aging of the light source, or its replacement, shall be compensated for by adjusting the 50-ohm, 2-watt resistor to produce the same chart reading for a given neutral density filter.

3-2.4

The recorder’s sensitivity shall be adjusted so that a full-scale chart reading is produced by a change in percent transmission of (approximately) 100 percent to 30 percent.

3-3 Flux Uniformity.

Uniformity of flux over the specimen shall be periodically checked and also checked after each heating element change to determine if it is within acceptable limits of ± 5 percent.

Chapter 4 Test Specimens

4-1 Specimen Preparation.

The standard size for vertically mounted specimens shall be 150 mm × 150 mm (5.9 in. × 5.9 in.) exposed surface with thickness up to 100 mm (3.9 in.). The standard size for horizontally mounted specimens shall be 100 mm × 150 mm (3.9 in. × 5.9 in.) exposed surface, up to 45 mm (1.8 mm) thick. Thin specimens such as wall or floor coverings shall be mounted in the same manner as used. For example, a wall covering to be glued to gypsum wall board shall be tested glued to a section of gypsum board using the same type of adhesive. The assembly shall be considered the specimen to be tested.

4-2 Specimen Conditioning.

Specimens shall be conditioned in standard laboration atmosphere [23°C (73.4°F) and 50 percent relative humidity] as described by Procedure A, ASTM D618, *Conditioning Plastics and Electrical Insulating Materials for Testing*.

4-3 Specimen Mounting.

Only one surface of a specimen shall be exposed during a test. A single layer of 0.025-mm (0.001-in.) thick aluminum foil shall be wrapped tightly on all unexposed sides with the dull side of the foil facing the specimen surface. The foil shall be continuous and shall not be torn. The retaining frame shall be placed behind the specimen between the back of the specimen and the pressure plate.

Chapter 5 Test Procedure

5-1

If piloted ignition is to be used, the pilot flame shall be lighted and its position, as described in Section 2-11, shall be checked.

5-2

The power supply to the radiant panel shall be set to produce the desired radiant flux. The flux shall be measured at the same point that the surface at the center of the specimen will occupy when positioned for test. The radiant flux shall be measured with the lower pilot flame displaced to the side of the environmental chamber and after airflow through the equipment is adjusted to the desired rate.

5-3*

The airflow to the equipment shall be set at 0.04 m^3/sec ± 0.001 m^3/sec [at atmospheric pressure and 23°C (73.4°F)]. The stop on the vertical specimen holder rod shall be adjusted so that the exposed surface of the specimen shall be positioned 100 mm (3.9 in.) from the entrance when injected into the environmental chamber.

5-4

Steady-state conditions, such that the radiant flux does not change more than 0.5 kW/m^2 (0.046 kW/ft^2) over a 10-minute period, shall be maintained before the specimen is inserted.

5-5

The specimen shall be placed in the hold chamber with the radiation shield doors closed. The airtight outer door shall be secured, recording devices started, and output of the thermopile and smoke particle detector set to “zero” on the recorder. “Zero” conditions are those existing at the time immediately before the specimen is injected. The specimen shall be retained in the hold chamber 60 sec ± 10 sec before injection.

5-6

When the specimen is to be inserted, the radiation doors shall be opened and the specimen inserted into the environmental chamber.

5-7

Unless immediate ignition occurs, a negative heat release will occur at elevated exposures due to heat absorption by the cold specimen holder. Data-acquisition devices shall have the capability of following these negative outputs. Correction for heat absorption by the holder is made by a blank run. (*See Section 5-10*.)

5-8

Injection of the specimen marks time zero. A continuous record of the output from the photometer circuit and thermopile shall be made during the time the specimen is in the environmental chamber.

5-9

Normal test duration time is 10 minutes. For specimens that are totally consumed in less than 10 minutes, the test shall be permitted to be terminated when heat and smoke particulate release have ceased.

5-10

A blank run (baseline) test shall be performed during which the specimen holder, without specimen, shall be injected and heat release versus time data shall be taken. At low heat fluxes, corrections for heat absorbed by the specimen holder are negligible, but at a heat flux over 10 kW/m^2 (0.93 kW/ft^2), a correction due to the specimen holder shall be permitted if necessary. (*See 6-1.2*.)

5-11

At least three determinations shall be made. If the release rate value or values being compared for a given specimen are outside the range described in B-1-2, a greater number of replicate determinations shall be required as given in B-1-3. (*See Appendix B*.)

Chapter 6 Calculations

6-1 Heat Release Rate.

6-1.1

Heat release rates shall be calculated from the chart reading of the thermopile output, the exposed surface area of the specimen, and the constant k_H that is obtained from calibration runs:

$$k_H = \frac{\text{heat release rate (kW)}}{\textit{chart reading}}$$

then:

heat release rate per unit area (kW/m^2) = k_H (chart reading)/A

where:

A = exposed surface area of specimen (m^2).

6-1.2

Heat release rates are determined from chart readings as a function of time. Sufficient points shall be permitted to be taken along the time axis to reproduce faithfully 0.10 cycle/sec fluctuations. Smoothed values every five seconds are adequate and shall be permitted to be taken less frequently when heat release rates change slowly. When blank run corrections (*see Section 5-10*) are greater than 3 percent of the maximum heat release rates, blank run corrections shall be applied to the observed values.

6-2 Smoke Release Rate.

6-2.1

Using the optical density versus chart-reading plot described in Section 3-2, values of optical density (*D*) shall be calculated at the same elapsed time selected for calculating heat release rates.

6-2.2

As described, air having a concentration of one SMOKE (Standard Metric Optical Kinetic Emission) unit per cubic meter (m^3) reduces the percent transmission (% *T*) of light through 1 meter of this air to 10 percent [i.e., optical density (absorbance) = 1.0].

6-2.3*

SMOKE release rate, expressed in SMOKE units per minute per m^2 of specimen's exposed surface area, shall be calculated as follows:

$$\text{SMOKE release rate} = \text{SRR} = \frac{D}{kLA} \times \frac{V_o}{t}$$

where:

k = absorption coefficient = 1.0 m^2/SMOKE.
D = optical density (absorbance) = log [100/(%T)].
L = light path = 0.134 m (stack width).
A = exposed surface area of specimen (m^2).
$\frac{V_o}{t}$ = flow rate of air (m^3/min) leaving apparatus.

$$\frac{V_o}{t} = \frac{V_i}{t} \times \frac{t_o}{T_i}$$

where:

$\frac{V_i}{t}$ = flow rate of air entering apparatus (m^3/min).
T_i, T_o = absolute temperature of air in and out of apparatus, respectively.

6-3 Cumulative Heat and Smoke Release.

Heat and visible smoke particles released between any two points in time are given by the area under the respective curves for release rate versus time between those points.

Chapter 7 Report

7-1

The report shall include the following:

(a) A description of specimen.

(b) The orientation of specimen and detailed description of mounting.

(c) The radiant heat flux to specimen, expressed in kW/m^2.

(d) The use of piloted or non-piloted ignition and location of pilot flame, and type of pilot if not standard.

(e) Data giving release rates of heat (in kW/m^2) and visible smoke (in $SMOKE/min/m^2$) as a function of time, either graphically or tabulated at intervals of no greater than 10 seconds.

(f) The use of piloted point ignition and the time at which total involvement is reached shall be noted.

(g) If melting, sagging, delaminating, or other behavior that affects exposed surface area or mode of burning occur, these behaviors shall be reported, together with the time at which such behaviors were observed.

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 ASTM Publication.

American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM D618, *Conditioning Plastics and Electrical Insulating Materials for Testing*, 1990.

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

Visible smoke is described in terms of the obscuration of transmitted light caused by combustion products released during the tests. The description is given in 6-2.2.

A-2-1

Fiberglass board insulation may be permitted to be an Owens-Corning flat duct board, type 475-FR; density, 65 kg/m^3 (4.0 lb/ft^3); thermal conductivity, 0.033 W/m^2 (0.003 W/ft^2), °K; thickness, 25 mm (0.98 in.) or its equivalent.

A-2-3.2

One or two washers should be adequate to obtain the best response to a square wave input.

A-2-4.1

The photocell shown in Figure 2-4.1(b) may be permitted to be a Clairex CL 505 photocell or one having a similar color response.

A-2-5

Silicon carbide elements are available from the Carborundum Co., Globar Division, Niagara Falls, New York.

If a heat flux of up to 100 kW/m^2 (9.3 kW/ft^2) is desired, a separate power supply for each pair of elements may be permitted to be used where maximum voltage is less than 270 volts.

A-2-8.1

The rigid insulation board may be permitted to be a Kaowool M-Board, Surface Rigidized, Babcock/Wilcox Refractories, Augusta, GA, or its equivalent.

A-2-9

A model R-8015-C radiometer for vertical specimens and a model P-8400-J pyroheliometer for horizontal specimens, available from Hy-Cal Engineering, Santa Fe Springs, CA, or their equivalents, should be used with water cooling and without quartz window.

A-5-3

Proper airflow to the equipment may be permitted to be set and monitored by (a) an orifice meter designed to produce a pressure drop of at least 200 mm (7.9 in.) of the manometric fluid, or (b) a rotometer (variable orifice meter) with a scale capable of being read to ± 0.0004 m^3/sec (0.014 ft^3/sec).

A-6-2.3

A major temperature correction (i.e., maximum difference in T_i and T_o) occurs when operating at a high heat flux and high heat release rates. At conditions of low heat release, an average temperature of effluent air (and therefore constant volumetric flow rate) can be assumed without significant error.

Appendix B Precision and Accuracy

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

B-1

The precision of the test method is still being established, although preliminary round-robin tests indicate the following:

B-1.1

Due to baseline “noise,” sensitivity of sensors, and repeatability of baseline setting, absolute values are no better than ± 0.03 kW for heat release and 0.025 SMOKE/min for smoke release rate. With permissible baseline drift and variation in setting, permissible baseline differences for 3-, 5-, and 10-minute heat and smoke release are ± 0.01, 0.018, and 0.03 MJ, and ± 0.10, 0.17, and 0.33 SMOKE, respectively. Note that the surface area for vertical and horizontal specimens is 0.0225 m^2 (0.242 ft^2) and 0.0150 m^2 (0.161 ft^2), respectively. Therefore, the repeatability for a heat release baseline setting for a horizontal specimen is 2.0 kW/m^2 (0.19 kW/ft^2).

B-1.2

For samples that burn from a constant surface area, the precision of the method can be expressed by the general equation:

$$S_{ti} = AX_i + B$$

where:

S_{ti} = overall precision as standard deviation for parameter I.

X_i = value of parameter I.

A, B = constants given in Table B-1.2.

Table B-1.2 Laboratory Reproducibility

Parameter	Units of S_{ti} and X_i	A	B Vertical	B Horizontal
Single laboratory				
Max. RHR	kW/m^2	0.07	1.3	2.0
10 min HR	MJ/m^2	0.04	1.3	2.0
Max. SRR	SMOKE/min m^2	0.13	4.5	6.8
10 min SR	SMOKE/m^2	0.05	15.0	22.0
Multilaboratory				
Max. RHR	kW/m^2	0.11	1.3	2.0
10 min HR	MJ/m^2	0.16	1.3	2.0
Max. SRR	SMOKE/min m^2	0.31	4.5	6.8
10 min SR	SMOKE/m^2	0.23	15.0	22.0

B-1.3

Additional round-robin tests are being conducted to get a better measure of reproducibility.

B-1.4

For materials or products that burn from a nonuniform surface due to warping, slumping, or melting, single laboratory standard deviation values for heat and smoke release can be 50 percent greater than those described in B-1.2. For such samples, at least five specimens should be tested. If two or more test values are greater by more than 50 percent of the standard deviation values in B-1.2, the test conditions or sample should be judged inappropriate for test by this method.

B-1.5

For materials whose self-propagating flux is greater than 0.0, repeatability of tests conducted at an incident flux [e.g., ± 3 kW/m^2 (0.28 kW/ft^2)] close to the specimen's self-propagating flux might be poor because small differences in operating conditions can result in a large change in release rates.

Appendix C Release Rate Calibration

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

C-1

The calibration data for heat release rates show a linear relationship between rate of heat release and millivolt output from the thermopile compensator thermocouples up to the recommended maximum of 8 kW. At heat release rates over 10 kW produced by a gas flame from a vertical 6.2-mm (0.14-in.) tube (not the calibration burner), flames can be seen above the chimney. Above this level of heat release, thermocouple output is no longer proportional to rate of gas flow. While flame height is lower for flames from a more diffuse source, such as from a specimen or the calibration burner, the recommended upper limit of heat release is 8 kW.

C-2

Methane is a convenient fuel for calibrating the apparatus for rate of heat release. Flow rates, and therefore, rates of heat release can be easily and accurately controlled for calibration. For methane, complete combustion can be assumed when calibration is conducted with the radiant panel off. Solid materials can also be used to check calibration in terms of total heat release. Samples of polymethyl-methacrylate have been burned and the cumulative heat release calculated from the area under the rate-of-heat-release versus time curve. When specimens of 58.0 g (2.05 oz) were burned, the total heat released from three determinations was 1390, 1421, and 1290 kJ, giving an average heat release of 1367 kJ. Cumulative heat released per unit mass, based on the average, is 23.5 MJ/kg. The theoretical net heat of combustion for this material is 21.1 MJ/kg. Based on these results, combustion efficiency is 93 percent, a reasonable value for polymethyl-methacrylate under normal burning conditions.

C-3

A typical calibration curve of chart reading versus percentage transmission for the smoke monitor is shown in Figure C-3(a). Points shown were experimentally determined using neutral-density filters described in Section 3-2. A smooth curve is drawn through the points, and values of optical density are calculated from selected points on the percentage transmission axis. Then a working curve of optical density versus chart reading is prepared as shown in Figure C-3(b). If data reduction is computer assisted, the relationship shown in Figure C-3(b) may be permitted to be converted to equation form using a power series:

$$Y = Ax + Bx^2 + Cx^3$$

where:

Y = optical density.
x = millivolt output.

A, B, and C = constants.

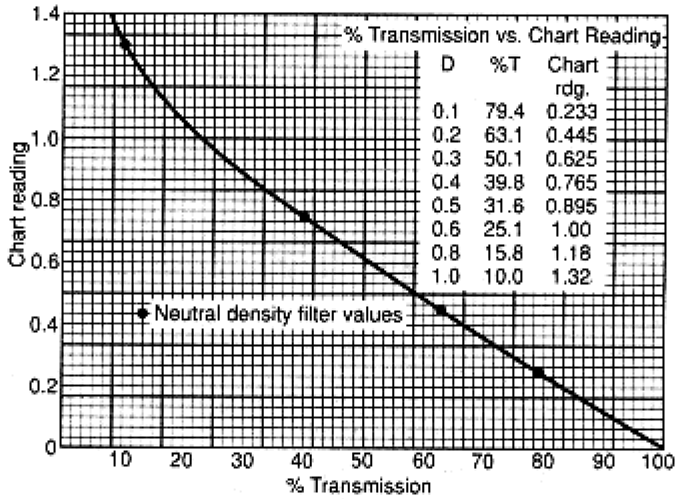


Figure C-3(a) Percentage transmission versus chart reading.

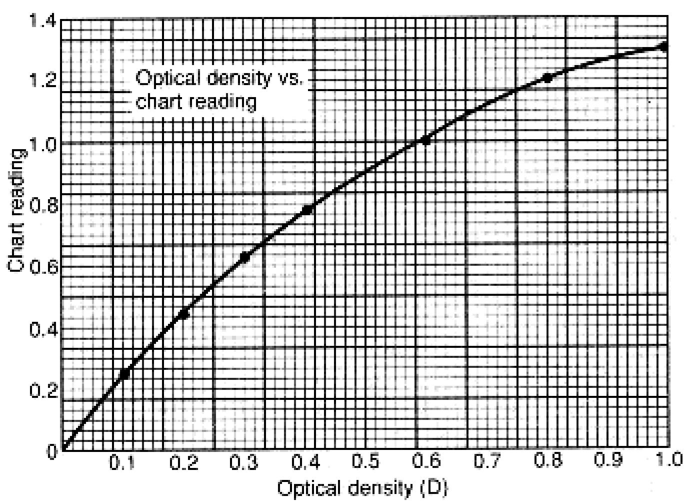


Figure C-3(b) Optical density versus chart reading.

C-4

The smoke monitor requires a 10- to 15-minute warm-up period to obtain a stable baseline. The condition of the detector then should be checked by inserting a 0.4 optical density filter in the light path and, if necessary, current flow should be adjusted to the lamp to give the same output as given during calibration. Normally, no adjustment is necessary.

C-5

Temperature of the effluent gases from the stack has no significant effect on the adjustment of the smoke monitor. No parts of the monitor are in contact with the effluent gases, and the elements of the monitor closest to the chimney, which can be subjected to low level radiant heat from the plume, are cooled by the purge air used to keep smoke from entering the monitor's openings.

Appendix D Flux Distribution

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

D-1

The distribution of radiant heat flux across the specimen's surface for both horizontal and vertical samples has been measured. Uniformity is achieved by the size and shape of the diamond-shaped mask (*see Section 2-5*), the bend on the top and bottom of the reflector behind the silicon carbide heating elements (*see Figure 2-5*), and a properly matched set of heating elements. When properly adjusted, a maximum difference of less than 4 kW/m^2 (0.37 kW/ft^2) is found over the area occupied by a 150 mm × 150 mm (5.9 in. × 5.9 in.) vertical specimen at 80 kW/m^2 (7.4 kW/ft^2) incident flux. Nonuniformity of flux over the area occupied by horizontal specimens is less than five percent of the average incident flux. Flux measurements over the vertical surface were made using a plate with nine covered holes slightly larger than the radiometer. The holes could be individually opened to admit and locate the radiometer at points corresponding to the corners, center, and edge of the specimen's surface. The plate fits over the opening covered by the radiation doors when closed. Flux measurements on a horizontal plane were made by placing the meter (*see Section 2-9*) at different positions on the horizontal specimen holder with the radiometer's surface in the same plane a specimen's surface would occupy. When checking the flux distribution, the 8-mm (0.3-in.) aluminum foil shield as specified in Section 4-3 should be used on the front and back edge of the specimen holder.

Appendix E Radiation Reflector for Horizontal Specimens

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

E-1

The best general purpose radiation reflector is that prepared from aluminum foil. Although it becomes coated with soot and, for some high heat release materials, melts during the course of a test, it provides a uniform, inexpensively renewable reflector that performs the task for which it was designed. The primary purpose of the reflector is to provide the desired incident flux to a horizontal specimen until the specimen is fire-involved. When a specimen burns at such a rate of heat and smoke release that the quality of the reflector is impaired, the influence of external radiation on release rates is small; the specimen "sees" the radiation from its own flame, not the externally applied flux. The only portion of the release rate curve that might be influenced by the change in quality of the reflector is the cool-down portion when flaming decreases to zero, a comparatively unimportant period of a release rate test.

Appendix F Commentary

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

F-1

Release rate is not a “property” of a sample in the same sense as are calorific value, density, etc. Except for liquids (or solids that melt and burn as liquids), release rates are not constant values, even when all external variables are constant; they are often discontinuous functions of exposure and, in practice and theory, are influenced by numerous external variables. There is no one value that uniquely describes the heat release of most items. In general, a dynamic characteristic is not a property of a material but a reflection of external driving forces and internal resistances to these forces.

F-2

Release rate data are obtained at a constant mass flow rate of air and constant externally applied flux for a specific test. The incident, or externally applied flux, is that flux to the gas-phase boundary generated by the specimen, not to the solid (or liquid) surface of the specimen.

F-3

A release rate test is not designed to simulate an actual fire. While it is theoretically possible to predict a sample’s performance in a real fire given adequate release rate data, a single release rate test simply measures certain characteristics at one, controlled, external exposure. For this reason, a single characteristic measured during a release rate test (e.g., maximum rate of heat release), taken by itself, could have little significance as a measure of general fire performance. Fire performance tests using conditions intended to simulate an actual fire usually measure the results of the individual characteristics that are individually measured by release rate tests. Therefore, use of release rate tests to describe performance in actual fires necessitates that all fire performance characteristics be considered and evaluated over a range of exposure conditions. While measurements of individual fire performance characteristics make direct interpretation of release rate data more complex, such data provide the advantage of some insight into which fire performance characteristics of a sample need improvement to upgrade the sample’s overall fire performance.

F-4

Using release rate tests, specimens can be examined at different exposure levels and their performance determined as a function of exposure level. This is a basically different approach to evaluating fire performance compared to the conventional performance tests. Using the conventional test, performance is determined at one set of exposure conditions and comparisons or ratings made on the basis of results at this test exposure. Extrapolation of data from single exposure tests is not advisable because performance does not change with temperature in the same way for different materials and products. Release rate tests provide a convenient means of getting information on performance at various exposure levels.

F-5

Release rate of visible smoke obtained using this test method is calculated from the optical density of the effluent gas stream. Smoke release is expressed using an arbitrarily defined unit, SMOKE (*see 6-2.2*). The SMOKE unit is used to give a quantitative description of visible smoke “concentration,” which is a direct function of optical density. By assuming an optical density value, [e.g., 0.82 (or 15 percent transmission)], as limiting visibility, the maximum light path (l) for visibility can be calculated:

$$l = D/kc$$

where:

D = optical density.
k = absorption coefficient (m^2/SMOKE) = 1.0 m^2/SMOKE.
c = concentration (SMOKE/m^3).

The visibility calculated in terms of l is based only on the optical properties of the smoke. The effect of eye irritants on visibility is not considered in this calculation.

F-6

Reliable results are dependent upon obtaining reproducible specimens. Rate of heat release is sensitive to slight differences in surface characteristics as well as physical and chemical properties on a micro-scale as well as macroscale.

F-7

This test method describes a standard procedure by which different parameters comprising combustibility can be separately evaluated.

F-8

A variety of materials and products can be tested by this procedure. The test has been applied to wall linings, ceiling tile, packaging materials, carpeting and other floor coverings, communication and electrical cable, plastic pipe and conduit, upholstery systems and furniture, foamed plastics and composites, and laminates of many types and uses.

The test is normally performed using the product in its end use configuration and orientation (vertical and horizontal). For example, a wall covering should be tested in a vertical orientation applied to the wall, (e.g., gypsum wallboard with the adhesive to be used in the field). For such nonthermally thick samples, the heat sink properties of the substrate or backing of the sample could have a significant effect on its release rate characteristics.

F-9

Combustion characteristics whose change would be most effective in improving overall fire performance are apparent from release rate test results.

F-10

All materials and products are evaluated using results from the same basic test, regardless of the item’s composition or use. Thus, a direct comparison of combustibility and the relative impact on a fire system can be made for any product (e.g., floor covering, ceiling tile, upholstery, drapery, etc.).

F-11

Release rate data can also be used as the basis for specifying the minimum fire performance levels of products at one (or several) exposure levels representative of that to which the product might be exposed in an actual fire. Maximum "loading" (i.e., allowable exposed surface area of combustible materials) can be calculated from release rate data so that total heat or visible smoke release within a fire system will not exceed some predetermined level, a useful concept in reducing the possibility of catastrophic fire in high-risk situations.

F-12

One of the problems in using release rate test data is the large amount of information obtained from one or a series of release rate tests. Because the potential fire hazard of an item depends both on its fire performance and on the system in which it is found, the relative importance of individual values will change, depending on where and how the item is used. For example, the maximum rate of heat release values for two items might have little relationship with the items' fire hazard. The maximum RHR for a foamed plastic panel might be less than 50 kW, while that for a treated wood panel might be over 100 kW when both are exposed to a flux of 30.0 kW/m^2 (2.8 kW/ft^2). However, when the foam is tested, the maximum RHR is reached in 5 seconds while, in the case of the treated wood, an exposure of over 5 minutes is necessary before the material starts to release heat and an exposure of over 9 minutes is necessary before the maximum RHR is reached.

F-13 Recommendations for the Selection of Test Parameters.

In order to use this test method, the variables in F-13.1 through F-13.3 should be selected.

F-13.1 Configuration.

(a) Horizontal

(b) Vertical.

F-13.2 Ignition Source.

(a) Non-piloted

(b) Piloted ignition, vertical specimen with impinging flame

(c) Piloted ignition, horizontal specimen with impinging flame

(d) Piloted ignition, vertical specimen without impinging flame

(e) Piloted ignition, horizontal specimen without impinging flame.

F-13.3 Radiant Heat Flux Level.

(a) 0 kW/m^2 to 100 kW/m^2 (0 kW/ft^2 to 9.3 kW/ft^2).

The selection of the test parameters should be related to the application of the test results (of the material). This selection effects some of the factors relating to the application of the test results.

F-13.4 Configuration.

The test method is capable of being run with a vertical or horizontal sample orientation. Data from particle board exposed at 20.0 kW/m^2 (1.9 kW/ft^2) [*see Table F-13.4(a)*] indicates that the vertical configuration (piloted impinging) will provide a more rapid increase in rate of heat release; the maximum rate of heat release is similar in both situations.

Table F-13.4(a) Sample Orientation/Heat Release

	Max RHR [Btu/(min/ft^2)]	Heat Release (Btu/ft^2)		
Orientation	*1 min*	*3 min*	*5 min*	*10 min*
Vertical	630	690	2600	2950
Horizontal	605	290	1310	3350

Note that the total heat released in 10 minutes is higher for the horizontal sample, but the maximum rate is slightly higher for the vertical orientation at an exposure of 20.0 kW/m^2 (1.9 kW/ft^2).

NOTE: This is true at 20.0 kW/m^2 (1.9 kW/ft^2) exposure; the opposite occurs at 60.0 kW/m^2 (5.6 kW/ft^2).

Similar comparisons on rates of smoke release indicate a much higher smoke production rate for the vertical sample but a higher total smoke production for the horizontal sample.

Further guidance on selecting sample orientation can be obtained by examining the effects of orientation on measured quantities for a variety of materials, as given in Table F-13.4(b). These data for only a few polymeric materials indicate several important features relative to orientation:

(a) Dripping can be a problem with vertically mounted samples.

(b) For a given material, the cumulative heat released is not a strong function of the orientation; on the other hand, the maximum heat release rate can vary widely with sample orientation.

The recommendation to users relative to orientation is to test the sample under both orientations and examine judiciously which data to use for the end result application.

For materials that drip excessively, it is probably conservative to use the horizontal orientation when assessing the total cumulative heat released by the sample.

Table F-13.4(b) Selected Test Method Results (Piloted Impinging)

				Cumulative Heat Released (Btu/ft^2)			
Material	**Orientation H = Horizontal V = Vertical**	**Applied Heat Flux (W/cm^2)**	**Maximum Heat Release Rate [Btu/(ft^2/min)]**	**1 min**	**3 min**	**5 min**	**10 min**
GM21/22	V	1.0	1200	505	1660	1920	1920

Flexible FU foam		3.0	1345	715	(drip)*		
	H	1.0*	1115	225	1835	2195	2195
		3.0	1230	1230	1830	1830	1830
GM23/24	V	1.0	1050	350	1350	1500	1500
Flexible FU foam		3.0	805	445	1110*	1245	
	H	1.0	940	285	1400	1500	1500
		3.0	1900	900	1555	1555	1555
GM47/48	V	1.0	500	325	850	1110	1110
Polystyrene expanded		3.0	440	175*	705*	860*	
	H	1.0	610	305	1005	1100	1100
		3.0	875	560	900	1050	1050
GM51/52	V	1.0	0	0	0	0	0
		3.0	720	0	625	950	
	H	1.0	0	0	0	0	0
		3.0	1370	10	1500	1770	1770

* Dripping occurred

F-13.5 Type of Ignition.

F-13.5.1 Selection. Selecting the most applicable type of ignition source is a slightly more complex problem. The basic guidance relative to selecting ignition type is embodied in the following:

(a) The impinging piloted ignition source introduces an additional exposure to the material, and hence, strictly speaking, does not allow “pure” heat release measurement. It does, however, represent a realistic case for hazard evaluation purposes.

(b) The non-impinging ignition source will, in general, need higher exposure levels to ignite the material, and ignition of the material will be delayed relative to the impinging piloted ignition case.

F-13.5.2 Use.

The use of a pilot ignition source impinging on the surface poses three potential problem areas:

(a) Uneven heating of the sample (i.e., the pilot flame heats the sample at a higher level locally than it does the remainder of the sample).

(b) The maximum rate of heat release might be lower for the impinging case, because the non-impinging case generally results in instantaneous surface involvement. However, extrapolation of release rate versus time data during the period of progressive involvement in order to find the maximum rate of heat release of total initial surface involvement is possible.

(c) The impinging flame might, when applied to very thin materials, give substantially different results.

It appears that the uneven heating problem and the “nonsimultaneous involvement” limitation have no real impact on the utility of heat release data except in the use of detailed mathematical models. The third problem has been compensated for by using a distributed piloted ignition source, such as a ribbon burner.

F-13.5.3 Impinging Piloted Ignition.

The main advantages of the impinging piloted ignition flame are:

(a) An impinging flame and subsequent ignition form an appropriate scenario for many applications.

(b) The high heat flux levels needed to obtain ignition of the surface under the non-impinging or non-pilot case are representative of postflashover fire conditions. Much of the illustrative data obtained from rate of heat release testing occurs below those high flux levels. Further, a major application of heat release testing has been relative to the contribution of materials leading to flashover or in the preflashover interval, where a material’s combustibility properties are the most important.

Another important point is that, while the non-impinging flame might yield slightly higher maximum rate of heat release levels, it is entirely possible for a material to burn at a substantial heat release rate under the impinging pilot flame case and never ignite at relatively low 2.0 W/cm^2 (12.9 W/in.^{2}) flux levels.

It is recommended that, for general hazard assessment purposes, the impinging pilot source should be used, bearing in mind the problems of very thin samples and the possibility of slightly reduced maximum rate of heat release values.

F-13.6 External Radiant Heat Flux Levels.

Perhaps one of the most useful aspects of this test method is the ability to vary flux levels over a wide variety of exposure conditions. This capability gives the test method great flexibility relative to assessing the hazard for a wide variety of use conditions. The level or levels chosen to run the test should reflect the purpose of the application of the results as well as the expected exposure level of the material in the installation being examined. Dr. E. E. Smith, the originator of this apparatus, has applied the test results to a number of applications and has proposed several ways of integrating the exposure level into the analysis.

Useful generic guidance for users or specifiers of this test method is to test all samples under a range of exposure conditions, from no externally applied heat flux to the maximum expected value. Notice in Table F-13.4(b) that, for many materials, the higher external heat flux has no significant impact on either the cumulative heat released or the maximum heat release rate above a certain exposure level. However, in some cases, the effects are substantial.

As a general rule, it is recommended that each material be tested under external flux conditions of 0.0, 10.0, 20.0, 30.0, 40.0, and 60.0 kW/m^2 (0.0, 0.93, 1.86, 2.79, 3.72, and 5.58 kW/ft^2) unless available test data indicate otherwise. This range of flux levels will cover the exposure to most materials in a room fire up to and including flashover. If the material heat release rate properties after flashover are needed, the range of exposure levels should be increased.

As an example, E. E. Smith has recommended various exposure levels and subsequent generic product specifications for typical exposure and acceptability conditions in room fires. The exposure level is a function of the expected type of fire (which could be related to occupancy) and the location of the material in the room. For example, the recommended flux level for testing materials that are located on a floor is less than the test flux level for materials located on a ceiling.

A high hazard occupancy class would dictate a higher exposure level under which the product would be required to perform suitably. Similarly, a high "fuel load" class would pose a higher level of exposure to materials. Typical heat release data are presented in Table F-13.6.

Table F-13.6 Typical RHR Data from OSU Test Method (Piloted Impinging)

				Total Heat Released (Btu/ft^2)	
Material	**Orientation**	**External Heat Flux (W/cm^2)**	**Maximum Heat Release Rate [$Btu/(ft^2/min)$]**	**3 min**	**10 min**
Oak, 1 in.	V	1.0	300	250	750
		2.0	420	800	3500
		2.5	550	1000	4000
Pine, 1 in.	V	1.5	600	900	6000
		2.5	800	1200	8000
Red oak, flooring	H	1.0	300	500	800
		2.0	450	900	3500
		2.75	600	1200	4500
Exterior plywood, 0.5 in.	V	1.0	400	700	1200
		2.0	600	1000	3000
Polyvinyl chloride, 90 mil sheet	V	1.0	300	500	2000
		2.0	500	1000	2000
Polystyrene, light diffuser	H	0	500	75	2400
		1.0	750	250	2500
Particle board, 0.5 in.	V	1.0	400	70	1800
		2.5	800	1800	5000
Particle board, 0.5 in. fire	V	1.5	20	0	50

2.5	350	200	1200

F-13.7 Acceptance Criteria.

It is generally inappropriate to specify a single acceptance criterion, (e.g., maximum rate of heat release). The required performance of a material should be specified by several test results (e.g., a combination of maximum rate of heat release and total heat release at 3 minutes and 10 minutes). Additional criteria that might be used include the slope, *E*, which is the slope of the line from the origin tangent to the heat release rate line. *E* is a surrogate measure of ignitibility; high heat release rate over a short period of time yields a high value for *E*. Other criteria might be maximum heat release rate over any 1-minute interval, for example. A sample of such a collection of acceptance criteria is given in Table F-13.7.

Users and specifiers of this test method should be cautioned that it is not possible to specify either test conditions or acceptance criteria unless a clear understanding of the purpose of applying the test, as well as experimental and analytical data, are available from which to derive both the test and acceptance conditions. There are no readily available pass/fail or nominal grading criteria for all situations.

Table F-13.7 Acceptable Characteristics

Characteristics	Maximum Permissible Value
Slope *E*	kW/(sec m^2)
Maximum heat release rate	kW/m^2
3-minute heat release rate	kW/m^2
10-minute heat release rate	kW/m^2

Appendix G Referenced Publications

G-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.

G-1.1 ASTM Publication.

American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM STP 685, *Design of Buildings for Fire Safety*, pp. 76-105, “Fire Response of Organic Polymeric Materials (Organic Materials in Fire: Combustibility),” 1979.

G-1.2 Technomic Publication.

Technomic Publishing Company, Inc., Westport, CT.

Fire Property Data — Cellular Plastics, H. A. Nadear et al., eds., 1980.

NFPA 264

1995 Edition

Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter

1995 Edition

This edition of NFPA 264, *Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*, was prepared by the Technical Committee on Fire Tests 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 264 was approved as an American National Standard on August 11, 1995.

Origin and Development of NFPA 264

The first edition of NFPA 264 was published in 1992. NFPA 264 is very closely related to and derived from NFPA 264A, *Standard Method of Test for Heat Release Rates for Upholstered Furniture Components or Composites and Mattresses Using an Oxygen Consumption Calorimeter*. This document is based on the methods of measuring rates of heat release using an oxygen consumption calorimeter developed at the National Institute of Standards and Technology by Dr. Vytenis Babrauskas et al. This document provides a general methodology for measuring the heat release rates of a variety of materials in a variety of end uses. It is intended that this approach be adopted and customized for the testing of specific products and materials. This bench-scale approach provides a mechanism for deriving information that can be used for product and material evaluation, mathematical modeling, and design purposes, as well as for research and development purposes.

This edition of NFPA 264 reflects changes that are both editorial and technical in nature. The technical revisions include standardizing the horizontal position as the orientation for testing of specimens. The horizontal orientation provides greater repeatable and reproducible results. The vertical orientation details are now located in an appendix and are intended to be used more for research purposes. The definition of sustained flaming has been revised from existence of flame for 10 seconds to 4 seconds in order to coordinate with other documents.

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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.

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 264

Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter

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 Appendices E and F.

Chapter 1 General

1-1 Scope.

1-1.1

This test method measures the response of materials exposed to controlled levels of radiant heating, with or without an external igniter.

1-1.2

This test method shall be used to determine the ignitibility, heat release rate, mass loss rates, effective heat of combustion, and visible smoke development of materials and products.

1-1.3

This test method has been developed for use for materials or product evaluations, mathematical modeling, design purposes, or research and development. The material shall comprise specimens from an end-use product or the various components used in the end-use product.

1-1.4

This test method shall not apply to end-use products that do not have planar, or nearly planar, external surfaces.

1-1.5*

This test method specifies testing of the specimen in the horizontal orientation.

1-1.6

This standard does not purport to address all safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.

1-1.7

The values stated in SI units shall be regarded as the standard.

1-2 Significance.

1-2.1

The test method provides measurements of the behavior of material and product specimens under a specified radiant heat exposure in terms of the rate of heat release, effective heat of combustion, mass loss rate, time to ignition, and smoke production. The relationship of the behavior of materials and products to radiant heat flux exposure shall be determined by testing specimens in a series of exposures that covers a range of radiant heat fluxes with and without piloted ignition.

1-2.2

The data obtained for a specific test describe the rate of heat and smoke release of the specimen when exposed to the specific environmental conditions and procedures used in performing that test.

1-2.3*

Release rates for a given material depend on how the material is used, its thickness, and the method of mounting.

1-2.4

Release rate measurements provide a quantitative measure of specific changes in performance caused by product modifications.

1-3 Test Limitations.

1-3.1

The test data shall be considered to have limited validity if any of the following occurs:

(a) Explosive spalling;

(b) The specimen swells to the point where it touches the spark plug prior to ignition;

(c) The specimen swells to a point where it reaches the plane of the heater base plate during combustion;

(d) Delamination.

1-3.2*

This test method shall be performed in a controlled environment under controlled laboratory conditions in order to obtain material properties data for use in evaluating the fire hazard of materials. These data alone do not describe the fire hazard of a material's specific end use or predict its response to real fires. The data obtained by this test method have not yet been correlated with the real world fire performance for most materials. Thus, caution shall be used when utilizing such data to evaluate the full-scale fire performance of the end use of materials tested in accordance with this method.

1-4 Summary of Test Method.

1-4.1

This test method is based on the observation that the net heat of combustion is directly related to the amount of oxygen necessary for combustion. Approximately 13.1×10^3 kJ of heat are released per 1 kg of oxygen consumed. Specimens in the test shall be combusted in ambient air conditions while being subjected to a predetermined external radiant heat flux, which ranges from 0 kW/m^2 to 100 kW/m^2. Combustion shall be initiated with or without a spark ignition.

1-4.2

The primary measurements are oxygen concentrations and exhaust gas flow rate. Additional measurements include the mass loss rate of the specimen, the time to sustained flaming and smoke obscuration, or other measurements as required in the relevant material or performance standard.

1-4.3

This test method is intended to determine the heat evolved by a product or material when exposed to an external radiant heat source. It also determines the effective heat of combustion, mass loss rate, time to sustained flaming, and smoke production. These properties shall be determined on small-size specimens that are representative of the intended end-use materials. This test method is applicable to various categories of products and is not limited to a single fire scenario. Additional information on testing is provided in Appendix E.

1-4.4

The rate of heat release shall be determined by measurement of the oxygen consumption, which is determined by the oxygen concentration and the flow rate in the exhaust product stream. The effective heat of combustion is determined from a concomitant measurement of specimen mass loss rate in combination with the heat release rate. Smoke development shall be measured by the obscuration of light by the combustion product stream.

1-4.5

Specimens shall be exposed to heating fluxes ranging from 0 kW/m^2 to 100 kW/m^2 in a horizontal orientation. External ignition, where used, shall be by electric spark. The value of the heating flux and the use of external ignition shall be specified by the relevant material or performance standard (*see E-2.3*) or by the test sponsor for research and development purposes.

1-4.6

Ignitibility shall be determined as a measurement of time from initial exposure to time of sustained flaming.

1-5 Definitions.

Effective Heat of Combustion. The measured heat release divided by the mass loss for a specified time period.

Heating Flux. The incident radiant heat flux imposed externally from the heater on the specimen at the initiation of the test.

Heat Release Rate. The heat evolved from the specimen, per unit of time.

Ignitibility. The propensity for ignition, as measured by the time to sustained flaming, in seconds, at a specified heating flux.

Net Heat of Combustion.* The oxygen bomb calorimeter value for the heat of combustion, corrected for the gaseous state of product water.

Orientation. The plane in which the exposed face of the specimen is located during testing (i.e., horizontally facing the heater).

Oxygen Consumption Principle. The expression of the relationship between the mass of oxygen consumed during combustion and the heat released.

Smoke Obscuration. The reduction of light transmission by smoke, as measured by light attenuation.

Sustained Flaming. The existence of flame on or over the surface of the specimen for periods of at least 4 seconds.

Visible Smoke. The obscuration of transmitted light caused by combustion products released during the test.

1-6 Symbols.

A_s	=	Nominal specimen exposed surface area (0.01 m^2).
C	=	Calibration constant for oxygen consumption analysis (m$^{1/2}$kg$^{1/2}$K$^{1/2}$).
ΔH_c	=	Net heat of combustion (kJ/kg).
$\Delta H_{c,eff}$	=	Effective heat of combustion (kJ/kg).

I	=	Actual beam intensity.
I_o	=	Beam intensity with no smoke.
k	=	Smoke extinction coefficient (m^{-1}).
L	=	Extinction beam path length (m).
m	=	Specimen mass (kg).
m_f	=	Final specimen mass (kg).
m_i	=	Initial specimen mass (kg).
$\dot{m}$	=	Specimen mass loss rate (kg/sec).
ΔP	=	Orifice meter pressure differential (Pa).
q''	=	Total heat release (kJ/m^2).
$\dot{q}$	=	Heat release rate (kW).
$\dot{q}''$	=	Heat release rate per unit area (kW/m^2).
r_o	=	Stoichiometric oxygen/fuel mass ratio.
t	=	Time (sec).
t_d	=	Oxygen analyzer delay time (sec).
Δt	=	Sampling time interval (sec).
T_e	=	Absolute temperature of gas at the orifice meter (K).
$\dot{V}$	=	Volume exhaust flow rate measured at the location of the laser photometer (m^3/sec).
X_{O2}	=	Oxygen analyzer reading, mole fraction of O_2.
X°_{O2}	=	Initial value of oxygen analyzer reading.
X^{1}_{O2}	=	Oxygen analyzer reading, before delay time correction.
s_f	=	Specific extinction area, for smoke (m^2/kg).

Chapter 2 Test Apparatus

2-1 General.

2-1.1

Unless otherwise stated, all dimensions included in the test and figures are mandatory and shall be followed within nominal tolerances of ±1 mm. Dimensions in figures that are not followed by an asterisk (*) shall not be considered mandatory.

2-1.2

The test apparatus shall consist of the following components:

(a) A conical-shaped radiant electric heater;

(b) Specimen holders;

(c) An exhaust-gas system with oxygen-monitoring and flow-measuring instrumentation;

(d) An electric ignition spark plug;

(e) A data collection and analysis system; and

(f) A load cell for measuring specimen mass loss.

A general view of the apparatus is shown in Figure 2-1.2(a). A cross-sectional view of the heater is shown in Figure 2-1.2(b), and an exploded view of the horizontal orientation is shown in Figure 2-1.2(c).

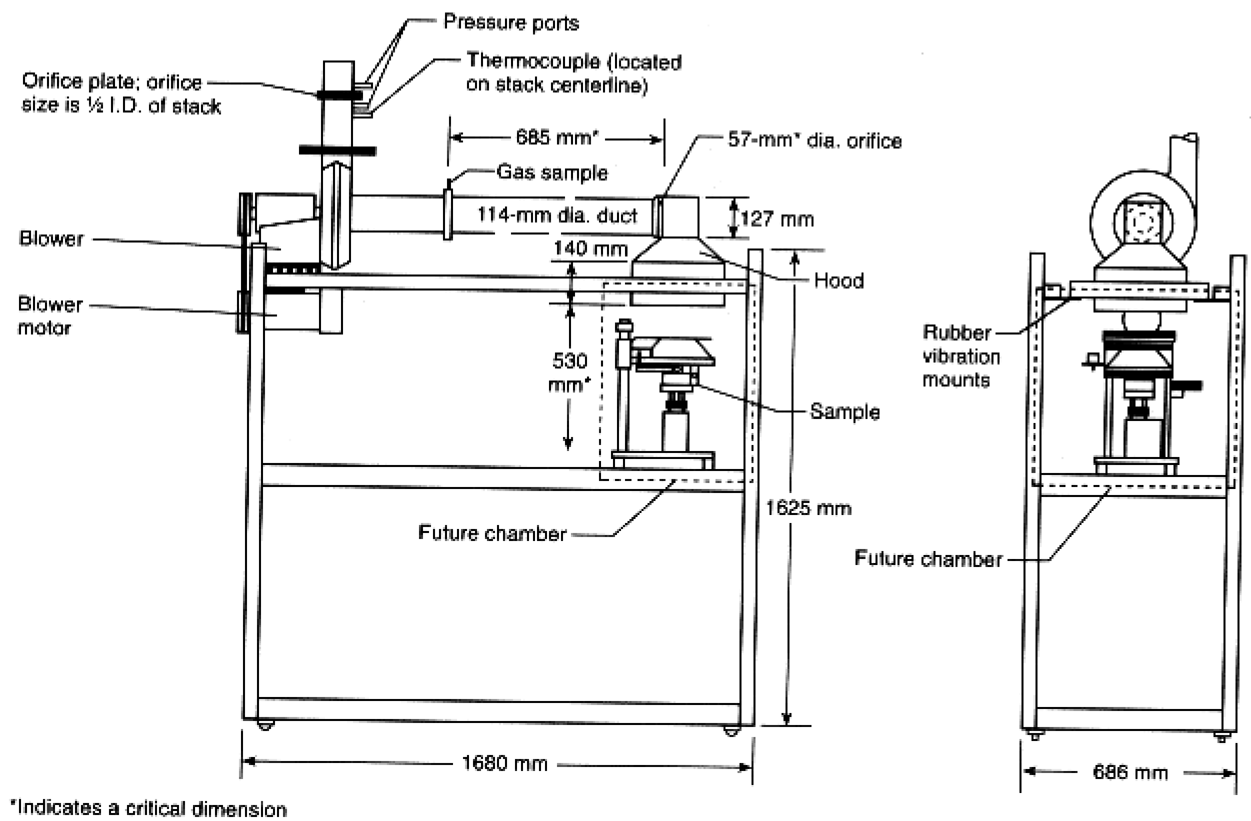


Figure 2-1.2(a) Overall view of apparatus.

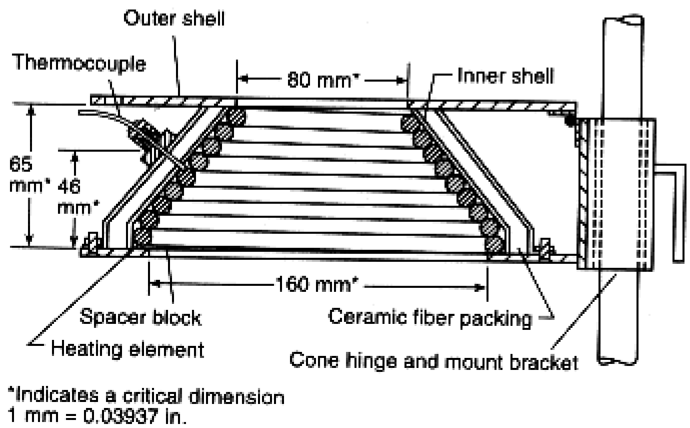


Figure 2-1.2(b) Cross-sectional view of heater.

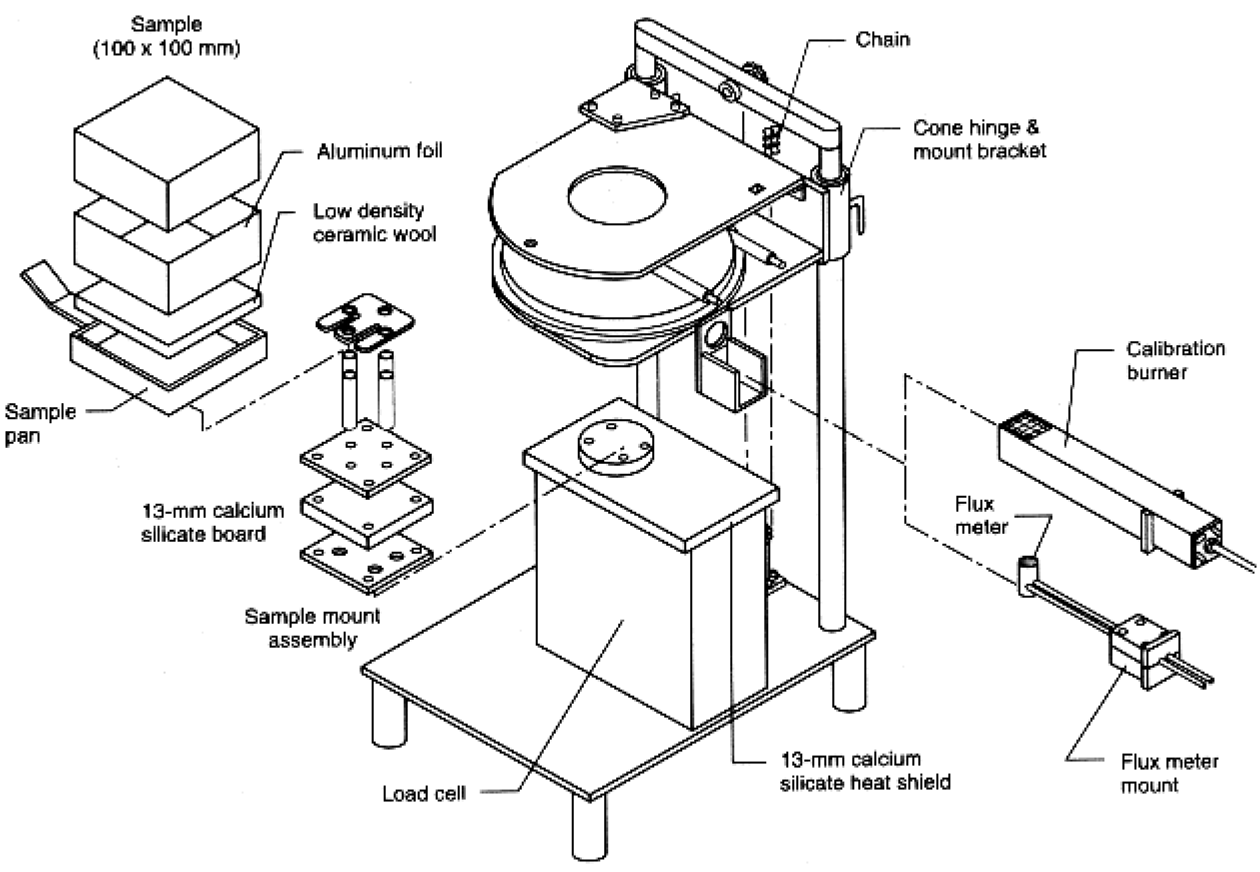


Figure 2-1.2(c) Exploded view, horizontal orientation.

2-2 Conical Heater.

2-2.1

The active element of the heater shall consist of an electrical heater rod, rated at 5000 W at 240 V, tightly wound into the shape of a truncated cone [*see Figure 2-1.2(b)*]. The heater shall be encased on the outside with a double-wall stainless steel cone packed with a refractory fiber material of approximately 100 kg/m^3 density.

2-2.2*

The heater shall be mounted in a horizontal orientation. The heater shall be capable of producing irradiances on the surface of the specimen of up to 100 kW/m^2. The irradiance shall be uniform within the central 50-mm × 50-mm area of the specimen to within ±10 percent.

2-2.3

The irradiance from the heater shall be capable of being held at a preset level by means of a temperature controller and three type K stainless steel-sheathed thermocouples, symmetrically dispersed and in contact with, but not welded to, the heater element [*see Figure 2-1.2(b)*]. The thermocouples shall be of equal length and wired in parallel to the temperature controller. The standard thermocouples are sheathed, 1.5 mm to 1.6 mm O.D., with an unexposed hot junction. Alternatively, either 3-mm O.D. sheathed thermocouples with an exposed hot junction, or 1-mm O.D. sheathed thermocouples with unexposed hot junction, shall be used.

2-3 Temperature Controller.

2-3.1

The temperature controller for the heater shall be capable of holding the element temperature steady to within ±2°C. An acceptable system is a "3-term" controller (proportional, integral, and derivative) and a thyristor unit capable of switching currents up to 25 A at 250 V.

2-3.2

The controller shall have a temperature input range of 0°C to 1000°C, a set scale capable of being read to 2°C or better, and automatic cold junction compensation. The controller shall be equipped with a safety feature so that, in the event of an open circuit in the thermocouple line, it causes the temperature to fall to near the bottom of its range.

2-3.3

The thyristor unit shall be of the "zero crossing" type and not of the "phase angle" type.

2-3.4

The heater temperature shall be monitored by a meter capable of being read to ±2°C or better.

2-4 Exhaust System.

2-4.1

The exhaust-gas system shall consist of a high temperature centrifugal exhaust fan, a hood, intake and exhaust ducts for the fan, and an orifice plate flow meter (*see Figure 2-4.1*). The exhaust system shall be capable of developing flows from 0.012 m^3/sec to 0.035 m^3/sec.

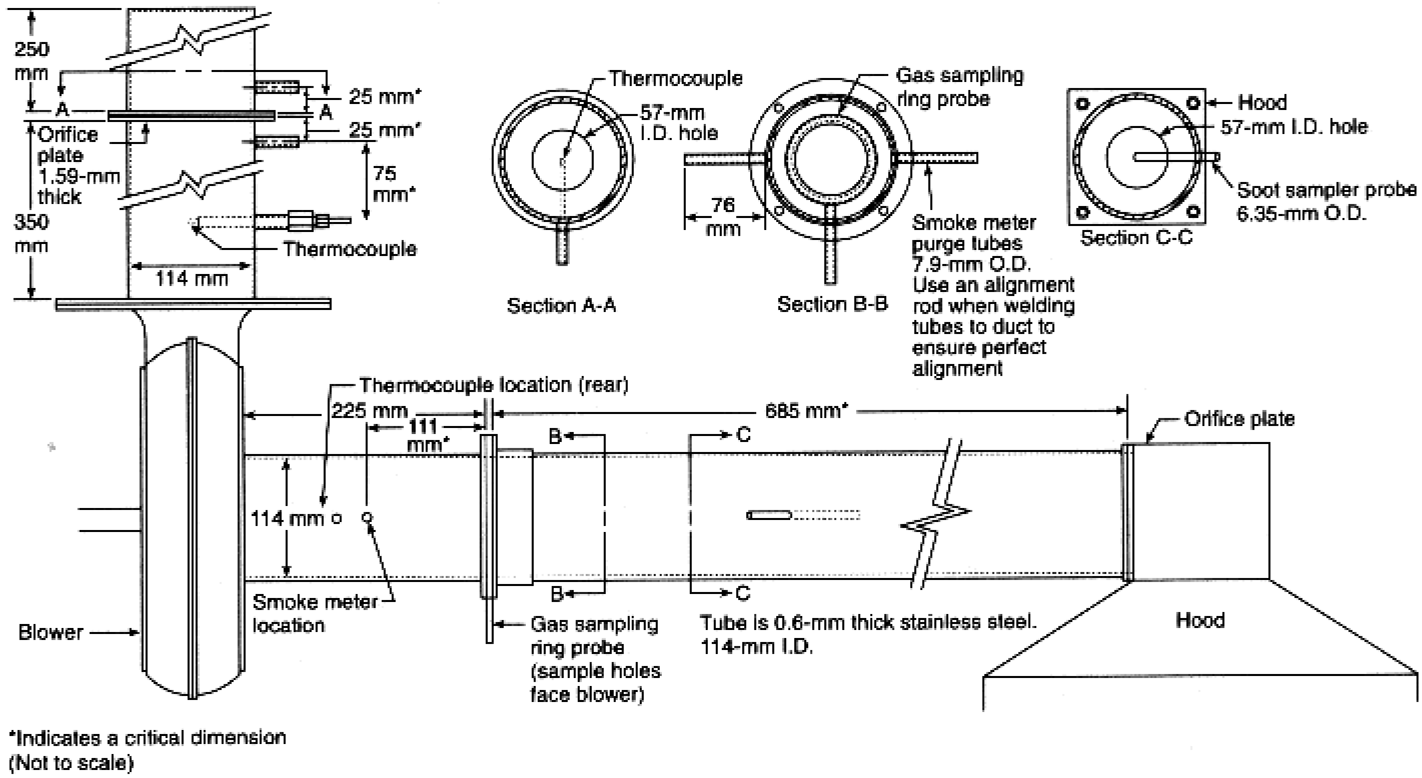


Figure 2-4.1 Exhaust system.

2-4.2

A restrictive orifice (57 mm I.D.) shall be located between the hood and the duct to promote mixing.

2-4.3

A ring sampler for gas sampling shall be located in the fan intake duct 685 mm from the hood [*see Figure 2-1.2(a)*]. The ring sampler shall contain twelve holes to average the stream composition, with the holes facing away from the flow to avoid soot clogging.

2-4.4

The temperature of the gas stream shall be measured using a 1.0-mm to 1.6-mm O.D. sheathed-junction thermocouple or a 3-mm O.D. exposed junction thermocouple positioned in the exhaust stack on the centerline and 100 mm upstream from the measuring orifice plate.

2-4.5

The flow rate shall be determined by measuring the differential pressure across a sharp-edged orifice (57 mm I.D.) in the exhaust stack at a location at least 350 mm downstream from the fan.

2-4.6

For other features, the geometry of the exhaust system is not critical. The undisturbed inflow distances to the gas sampling probe and the measuring orifice shall be sufficient for the flow to be uniformly mixed.

2-5 Load Cell.

The arrangement of the specimen holders on the load cell is indicated in Figure 2-1.2(c). The load cell shall have an accuracy of 0.1 g, a measuring range of 500 g, and a mechanical tare adjustment range of 3.5 kg.

2-6 Specimen Mounting.

2-6.1

The horizontal specimen holder is shown in Figure 2-6.1.

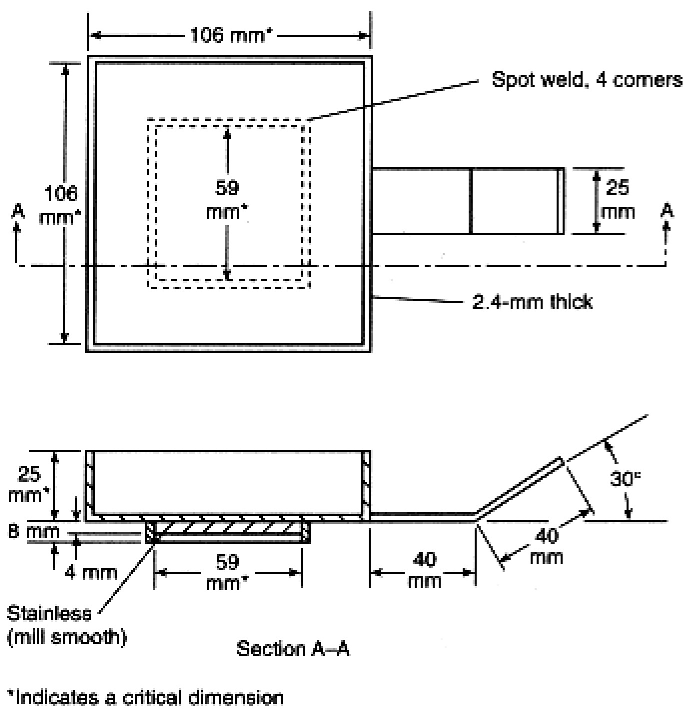


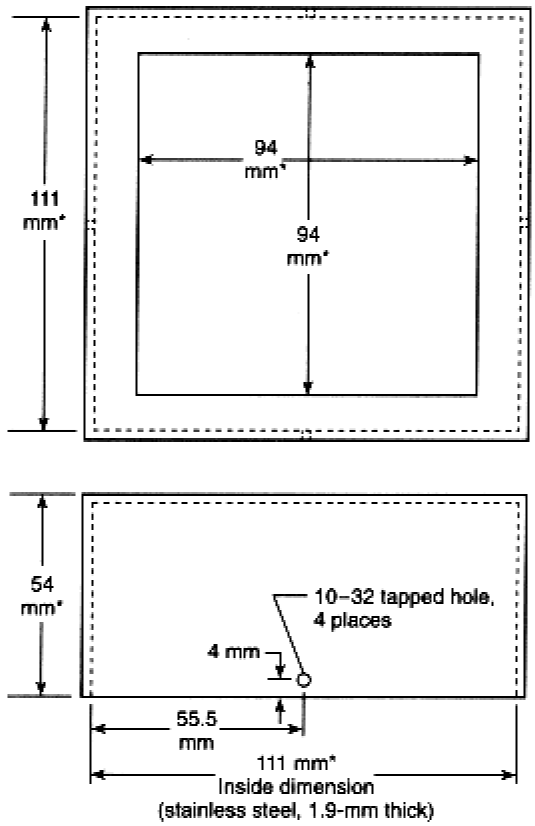
Figure 2-6.1 Horizontal specimen holder.

2-6.2

The bottom of the horizontal specimen holder shall be lined with a layer of low density (nominal density 65 kg/m^3) refractory fiber blanket with a thickness of at least 13 mm. The distance between the bottom surface of the cone heater and the top of the specimen shall be adjusted to 25 mm by using the sliding cone height adjustment. [*See Figure 2-1.2(b).]*

2-6.3

A retainer frame and a wire grid as shown in Figures 2-6.3(a) and (b), respectively, shall be used when testing intumescing specimens to reduce unrepresentative edge-burning of composite specimens and for retaining specimens prone to delamination. Other techniques shall be permitted to be utilized if documented in the test report.



*Indicates a critical dimension

Figure 2-6.3(a) Optional retainer frame.

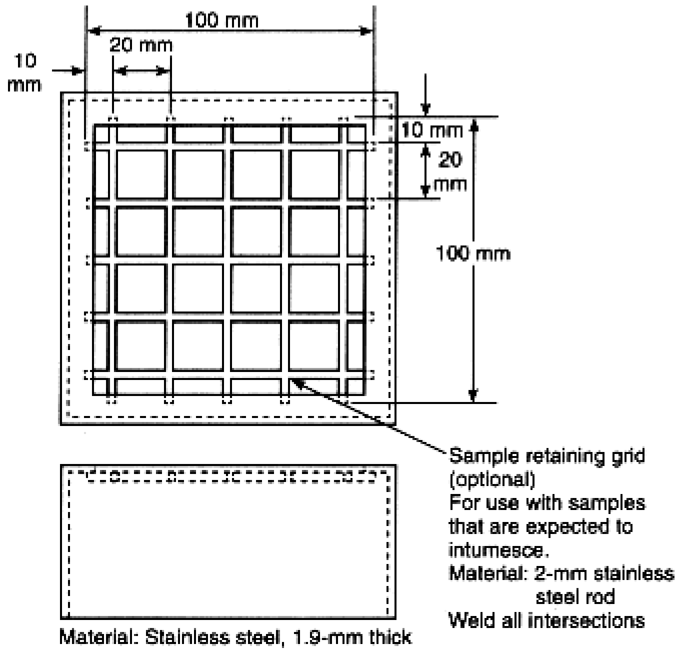


Figure 2-6.3(b) Optional wire grid.

2-7 Ignition Circuit.

External ignition shall be accomplished by a spark plug powered from a 10-kV transformer. The spark plug shall have a gap of 3 mm. The transformer shall be of a type specifically designed for spark ignition use. The transformer shall have an isolated (ungrounded) secondary to minimize interference with the data transmission lines. The electrode length and location of the spark plug shall be such that the spark gap is located 13 mm above the center of the specimen in the horizontal orientation. The spark plug shall be removed when sustained flaming is achieved.

2-8 Ignition Timer.

The timing device for measuring time to sustained flaming shall be capable of recording elapsed time to the nearest second and shall be accurate to within 1 second in 1 hour.

2-9* Gas Sampling.

Gas sampling arrangements are shown in Figure 2-9 and incorporate a pump, a filter to prevent entry of soot, a cold trap to remove most of the moisture, a bypass system set to divert all flow except that required for the oxygen analyzer, a further moisture trap, and a trap for CO_2 removal where CO_2 is not measured.

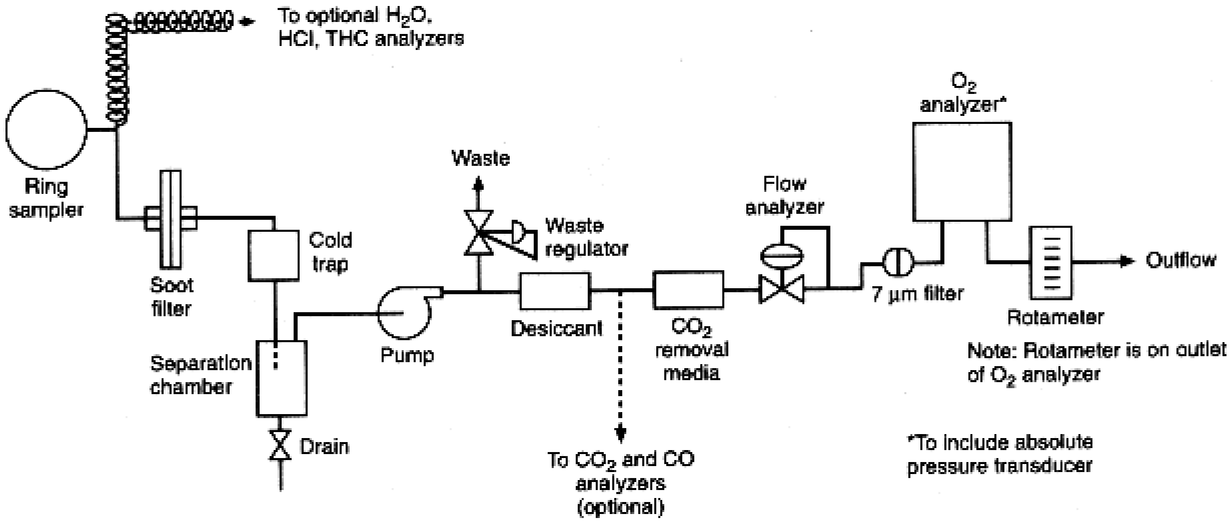


Figure 2-9 Gas analyzer instrumentation.

2-10 Oxygen Analyzer.

The analyzer shall be of the paramagnetic type with a range of 0 percent to 25 percent O_2. The analyzer shall exhibit a linear response and drift of not more than ±50 ppm O_2 (root-mean-square value) over a period of $^1/_2$ hour. The stream pressure shall be regulated upstream of the analyzer to allow for flow fluctuations, and the readings from the analyzer shall be compensated with an absolute pressure regulator to allow for atmospheric pressure variations. The analyzer and the absolute pressure regulator shall be located in a constant-temperature environment. The oxygen analyzer shall have a 10 percent to 90 percent response time of less than 12 seconds.

2-11 Smoke Obscuration Measuring System.

The smoke-measuring system (*see Figure 2-11*) shall consist of a helium-neon laser, silicon photodiodes as main beam and reference detectors, and appropriate electronics to derive the extinction coefficient and to set the zero reading. The system shall be designed for split yoke mounting in two pieces that are rigidly screwed together and resiliently attached to the exhaust duct by means of refractory gasketing at the location shown in Figure 2-4.1. The meter shall be located in place by means of two small-diameter tubes welded onto each side of the exhaust duct. These tubes shall serve as part of the light baffling for the air purging and also allow for any smoke that enters despite the purge flow to be deposited on tube walls before reaching the optical elements.

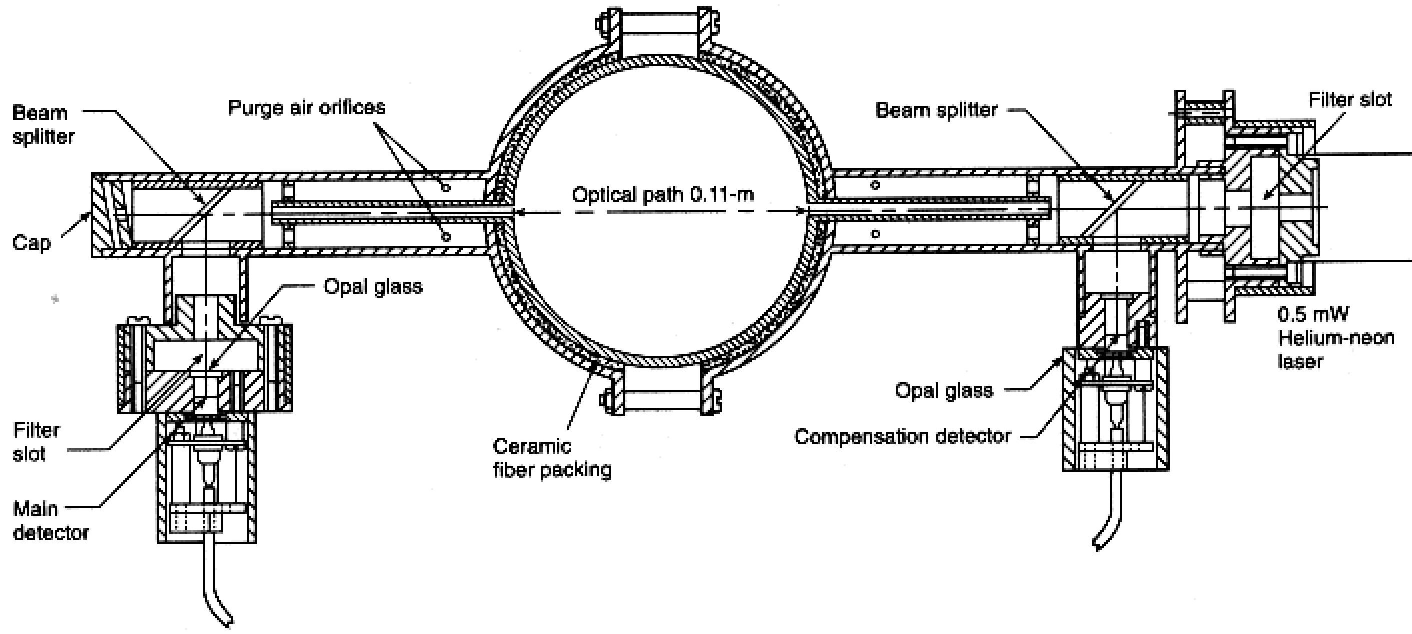


Figure 2-11 Smoke obscuration measuring system.

2-12 Heat Flux Meter.

2-12.1

The total heat flux meter shall be of the Gardon (foil) or Schmidt-Boetler (thermopile) type, with a design range of 100 kW/m^2. The target receiving radiation shall be flat, circular, approximately 12.5 mm in diameter, and coated with a durable matt black finish. The target shall be water-cooled. Radiation shall not pass through any window before reaching the target. The instrument shall be robust, simple to set up and use, and stable in calibration. The instrument shall have an accuracy within ±3 percent and a repeatability within 0.5 percent.

2-12.2

The calibration of the heat flux meter shall be checked whenever the apparatus is recalibrated by comparison with an instrument (of the same type as the working heat flux meter and of similar range) used only as a reference standard. The reference standard shall be fully calibrated at a standardizing laboratory at yearly intervals.

2-12.3

This meter shall be used to calibrate the heater temperature controller [*see Figure 2-1.2(c)*]. It shall be positioned at a location equivalent to the center of the specimen face during the calibration.

2-13 Calibration Burner.

A calibration burner shall be used to calibrate the rate of heat release apparatus [*see Figure 2-1.2(c)*]. The burner shall be constructed from a square-section brass tube with a square orifice covered with wire gauze through which the machine diffuses (*see Figure 2-13*). The tube shall be packed with ceramic fiber to improve uniformity of flow. The calibration burner shall be connected to a metered supply of methane with a purity of at least 99.5 percent.

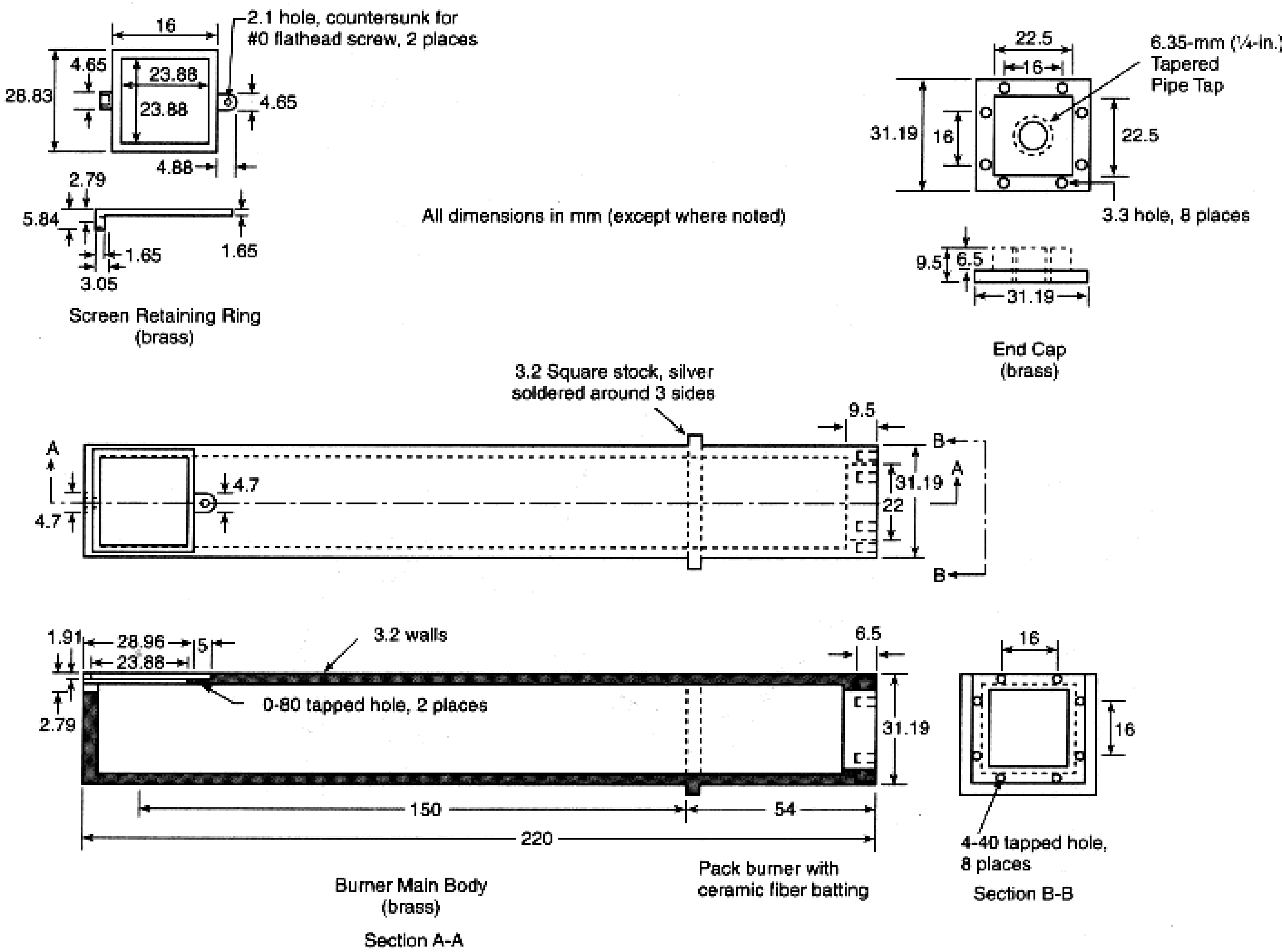


Figure 2-13 Calibration burner.

2-14 Optical Calibration Filters.

Glass neutral density filters of at least two different values and accurately calibrated at the laser wavelength of 0.6328 mm shall be provided.

2-15 Digital Data Collection.

The data collection system used shall have facilities for the recording of the output from the O_2 analyzer, the orifice meter, the thermocouples, the load cell, and the smoke-measuring system. The data collection system shall have an accuracy corresponding to at least 50 ppm O_2 for the oxygen channel, 0.5°C for the temperature-measuring channels, and 0.01 percent of full-scale instrument output for all other instrument channels. The system shall be capable of recording data for at least 1 hour at intervals not exceeding 2 seconds.

Chapter 3 Calibration of Equipment

3-1 Heater Flux Calibration.

The temperature controller shall be set at the required flux by using the heat flux meter at the start of the test day or after changing to a new flux level. A specimen or specimen holder shall not be used when the heat flux meter is inserted into the calibration position. The cone heater shall be operated for at least 10 minutes, and it shall be ensured that the controller is within its proportional band before the calibration is begun.

3-2 Oxygen Analyzer Calibration.

3-2.1 Preliminary Calibration.

3-2.1.1 The oxygen analyzer delay time shall be determined. This shall be done by setting a methane flow rate to the calibration burner that is equivalent to 10 kW. The heater shall not be turned on for this calibration. The output of the analyzer shall be recorded on a strip chart recorder as the methane supply, turned on and ignited, reaches a steady value and then returns to baseline after the supply is cut off. The temperature for the exhaust orifice meter shall be recorded at the same time. The turn-on delay shall be determined from the difference between the time the temperature reading reaches 50 percent of its ultimate deflection and the time the oxygen reading reaches 50 percent of its ultimate deflection. The turn-off delay shall be determined similarly at turn-off. The delay time shall be the average of the turn-on delay and turn-off delay. The delay time value, t_d, subsequently shall be used to time-shift all the oxygen readings.

3-2.1.2 If the oxygen analyzer is equipped with an electric response time adjustment, it shall be set so that at turn-off there is just a trace of overshoot when switching rapidly between two different calibration gases.

3-2.1.3 The timing of the scans by the data collection system shall be calibrated with a timer accurate to within 1 second in 1 hour. The data output shall show event times correct to within 3 seconds.

3-2.2 Operating Calibrations.

At the start of testing each day, the oxygen analyzer shall be zeroed and calibrated. For zeroing, the analyzer shall be fed with nitrogen gas using the same flow rate and pressure as for the sample gases. Calibration shall be achieved similarly using ambient air and adjusting for a response of 20.95 percent. Analyzer flow rates shall be monitored and set to be equal to the flow rate used when testing specimens. After each specimen has been tested, a response level of 20.95 percent obtained using ambient air shall be verified.

3-3* Heat Release Calibration.

The heat release calibration shall be performed each day at the start of testing. Methane with a purity of at least 99.5 percent shall be introduced into the calibration burner at a flow rate corresponding to 10 kW based on the net heat of combustion of methane (50.0×10^3 kJ/kg) using a precalibrated flow meter. The flow meter used shall be a dry test meter, a wet test meter, or an electronic mass flow controller. If an electronic mass flow controller is used, it shall be calibrated periodically against a dry test meter or a wet test meter. The test meter shall be equipped with devices to measure the temperature and pressure of the flowing gas so that appropriate corrections to the reading are made. If a wet test meter is used, the readings also shall be corrected for the moisture content. The exhaust fan shall be set to the speed to be used for subsequent testing. The required calculations are provided in Chapter 6.

3-4* Load Cell Calibration.

The load cell shall be calibrated with standard weights in the range of test specimen weight on each day of testing or when the load cell mechanical zero requires adjustment.

3-5* Smoke Meter Calibration.

The smoke meter initially shall be calibrated to read correctly for two different value neutral density filters and also at 100 percent transmission.

Chapter 4 Test Specimens

4-1 Size and Preparation.

4-1.1

Test specimens shall be 100 mm × 100 mm, shall be up to 50 mm thick, and shall be cut to be representative of the construction of the end-use product. For testing, the sides and bottom of the specimens shall be wrapped in a single layer of aluminum foil, with the shiny side facing the specimen.

4-1.2

Composite specimens shall be exposed in a manner typical of the end-use condition. They shall be prepared so that the sides are covered with the outer layer(s).

4-1.3

Composite and intumescing materials shall be mounted using techniques that hold them in place within the specimen holder during combustion. Such mounting techniques include the use of an edge frame [*see Figure 2-6.3(a)*], wire grid, or other special mounting procedure suitable to the specimen being tested. Figure 2-6.3(b) shows a wire grid suitable for several types of intumescing specimens. The exact mounting and retaining method used shall be specified in the test report.

4-2 Conditioning.

Specimens shall be conditioned to moisture equilibrium (constant weight) at an ambient temperature of 23°C ±3°C and a relative humidity of 50 percent ±5 percent.

Chapter 5 Test Procedure

5-1 Preparation.

5-1.1

The CO_2 trap and the final moisture trap shall be checked. The absorbents shall be replaced when they are no longer effective. Any accumulated water in the cold trap separation chamber shall be drained. The normal operating temperature of the cold trap shall be 0°C or lower.

5-1.2

The power to the cone heater and the exhaust blower shall be turned on. Power to the oxygen analyzer, load cell, and pressure transducer shall not be turned off on a daily basis.

5-1.3*

An exhaust flow rate of 0.024 m^3/sec ±0.002 m^3/sec shall be set.

5-1.4

The required calibration procedures specified in Chapter 3 shall be performed. An empty specimen holder with refractory blanket in place shall be placed in the horizontal orientation during warm-up and in between tests to avoid excessive heat transmission to the load cell.

5-1.5

Where external ignition is used, the spark plug holder shall be positioned in the location appropriate to the orientation being used.

5-2 Procedure.

5-2.1

When ready to test, the empty specimen holder shall be removed.

5-2.2

The specimen, held in the appropriate holder, shall be put in place and the data collection shall begin. The data collection intervals shall be 2 seconds or less. The holder initially shall be at room temperature.

5-2.3

The ignition timer shall be started. The spark plug shall be moved into place and the spark power shall be turned on.

5-2.4*

The times when flashing or transitory flaming occurs shall be recorded. When sustained flaming occurs, the time shall be recorded, the spark shall be turned off, and the spark igniter shall be removed. If the flame self-extinguishes in less than 60 seconds after turning off the spark, the spark igniter shall be reinserted and the spark shall be turned on. If flaming reoccurs, the test shall be stopped, the test data shall be discarded, and the test shall be repeated without removing the spark igniter until the entire test is completed. These events shall be included in the test report.

5-2.5

Data shall be collected until 2 minutes after any flaming or other signs of combustion cease, until the average mass loss over a 1-minute period has dropped below 150 g/m^2, or until 60 minutes have elapsed, whichever occurs first.

5-2.6

The specimen holder shall be removed.

5-2.7

The empty specimen holder shall be replaced.

5-2.8*

After the start of the test, if the specimen does not ignite within 15 minutes, it shall be removed and discarded unless the specimen is showing signs of heat evolution.

5-2.9

Unless otherwise specified in the material or performance standard, three determinations shall be made and reported as specified in Chapter 7. The 180-second mean heat release rate readings shall be compared for the three specimens. If any of these mean readings differs by more than 10 percent from the average of the three readings, then an additional set of three specimens shall be tested. In such cases, the averages for the set of six readings shall be reported.

5-3 Safety Precautions.

5-3.1

The test procedures involve high temperature and combustion processes. Therefore, hazards exist for burns, ignition of extraneous objects or clothing, and inhalation of combustion products. The operator shall use protective gloves for insertion and removal of test specimens. Neither the cone heater nor the associated fixtures shall be touched while hot except with the use of protective gloves.

5-3.2

The exhaust shall be checked for proper operation before testing and shall discharge into a building exhaust system with adequate capacity. Provision shall be made for collecting and venting any combustion products that fail to be collected by the normal exhaust system of the apparatus.

Chapter 6 Calculations

6-1 General.

The equations in this section assume that only O_2 is measured, as indicated on the gas analysis system in Figure 2-9. Appropriate equations for cases where additional gas analysis equipment (CO_2, CO, H_2O) is used are provided in Appendix C.

6-2* Calibration Constant Using Methane.

The methane calibration shall be performed prior to the day's testing to check for the proper operation of the instrument and to compensate for minor changes in mass flow determination. The calibration constant, C, shall be determined from the following equation:

$$C = \frac{10.0}{1.10\,(12.54 \times 10^3)} \sqrt{\frac{T_e}{\Delta P}} \; \frac{1.105 - 1.5\,X_{O_2}}{X^0_{O_2} - X_{O_2}}$$

where 10.0 corresponds to 10.0 kW methane supplied, 12.54×10^3 equals $\Delta H_c/r_o$ for methane, 1.10 is the ratio of oxygen to air molecular weight, and the variables are as provided in Section 1-4.

6-3 Calculations for Test Specimen. The calculations in this section shall be used for various applications. The applicable material or performance standard shall be consulted for additional calculations.

6-3.1 Heat Release.

6-3.1.1 Prior to performing other calculations, the oxygen analyzer time shift shall be determined by the following equation:

$$XO_2\ (t) = X^1O_2\ (t + t_d)$$

6-3.1.2 The heat release rate then shall be determined by the following equation:

$$\dot{q}(t) = (\Delta H_c/r_o)\ (1.10)\ C \sqrt{\frac{\Delta P}{T_e}}\ \frac{X^0_{O_2} - X_{O_2}\ (t)}{1.105 - 1.5\ X_{O_2}\ (t)}$$

6-3.1.3 The value of H_c/r_o for the test specimen shall be set to equal 13.1×10^3 kJ/kg, unless a more accurate value is known for the test material. The heat release rate per unit area shall be determined as follows:

$$\dot{q}''\ (t) = \dot{q}(t)/A_s$$

where $A_s = 0.01\ m^2$.

6-3.1.4 The total heat released during combustion, q", shall be determined by summation:

$$\dot{q}'' = \sum_i \dot{q}''i\ (t)\ \Delta\ t$$

where the summation begins with the first reading after the last negative rate of heat release reading that occurs at the beginning of the test and continues until the final reading recorded for the test.

6-3.2 Mass Loss Rate and Effective Heat of Combustion.

The required mass loss rate, dm/dt, shall be computed at each time interval using five-point numerical differentiation. The equations to be used shall be as follows:

For the first scan (i = 0):

$$-\left[\frac{dm}{dt}\right]_{i=0} = \frac{25m_0 - 48m_1 + 36m_2 - 16m_3 + 3m_4}{12\Delta t}$$

For the second scan (i = 1):

$$-\left[\frac{dm}{dt}\right]_{i=1} = \frac{3m_0 + 10m_1 - 18m_2 + 6m_3 - m_4}{12\Delta t}$$

For any scan for which 1 < i < n-1 (n=total number of scans):

$$-\left[\frac{dm}{dt}\right]_{i} = \frac{-m_{i-2} + 8m_{i-1} - 8m_{i+1} + m_{i+2}}{12\Delta t}$$

For the next to the last scan (i = n-1):

$$-\left[\frac{dm}{dt}\right]_{i=n-1} = \frac{-10m_n - 3m_{n-1} + 18m_{n-2} - 6m_{n-3} + m_{n-4}}{12\Delta t}$$

For the last scan (i = n):

$$-\left[\frac{dm}{dt}\right]_{i=n} = \frac{-25m_n + 48m_{n-1} - 36m_{n-2} + 16m_{n-3} - 3m_{n-4}}{12\Delta t}$$

The average effective heat of combustion shall be determined as follows, with the summation taken over the entire test length:

$$\Delta H_{c,eff} = \frac{\sum_i \dot{q}(t)\,\Delta t}{m_i - m_f}$$

A time-varying value also shall be determined as follows:

$$\Delta H_{c,eff}(t) = \frac{\dot{q}(t)}{-(dm/dt)}$$

6-3.3 Smoke Obscuration.

6-3.3.1 The extinction coefficient, k, shall be determined by the smoke meter electronics as follows:

$$k = \left(\frac{1}{L}\right) ln \left(\frac{I_o}{I}\right)$$

6-3.3.2 The average specific extinction area obtained during the test shall be as follows:

$$\sigma_f (Avg) = \frac{\sum_i \dot{V}_i k_i \Delta t_i}{m_i - m_f}$$

Chapter 7 Report

7-1 Required Information.

The test report shall include the following information unless otherwise specified in the relevant material or performance standard:

(a) Specimen identification code or number;

(b) Manufacturer or submitter;

(c) Date of test;

(d) Operator;

(e) Composition or generic identification;

(f) Specimen thickness;

(g) Specimen mass;

(h) Specimen color(s) and description;

(i) Details of specimen preparation by the testing laboratory;

(j) Test orientation, specimen mounting, and whether the retainer frame, the wire grid, or other special mounting procedure was used;

(k) Heating flux and exhaust system flow rate;

(l) Number of replicate specimens tested under the same conditions; there shall be a minimum of three;

Exception: Exploratory testing.

(m) Time to sustained flaming (sec);

(n) Heat release rate (per unit area) curve (kW/m^2);

(o)* Peak $\dot{q}''$ and average $\dot{q}''$ values for the first 60 seconds, 180 seconds, and 300 seconds after ignition, or for other appropriate periods. For specimens that do not show sustained flaming, the above quantities, tabulated for periods beginning with the first reading after the last negative rate of heat release reading that occurs at the beginning of the test, shall be reported;

(p) Total heat released by the specimen (MJ/m^2). The total heat shall be computed beginning with the first reading after the last negative rate of heat release reading that occurs at the beginning of the test, and continuing until the final reading recorded for the test;

(q) Average $\Delta H_{c,eff}$ for the entire test (MJ/kg);

(r) Curve of $\Delta H_{c,eff}$ (MJ/kg). This information is optional;

(s) Mass remaining after test (g);

(t) Sample mass loss (kg/m^2). Sample mass loss is the average specimen mass loss rate (g/m^2-sec) computed over the period that begins when 10 percent of the ultimate specimen mass loss occurs and that ends when 90 percent of the ultimate specimen mass loss occurs;

(u) Smoke obscuration. Smoke obscuration shall be reported as the average specific extinction area (m^2/kg);

(v) Values determined for Sections 7-1(l), (o), (p), and (t), averaged for all specimens;

(w) Additional observations, including times of transitory flaming or flashing, if any;

(x) Difficulties encountered in testing, if any;

(y) Duration of test and the criteria used to end the test;

(z) Data recording interval (sec).

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-1-1.5

Testing of materials in the horizontal orientation is currently preferred, especially for regulatory purposes, since such testing is much more reproducible and repeatable than when performed in the vertical orientation and generally appears to provide a more severe exposure condition. Where using the vertical orientation, it is more difficult to control the pyrolyzates that evolve from the material's surface for the purpose of external ignition using the point source spark ignition. Convective heat flow along the exposed surface of the sample is also a complicating factor.

A-1-2.3

Other factors, some of which cannot be controlled, that also can affect the heat release rate for a given material include the material's orientation (vertical, horizontal, or otherwise), types of joints or other methods used for installation, the way the material reacts to fire (melts and drips, recedes, chars, pyrolyzes, intumesces or flames), and the use of fire retardants.

A-1-3.2

It cannot be assumed that the behavior of materials tested in accordance with this method will be replicated in a real fire situation. A material's response to a real fire is affected by many factors, including the specific end use of the material, the environment in which it is used, and the fire condition to which it might be exposed.

A-1-5 Net Heat of Combustion.

For additional information, see ASTM D3286, *Standard Test Method for Gross Calorific Value of Coal and Coke by the Isoperibol Bomb Calorimeter*.

A-2-2.2

Because the geometry of the heater is critical, the dimensions shown in Figure 2-1.2(b) should be adhered to closely.

A-2-9

If an optional CO_2 analyzer is used instead of removing CO_2 from the oxygen analyzer stream, the equations used to calculate the rate of heat release are different from those for the standard case indicated in Chapter 6. The appropriate equations are provided in Appendix C.

A-3-3

Calibration may be permitted to be performed with or without the cone heater operating but should not be performed during heater warm-up.

A-3-4

The load cell mechanical zero might have to be adjusted when using the edge frame or if the apparatus was not last used in the horizontal orientation.

A-3-5

Once this calibration is set, only the zero value of the extinction coefficient (100 percent transmission) normally needs to be verified prior to each test.

A-5-1.3

Under room temperature conditions, this volume flow rate corresponds to a mass flow rate of approximately 30 g/sec.

A-5-2.4

The time of sustained flaming to be reported is the time at which the flaming initially is observed, not when the 4-second period that defines sustained flaming has elapsed.

A-5-2.8

Testing should be stopped if explosive spalling or excessive swelling occurs. The procedures described in Chapter 4 might be useful in mitigating these effects.

A-6-2

A calibration differing more than 5 percent from the previous calibration is not normal and suggests instrument malfunction.

A-7-1 (o) Certain specimens do not show visible, sustained flaming but do indicate positive rate of heat release values.

Appendix B Precision and Bias

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

B-1 Precision.

B-1.1

Interlaboratory trials were conducted by ASTM Committee E-5 to determine the repeatability and reproductibility of this test method. The results were analyzed in conjunction with the results of a parallel set of interlaboratory trials sponsored by the International Organization for Standardization (ISO). The complete results have been placed on file at ASTM headquarters as a research report (request RR: E05-1008). The results obtained for repeatability and reproducibility are provided below; further details of the interlaboratory trials are provided in Section B-2.

B-1.2

The following definitions of repeatability (*r*) and reproducibility (*R*) should be used:

$$r = f\sqrt{2}\sigma_r$$

$$R = f\sqrt{2}\sigma_R$$

where σ r is the repeatability standard deviation, σ*R* is the reproducibility standard deviation, the coefficient √2 is derived from the fact that *r* and *R* refer to the difference between two single test results, and *f*, which equals approximately 2, corresponds to the probability level of 95 percent being taken. These products then are rounded off as follows:

$$r = 2.8\ s_r$$

$$R = 2.8\ s_R$$

For calculations, the sample-based standard deviation estimates, *s*, are substituted for the population standard deviations, σ, since the latter are not known.

B-1.3

For the materials tested, values for repeatability, *r*, and reproducibility, *R*, have been calculated for six variables. These variables, chosen as representative of the test results are t_{ig}, $\dot{q}''_{max}$, $\dot{q}''_{180}$, $\dot{q}''_{tot}$, $\Delta h_{c,eff}$ and σ_f. A linear regression model was used to describe *r* and *R* as a function of the mean overall replicates and overall laboratories for each of the six variables. The regression equations are provided below. The range of mean values over which the fit was obtained is also indicated. The results for time to sustained flaming, t_{ig}, in the range of 5 seconds to 150 seconds were:

$$r = 4.1 + 0.125\ t_{ig}$$

$$R = 7.4 + 0.220\ t_{ig}$$

The results for peak heat release rate, $\dot{q}''_{max}$, in the range of 70 kW/m^2 to 1120 kW/m^2 were:

$$r = 13.3 + 0.131\ \dot{q}''_{max}$$

$$R = 60.4 + 0.141\ \dot{q}''_{max}$$

The results for 180-second average heat release rate, $\dot{q}''_{180}$, in the range of 70 kW/m^2 to 870 kW/m^2 were:

$$r = 23.3 + 0.137\ \dot{q}''_{180}$$

$$R = 25.5 + 0.151\ \dot{q}''_{180}$$

The results for total heat released $\dot{q}''_{tot}$, in the range of 5 MJ/m^2 to 720 MJ/m^2 were:

$$r = 7.4 + 0.068\ \dot{q}''_{tot}$$

$$R = 11.8 + 0.088\ \dot{q}''_{tot}$$

The results for peak effective heat of combustion $\Delta H_{c,eff}$, in the range of 7 kJ/g to 40 kJ/g were:

$$r = 1.23 + 0.050\ \Delta H_{c,eff}$$

$$R = 2.42 + 0.055\ \Delta H_{c,eff}$$

The results for average specific extinction area, σ_f, in the range of 30 m^2/kg to 2200 m^2/kg were:

$$r = 59 + 0.076\ \sigma_f$$

$$R = 63 + 0.215\ \sigma_f$$

B-2 Bias.

For solid specimens of unknown chemical composition, as used in building materials, furnishings, and common occupant fuel load, it has been documented that the use of the oxygen consumption standard value of $\Delta H_c/r_o = 13.1 \times 10^3$ kJ/kg oxygen results in an expected error band of ±5 percent compared to true value. For homogeneous materials with only a single pyrolysis mechanism, this uncertainty can be reduced by determining ΔH_c from oxygen bomb measurements and r_o from ultimate elemental analysis. For most testing, this is not practical, since specimens might be composite and nonhomogeneous and might exhibit several degradation reactions. Therefore, for unknown samples, a ±5 percent accuracy limit is recommended. For reference materials, however, careful determination of $\Delta H_c/r_o$ can reduce this source of uncertainty substantially.

Appendix C Calculation of Heat Release with Additional Gas Analysis

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

C-1 Introduction.

The equations used to calculate heat release rate assume CO_2 is removed from the gas sample in a chemical scrubber before O_2 is measured. Some laboratories are equipped to measure CO_2; in such a case, it is not necessary to remove the CO_2 from the O_2 line. The advantage in this case is that the chemical scrubbing agent, which is costly and necessitates careful handling, can be avoided.

In this appendix, equations are provided that should be used when CO_2 is measured but not scrubbed out of the sampling lines. Two cases are considered. In the first case, part of the dried and filtered sample stream is diverted into infrared CO_2 and CO analyzers. To avoid condensation, the measurement of H_2O concentration in the flow of combustion products necessitates a separate sampling system with heated filters, heated sampling lines, and a heated analyzer.

C-2 Symbols.

The following symbols are used:

M_a	=	Molecular weight of air (kg/kmol).
M_e	=	Molecular weight of the combustion products (kg/kmol).
$\dot{m}_e$	=	Exhaust duct mass flow rate (kg/sec).
t^1_d	=	Delay time of the CO_2 analyzer (sec).
t^2_d	=	Delay time of the CO analyzer (sec).

$t^3{}_d$	=	Delay time of the H_2 analyzer (sec).
$X°_{CO2}$	=	Initial CO_2 reading, mole fraction.
$X°_{CO}$	=	Initial CO reading, mole fraction.
$X°_{H2}O$	=	Initial H_2O reading, mole fraction.
$X^a{}_{O2}$	=	Ambient O_2 reading, mole fraction.
$X^1{}_{CO2}$	=	CO_2 reading before delay time correction, mole fraction.
$X^1{}_{CO}$	=	CO reading before delay time correction, mole fraction.
$X^1{}_{H2O}$	=	H_2O reading before delay time correction, mole fraction.
X_{CO2}	=	CO_2 reading after delay time correction, mole fraction.
X_{CO}	=	CO reading after delay time correction, mole fraction.
X_{H2O}	=	H_2O reading after delay time correction, mole fraction.
Ø	=	Oxygen depletion factor.

C-3 Where CO_2 and CO Are Measured.

As in the case of the oxygen analyzer, measurements of CO_2 and CO should be time-shifted to take into account the transport time in the sampling lines:

$$X_{O2}(t) = X^1{}_{O2}(t + t_d)$$

$$X_{CO2}(t) = X^1{}_{CO2}(t + t^1{}_d)$$

$$X_{CO}(t) = X^1{}_{CO}(t + t^2{}_d)$$

C-3.1

In this case, the delay times, $t_d{}^1$ and $t_d{}^2$, for the CO_2 and CO analyzers, respectively, are usually different (smaller) than the delay time, t_d, for the O_2 analyzer.

The exhaust duct flow is calculated as follows:

$$\dot{m} = C\sqrt{\frac{\Delta P}{T_e}}$$

C-3.2

The rate of heat release now can be determined as follows:

$$\dot{q} = 1.10 \left[\frac{\Delta H_c}{r_o} \right] X^a_{O_2} \left[\frac{\phi - 0.172 (1 - \phi) \frac{X_{CO}}{X_{CO_2}}}{(1 - \phi) + 1.105 \phi} \right] \dot{m}_e$$

C-3.3

The oxygen depletion factor, Ø, is calculated as follows:

$$\phi = \frac{X^O_{O_2} (1 - X_{CO_2} - X_{CO}) - X_{O_2} (1 - X^O_{CO_2})}{X^O_{O_2} (1 - X_{CO_2}2 - X_{CO} - X_{O_2})}$$

C-3.4

The ambient mole fraction of oxygen is calculated as follows:

$$X^a_{O2} + (1 - X°_{H2}O) X°_{O2}$$

The second value in the denominator of the value in brackets in the equation in C-3.2 is a correction factor for incomplete combustion of some carbon to CO instead of CO_2. In fact, the value of X_{CO} is usually very small, so that it can be disregarded in the equations in C-3.2 and C-3-3. The practical implication of this correction factor is that a CO analyzer generally does not result in a noticeable increase in accuracy of heat release rate measurements. Consequently, the equations can be used, even if no CO analyzer is present, by setting $X_{CO} = 0$.

C-4 Where H_2O Also Is Measured.

In an open combustion system, such as is used in this method, the flow rate of air entering the system cannot be measured directly but is inferred from the flow rate measured in the exhaust duct. An assumption regarding the expansion due to combustion of the fraction of the air that is fully depleted of its oxygen needs to be made. This expansion depends on the composition of the fuel and the actual stoichiometry of the combustion. A suitable average value for the volumetric expansion factor is 1.105, which is accurate for methane.

This value is already incorporated within the equation in C-3.2 for q. For cone calorimeter tests, it can be assumed that the exhaust gases consist primarily of N_2, O_2, CO_2, H_2O, and CO; thus, measurements of these gases can be used to determine the actual expansion. (It is assumed that the measurements of O_2, CO_2, and CO correspond to a dry gas stream, while the H_2O measurement corresponds to total stream flow.) The mass flow rate in the exhaust duct is then more accurately provided by the following equation:

$$\dot{m}_e = \sqrt{M_e/M_a}\, C \sqrt{\frac{\Delta P}{T_e}}$$

C-4.1

The molecular weight, M_e, of the exhaust gases is calculated as follows:

$$M_e = \left[4.5 + (1 - X_{H_2O})(2.5 + X_{O_2} + 4X_{CO_2})\right] \times 1$$

C-4.2

Using 28.97 as the value for M_a, the heat release rate is calculated as follows:

$$q(t) = 1.10 \left[\frac{H_c}{r_o}\right] (1 - X_{H_2O}) \left[\frac{X^0_{O_2}\left[1 - X_{O_2} - X_{CO_2}\right]}{1 - X^0_{O_2} - X^0_{CO_2}} - X_{O_2}\right] m_e$$

C-4.3

The H_2O readings used in the equation in C-4.2 are time-shifted in a way similar to that for the equations in Section C-3 for the other analyzers.

$$X^0_{H2O}(t) = X^1_{H2O}(t + t^3 d)$$

Additional background on these computations is given in footnote 15 to Appendix E.

Appendix D Testing of Specimens in the Vertical Orientation

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

D-1 Introduction.

This appendix is provided so that the user of this standard has access to a standardized methodology for testing specimens in a vertical orientation using the same apparatus specified in this standard. Although the recommended method of testing specimens is in the horizontal orientation, especially for the purpose of regulating the use of materials, it is believed that testing specimens in the vertical orientation might be useful for research and development purposes. With time and experience, this method of testing might be found suitable for more widespread use.

D-2 Purpose.

This test method allows testing of the specimen in the vertical position.

D-3 Basis of Test Method.

This alternative test method using the vertical orientation of the test specimen is based on the text of Chapters 1 through 7. To accommodate the vertical orientation of the specimen, the wording has been revised as necessary, and section and paragraph numbers in parentheses have been provided for quick reference.

D-4 Test Limitations.

(Section 1-3) The test data should be considered to have limited validity if any of the following occurs:

(a) Explosive spalling;

(b) The specimen swells to the point where it touches the spark plug prior to ignition;

(c) The specimen swells to the point where it reaches the plane of the heater base plate during combustion;

(d) Delamination;

(e) In the vertical orientation, the specimen melts sufficiently to overflow the melt-trough.

D-5 Exposure.

(1-4.5) Specimens should be exposed to heating fluxes ranging from 0 kW/m^2 to 100 kW/m^2 in a vertical orientation. External ignition, where used, should be by electric spark. The value of the heating flux and the use of external ignition should be specified by the relevant material or performance standard (*see E-2.3*) or by the test sponsor for research and development purposes.

D-6 Definitions.

Orientation. (Section 1-5) The plane in which the exposed face of the specimen is located during testing, (i.e., vertically facing the heater).

D-7 Test Apparatus.

(2-1.2) The test apparatus should consist of the following components:

(a) A conical-shaped radiant electric heater;

(b) Specimen holders;

(c) An exhaust-gas system with oxygen-monitoring and flow-measuring instrumentation;

(d) An electric ignition spark plug;

(e) A data collection and analysis system; and

(f) A load cell for measuring specimen mass loss.

A general view of the apparatus is shown in Figure 2-1.2(a), and an exploded view of the vertical orientation is shown in Figure D-7.

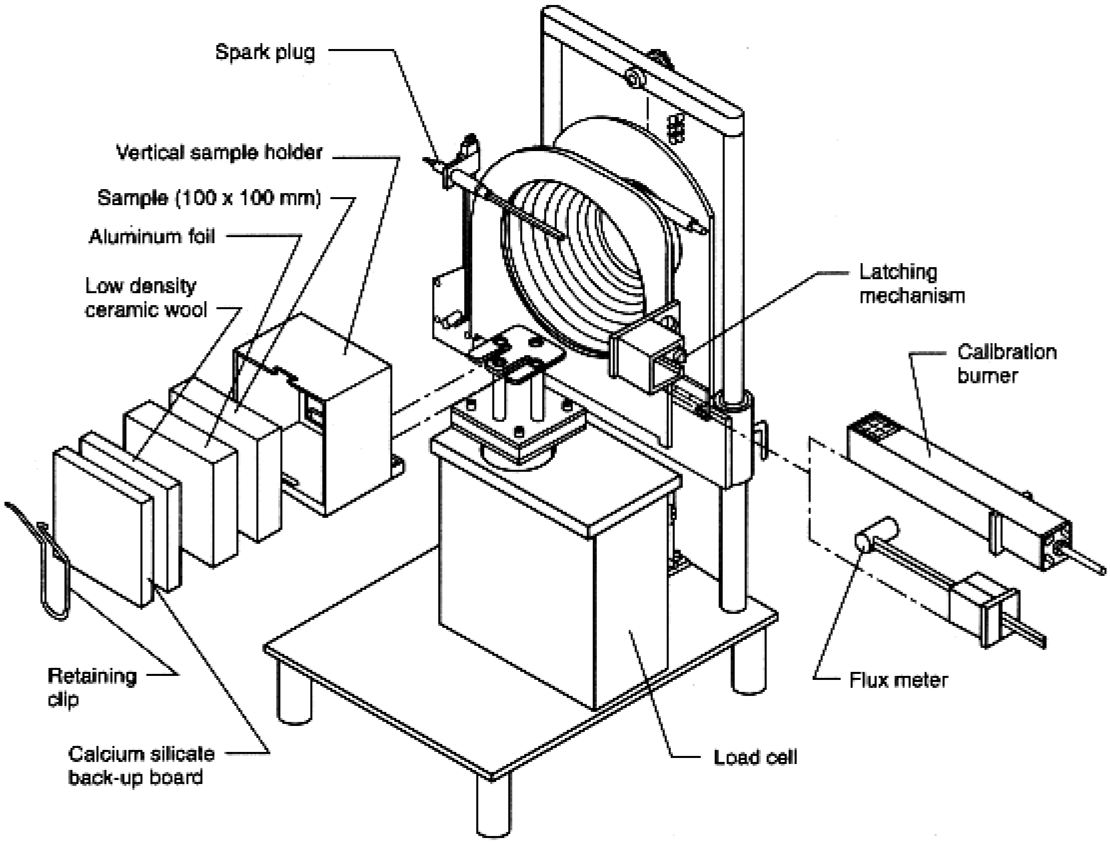


Figure D-7 Exploded view, vertical orientation.

D-8 Heater.

(2-2.2) The heater should be mounted in a vertical orientation. The heater should be capable of producing irradiances on the surface of the specimen of up to 100 kW/m^2. The irradiance should be uniform within the central 50-mm × 50-mm area of the specimen to within ±10 percent.

D-9 Specimen Holder.

(2-6.1) The vertical specimen holder is shown in Figure D-9 and includes a small drip trap to contain a limited amount of molten material. A specimen should be installed in the vertical specimen holder by backing it with a layer of refractory fiber blanket (nominal density 65 kg/m^3). The thickness of the refractory fiber blanket depends on the specimen’s thickness but should be at least 13 mm. A layer of rigid, ceramic fiber millboard should be placed behind the fiber blanket layer. The millboard thickness should be such that the entire assembly is rigidly bound together once the retaining spring clip is inserted behind the millboard. In the vertical orientation, the cone heater height should be set so the center of the heater lines up with the specimen center.

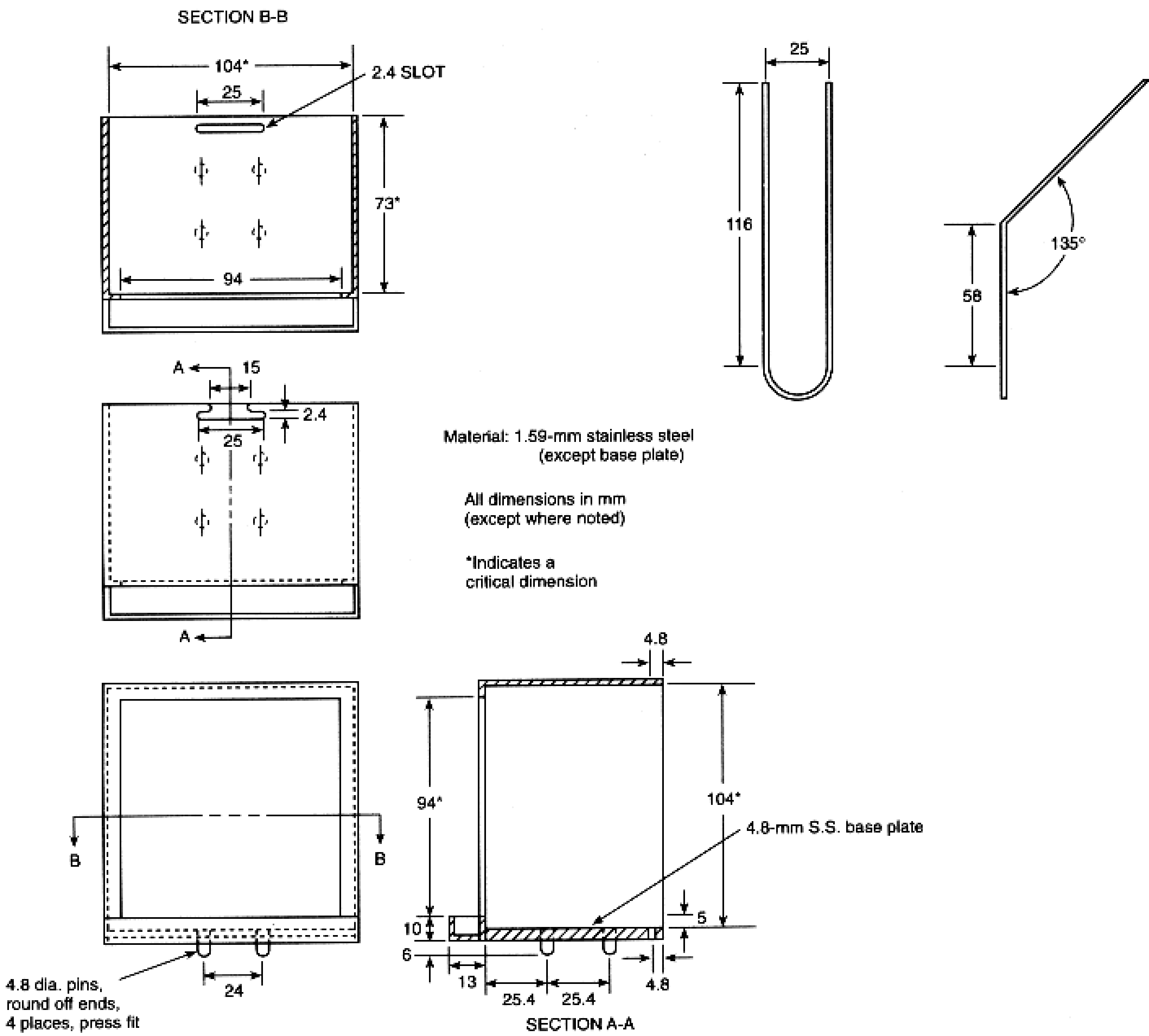


Figure D-9 Vertical specimen holder.

D-10 Ignition Circuit.

(Section 2-7) External ignition should be accomplished by a spark plug powered from a 10-kV transformer. The spark plug should have a gap of 3 mm. The transformer should be of a type specifically designed for spark ignition use. The transformer should have an isolated (ungrounded) secondary to minimize interference with the data transmission lines. The electrode length and location of the spark plug should be such that the spark gap is located in the plane of the specimen face in the vertical orientation and 5 mm above the top of the holder. The spark plug should be removed when sustained flaming is achieved.

Appendix E Commentary

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

E-1 Introduction.

This commentary is provided to:

(a) Furnish some insight into the development of the method;

(b) Describe the rationale for the design of various features of the apparatus; and

(c) Describe the use of the data.

Additional guidance to user of this test is provided in footnote 15.

E-2 Rate of Heat Release Measurements.

E-2.1

A product's rate of heat release is one of the most important variables in determining its potential hazard in a fire. With many products that are composed of many surfaces contributing to a fire, their evaluation is complex.[1] For each separate surface, it first should be determined when, if at all, that surface can ignite. The size of the fire should be determined from any items already burning, since this constitutes the external irradiance to nearby items. The flame spread over the surface in question then should be evaluated. The rate of heat release from the whole surface then can be evaluated using the rate of heat release per unit area, for a given irradiance, as a function of time. The rate of heat release per unit area is the only value that can be measured in a bench-scale test. The total heat release rate output from the burning object equals the sum of the rates for all surfaces. The fact that some elements might burn out and no longer contribute to the fire also should be considered. The procedure is conceptually straightforward but can be very cumbersome to compute.

E-2.2

Many common combustibles do not have the geometrically simple surfaces that are necessary to do computations of this kind. Other complications, such as melting, dripping, or collapsing, also can preclude a detailed mathematical analysis. In such cases, a simpler, more empirical model is appropriate. An example of the use of bench-style heat release rate measurements in deriving a fire hazard assessment is available.[2]

E-2.3

The test method does not prescribe the irradiance levels nor whether external ignition should be used. This should be determined separately for each product class. For a given class of applications and products, a comparison with some full-scale fires generally is necessary to determine the time period over which the heat release rate should be calculated. A material or performance standard then can be developed for that product category that can provide further guidance and limitations for testing. For exploratory testing, in the absence of more specific determinations for a given class of applications, a value of 35 kW/m^2 may be permitted to be utilized first. The results obtained might then suggest whether additional testing at different irradiance levels should be performed.

Studies to address the degrees of combustibility of building materials have been performed by Forintek Canada Corporation and Underwriters Laboratories of Canada (ULC). These studies suggest that an irradiance level of 50 kW/m^2 for an exposure period of 15 minutes might be appropriate for regulatory purposes, whereas the National Institute of Standards and Technology (NIST) research suggests a level of 75 kW/m^2 for 10 minutes.[3,4]

E-3 Choice of Operating Principles.

E-3.1

A number of apparatus have been developed over the years for measuring rate of heat release; most of these have been reviewed in detail.[5] Traditionally, the simplest measurement scheme is a direct measurement of flow enthalpy from a chamber thermally insulated to create an adiabatic environment. A truly adiabatic apparatus, with the use of guard heaters, is possible but, because of the expense, has not been implemented. A simply-insulated combustion chamber leads to a significant undermeasurement of the heat release, so that only an empirical calibration is possible. An example of such an insulated chamber method is described in NFPA 263, *Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products*. Furthermore, that calibration could be sensitive to the radiant fraction (or sootiness) of the combustion products.[6,7] A more advanced scheme is an isothermal rather than adiabatic instrument, with the heat release rate defined as that which is supplied by a substitution burner to maintain isothermal conditions.[8] This scheme provides better results, since only second-order heat loss error terms remain; however, its practical implementation is complex and costly.

E-3.2

It can be concluded that it is difficult to measure heat directly without some heat loss. However, it is simple to capture all combustion products without losing any heat and to measure the oxygen concentration in that stream. Heat release can be computed from such measurements with the availability of the oxygen consumption principle.[9] This principle states that for most common combustibles an amount of heat equal to 13.1×10^3 kJ is released for each kilogram of oxygen consumed from the airstream. This constant varies only about ±5 percent for most common combustibles; some exceptions are known.[9] The method remains useful even if a significant fraction of the products become CO or soot, rather than CO_2; in these cases, correction terms can be applied.[9,10] A typical case, involving cellulose-producing CO from 10 percent incomplete combustion, has been analyzed with less than 2 percent error.[9] It should be noted that excessively high CO produced as a result of restricted oxygen supply cannot occur in the calorimeter used in this test method, since oxygen intake is not restricted. By adopting the oxygen consumption principle as the method of measurement, it is possible to design an apparatus of significantly improved precision but without excessive complexity. Since heat measurements are not necessary, the apparatus does not need thermal insulation.

E-4 Heater Design.

E-4.1

Experience with various rate of heat release techniques suggests that, for minimal errors in irradiance, the specimen should be exposed to only the following:

(a) A thermostatically controlled heater;

(b) A water-cooled plate; or

(c) Open air.

If nearby solid surfaces are not temperature controlled, the surface temperatures can rise due to specimen flame heating and then act as additional sources of radiation to the specimen. Furthermore, where oxygen consumption is used as the measurement principle, a gas-fired heater should not be used, because it can cause fluctuations in the oxygen readings, even though they can be removed by steady-state measurements.

E-4.2

A heater in the shape of a truncated cone first was explored for use in an ignitibility apparatus by the International Organization for Standardization (ISO).[11] The heater adopted in the current method is similar, but not identical, to the ISO cone. The main differences include higher heat fluxes, temperature control, and more rugged design details. In the horizontal orientation, the conical shape approximately follows the fire plume contours, while the central hole allows the stream to emerge without impacting on the heater. A thick layer of cool air is pulled along, and the flames do not attach to the side of the cone. The central hole has an additional function: without the hole, the middle of the specimen would receive a higher irradiance than the edges. With the hole, the irradiance is uniform to within ±2 percent. In the vertical orientation, the hole still serves the purpose of providing radiation uniformity although, because of the presence of a natural convection boundary layer, the deviations are higher (from ±5 percent to ±10 percent).[12]

E-5 Pilot Ignition.

Ignition of test specimens in many apparatus is achieved by a gas pilot. This method tends to pose difficulties such as sooting, deterioration of orifices, and contribution to the heat release rate. It is difficult to design a pilot that is centrally located over the specimen, is resistant to blowout, and, yet, does not apply an additional heat flux to the specimen. (A point of elevated heating on the specimen makes it mathematically difficult to analyze the response of the specimen.) An electric spark is free of most of these difficulties, needing only occasional cleaning and adjustment of the electrodes. For these reasons, an electric spark ignition is recommended.

E-6 Back Face Conditions.

The heat loss through the specimen back face can have an influence on the burning rate near the end of the burning time of the back face. For reproducible measurements, the losses through the back face should be standardized. The simplest theoretical boundary conditions — an adiabatic or an isothermal boundary at ambient temperature — are not achievable. However, a reasonable approximation of the former can be made by using a layer of insulating material. This is easier to achieve for the horizontal orientation, in which case a very low density refractory blanket is used. In the vertical orientation, some structural rigidity of the backing is desired; consequently, a layer of high density backing might be necessary.

E-7 Oxygen Analyzer.

The analyzer should be of the paramagnetic type, with baseline noise and short-term drift of approximately ±50 ppm O_2 or less. Other types of analyzers (e.g., electrochemical and catalytic) generally cannot meet this recommendation. Paramagnetic analyzers also exhibit a linear response. The linearity is normally better than can be determined with ±0.1 percent O_2/N_2 gas mixtures. Since an oxygen analyzer is sensitive to stream pressures, either the readings should be compensated with an absolute pressure transducer connected to the analyzer or the pressure should be mechanically regulated for flow fluctuations and atmospheric pressure variations. The analyzer and the pressure-regulating or measuring devices should be located in a constant-temperature environment to avoid flow errors.

E-8 Limits to Resolution.

E-8.1

Methane calibration studies showed typical fluctuations of ±1.5 percent, with a linearity to within 5 percent over the range of 5 kW to 12 kW.[12] Calibrations with other gases show similar results. Calibration gases can be delivered to the burner in a highly steady manner. The uniformity of solid fuels combustion, however, is governed by the pyrolysis at the surface and, under some circumstances, shows substantial fluctuations. For instance, the fluctuations for polymethylmethacrylate are greater than for red oak.[12] Burning thermoplastic specimens occasionally eject individual molten streamers. With solid materials, the limits to resolution can be expected to be set by the specimen pyrolysis process, rather than by instrument limits.

E-8.2

The limits to the speed of any heat release rate technique are set by the slowest responding element. In the case of the current method, this is the oxygen analyzer, which typically shows a 10 percent to 90 percent response time of 6.9 seconds. The response times of the pressure transducer and thermocouple can be much quicker. They should be set only slightly faster, however, to avoid introducing instrument noise without increasing resolution.

E-9 Effective Heat of Combustion.

The effective heat of combustion is a constant during the combustion of homogeneous specimens having only a single mode of degradation and is less than the value of the theoretical net heat of combustion. Most organic liquids have a single mode of degradation and, therefore, a constant effective heat of combustion. By contrast, cellulosic products typically show more than one mode of degradation and varying effective heat of combustion. For materials having more than one mode of degradation, or for composites or nonhomogeneous materials, the effective heat of combustion is not necessarily constant.

E-10 Smoke Obscuration Measurements.

E-10.1

The smoke measurement system is different from that used in NFPA 258, *Standard Research Test Method for Determining Smoke Generation of Solid Materials*, for the following reasons:

(a) Simultaneous mass measurements are available;

(b) Irradiances up to 100 kW/m^2 are available;

(c) The combustion takes place in a flow stream, not in a closed box; and

(d) A monochromatic light source is used.

E-10.2

Accurate measurement of smoke obscuration requires, among other considerations, the following:

(a) A highly collimated light source, insensitive to stray light;

(b) Measurement in a well-mixed, unstratified stream;

(c) A high degree of stability against drift due to voltage fluctuations, such as source aging and thermal effects; and

(d) The ability to make extended measurements without error due to progressive coating of optics by soot.

E-10.3

In addition, a monochromatic source should be selected, preferably in the red portion of the spectrum, for ease of interpreting the data according to the theoretical modes.[13] For convenience, direct electric output in logarithmic units to avoid the need for manual range switching or resulting inaccuracies at the high end of the scale should be provided. An instrument has been designed that is intended to meet all of these specifications (*see Figure 2-11*).[14] Additional construction details are given in construction drawings available from the Building and Fire Research Laboratory, National Institute of Standards and Technology, Gaithersburg, MD 20899. The theory for data analysis is from footnote 15.

[1]V. Babrauskas, J. R. Lawson, W. D. Walton, and W. M. Twilley, "Upholstered Furniture Heat Release Rates Measured with a Furniture Calorimeter," Nat. Bur. Stand. (U.S.), NBSIR 82-2604 (1982).

[2]V. Babrauskas and J. F. Krasny, "Fire Behavior of Upholstery Furniture," NBS monograph 173, the Nat. Bur. Stand. (U.S.) (1985).

[3]L. R. Richardson, "Determining Degrees of Combustibility of Building Materials," *National Building Code of Canada*, 1st International Conference and Exhibition on Fire and Materials, September 24-25, 1992.

[4]V. Babrauskas, "North American Experiences in the Use of Cone Calorimeter Data for Classification of Products," Proceedings of the International EUREFIC Seminar, pp. 89-103, 1991.

[5]M. Janssens, "Calorimetry," *SFPE Handbook*, Second Edition, Section 3, Chapter 2, 1995.

[6]R. F. Krause and R. G. Gann, "Rate of Heat Release Measurements Using Oxygen Consumption," *J. Fire and Flammability*, Vol. 11, pp. 117-130 (April 1980).

[7]V. Babrauskas, "Performance of the Ohio State University Rate of Heat Release Apparatus Using Polymethylmetharcylate and Gaseous Fuels," *Fire Safety J.* Vol. 5, pp. 9-20 (1982).

[8]J. Tordella and W. H. Twilley, "Development of a Calorimeter for Simultaneously Measuring Heat Release and Mass Loss Rates," Nat. Bur. Stand. (U.S.), NBSIR 83-2708 (1983).

[9]C. Hugget, “Estimation of Rate of Heat Release by Means of Oxygen Consumption Measurements,” *Fire and Materials*, Vol. 4, pp. 61-65 (1980).

[10]W. J. Parker, “Calculations of the Heat Release Rate by Oxygen Consumption for Various Applications,” Nat. Bur. Stand. (U.S.), NBSIR 81-2427 (1982).

[11] “Fire Test — Reaction to Fire Ignitability of Building Products,” ISO 5657, International Organization for Standardization, Geneva, 1986.

[12]V. Babrauskas, “Development of Cone Calorimeter — A Bench-Scale Heat Release Rate Apparatus Based on Oxygen Consumption,” Nat. Bur. Stand. (U.S.), NBSIR 82-2611 (1982).

[13]G. Mullholland, “How Well Are We Measuring Smoke?” *Fire and Materials,* Vol. 6, pp. 65-67 (1982).

[14]V. Babrauskas and G. Mullholland, “Smoke and Soot Data Determinations in the Cone Calorimeter, ASTM STP 983,” *Mathematical Modeling of Fires*, pp. 83-104, American Society for Testing and Materials, Philadelphia (1987).

[15]W. H. Twilley and V. Babrauskas, “User’s Guide for the Cone Calorimeter,” Special Publication SP 745, Nat. Bur. Stand (U.S.) (1988).

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 258, *Standard Research Test Method for Determining Smoke Generation of Solid Materials*, 1994 edition.

NFPA 263, *Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products*, 1994 edition.

F-1.2 Other Publications.

F-1.2.1 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM D3286, *Standard Test Method for Gross Calorific Value of Coal and Coke by the Isoperibol Bomb Calorimeter*, 1991.

ASTM Research Report RR: E05-1008.

NFPA 264A

1994 Edition

Standard Method of Test for Heat Release Rates for

Upholstered Furniture Components or Composites and

Mattresses Using an Oxygen Consumption Calorimeter

1994 Edition

This edition of NFPA 264A, *Standard Method of Test for Heat Release Rates for Upholstered Furniture Components or Composites and Mattresses Using an Oxygen Consumption Calorimeter*, was prepared by the Technical Committee on Fire Tests 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 264A

The original 1990 edition of NFPA 264A is based on the methods of measuring rates of heat release using an oxygen consumption calorimeter developed at the National Bureau of Standards (now the National Institute of Standards and Technology) by V. Babrauskas et al. It addresses only upholstered furniture and mattresses. This edition of NFPA 264A is a reconfirmation of the original document with minor editorial changes. The methods of measuring rates of heat release are still being used within the industry in areas such as product development. In testing of other various materials, a new document, NFPA 264, *Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*, was developed. The NFPA 264 document is closely related to and derived from NFPA 264A.

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Committee Scope: This Committee shall have primary responsibility for documents on fire testing procedures where such documents are not available. The Committee shall 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; and act in a liaison capacity between NFPA and the committees of other organizations writing fire test standards. The Committee shall not be responsible for fire tests that are used to evaluate extinguishing agents, devices, or systems.

NFPA 264A
Standard Method of Test for
Heat Release Rates for UpholsteredFurniture Components or Composites andMattresses Using an Oxygen Consumption Calorimeter

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 Appendix D and Appendix E.

Chapter 1 General

1-1 Scope.

1-1.1

The test method is used to determine the ignitibility and the release rates of heat from components or composite structures of upholstered furniture and mattresses using an oxygen consumption calorimeter.

1-1.2

The method provides for radiant thermal exposure of a horizontally oriented specimen using spark ignition.

1-1.3

The radiant exposure shall be maintained at a constant rate of 35 kW/m^2 to determine time to sustained flaming, rate of heat release (kW/m^2), and effective heat of combustion (MJ/kg).

1-1.4

The rate of heat release is determined by measurement of oxygen consumption as determined by the level of oxygen concentration and the flow rate in the combustion product stream; the effective heat of combustion is determined from a concomitant measurement of specimen mass loss rate in combination with the heat release rate.

1-1.5

The testing is done on bench-scale specimens combining the furniture or mattress cover fabrics and padding.

1-1.6

This method can involve the use of hazardous materials and hazardous equipment, or materials and equipment that can generate gases/liquids that are hazardous or can cause chronic health problems for those performing the tests and that require special waste disposal procedures. This standard does not purport to address all the safety/health problems associated with its use. It is the responsibility of the users of this standard to consult with and establish safety and health practices with those individuals actually performing the tests and to determine the applicability of regulatory limitations prior to use.

1-1.7 Metric Units.

For consistency with the common practice employed by testing laboratories, all units are expressed in metric terms throughout the document.

1-2 Significance and Use.

1-2.1

This test method is used to determine the time of ignition and heat release rates of materials and composites exposed to a prescribed heat flux.

NOTE: The rate of heat release at different flux exposure levels is permitted to be determined using this test method. Mass loss, mass loss rate, production of smoke and other gases, carbon dioxide production, and carbon monoxide production can be observed and noted while using the test apparatus, but none of the values of these observed conditions are to be considered a part of this method.

1-2.2

Quantitative heat release measurements provide information that can be used in the design of upholstery and mattress products and in product development.

1-2.3

Release rate measurements are a source of useful information for product development, as they provide a quantitative measure of specific changes in fire performance caused by product modifications.

1-2.4 Test Limitations.

The test data can have limited validity if:

(a) Explosive spalling occurs.

(b) The specimen swells sufficiently prior to ignition to cause it to touch the spark plug or if it swells up to the plane of the heater base during combustion.

1-3 Summary of Test Method.

1-3.1*

This test method is based on the observation that, generally, the net heat of combustion is directly related to the amount of oxygen required for combustion. Approximately 13.1×10^3 kJ of heat are released per 1 kg of oxygen consumed. Specimens in the test shall be burned in ambient air conditions while being subjected to a prescribed external heat flux of 35 kW/m^2.

1-3.2

The rate of heat release is determined by measurement of the oxygen consumption, as determined by the oxygen concentration and the flow rate in the combustion product stream.

1-3.3

The primary measurements are of oxygen concentration and exhaust gas flow rate. Additional measurements include the mass loss rate of the specimen, the time to sustained flaming, the effective heat of combustion, and other measurements as required in the relevant material or performance standard. Ignitibility is determined as the measure of time from initial exposure to time of sustained flaming.

1-4 Definitions and Terms.

Effective Heat of Combustion. The measured heat release divided by the mass loss for a specified time period.

Gas-Phase Ignition. Ignition of pyrolysis products leaving a heated surface.

Heat Release Rate. The heat evolved from a specimen, expressed as a unit of exposed specimen area per a unit of time.

Heating Flux. The prescribed incident flux imposed externally by the heater on the specimen at the initiation of the test.

Ignitibility. The propensity for ignition, as measured by the time to sustained flaming at a specified heating flux.

Net Heat of Combustion. The oxygen bomb calorimeter value for the heat of combustion, corrected for the gaseous state of water produced.

Orientation. The plane in which the exposed face of the specimen is located during testing, either horizontal with face up or vertical.

Oxygen Consumption Principle. The expression of the relationship between the mass of oxygen consumed during combustion and the heat released.

Shall. Indicates a mandatory requirement.

Smoke Obscuration. Reduction of light transmission by smoke, as measured by light attenuation.

Sustained Flaming. Existence of flame on or over the surface of the specimen for a period of over 10 seconds.

Upholstered. A surface padded with a resilient material and covered with a fabric, film, or other external covering.

Upholstered Furniture. Chairs, sofas, or similar items, each including a structural frame having both seat and back surfaces padded with resilient material and covered with an external fabric, film, or leather and providing seating for one or more persons.

Visible Smoke. The obscuration of transmitted light caused by combustion products released during the test.

1-5 Symbols.

A_s = nominal specimen exposed surface area (0.01 m^2).

C = calibration constant for oxygen consumption analysis ($m^{1/2}kg^{1/2}K^{1/2}$).

Δh_c = net heat of combustion (kJ/kg).

Δh_c, eff = effective heat of combustion (kJ/kg).

m = specimen mass (kg).

m_f = final specimen mass (kg).

m_i = initial specimen mass (kg).

$\dot{m}$ = specimen mass loss rate (kg/s).

ΔP = orifice meter pressure differential (Pa).

$\dot{q}$ = heat release rate (kW).

$\dot{q}''$ = heat release rate per unit area (kW/m^2).

r_o = stoichiometric oxygen/fuel mass ratio.

t = time (s).

t_d = oxygen analyzer delay time (s).

Δt = sampling time interval (s).

T_e = absolute temperature of gas at the orifice meter (K).

$\dot{V}$ = volume exhaust flow rate (m^3/s).

X_{O2} = oxygen analyzer reading, mole fraction of O_2.

$X°_{O2}$ = initial value of oxygen analyzer reading.

X'_{O2} = oxygen analyzer reading, before delay time correction.

Chapter 2 Test Apparatus

2-1 General.

The test apparatus includes the following main components: a conical-shaped radiant electric heater capable of horizontal orientation; specimen holders; a load cell for monitoring specimen mass; an exhaust-gas system with oxygen-monitoring and flow-measuring instrumentation; and a data collection and analysis system. A general view of the apparatus is shown in Figure 2-1(a). A cross section view through the heater is shown in Figure 2-1(b). An exploded view is shown in Figure 2-1(c).

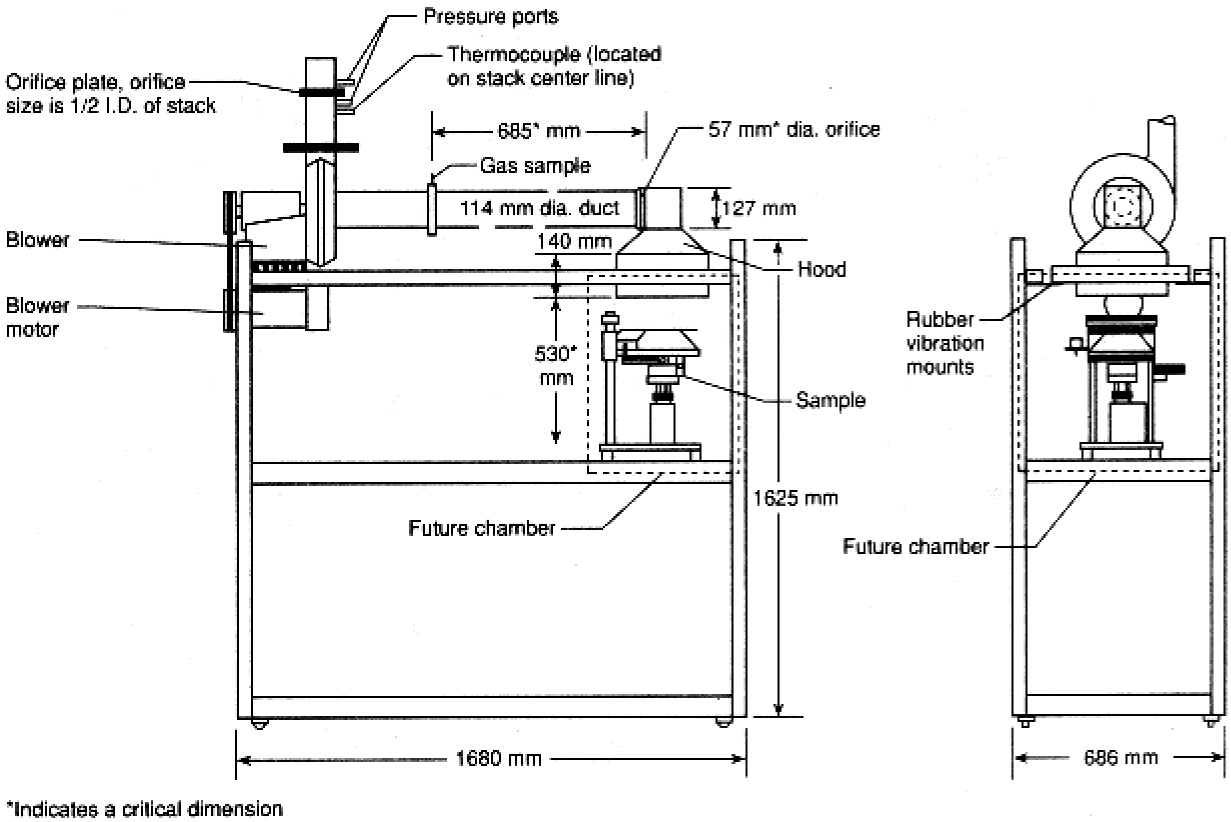

Figure 2-1(a) Overall view of apparatus.

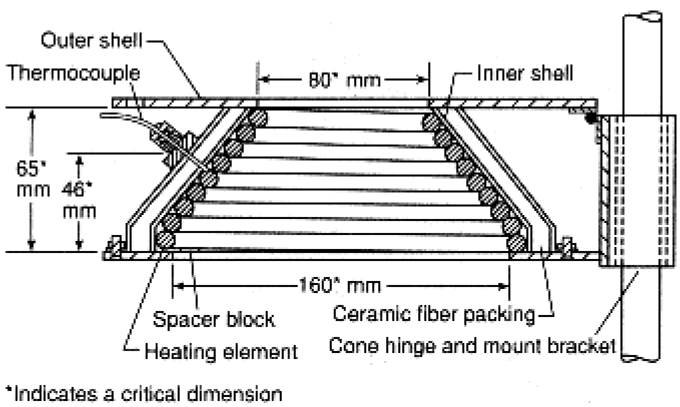

Figure 2-1(b) Cross section view through the heater.

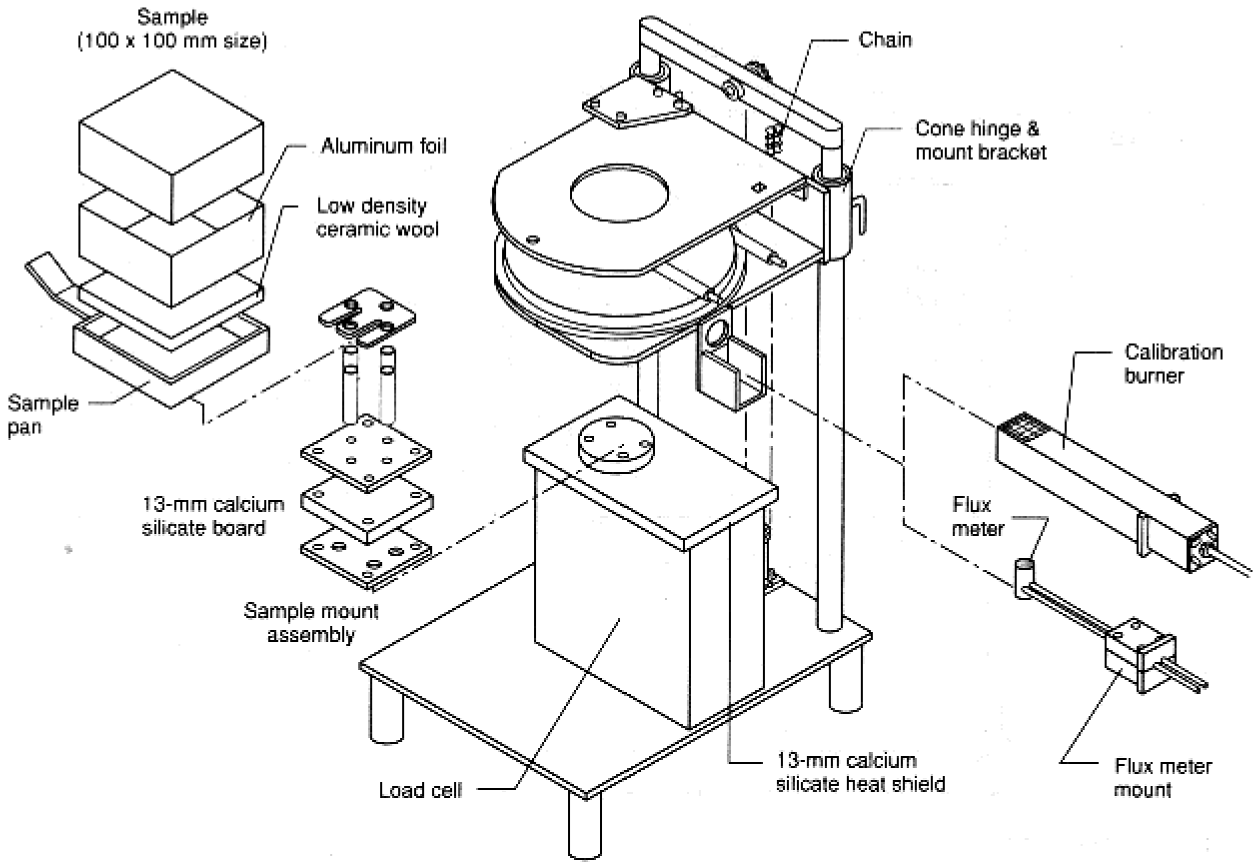

Figure 2-1(c) Exploded view, horizontal orientation.

2-2 Conical Heater.

The active element is an electrical heater rod rated at 5000 W at 240 V and tightly wound into the shape of a truncated cone [*see Figure 2-1(b)*]. The heater is encased on the outside with a double-wall, stainless steel cone packed with refractory fiber material of approximately 100 kg/m^3 density. The heat flux from the heater is held at preset levels by means of a temperature controller using three thermocouples symmetrically located and in contact with, but not welded to, the heater. The heater produces heating fluxes at the surface of the specimen up to 100 kW/m^2.

2-3 Load Cell and Specimen Mounting.

2-3.1 Load Cell.

The general arrangement of the specimen holders on the load cell is indicated in Figure 2-1(c). The load cell has a load capacity of 500 g and a tare adjustment range of 3.5 kg.

2-3.2 Specimen Mounting.

The horizontal specimen mounting is shown in Figure 2-3.2(a). An optional retainer frame and wire grid, shown in Figures 2-3.2(b) and (c), are used with intumescing specimens. This frame is also used to reduce unrepresentative edge-burning of composite specimens and to retain specimens prone to delamination. The bottom of the horizontal specimen holder is lined with a 13-mm or greater layer of low density (nominal 65 kg/m^3) refractory fiber blanket. In the horizontal orientation, the distance between the bottom surface of the cone heater and the top of the specimen is adjusted to be 25 mm ± 2 mm by means of the sliding cone height adjustment. [*See Figure 2-1(b).*]

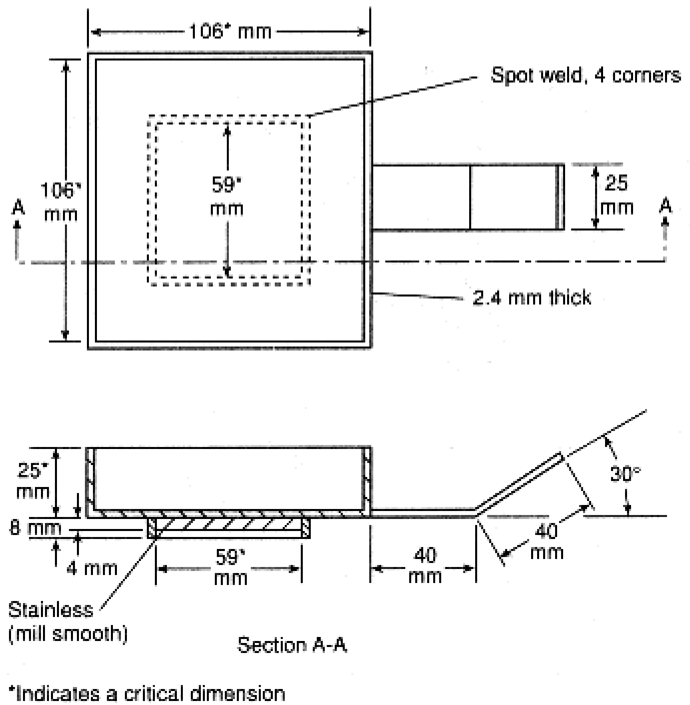

Figure 2-3.2(a) Horizontal specimen holder.

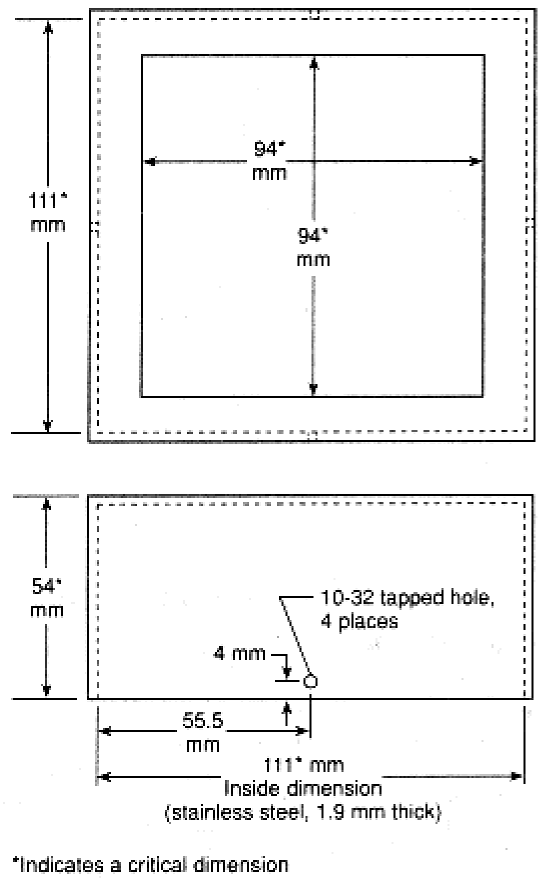

Figure 2-3.2(b) Optional retainer frame for horizontal orientation testing.

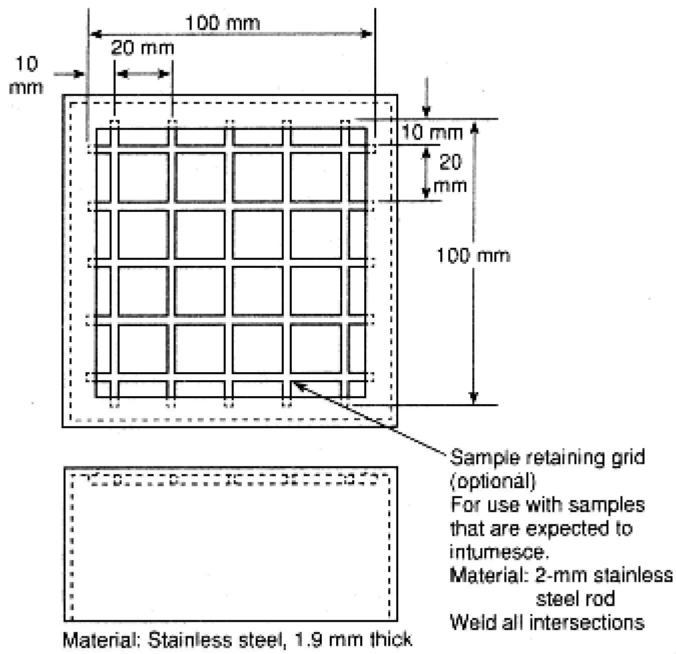

Figure 2-3.2(c) Wire grid for use in the horizontal retaining frame or in the vertical holder.

2-4 Exhaust System.

The exhaust-gas system consists of a high-temperature blower, a hood, intake and exhaust ducts for the blower, and an orifice plate flow meter (*see Figure 2-4*). A ring sampler is located in the blower intake duct for gas sampling. The ring sampler has 12 small holes to average the stream composition; the holes face away from the flow to avoid soot clogging. A restrictive orifice is located between the hood and the duct to promote mixing. The exhaust system shall be capable of developing flows from 0.012 m^3/s to 0.035 m^3/s. The flow rate is determined by measuring the differential pressure across a sharp-edged orifice using a capacitive pressure transducer. The gas stream temperature is measured using a thermocouple.

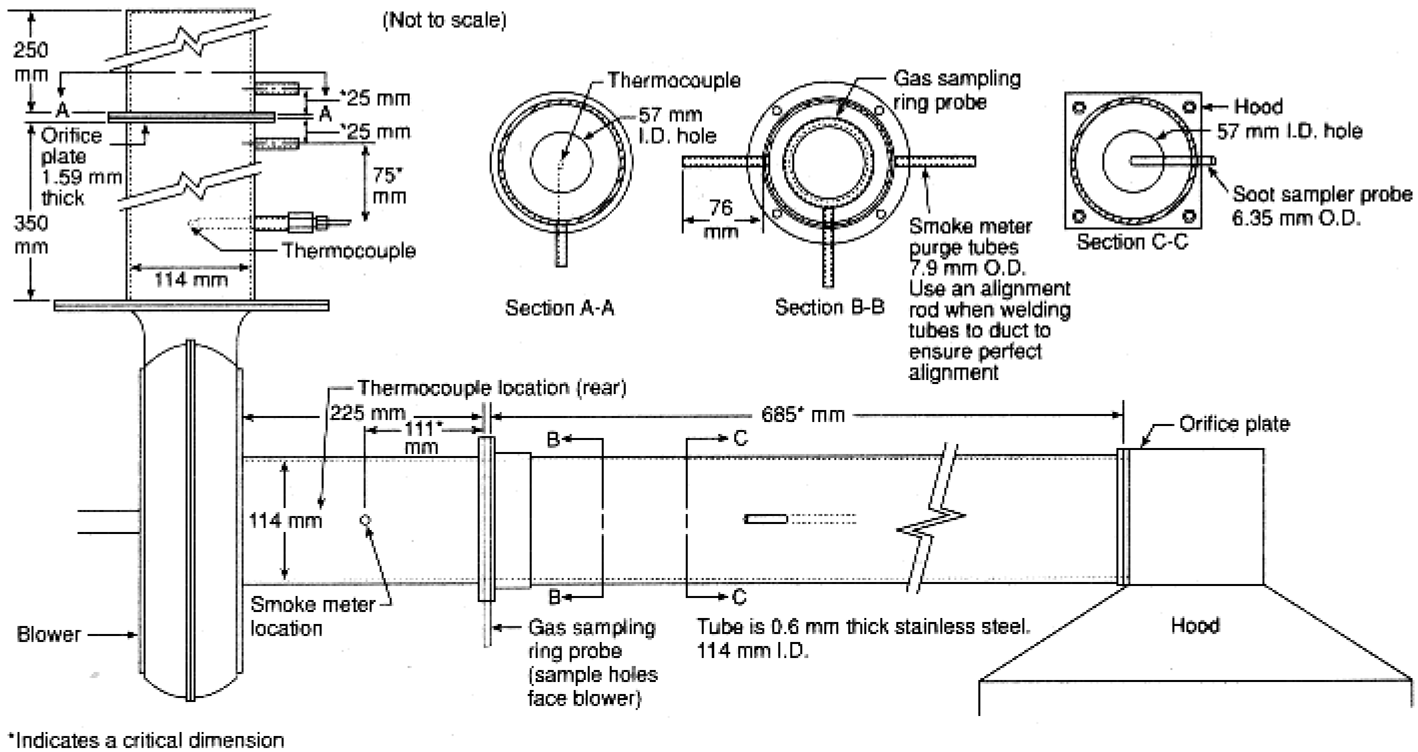

Figure 2-4 Exhaust system.

2-5 Gas Sampling Arrangements.

The gas sampling arrangements are shown in Figure 2-5. A soot filter is used to prevent the entry of soot. A thermoelectric (or mechanically chilled) cold trap removes most of the moisture. To speed up the response of the system, a waste regulator is set to dump all the flow except the amount needed for the oxygen analyzer. The flow then is passed through a final moisture trap and a trap for CO_2 removal. A paramagnetic oxygen analyzer with the ability to measure the proportion of O_2 from a range of approximately 0 to 25 percent is used.

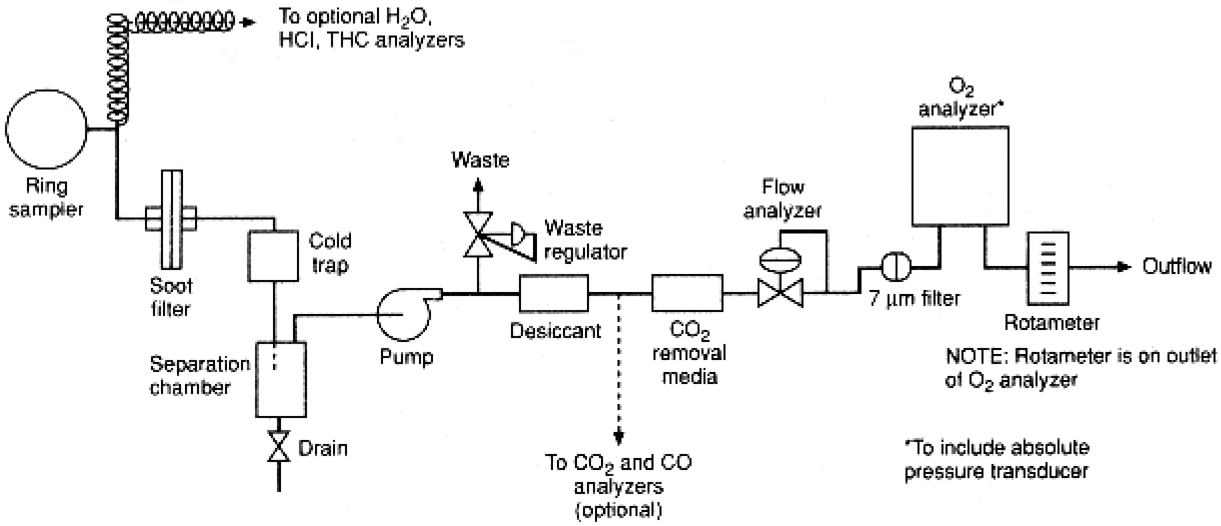

Figure 2-5 Gas analyzer instrumentation.

2-6 Ignition Circuit.

Ignition is accomplished by a spark plug fed from a 10-kV transformer. The spark plug electrode length and location are such that the spark gap is located 13 mm ± 2 mm above the center of the specimen in the horizontal orientation. The spark plug is retracted out of the fire flow when sustained flaming is achieved.

2-7 Calibration Equipment.

2-7.1 Heat Flux Meter.

A 12.5-mm diameter total heat flux meter of the Schmidt-Boelter or Gardon type is positioned at a location equivalent to the specimen face center in either orientation. The flux meter is used to calibrate the heater temperature controller. [*See Figure 2-1(c).*]

2-7.2 Calibration Burner.

A calibration burner [*see Figure 2-1(c)*] is used to calibrate the apparatus. The burner is fed through a calibrated flow meter using methane gas of at least 99.9 percent purity.

2-7.3 Optical Calibration Filters.

Glass neutral density filters of at least two different values, accurately calibrated at a laser wavelength of 0.6328 mm, are required.

2-8 Digital Data Collection.

Data collection shall include oxygen analyzer output, orifice meter DP and temperature measurements, load cell measurements, and smoke extinction beam measurements. Speed and capacity shall be sufficient to collect data every 5 seconds for at least 3600 seconds. For digital data collection, a system with a minimum of 16-bit resolution capability shall be used, and the input sensitivity shall be scaled for all channels individually according to the maximum expected signal level. For determining ignitibility measurements, a timing device with a resolution of 1 second, or better, is needed.

Chapter 3 Calibration of Equipment

3-1 Exhaust Flow Rate.

The exhaust flow rate shall be set to the value specified in 5-1.3.

3-2 Heater Flux Calibration.

At the start of the day, the temperature controller shall be calibrated to the required flux (35 kW/m^2 ± 2 kW/m^2) by using the heat flux meter. A specimen or specimen holder shall not be used when the heat flux meter is inserted into the calibration position. The cone heater shall be operated for at least 10 minutes and the controller shall be within its proportional band before the calibration is begun.

3-3 Oxygen Analyzer Calibration.

3-3.1 Preliminary Calibrations.

3-3.1.1 The oxygen analyzer delay time shall be determined. This is done by providing a methane flow rate equivalent to 10 kW ± 0.5 kW to the calibration burner. As the methane supply, while turned on and ignited, reaches a steady value and then returns to the baseline after it is cut off, the output of the analyzer shall be recorded on a strip chart recorder. The temperature for the exhaust orifice meter shall be recorded at the same time. The turn-on delay shall be determined by calculating the difference between the time when the temperature reading reaches 50 percent of its final deflection and the time when the oxygen reading reaches 50 percent of its final deflection.

The turn-off delay shall be determined in a similar manner to that used for the turn-on delay. The delay time, t_d, shall be used as the average of the turn-on delay and the turn-off delay. The oxygen analyzer delay time (t_d) shall be used to time-shift all the subsequent oxygen readings.

3-3.1.2 If the oxygen analyzer is equipped with an electric response time adjustment, it shall be set so that there is just a trace of overshoot when switching rapidly between two different calibration gases.

3-3.1.3 The timing of the scans by the data collection system shall be checked with a stop watch and the calibration burn. The reduced data output shall show the burner turn-off time correct to within one-half of the interval between data collection scans.

3-3.2 Operating Calibrations.

Each day before testing, the oxygen analyzer shall be range-spanned and zeroed. For zeroing, the analyzer shall be fed with nitrogen gas flowing at the same range and pressure as set for sample gases. Range-spanning shall be done by running ambient room air and adjusting for a response of 20.95 percent ± 0.01 percent.

3-4 Heat Release Rate Calibration.

3-4.1

The heat release rate calibration shall be performed by introducing methane into the calibration burner at a flow rate corresponding to 10 kW, based on the net heat of combustion of methane (50.0×10^3 kJ/kg). Methane of at least 99.9 percent purity shall be used. Flow measurement shall be made using a wet or dry laboratory test meter. Other types of flow meters, if used, shall be calibrated against an appropriate test meter. The calibration shall be conducted at the same exhaust blower setting to be used for subsequent testing. Calibration shall be permitted to be performed with or without the cone heater operating but shall not be required to be performed during heater warm-up. Heat release rate calibration shall be performed daily when testing. The required calculations are given in Section 6-1.

3-4.2

At least once a month and also after any instrument repairs, an additional calibration check shall be performed after the 10-kW calibration. This check shall be performed at a flow rate corresponding to 5 kW using the basic procedure as described in 3-4.1. With the instrument properly calibrated using the 10-kW calibration, the 5-kW check shall give a heat release rate value to within ± 5 percent accuracy.

3-5 Load Cell Calibration.

The load cell calibration shall be checked with standard weights in the range of the test specimen weight before each series of tests. The load cell mechanical zero shall be permitted to be adjusted when using the edge frame or if the apparatus was not previously used in the horizontal orientation.

Chapter 4 Test Specimens

4-1 Size and Preparation.

4-1.1

The construction of the test specimens shall reflect the actual construction used in the upholstered or mattress items. The test specimens shall represent padding and upholstery fabric materials but not frame materials, welt cords, decking construction articles, and dust covers. The test specimen shall in all cases comprise the upholstery or mattress fabric and any intermediate layers found between the upholstery fabric and the padding that are of a thickness of 8 mm or less. If there is only one padding material, then its thickness shall be such that the total specimen thickness, including the fabric and any intermediate layers, is 50 mm.

If the construction involves several material layers, then the test specimen shall comprise all the types of layers sampled in the following manner: upholstery, fabric, or intermediate layers 8 mm thick or less shall be used in full thickness. The depth used by the full-thickness layers shall be totaled and subtracted from 50 mm. For the balance of the depth, the remaining layers shall be sectioned in thickness such that the ratio of their thicknesses in the test specimen is the same as in the upholstered item.

4-1.2

The upholstery or mattress fabric and intermediate layers (if any) shall be cut to a size of approximately 200 mm × 200 mm, with a square measuring 50 mm × 50 mm removed at each corner. The length and width of the padding layers shall be slightly less than 100 mm, so that the fabric and intermediate layers can be folded over each of the four sides to produce a specimen measuring 100 mm × 100 mm. The folded-over sides shall be edge-stapled to the padding near the bottom of the specimen.

4-1.3

The finished test specimen shall be covered with aluminum foil approximately 0.04 mm thick on the four sides and the bottom. A single sheet of aluminum foil, approximately 200 mm × 200 mm, shall be used. The corners shall be folded at a 45-degree angle flush against the sides.

4-2 Conditioning.

Specimens shall be conditioned to the point of moisture equilibrium (constant weight) at an ambient temperature of 23°C ± 3°C and a relative humidity of 50 percent ± 5 percent.

Chapter 5 Test Procedure

5-1 Preparation.

5-1.1

The CO_2 trap and the final moisture trap shall be checked. The sorbents shall be replaced, if necessary. Any accumulated water in the cold trap separation chamber shall be drained. Normal operating temperature of the cold trap shall be 0°C, or lower.

5-1.2*

The power to the cone heater and the exhaust blower shall be turned on.

5-1.3

The exhaust flow rate shall be set at 0.024 m^3/s ± 0.002 m^3/s.

5-1.4

The required calibration procedures specified in Chapter 3 shall be performed. An empty specimen holder (with refractory blanket) shall be put in place during warm-up and in between tests to avoid excessive heat transmission to the load cell.

5-1.5

The spark plug holder shall be positioned in the location appropriate to the orientation being used.

5-2 Procedure.

5-2.1

When ready to test, the empty specimen holder shall be removed. It shall be verified that the distance between the bottom of the cone heater base plate and the top of the specimen is 25 mm ± 2 mm.

5-2.2

With the specimen held in the appropriate holder, the holder shall be set in place and the data collection shall begin. Initially, the holder shall be at room temperature.

5-2.3

The ignition timer shall be started. The spark plug shall be moved into place and the spark power shall be turned on. This procedure shall be performed as rapidly as possible upon specimen insertion.

5-2.4

When sustained flaming occurs, the timer shall be stopped and the spark power shall be turned off. The spark plug shall be moved out of the flame. Note that the ignition time marks the start of sustained flaming; therefore, if the timer is stopped at the end of the 10-second observation period, that time minus 10 seconds shall be reported.

5-2.5

Data shall be collected until flaming or other signs of combustion cease or until 20 minutes have elapsed. Physical changes to the sample, such as melting, swelling, and cracking shall be recorded.

5-2.6

The specimen holder shall be removed.

5-2.7

The specimen holder shall be replaced with an empty specimen holder to avoid heat damage to the load cell.

5-2.8

If the specimen does not ignite within 10 minutes, it shall be removed and discarded.

> **IMPORTANT:** Testing shall be stopped if explosive spalling or excessive swelling occurs.

5-2.9

The test procedures shall be performed three times and the average shall be reported.

5-3 Safety Precautions.

5-3.1

These test procedures involve high temperatures and combustion processes. Therefore, hazards can exist that pose the potential for burns, ignition of extraneous objects or clothing, and inhalation of combustion products. The operator shall use protective gloves for insertion and removal of test specimens. Neither the cone heater nor the associated fixtures shall be touched while hot except when using protective gloves.

5-3.2

The exhaust system shall be checked for proper operation before testing and shall discharge into a building exhaust system with adequate capacity. Provision shall be made for collecting and venting any combustion products that might fail, for any reason, to be covered by the normal exhaust system of the apparatus.

Chapter 6 Calculations

6-1* Calibration Constant with Methane.

The methane calibration shall be performed regularly to check for the proper operation of the instrument and to compensate for minor changes in mass flow determination. (A calibration differing significantly from the previous calibration is not normal and suggests instrument malfunction.) The calibration constant, C, shall be determined from the following equation:

$$10.0 = (12.54 \times 10^3)(1.10)\,C\sqrt{\frac{\Delta P}{T_e}}\;\frac{X^{o}_{O_2} - X_{O_2}}{1.105 - 1.5\,X_{O_2}}$$

where 10.0 corresponds to 10.0 kW methane supplied, 12.54×10^3 equals $\Delta h_c/r_o$ for methane, 1.10 is the ratio of oxygen to air molecular weight, and the variables are given in Section 1-5.

6-2 Calculations for Test Specimen.

6-2.1 Heat Release Rate.

6-2.1.1 Prior to performing other calculations, the oxygen analyzer time shift shall be incorporated using the following equation:

$$X_{O2}(t) = X`_{O2}(t + t_d)$$

6-2.1.2 The heat release rate shall be determined by the following equation:

$$\dot{q}(t) = (\Delta h_c r_o)(1.10)\,C\sqrt{\frac{\Delta P}{T_e(t)}}\;\frac{X^{o}_{O_2} - X_{O_2}(t)}{1.105 - 1.5\,X_{O_2}(t)}$$

6-2.1.3 The value $\Delta h_c/r_o$ for the test specimen shall be set at 13.1×10^3 kJ/kg, unless a more accurate value is known for the test material. The heat release rate per unit area shall be determined from the following equation:

$$\dot{q}''(t) = \dot{q}(t)/A_s$$

where $A_s = 0.01\ m^2$.

6-2.2 Mass Loss Rate and Effective Heat of Combustion.

The required mass loss rate, -dm/dt, at each time interval shall be calculated and then expressed as a running average over 10-second intervals. An effective heat of combustion shall be determined from the following equation:

$$\Delta h_c, \mathrm{eff} = \frac{\sum_i \dot{q}_i(t)\, \Delta t}{m_i - m_f}$$

where $\dot{q}_i(t)$ is given in the equation in 6-2.1.2 for each time step, i, with the summation taken for the duration of the test. A time-varying value also shall be determined by the following equation:

$$\Delta h_c, \mathrm{eff} = \frac{\dot{q}_i(t)}{-(dm/dt)}$$

6-2.3 Final Numbers.

6-2.3.1 The ignition time shall be determined and reported as "time to sustained flaming" in seconds (s).

6-2.3.2 The heat release rate per unit area (kW/m^2), averaged over the first 180 seconds after specimen ignition shall be calculated and reported.

6-2.3.3 The effective heat of combustion (MJ/kg) average for the duration of the test period shall be calculated and reported. This shall be determined by dividing total heat released by the total specimen mass lost.

6-2.4 Reported Values.

The values reported shall be the average for the three test replicates.

Chapter 7 Report of Results

7-1

The following shall be reported as a summary for all specimens of a particular material or product:

(a) Specimen identification or number;

(b) Manufacturer or submitter;

(c) Date of test;

(d) Operator;

(e) Composition or generic identification;

(f) Details of preparation; and

(g) Number of replicate specimens tested. This shall be a minimum of three.

7-2

The following information shall be included for each specimen:

(a) Specimen thickness;

(b) Specimen mass;

(c) Heating flux and exhaust system flow rate;

(d) Time to sustained flaming (s);

(e) Heat release rate (per unit area) curve;

(f) Average $\dot{q}''$ values for the first 180 seconds after ignition;

(g) Total heat released by the specimen;

(h) Average Δh_c, eff for entire test;

(i) Peak Δh_c, eff;

(j) Curve of Δh_c, eff (optional);

(k) Mass remaining after test;

(l) Sample mass loss;

(m) Additional observations, if any; and

(n) Difficulties encountered in testing, if any.

7-3

The following values shall be averaged for all specimens:

(a) Time to sustained flaming (s);

(b) Average heat release rate $\dot{q}''$ value (kW/m^2) for 180 seconds after ignition; and

(c) Average heat of combustion (Δh_c, eff) (MJ/kg) for the entire 20-minute test.

Chapter 8 Precision and Bias

8-1 Precision.

A series of interlaboratory tests for this method were run using five laboratories and three constructions simulating upholstered furniture components.

8-1.1 Within Laboratory (Repeatability).

Material: Nylon fabric on a fire retardant treated polyurethane foam

Parameter	Units	Mean Value	SD(2)	RSD %(3)
Time to sustained flaming	seconds	9	1	11
Avg. heat release rate at 180 seconds(1)	kW/m^2	258	6	2

Peak heat release rate	kW/m^2	364	27	7
Total heat release	MJ/m^2	89	1.5	2
Heat of combustion	MJ/kg	24	0.6	3

Material: Polyolefin fabric on a standard polyurethane foam

Parameter	Units	Mean Value	SD(2)	RSD %(3)
Time to sustained flaming	seconds	8	0	0
Avg. heat release rate at 180 seconds(1)	kW/m^2	374	11	3
Peak heat release rate	kW/m^2	474	16	3
Total heat release	MJ/m^2	80	1	1
Heat of combustion	MJ/kg	25	1	4

Material: Cotton velvet with fiberglass liner on a standard polyurethane foam

Parameter	Units	Mean Value	SD(2)	RSD %(3)
Time to sustained flaming	seconds	8	0.5	6
Avg. heat release rate at 180 seconds(1)	kW/m^2	113	8	7
Peak heat release rate	kW/m^2	316	10	3
Total heat release	MJ/m^2	52	0.2	0
Heat of combustion	MJ/kg	16	0.8	5

(1) After ignition
(2) Standard deviation
(3) Relative standard deviation (RSD = sd/mean × 100)

8-1.2 Between Laboratories (Reproducibility).

Material: Nylon fabric on a fire retardant treated polyurethane foam

Parameter	Units	Mean Value	SD(2)	RSD %(3)
Time to sustained flaming	seconds	12	2.5	21
Avg. heat release rate at 180 seconds(1)	kW/m^2	214	29	13
Peak heat release rate	kW/m^2	309	54	17

Total heat release	MJ/m^2	85	6	7
Heat of combustion	MJ/kg	24	1.6	7

Material: Polyolefin fabric on a standard polyurethane foam

Parameter	Units	Mean Value	SD(2)	RSD %(3)
Time to sustained flaming	seconds	10	2.3	23
Avg. heat release rate at 180 seconds(1)	kW/m^2	369	19	5
Peak heat release rate	kW/m^2	442	64	14
Total heat release	MJ/m^2	77	2.8	4
Heat of combustion	MJ/kg	27	2.1	8

Material: Cotton velvet with fiberglass liner on a standard polyurethane foam

Parameter	Units	Mean Value	SD(2)	RSD %(3)
Time to sustained flaming	seconds	12	3	25
Avg. heat release rate at 180 seconds(1)	kW/m^2	92	29	32
Peak heat release rate	kW/m^2	262	52	20
Total heat release	MJ/m^2	48	7	15
Heat of combustion	MJ/kg	20	4	21

(1) After ignition
(2) Standard deviation
(3) Relative standard deviation (RSD = sd/mean × 100)

8-2 Bias.

For solid specimens of unknown chemical composition, as used in building materials, furnishings, and common occupant fuel load, it has been documented that the use of the oxygen consumption standard value of $\Delta h_c/r_o = 13.1 \times 10^3$ kJ/kg oxygen results in an expected error band of ± 5 percent compared to true value. For homogeneous materials with only a single pyrolysis mechanism, this uncertainty can be reduced by determining Δh_c from oxygen bomb measurements and r_o from ultimate elemental analysis. For most testing this is not practical, since specimens can be composite, can be nonhomogenous, and can exhibit several degradation reactions. Therefore, for unknown samples, a ± 5 percent accuracy limit is anticipated. For reference materials, however, careful determination of $\Delta h_c/r_o$ can substantially reduce this source of uncertainty.

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-1-3.1

For further information, see "Estimation of Rate of Heat Release by Means of Oxygen Consumption Measurements." *(See Appendix D, footnote 13.)*

A-5-1.2

Power to the oxygen analyzer, load cell, and pressure transducer should not be turned off on a daily basis.

A-6-1

The derivation of this relationship can be found in "Estimation of Rate of Heat Release by Means of Oxygen Consumption Measurements" and "Development of Cone Calorimeter — A Bench-Scale Heat Release Rate Apparatus Based on Oxygen Consumption." (*See Appendix D, footnotes 13 and 4.*)

Appendix B Commentary: Rate of Heat Release for Furniture

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

B-1

Extensive studies over the last 15 years at several laboratories have shown that the rate of heat release (RHR) is the single most important variable determining the fire hazard performance of furniture and beds. For a real combustible, the value of the rate of heat release is not a constant but usually a triangular-shaped curve of RHR versus time. Studies have also shown that the most important quantity of RHR — using a full-scale calorimeter — is the peak value. The unit for full-scale measurements of RHR is kilowatts (kW). In 1982, the "furniture calorimeter" was developed, which permits the RHR of actual full-size furniture to be determined quantitatively. Testing standards for the use of the furniture calorimeter have been developed by Underwriters Laboratories[1] and by the Nordic countries' standards association, NORDTEST.[2] The development of furniture calorimeter testing methods is discussed in depth in the reference cited in footnote 3.

B-2

Testing furniture in the full scale is often inconvenient due to cost, the specialized facilities required, or specimen requirements. Thus, simultaneous with the development of full-scale furniture calorimeter methods, efforts have been made to develop a bench-scale method that could provide the same basic information. One of the earliest applications for the cone calorimeter[4] was, in fact, its use in the characterization of upholstered furniture. The studies conducted at the National Bureau of Standards (now the National Institute of Standards and Technology) have produced a predictive relationship between the peak rate of heat release in full scale (kW) and the average rate of release, as measured in the cone calorimeter (kW/m^2).

While peak heat release is the important parameter with respect to full-scale calorimeters, average rate of heat release is used as the primary parameter for cone calorimeter testing of furniture components/composites in this document. Due to the sample size and ratio of fabric to cushioning in this document's test procedures, initial instantaneous peaks can occur that are misleading and do not relate in any way to the rate of burning or total heat from full-scale furniture and to the subsequent contributions to flashover in a real fire scenario.

B-3

The studies[3] showed the following relationship:

q_{fs} = 0.63 [$''_{bs}$] [mass factor] [frame factor] [style factor]

where [$''_{bs}$] = rate of heat release (kW/m^2) in the bench-scale test,

[mass factor] = combustible mass of full-scale specimen (kg)

[frame factor] = 1.66 for noncombustible
0.58 for melting plastic
0.30 for wood
0.18 for charring plastic

[style factor] = 1.0 for plain, primarily rectilinear construction
1.5 for ornate, convolute shapes and intermediate values for intermediate shapes

The constant, 0.63, has units of m^2/kg. The bench-scale data are determined from the cone calorimeter as an average using the time period from ignition to 180 seconds later.

B-4

The relationship described in B-3 does not apply where both the fabric and the padding are highly fire-resistive (e.g., wool and neoprene foam) or where highly effective interbarriers are used. In these cases, full involvement of the furniture item does not take place. Where the bench-scale rate of heat release value is less than about 75 kW/m^2 to 100 kW/m^2, such spread is not expected to take place. Note that such desirable results might not occur where the furniture item in question is not the sole burning item in a room fire.[5]

B-5

For applications where the shape of the full-scale rate of heat release curve and not only the value of the peak is to be predicted, a method has also been developed.[6] This is mainly useful in specialized fire modeling applications.

B-6

The bulk of the studies done to date have been on simple furniture constructions where the same type of construction is used in all portions of the chair. In many cases, commercial furniture has mixed construction types. A conservative method of treating these cases is as follows: All types of construction that are represented by the test article should be measured in the cone calorimeter. The results for that construction type should be reported that indicate the highest 180-second average rate of heat release.

B-7

Both the fabric and the padding material (and any intermediate layers, if used) play a part in determining the fire performance of the overall composite. Nonetheless, there are large variations in performance levels among commonly used padding materials. Recently, data collected at the National Institute of Standards and Technology were examined to identify some typical ranges of padding performance. A summary of a large number of tests that were conducted was compiled. The fabrics tested included a large range of common upholstery fabrics and were not restricted to one type or family.

It was determined from analysis of the data that numerical cut-off values that are essentially independent of the fabric used could be established for each fabric type represented in the tests. However, the results are not applicable to the testing of bare foams without fabric covering. The results are as follows (values are approximate):

Type	Rate of heat release (avg. for 180 seconds after ignition) (kW/m^2)
Ordinary polyurethane foam	>280
Melamine-treated polyurethane foam	<280
CMHR-type polyurethane foam	<160
Hydrophilic-type polyurethane foam	< 85
Neoprene foam	< 45

B-8

The construction and the fire behavior of mattresses are very similar to those of upholstered furniture. Nonetheless, there are some differences, due to both the geometrical configuration and to differences in the types of materials used. A correlation such as that shown above has not been currently established for mattresses. The reference cited in footnote 3, however, shows a correlation obtained on the basis of some older data.

Appendix C Commentary: Instrument Details

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

C-1 Introduction.

This commentary is provided (a) to give some insight into the development of the method, (b) to describe the rationale for the design of various features of the apparatus, and (c) to describe the use of the data.

C-2 Rate of Heat Release Measurements.

C-2.1

The rate of heat release is one of the most important variables in determining the potential hazard posed by a fire. With so many items composed of so many surface materials that can contribute to a fire, the evaluation of the rate of heat release is quite complex.[7] For each individual surface, it must first be determined when, if ever, that surface will become ignited. The size of the fire from any items that are already burning must be known, since that fire constitutes the external irradiance to nearby items. Next, the flame spread over the surface in question must be evaluated. The rate of heat release from the entire surface can then be evaluated using the rate of heat release per unit area, for a given irradiance, as a function of time. The heat release rate is the only value that can be measured in a bench-scale test. The total heat release rate output from the burning object includes the total output of all surfaces. The fact that some elements might burn out and then no longer contribute to the fire must also be considered. This procedure is conceptually straightforward but, in practice, can be very cumbersome to compute.

C-2.2

Many common combustibles do not have the geometrically simple surfaces that easily lend themselves to making computations of this kind. Other complications, such as melting, dripping, or collapsing, can also preclude a detailed mathematical analysis. In such cases, a simpler, more empirical model is appropriate. An example of the use of bench-scale heat release rate measurements in assessing a fire hazard is available.[8]

C-3 Choice of Operating Principle.

C-3.1

A number of apparatus have been developed over the years for measuring rate of heat release; most of these have been reviewed in detail. Traditionally, the simplest measurement scheme is a direct measurement of flow enthalpy from a chamber thermally insulated to create an adiabatic environment. A truly adiabatic apparatus with the use of guard heaters is possible, but because of the expense, it has not been developed. A simply insulated combustion chamber leads to a measurement of the heat release that is significantly lower than its true value, so that only an empirical calibration is possible. An example of such an insulated chamber method is described in NFPA 263, *Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products*.[9] Furthermore, that calibration can be sensitive to the radiant fraction (or sootiness) of the combustible.[10,11] A more advanced scheme is an isothermal rather than an adiabatic instrument, with the heat release rate taken to be that which must be supplied by a substitution burner to maintain isothermal conditions.[12] This scheme yields better results, since only second-order heat loss error terms remain; however, its practical implementation is complex and costly.

C-3.2

It can be concluded that it is difficult to measure heat directly without losing some of it. However, it is simple to capture all combustion products without losing any and to measure the oxygen levels in that stream. Heat release can be computed from each measurement with the use of the oxygen consumption principle.[13] This principle states that for most common combustibles an amount of heat equal to 13.1×10^3 kJ is released for each kg of oxygen consumed from the air stream. This constant varies only about ± 5 percent for most common combustibles; some exceptions are known.[13] The method remains useful even if a significant fraction of the products become CO or soot rather than CO_2; in those cases, correction terms can be applied.[13,14] A typical case involving cellulose that produces CO from 10 percent incomplete combustion has been analyzed with less than 2 percent error.[13] Note that excessively high CO production values, resulting from restricted oxygen supply, cannot occur in the calorimeter used in this test method, since oxygen intake is not restricted. By adopting the oxygen consumption principle as the method of measurement, it is possible to design an apparatus of significantly improved precision but without excessive complexity. Since heat measurements are not required, the apparatus does not need thermal insulation.

C-4 Heater Design.

C-4.1

Experience with various rates of heat release techniques suggests that, for minimal errors in irradiance, the specimen should be exposed to only (a) a thermostatically controlled heater, or (b) a water-cooled plate, or (c) open air. If nearby solid surfaces are not temperature-controlled, the surface temperatures can rise due to specimen flame heating and then act as further sources of radiation to the specimen. Furthermore, where oxygen consumption is used as the measurement principle, a gas-fired heater should not be used because it can cause fluctuations in the oxygen readings, even though they can be eliminated by steady-state measurements.

C-4.2

A heater in the shape of a truncated cone was first explored for use in an ignitibility apparatus by the International Organization for Standardization (ISO).[15] The heater adopted in the present method is similar but not identical to the ISO cone. The main differences include higher heat fluxes, temperature control, and more rugged design details. In the horizontal orientation, the conical shape approximately follows the fire plume contours, while the central hole allows the stream to emerge without impacting on the heater. A thin layer of cool air is pulled along, and the flames do not attach to the sides of the cone. The central hole has an additional function: without it, the middle of the specimen would receive a higher irradiance than the edges. With the hole, the irradiance is uniform to within ± 2 percent. In the vertical orientation, the hole still serves the purpose of providing radiation uniformity, although, because of the presence of a natural convection boundary layer, the deviations are higher (± 5 percent to ± 10 percent).[4]

C-5 Pilot Ignition.

Ignition of test specimens in many apparatus is achieved by a gas pilot. This tends to pose numerous difficulties such as sooting, deterioration of orifices, and contribution to the heat release rate. It is difficult to design a pilot that is centrally located over the specimen, that is resistant to blowout, and yet does not apply an additional heat flux to the specimen. (A point of elevated heating on the specimen makes it mathematically difficult to analyze the response of the specimen.) An electric spark is free of most of these difficulties, requiring only occasional cleaning and adjustment of the electrodes. For these reasons, an electric spark ignition was adopted.

C-6 Back Face Conditions.

The heat lost through the specimen back face can have an influence on the burning rate during the end of its burning time. For reproducible measurements, the losses through the back face should be standardized. The simplest theoretical boundary conditions — an adiabatic or isothermal boundary at ambient temperature — are not achievable. However, a reasonable approximation of the former can be made by using a layer of insulating material. This is easier to do using the horizontal orientation, in which case a very low density refractory blanket is used. In the vertical orientation, some structural rigidity of the backing is desired; consequently, a higher density backing might be necessary.

C-7 Oxygen Analyzer.

The analyzer should be of the paramagnetic type, with baseline noise and short-term drift of approximately ± 50 parts per million (ppm) O_2. Other types of analyzers (e.g., electrochemical and catalytic) generally cannot meet this requirement. Paramagnetic analyzers also exhibit a linear response. The linearity is normally better than can be determined with ± 0.1 percent O_2/N_2 gas mixtures. Since an oxygen analyzer is sensitive to stream pressures, either the readings have to be adjusted with an absolute pressure transducer connected to the analyzer, or the pressure has to be mechanically regulated for flow fluctuations and atmospheric pressure variations. The analyzer and the pressure-regulating or measuring devices must be located in a constant-temperature environment to avoid flow errors.

C-8 Limits to Resolution.

C-8.1

Methane calibration studies[4] show typical fluctuations of ± 1.5 percent, with a linearity to within 5 percent over the range of 5 kW to 12 kW. Calibrations with other gases show similar results. Calibration gases can be delivered to the burner in a highly steady manner. The uniformity of solid fuels combustion, however, is governed by the pyrolysis at the surface, which can, under some circumstances, show substantial fluctuations. For instance, the fluctuations for polymethylmetharcylate are greater than for red oak.[4] Burning thermoplastic specimens occasionally eject individual molten streamers. With solid materials, the limits to resolution can be expected to be set by the specimen pyrolysis process, rather than by the instrument limits.

C-8.2

The limits to the speed of response of any heat release rate technique are set by the slowest responding element. In the case of the present method, this is the oxygen analyzer, which typically shows a 10 to 90 percent response time of 6.9 seconds. Response times of the pressure transducer and the thermocouple can be significantly faster. However, they should be set only slightly faster to avoid introducing instrument noise without increasing resolution.

C-9 Effective Heat of Combustion.

The effective heat of combustion is a constant during the combustion of homogenous specimens having only a single mode of degradation and is less than the value of the theoretical net heat of combustion. Most organic liquids have a single mode of degradation and, therefore, a constant effective heat of combustion. By contrast, cellulosic products typically show more than one mode of degradation and a varying effective heat of combustion. For materials having more than one mode of degradation, or for composites or nonhomogenous materials, the effective heat of combustion is not necessarily constant.

Appendix D

Footnotes to Appendix B and Appendix C

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

[1] UL 1056, *Standard for Fire Test of Upholstered Furniture*, Underwriters Laboratories Inc., Northbrook, IL (October 1989).

[2] "Upholstered Furniture: Burning Behaviour—Full Scale Test" (NT FIRE 032), NORDTEST, Helsinki (1987).

[3] V. Babrauskas and J. F. Krasny, "Fire Behavior of Upholstered Furniture," National Bureau of Standards (U.S.), NBS Monograph 173 (November 1985).

[4] V. Babrauskas, "Development of Cone Calorimeter — A Bench-Scale Heat Release Rate Apparatus Based on Oxygen Consumption," National Bureau of Standards (U.S.), NBSIR 82-2611 (1982).

[5] V. Babrauskas, R. H. Harris, Jr., R. G. Gann, B. C. Levin, B. T. Lee, R. D. Peacock, M. Paabo, W. Twilley, M. F. Yoklavich, and H. M. Clark, "Fire Hazard Comparison of Fire-Retarded and Non-Fire-Retarded Products," National Bureau of Standards (U.S.), NBS SP 749 (1988).

[6] V. Babrauskas and W. D. Walton, "A Simplified Characterization for Upholstered Furniture Heat Release Rates," *Fire Safety Journal*, Vol. 11 (1986), pp. 181–192.

[7] V. Babrauskas, J. R. Lawson, W. D. Walton, and W. H. Twilley, "Upholstered Furniture Heat Release Rates Measured with a Furniture Calorimeter," National Bureau of Standards (U.S.), NBSIR 82-2604 (1982).

[8] V. Babrauskas and J. F. Krasny, "Prediction of Upholstered Chair Heat Release Rates from Bench-Scale Measurements," *Fire Safety Science and Engineering* (ASTM STP 882), pp. 268–284, T. Z. Harmathy, ed., American Society for Testing and Materials (1985).

[9] NFPA 263, *Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products*, 1994 edition, National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

[10] R. F. Krause and R. G. Gann, "Rate of Heat Release Measurements Using Oxygen Consumption," *Journal of Fire and Flammability*, Vol. 11 (April 1980), pp. 117–130.

[11] V. Babrauskas, "Performance of the Ohio State University Rate of Heat Release Apparatus Using Polymethylmetharcylate and Gaseous Fuels," *Fire Safety Journal*, Vol. 5 (1982), pp. 9–20.

[12] J. Tordella and W. H. Twilley, "Development of a Calorimeter for Simultaneously

Measuring Heat Release and Mass Loss Rates," National Bureau of Standards (U.S.), NBSIR 83-2708 (1983).

[13] C. Hugget, "Estimation of Rate of Heat Release by Means of Oxygen Consumption Measurements," *Fire and Materials,* Vol. 4 (1980), pp. 61–65.

[14] W. J. Parker, "Calculations of the Heat Release Rate by Oxygen Consumption for Various Applications," National Bureau of Standards (U.S.), NBSIR 81-2427 (1982).

[15] "Fire Tests — Reaction to Fire Ignitability of Building Products," ISO 5657, International Organization for Standardization (1986).

Appendix E Additional Publications

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

"Construction Drawings for the Cone Calorimeter," Center for Fire Research, National Bureau of Standards, Gaithersburg, MD 20899.

V. Babrauskas, "Applications of Predictive Smoke Measurements," *Journal of Fire and Flammability*, Vol. 12 (January 1981), pp. 51–64.\r\n

NFPA 265

1994 Edition

Standard Methods of Fire Tests for Evaluating Room Fire

Growth Contribution of Textile Wall Coverings

1994 Edition

This edition of NFPA 265, *Standard Methods of Fire Tests for Evaluating Room Fire Growth Contribution of Textile Wall Coverings*, 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 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.

The 1994 edition of this document has been approved by the American National Standards Institute.

Origin and Development of NFPA 265

The danger of carpet-like textile coverings used on walls and ceilings is well known and these coverings have been recognized as a major contributing factor in many fires. Research conducted by the Fire Research Laboratory of the University of California at Berkeley and the American Textile Manufacturers Institute produced a report “Room Fire Experience of Textile Wall Coverings,” which indicated that consideration of only the flame spread rating as measured by NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, might not reliably predict the fire behavior of textile wall and ceiling coverings. Concerns were raised regarding the findings that low flame-spread textile wall coverings, when placed in a room/corner test procedure, produced a rapidly growing, large fire.

This proposed standard will fill a void and complement the series of interior finish fire tests that are currently being referenced in other codes, i.e., NFPA *101*®, *Life Safety Code*®. This standard creates a testing method that would address the recognized hazards of using textile materials for wall coverings by supplying a means to evaluate the performance characteristics under specified fire exposure conditions and providing a valid repeatable and reproducible fire test method.

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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.

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. The Committee also shall 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; and act as liaison between NFPA and the committees of other organizations developing fire test standards. The Committee is not responsible for fire tests that are used to evaluate extinguishing agents, devices, or systems.

NFPA 265
Standard Methods of
Fire Tests for Evaluating Room Fire Growth

Contribution of Textile Wall Coverings

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 10 and Appendix C.

Chapter 1 General

1-1 Scope.

1-1.1

This standard describes a method for determining the contribution of textile wall coverings to room fire growth during specified fire exposure conditions. This method shall be used to evaluate the flammability characteristics of textile wall coverings where such materials constitute the exposed interior surfaces of buildings.

1-1.2

This method is not intended to evaluate the fire endurance of assemblies, nor is it able to evaluate the effect of fires originating within a wall assembly. The method is not intended for the evaluation of floor or ceiling finishes. This test method shall not apply to fabric-covered, lower-than-ceiling-height, freestanding, prefabricated panel furniture systems or demountable, relocatable, full-height partitions used in open building interiors. Freestanding panel furniture systems include all freestanding panels that provide visual and/or acoustical separation and are intended to be used to divide space and that might support components to form complete work stations. Demountable, relocatable, full-height partitions include demountable, relocatable, full-height partitions that fill the space between the finished floor and the finished ceiling.

1-2 Significance.

1-2.1

This method of test measures certain fire performance characteristics of textile wall covering materials in an enclosure under specified fire exposure conditions. It determines the extent to which the textile wall covering materials might contribute to fire growth in a room and the potential for fire spread beyond the room, under the particular conditions simulated.

The method of test provides:

(a) Extent of fire growth in the test room.

(b) Rate of heat release in the test room.

(c) Time to flashover in the test room, if it occurs.

(d) Time to flame extension beyond the doorway of the test room, if it occurs.

(e) Total heat flux incident to the floor of the test room.

(f) Upper level gas temperature in the test room.

(g) Rate of production of carbon monoxide.

This method does not provide data that can be generalized to apply to rooms or spaces of different shapes, sizes, and ventilation. However, the method does provide a general ranking of wall covering materials for use in making judgments, provided it is understood that the conditions observed in the test might or might not be repeated in actual exposures of the tested wall coverings to fire.

1-2.2

The method of test does not provide:

(a) The full information concerning toxicity of combustion gases.

(b) Fire resistance of wall/ceiling systems.

1-3 Summary of Method.

1-3.1

The sample shall be tested by one of the two protocols described. The Method A protocol shall use a corner test exposure with the specimens mounted on two walls of the test compartment. The Method B protocol shall use the same test in a compartment having three fully lined walls.

These methods shall use a gas burner to produce a diffusion flame to expose the walls in the corner of a room 8 ft × 12 ft × 8 ft (2.4 m × 3.7 m × 2.4 m). The burner shall produce a prescribed rate of heat output of 40 kW (gross) for 5 min followed by 150 kW (gross) for 10 min, for total exposure period of 15 min. The contribution of the textile wall covering to fire growth shall be measured by constant monitoring of the incident heat flux on the center of the floor, the temperature of the gases in the upper part of the room, the rate of heat release, and the time to flashover. The test shall be conducted with natural ventilation to the room provided through a single doorway of 30 in. × 80 in. (0.8 m × 2.0 m). The combustion products shall be collected in a hood feeding into a plenum connected to an exhaust duct in which measurements of the gas velocity, temperature, and concentrations of selected gases are made.

1-4 Definitions.

Average Upper Gas Layer Temperature. This temperature shall be based on the average of the four ceiling quadrant thermocouples and the center of the room ceiling thermocouple.

Flashover. Flashover shall be determined to have occurred when any two of the following conditions have been attained:

(a) Heat flux at floor reaches 25 kW/m^2

(b) Average upper air temperature exceeds 1200°F (650°C)

(c) Flames exit doorway

(d) Spontaneous ignition of paper target on floor occurs.

Chapter 2 Test Equipment

2-1 Ignition Source.

2-1.1

The ignition source for the test shall be a gas burner with a nominal 12 in. × 12 in. (0.3 m × 0.3 m) porous top surface of refractory material (*see Figure 2-1.1*). A burner shall be constructed with a 1 in. (25.4 mm) thick porous ceramic fiberboard over a 6 in. (152 mm) plenum, or a minimum 4 in. (102 mm) layer of Ottawa sand shall be permitted to be used to provide the horizontal surface through which the gas is supplied.

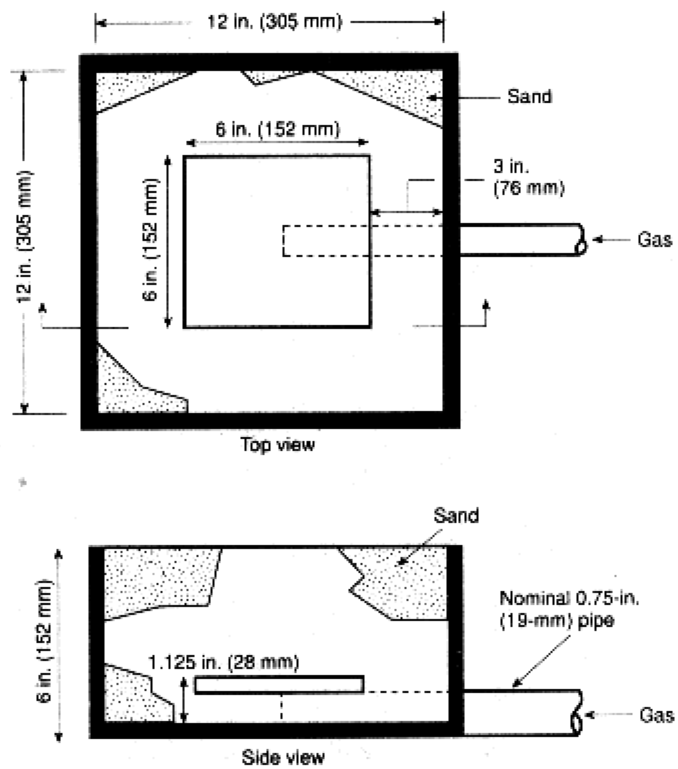

Figure 2-1.1 Gas burner.

2-1.2

The top surface of the burner through which the gas is applied shall be 12 in. (0.3 m) above the floor, and the burner enclosure shall be located such that the edge of the diffusion surface is located 2 in. (51 mm) from both walls, in the left corner of the room, opposite the door.

2-1.3

The gas supply to the burner shall be of C.P. grade propane (99 percent purity). The burner shall be capable of producing a gross heat output of 40 kW ± 1 kW (net heat output of 37 kW) for 5 min followed by a gross heat output of 150 kW ± 5 kW (net heat output of 138 kW) for 10 min.

Flow rates shall be calculated using propane’s net heat of combustion, which is 2280 Btu/ft^3 (85 MJ/m^3) at 68°F (20°C) and 14.70 psia (100 kPa) The flow rate shall be metered throughout the test. The burner design shall allow switching from 40 kW to 150 kW within 10 sec. Burner controls shall be permitted to be provided for automatic shutoff of the gas supply if flameout occurs. Two typical arrangements for a gas supply are illustrated in Figures B-1(a) and B-1(b).

2-1.4

The burner shall be ignited by a pilot burner or a remotely controlled spark ignitor.

2-2 Compartment Geometry and Construction.

2-2.1*

The interior dimensions of the floor of the fire room, when the specimens are in place, shall measure 8 ft ± 3.9 in. × 12 ft ± 3.9 in. (2.44 m ± 0.1 m × 3.66 m ± 0.1 m). The finished ceiling shall be 8 ft ± 3.9 in. (2.44 m ± 0.1 m) above the floor. There shall be four walls at right angles defining the compartment. (*See Figure 2-2.1.*)

2-2.2

There shall be a 30 in. ± 0.25 in. × 80 in. ± 0.25 in. (0.76 m ± 6.4 mm × 2.03 m ± 6.4 mm) doorway in the center of one of the 8 ft × 8 ft (2.44 m × 2.44 m) walls, and no other wall, floor, or ceiling openings that allow ventilation.

2-2.3

The inside surface of the wall containing the door shall be of calcium silicate board of 46 lb/ft^3 (736 kg/m^3) density and 0.5 in. (12 mm) in nominal thickness or 0.5 in. (12 mm) gypsum wallboard. The door frame shall be constructed to remain unchanged during the test period to a tolerance of ± 1 percent in height and width.

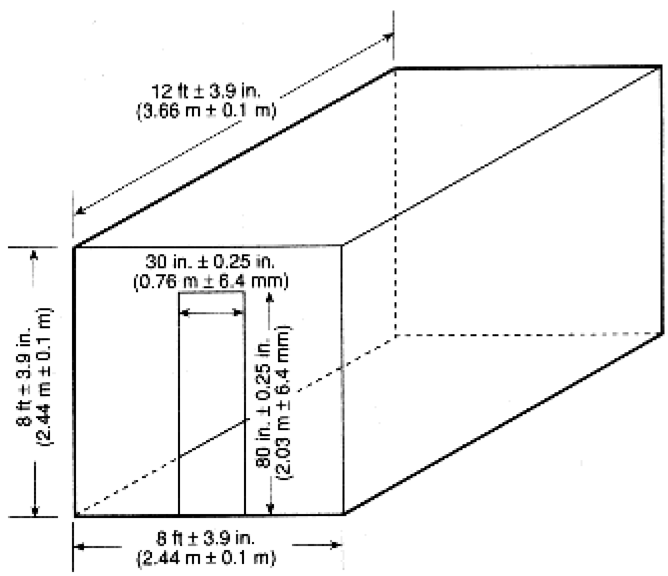

Figure 2-2.1 Interior room dimensions and interior doorway dimensions.

2-2.4

The test compartment shall be permitted to be a framed or a concrete block structure. If self-supporting panels are tested, a separate exterior frame or block compartment might not be required.

2-2.5

The floor, ceiling, and walls of the test compartment shall be covered by calcium silicate board or by gypsum wallboard.

Chapter 3 Specimen Mounting

3-1 Specimen Mounting.

3-1.1

Test specimens shall be mounted on a framing or support system comparable to that intended for their actual use using substrates, backing materials, insulation, or air gaps as appropriate to the intended application and representing a typical value of thermal resistance for the wall system. Where a manufacturer specifies use of an adhesive, specimens shall be mounted using an adhesive and application rate specified by the manufacturer and comparable to actual field installations.

NOTE: It has been shown that the specific adhesive used to secure a specimen might significantly affect the performance of a textile wall covering, and, therefore, the adhesive utilized should be the same as that intended for actual use.

3-1.2

Where a textile wall covering exhibits a distinct direction, the sample shall be mounted such that the machine direction is vertical, unless the manufacturer indicates that a different method of mounting will be used in actual installations.

3-1.3

For the Method A test protocol, specimens shall be mounted on the left sidewall and the rear walls (as viewed from the room door) and as illustrated in Figure 3-1.3. Vertically mounted portions of test specimens shall extend 2 ft (0.6 m) from the ceiling and shall be installed for the full 8 ft (2.44 m) width of the rear wall and the full 12 ft (3.66 m) length of the left sidewall.

3-1.4

For the Method B test protocol, specimens shall be mounted to cover fully both 8 ft × 12 ft (2.44 m × 3.66 m) walls, and the 8 ft × 8 ft (2.44 m × 2.44 m) wall not having the door.

3-1.5

Prior to testing, mounted specimens shall be conditioned until the sample reaches a rate of weight change of less than 0.1 percent per day at a temperature of 70°F ± 5°F (49°C ± 2.8°C) and a relative humidity of 50 percent ± 5 percent.

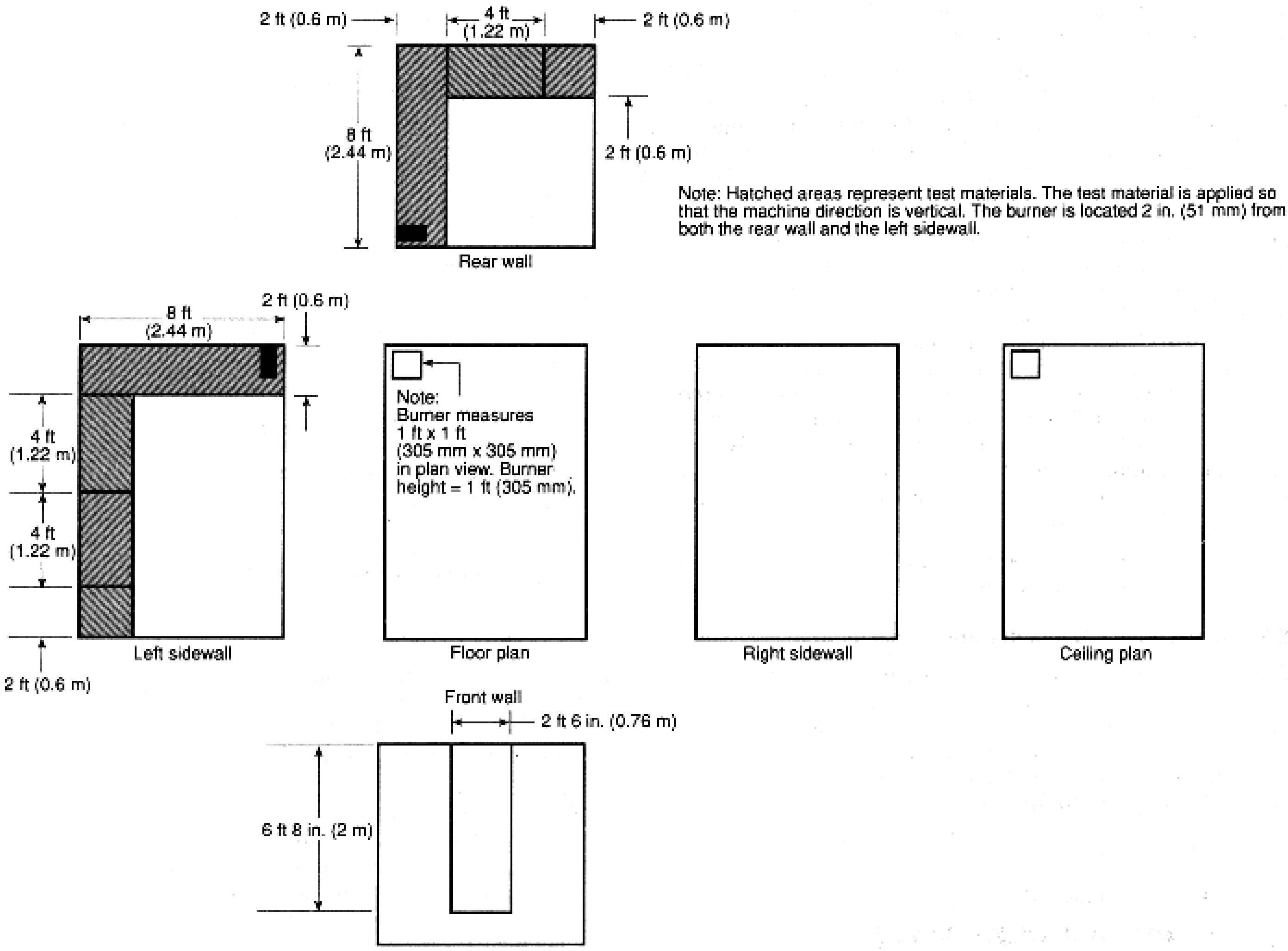

Figure 3-1.3 Specimen mounting for Method A test protocol.

Chapter 4 Environmental Conditions

4-1 Fire Room Environment.

4-1.1

The test building in which the fire room is located shall have vents for the discharge of combustion products and have provisions for fresh air intake, so that no oxygen-deficient air shall be introduced into the fire room during the test. Prior to the start of the test, the ambient air at the mid-height entrance to the compartment shall have a velocity of less than 100 ft/min (0.5 m/sec) in any direction. The building shall be of adequate size so that there shall be no smoke accumulation in the building below the level of the top of the fire compartment.

4-1.2

The ambient temperature in the test building at locations around the fire compartment shall be above 40°F (4°C), and the relative humidity shall be less than 75 percent for the duration of the test.

4-1.3

If test samples are installed within the test room for two or more hours prior to test, the following ambient conditions shall be maintained:

(a) The ambient temperature in the fire room measured by one of the thermocouples in 5-1.3.2 shall be 65°F to 75°F (18°C to 24°C).

(b) The ambient relative humidity in the fire room shall be 50 percent ± 5 percent.

Chapter 5 Instrumentation

5-1 Instrumentation.

5-1.1

The following instrumentation shall be provided for this test.

5-1.2

A total heat flux gauge shall be mounted a maximum of 2 in. (51 mm) above the floor surface, facing upward in the geometric center of the test room. (*See Figure 5-1.2.*)

5-1.2.1 The gauge shall be of the Gardon or Schmidt-Boetler type, with a circular flat black surface of $^1/_2$ in. (13 mm) diameter and a 180° view angle. In operation, it shall be maintained at a constant temperature [within ± 5 percent °F (2.8°C)] above the dewpoint by water supplies at a temperature of 120°F to 150°F (50°C to 65°C). This will normally require a flow rate of at least 0.1 gal/min (.38 L/min). The full-scale output range shall be 50 kW/m^2 for the gauge.

5-1.3

Bare Type K thermocouples, 20 mil (0.5 mm) in diameter, shall be used at each required location. The thermocouple wire within 0.5 in. (13 mm) of the bead shall be run along expected isotherms to minimize conduction errors. The insulation between the chromel and alumel wires shall be stable to at least 2000°F (1100°C), or the wires shall be separated.

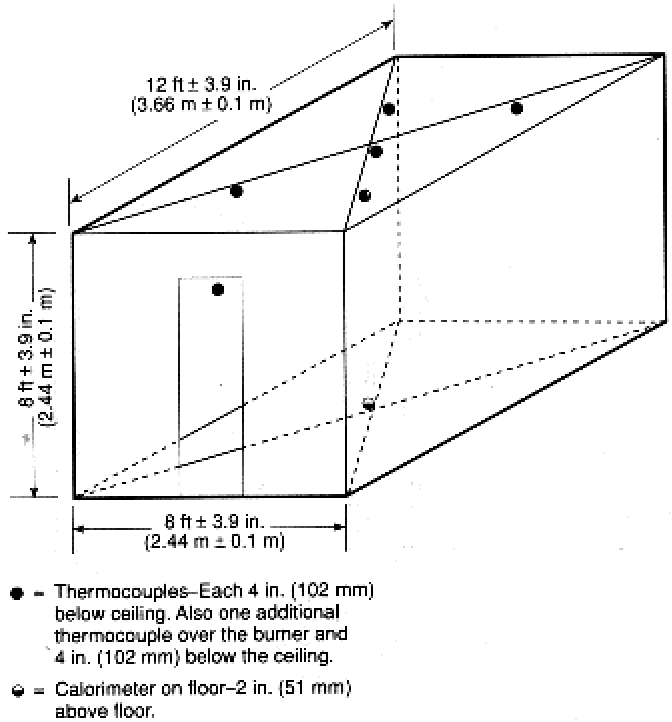

Figure 5-1.2 Thermocouple and calorimeter placement.

5-1.3.1 A thermocouple shall be located in the interior plane of the door opening on the door centerline, 4 in. (100 mm) from the top. (*See Figure 5-1.2*.)

5-1.3.2 Thermocouples shall be located 4 in. (100 mm) below the ceiling, at the center of the ceiling, at the center of each of the four ceiling quadrants, and directly over the center of the ignition burner. The thermocouples shall be mounted on supports or penetrate through the ceiling with their junctions 4 in. (100 mm) away from a solid surface (*see Figure 5-1.2*). Any ceiling penetration shall be just large enough to permit passage of the thermocouples. Spackling compound or ceramic fiber insulation shall be used to backfill the holes around the thermocouple wire.

5-1.3.3 One pair of thermocouples shall be placed 11 ft (3.4 m) downstream of the entrance to the horizontal duct. The pair of thermocouples shall straddle the center of the duct and be separated 2 in. (50 mm) from each other. (*See Figure 5-1.3.3*.)

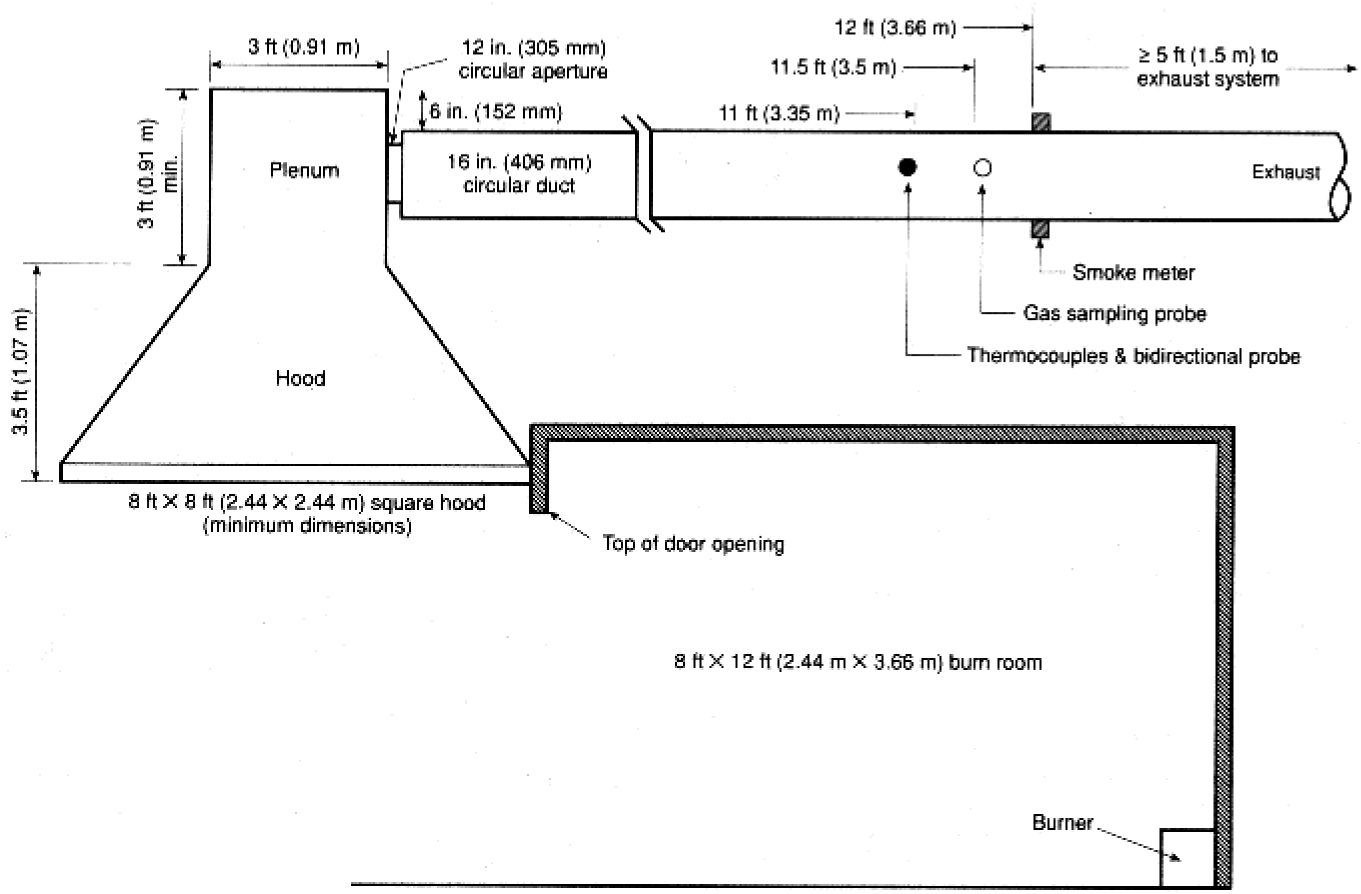

Figure 5-1.3.3 Canopy hood and exhaust duct.

5-1.4

A hood shall be installed immediately adjacent to the door of the fire room. The bottom of the hood shall be level with the top surface of the room. The face dimensions of the hood shall be at least 8 ft × 8 ft (2.44 m × 2.44 m), and the depth shall be 3.5 ft (1.1 m). The hood shall feed into a plenum having a 3 ft × 3 ft (0.92 m × 0.92 m) cross section. The plenum shall have a minimum height of 3 ft (0.92 m). This height shall be permitted to be increased to a maximum of 6 ft (1.8 m) to satisfy building constraints. The exhaust duct connected to the plenum shall be at least 16 in. (0.4 m) in diameter, horizontal, and shall be permitted to have a circular aperture of at least 12 in. (0.3 m) at its entrance or mixing vanes in the duct. (*See Figures 5-1.3.3 and 5-1.4.*)

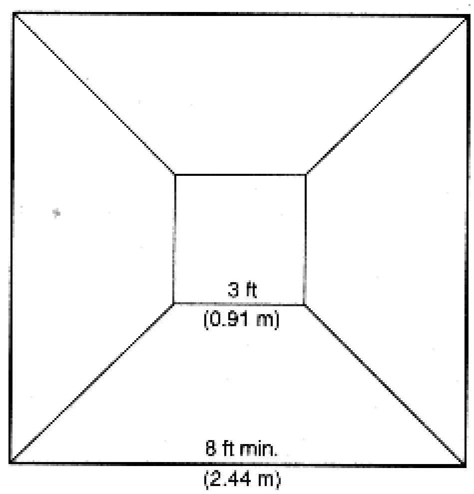

Figure 5-1.4 Plan view of canopy head.

5-1.4.1 The hood shall have sufficient draft to collect all of the combustion products leaving the room. [This draft shall be capable of moving up to 7000 standard ft^3/min (3.4 m^3/sec) equivalent to 16,100 cfm at 750°F (399°C) during the test]. Provision shall be made so that the draft can operate at 1000 to 7000 standard ft^3/min (0.47 to 3.4 m^3/sec). Mixing vanes shall be required in the duct if concentration gradients are found to exist.

5-1.4.2 An alternative exhaust system design shall be permitted to be used if it meets the requirements outlined in Chapter 6.

5-1.5

A bidirectional probe or an equivalent measuring system shall be used to measure gas velocity in the duct. A typical probe is shown in Figure 5-1.5, and it consists of a short, stainless steel cylinder 1.75 in. (44 mm) long and of 0.875 in. (22 mm) inside diameter with a solid diaphragm in the center. The pressure taps on either side of the diaphragm support the probe. The axis of the probe shall run along the centerline of the duct 11 ft (3.35 m) downstream from the entrance. The taps shall be connected to a pressure transfuser that shall be able to resolve pressure differences of 0.001 in. H_2O (0.25 Pa).

NOTE: Capacitance transducers have been found to be most stable for this application.

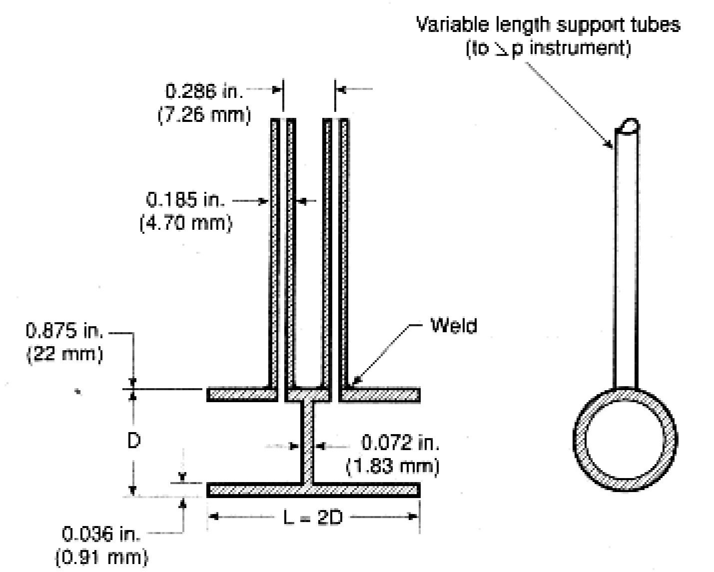

Figure 5-1.5 Bidirectional probe.

5-1.6

A stainless steel gas sampling tube shall be located 13 ft (4.0 m) downstream from the entrance to the duct at the geometric center of the duct, ± $^1/_2$ in. (± 13 mm), to obtain a continuously flowing sample for determining the oxygen concentration of the exhaust gas as a function of time. A suitable filter and cold trap shall be placed in the line ahead of the analyzer to remove particulates and water. The oxygen analyzer shall be of the paramagnetic or polarographic type and shall be capable of measuring oxygen concentration in a range of 21 percent to 15 percent, with a relative accuracy of 50 ppm in this concentration range. The signal from the oxygen analyzer shall be within 5 percent of its final value and occur within 30 sec of introducing a step change in composition of the gas stream flowing past the inlet to the sampling tube. See NFPA 264, *Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*.

5-1.7

The gas sampling tube described in 5-1.6 shall be used to provide a continuous sample for the measurement of the carbon dioxide concentration using an analyzer with a range of 0 to 20 percent, with a maximum relative error of 2 percent of full scale. The total system-response time between the sampling inlet and the meter shall be no longer than 30 sec.

5-1.8

The gas sampling tube defined in 5-1.6 shall be used to provide a continuous sample for the measurement of the carbon monoxide concentration using an analyzer with a range of 0 to 10 percent, with a maximum relative error of 2 percent of full scale. The signal from the analyzer shall be within 5 percent of its final value and occur within 30 sec after introducing a step change in composition of the gas stream flowing past the inlet to the sampling tube.

5-1.9

Two paper target flashover indicators shall be placed on the floor of the test room (*see Figure 5-1.9*). The targets shall consist of a single piece of newsprint crumpled into an approximate 6 in. (152 mm) diameter ball.

5-1.10

Photographic or video equipment shall be used to record the firespread in the room and the fire projection from the door of the room. The location of the camera shall avoid interference with airflow. The interior wall surfaces of the test room adjacent to the corner in which the burner is located shall be clearly marked. A clock shall appear in all photographic records, showing the time to at least the nearest 1 sec from the start of the test. This clock shall be accurately synchronized with all other measurements, or other provision shall be made to correlate the photo record with time. Color slides or photographs shall be taken at intervals for the duration of the test, and a continuous video recording shall be made.

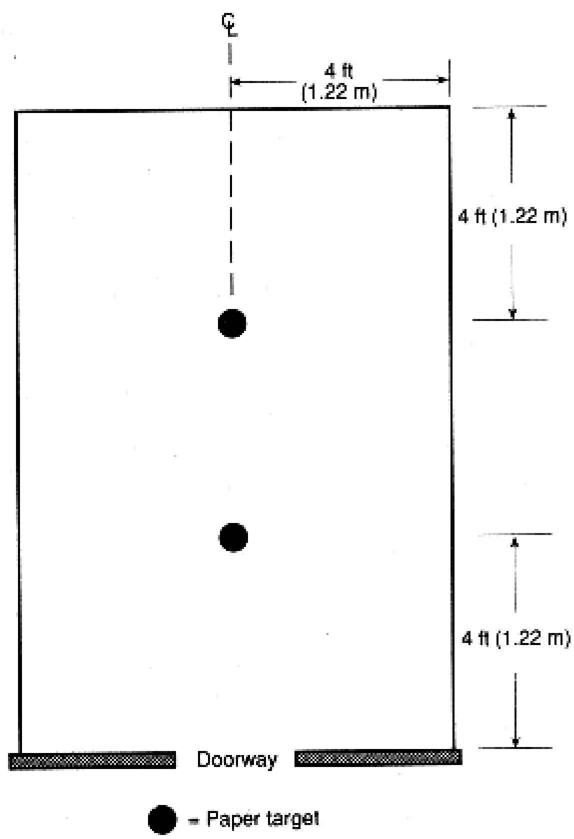

Figure 5-1.9 Paper target arrangement — plan view.

Chapter 6 Calibration

6-1 Calibration and Documentation of Ignition Source and Test Equipment.

6-1.1

A calibration test shall have been performed prior to and within 30 days of any fire test. The calibration test, which shall last for 15 min, shall use the standard ignition source with inert wall and ceiling materials [calcium silicate board of 56 lb/ft^3 (736 kg/m^3) density, 0.50 in. (13 mm) thickness, or gypsum wallboard].

6-1.2

The data resulting from a calibration test shall provide:

(a) The output as a function of time, after the burner is activated, of all instruments normally used for the standard fire test.

(b) The maximum extension of the burner flame, as recorded by still photographs taken at 30-sec intervals or continuous video recording.

(c) The temperature and velocity profiles across the duct cross section at the location of the bidirectional probe. These profiles shall be used to determine the factor, k, in the following equation:

$$V_S = 0.926\ kA\ (2\Delta pT_0)\ {}^1/_2 = 20.1\ kA\ (\Delta p/T)\ \rho_0 T$$

where:

0.926 = Suitable calibration factor for air velocities in excess of 10 ft/s (3.0 m/s) in a 16 in. (0.4 m) duct

k = Ratio of the average duct gas mass flow per unit area, as determined by measuring the velocity and temperature profiles across the stack, and the velocity and temperature at the centerline where the bidirectional probe is located during the test,

A = Cross-sectional area of the duct at the location of the probe, m^2

Δp = Differential pressure measured with the probe, Pa

ρ_0 = Density of air, kg/m^3, at the reference temperature T_0, K

T = Duct gas temperature, K.

(d) The total rate of heat production as determined by the oxygen consumption calculation, independent measurement of the volumetric flow rate, and weight loss of propane supply shall agree to within 5 percent. The net heat of combustion is 2280 Btu/ft^3 (85 MJ/m^3) for propane at 68°F (20°C) and 14.70 psia (100 kPa). This value shall be used for this calculation.

Chapter 7 Test Procedure

7-1 Procedure.

7-1.1

Method A protocol and Method B protocol shall follow the same test procedure, except for specimen mounting. Either test method shall be used.

7-1.2

The test procedure shall be as follows:

(a) Establish an initial volumetric flow rate of at least 1000 ft^3/min (0.47 m^3/sec) through the duct and increase the volume flow rate to 7000 ft^3/min (3.4 m^3/sec) as required to keep the oxygen content above 14 percent and to capture all effluents from the burn room.

(b) Turn on all sampling and recording devices, and establish steady-state baseline readings for at least 3 min.

(c) Ignite the gas burner and simultaneously start the clock and increase flow rate to provide a rate of heat release of 40 kW ± 1 kW by the burner. Continue the exposure at the 40 kW ± 1 kW level for 5 min. Within 10 sec following the 5-min exposure, increase the gas flow to provide a rate of heat release by the burner of 150 kW ± 5 kW exposure for 10 min.

(d) Take 35-mm color photographs at 30-sec intervals, or provide a continuous video recording to document the growth of the fire.

(e) Provide a voice or written record of the fire, which will provide the times of all significant events, such as times of ignition, escape of flames through the doorway, flashover, etc.

(f) The ignition burner shall be shut off 15 min after start of the test and the test terminated at that time, unless safety considerations dictate an earlier termination.

(g) Document damage after the test, using words, pictures, and drawings.

Chapter 8 Calculations

8-1 Calculations.

8-1.1

The calculation methods used to determine the total rate of heat release shall be as described in 10-1.1, *Fire Technology*, "Measuring Rate of Heat Release by Oxygen Consumption."

Chapter 9 Report

9-1 Report.

The report shall include the data and information specified in 9-1.1 through 9-1.7.

9-1.1 Materials.

Materials shall include the following:

(a) Name, thickness, density, and size of the test material, along with other identifying characteristics or labels

(b) Mounting and conditioning of materials

(c) Layout of specimens and attachments in test room (include appropriate drawings)

(d) Relative humidity and temperature of the room and the test building prior to and during the test.

9-1.2 Burner Gas Flow.

The burner gas flow is the fuel gas flow to the ignition burner and its calculated rate of heat output.

9-1.3 Time History of the Total Heat Flux to Floor.

The time history of the total heat flux to floor is the total incident heat flux at the center of the floor for the heat flux gauge as a function of time starting 3 min prior to the test.

9-1.4 Time History of the Gas Temperature.

The time history of the gas temperature is the temperature of gases in the room, in the doorway, and in the exhaust duct for each thermocouple as a function of time starting 3 min prior to the test.

9-1.5 Time History of the Total Rate of Heat Production of the Fire.

The total rate of heat production is calculated from the measured oxygen and carbon monoxide concentrations or measured oxygen, carbon monoxide, and carbon dioxide concentrations and the temperature and volumetric flow rate of the gas in the duct.

9-1.6 Time History of the Fire Growth.

The time history of the fire growth is a transcription of the visual, photographic, audio, and written records of the fire test. The records shall indicate the time of ignition of the wall finish, the approximate location of the flame front most distant from the ignition source at intervals not exceeding 15 sec during the fire test, the time of flashover, and the time at which flames extend outside the doorway. In addition, still photographs taken at intervals not exceeding 30 sec or continuous video recording shall be supplied. Drawings and photographs or video recording showing the extent of the damage of the materials after the test also shall be supplied.

9-1.7 Discussion of Performance.

A complete discussion of sample performances shall be conducted and shall include:

(a) Flame spread to ceiling during 40 kW exposure.

(b) Burning to outer extremities of 2 ft (0.6 m) wide samples mounted vertically in the corner of the room with testing under Method A protocol.

(c) Presence of burning droplets on the floor that persist in burning 30 sec or more.

(d) Other pertinent details with respect to fire growth.

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.

Janssens, M. L., “Measuring Rate of Heat Release by Oxygen Consumption,” *Fire Technology*, pp. 234-249, August 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-2-2.1

A study by R. D. Peakcock and J. N. Breese (NBSIR 82-2516, *Computer Fire Modeling for the Prediction of Flashover,* Natl. Bur. Stand., 1982) examined the effect of geometric room changes on the minimum energy required to cause flashover. It showed that increased room height beyond 3.9 ft (2.4 m) changed the minimum needed flashover energy (expressed as percent):

(Percent - 100 + 5.3 ΔH)

Where Δ H is the increase in room height (expressed as meters.) Thus, for instance, if the height was changed by 0.2 m, the energy scaling would be changed by 1.06 percent. This is completely insignificant, since few fire measurements can be made to a repeatability or reproducibility of better than 10 percent. The effects of changing floor areas were similarly modest. Room dimensions having a tolerance of ±0.1 m should be entirely adequate for reproducibility.

Appendix B

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

B-1

The following acceptance criteria have been used by several of the model code organizations such as the International Conference of Building Officials (ICBO), Building Officials and Code Administration, Inc. (BOCA), and Southern Building Code Congress International (SBCCI) and are provided as a guide for the user of this test method.

B-1-1

Textile wall coverings should be considered as demonstrating satisfactory performance if, during the Method A test protocol, the following conditions are met:

(a) Flame should not spread to the ceiling during the 40 kW exposure.

(b) During the 150 kW exposure, the following criteria should be met:

1. Flame should not spread to the outer extremity of the sample on the 8 ft × 12 ft (2.44 m × 3.66 m) wall.

2. The specimen should not burn to the outer extremity of the 2 ft (0.6 m) wide samples mounted vertically in the corner of the room.

3. Burning droplets should not be formed and dropped to the floor that are judged to be capable of igniting the textile wall covering or that persist in burning for 30 sec or more.

4. Flashover should not occur.

5. The maximum instantaneous net peak rate of heat release should not exceed 300 kW. The maximum instantaneous net peak rate of heat release is derived by subtracting the burner output from the measured maximum rate of heat release.

B-1-2

Textile wall coverings should be considered as demonstrating satisfactory performance if, during the Method B test protocol, the following conditions are met:

(a) Flame should not spread to the ceiling during the 40 kW exposure.

(b) During the 150 kW exposure, the following criteria should be met:

1. Flame should not spread to the outer extremities of the samples on the 8 ft × 12 ft (2.44 m × 3.66 m) walls.

2. Flashover should not occur.

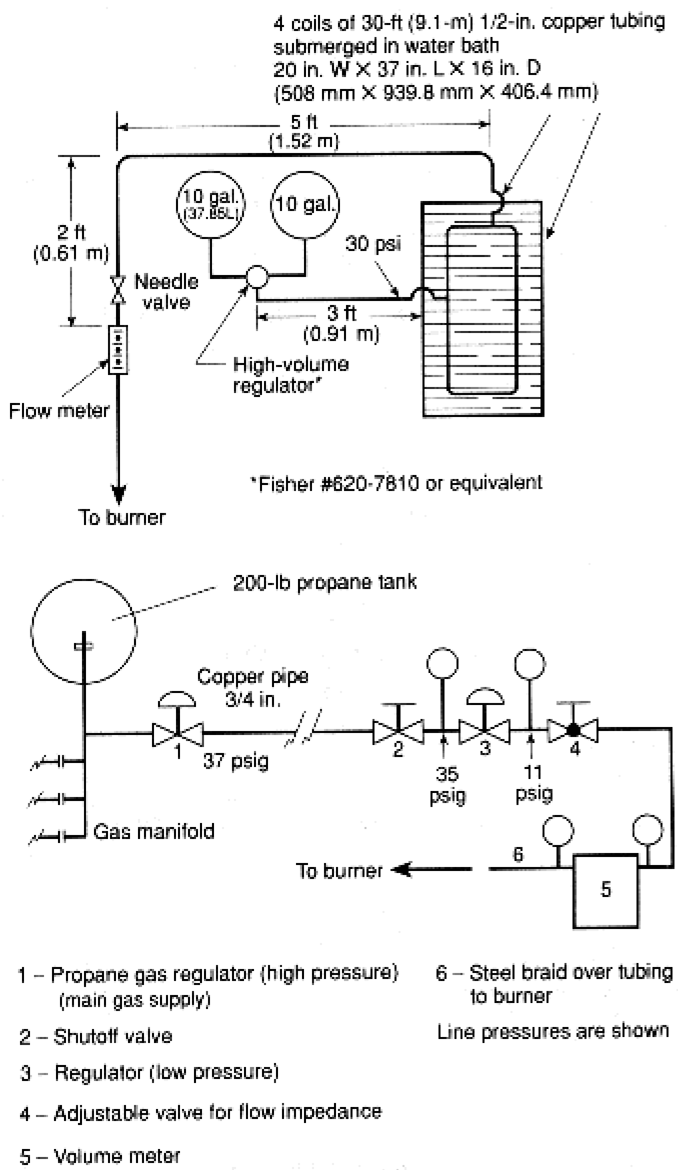

Figure B-1 Two typical gas flow regulation systems.

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 264, *Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*, 1992 edition.

C-1.2 Other Publications.

C-1.2.1 NBSIR Publication. National Institute of Standards and Technology, U. S. Department of Commerce Fire Research Information Service Building and Fire Research Laboratory, Gaithersburg, MD 20899.

NBSIR 82-2516, *Computer Fire Modeling for the Prediction of Flashover*.

C-1.2.2 Other References.

Fisher, F. L., MacCracken, B., and Williamson, R. B., "*Room Fire Tests of Textile Wall Coverings*," ES-7853, Service to Industry Report No. 85-4, Fire Research Laboratory, University of California, Berkeley, CA, April 1986.

Gardon, R., "An Instrument for the Direct Measurement of Intense Thermal Radiation," *Review of Scientific Instruments*, Vol. 24, No. 5, pp. 366-370, May 1953.

McCaffrey B. J., and Heskestad, G., "A Robust Bidirectional Low-Velocity Probe for Flame and Fire Application," *Combustion and Flame*, Vol. 26, No. 1, 125-127, February 1976.

NFPA 266

1994 Edition

Standard Method of Test for Fire Characteristics of Upholstered Furniture Exposed to Flaming Ignition Source

1994 Edition

This edition of NFPA 266, *Standard Method of Test for Fire Characteristics of Upholstered Furniture Exposed to Flaming Ignition Source*, was prepared by the Technical Committee on Fire Tests 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 266

This is a new standard that represents the current testing procedures for fire characteristics of upholstered furniture exposed to a flaming ignition source. This procedure was developed in response to the need to investigate the fire performance of upholstered furniture when exposed to a flaming ignition source. The performance data, heat release measurements, smoke density measurements, weight loss, and generation of carbon monoxide have been found to be useful in assessing the fire hazard of upholstered furniture. This standard was developed by research conducted by the National Institute of Standards and Technology (NIST) using a furniture calorimeter, Underwriters Laboratories Inc. (UL), and the California Bureau of Home Furnishings and Thermal Insulation (BHFTI).

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Committee Scope: This Committee shall have primary responsibility for documents on fire testing procedures where such documents are not available. The Committee shall 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; and act in a liaison capacity between NFPA and the committees of other organizations writing fire test standards. The Committee shall not be responsible for fire tests that are used to evaluate extinguishing agents, devices, or systems.

NFPA 266
Standard Method of Test for Fire Characteristics of Upholstered Furniture Exposed to Flaming Ignition Source

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 D.

Chapter 1 General

1-1 Scope.

1-1.1

This test method, using a full-scale furniture calorimeter, shall be used to determine heat release, smoke density, weight loss, and generation of carbon monoxide of upholstered furniture or full-scale mock-up of furniture.

1-1.2

This test procedure shall be used to determine performance of upholstered furniture exposed to a flaming ignition source. This performance data has been found to be useful in assessing the fire hazard of upholstered furniture in occupancies that are identified as or considered to be public occupancies. Such occupancies include jails, prisons, nursing care homes, health care facilities, public auditoriums, and the public gathering areas of hotels and motels.

1-1.3

Heat release rate is indicated by measurement of oxygen depletion, and smoke generation is determined by smoke density measurement systems. Weight loss and carbon monoxide (CO) and carbon dioxide (CO_2) evolution are continuously recorded.

1-1.4*

While this test method utilizes a full-scale furniture calorimeter, research has shown that both ASTM E1537, *Standard Method for Fire Testing of Real Scale Upholstered Furniture Items,* and California Technical Bulletin 133, *Flammability Test Procedure for Seating Furniture for Use in Public Occupancies*, provide comparable results for test specimens having heat release rates of 600 kW or less.

1-1.5

With respect to measurement of smoke and CO production, a quantitative relationship has not been established between measurements taken in the duct of the calorimeter exhaust system and measurements taken within the room. Accordingly, results of measurements of CO and smoke taken at different locations in different test environments shall not be considered equivalent.

1-2 Significance and Use.

1-2.1

This test method shall be used to determine the resulting fire performance characteristics of upholstered furniture or full-scale mock-ups where exposed to a standard flaming ignition source.

1-2.2

The results from this procedure provide information that can be used as an aid in the selection of upholstered furniture items that provide less contribution of heat, flame, smoke, and gases to fire scenarios.

1-2.3

Heat and smoke release rate measurements are sources of useful information for product development that provide a quantitative measure of specific changes in fire performance caused by product modifications.

1-2.4*

For upholstered furniture products containing only wood or metal frame, or a combination of both, the procedure using a mock-up sample provides an indication of the open-flame performance of the finished article. For upholstered furniture products containing plastic frames and plastic decorative parts or special construction features, a mock-up sample is not always an accurate indicator of the open-flame performance of the finished article.

1-3 Summary of Test Method.

1-3.1

This procedure provides for exposure of full-size upholstered furniture specimens or furniture mock-ups to a standard flaming ignition source in a full-scale furniture calorimeter.

1-3.2

The standard ignition source shall be a gas burner.

1-3.3

Determinations shall be made and recorded for parameters including density of smoke, concentrations of carbon monoxide and carbon dioxide, weight loss, heat release rate, and total heat release.

Chapter 2 Test Specimens

2-1 Size and Preparation.

2-1.1

The test specimen shall consist of the actual upholstered furniture item or a full-scale mock-up of the furniture.

2-1.2

The construction of any full-scale mock-up of the furniture shall reflect the actual construction used in the upholstered items.

2-1.3

The test specimen for a full-scale mock-up shall consist of component cushions that duplicate the thickness, construction, and design features of the product.

2-1.4

In the case of mock-up testing, a metal test frame [*see Figures 2-1.4(a) and 2-1.4(b)*] shall be used to support the seat and back cushions and, if necessary, arm cushions. The chair frame shall be constructed of slotted L-angle iron and slotted flat-angle iron. The back shall be constructed so that it is adjustable to a maximum angle of 135 degrees ± 2 degrees from the horizontal plane. The test frame shall be adjustable to accommodate test cushions of various thicknesses and sizes, with or without arm cushions.

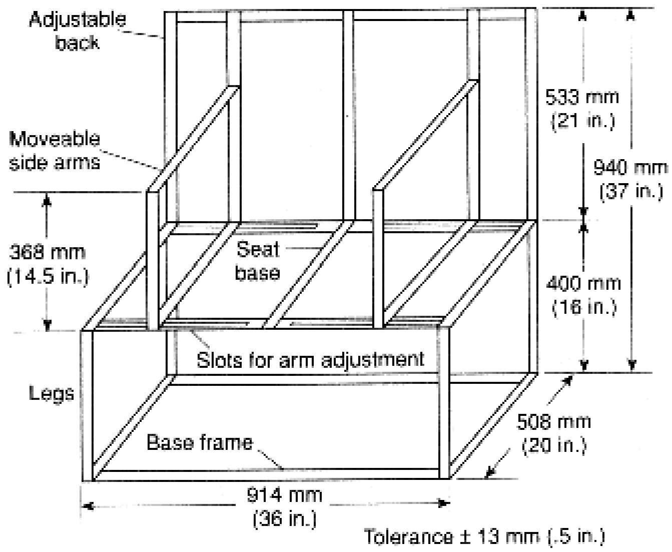

Figure 2-1.4(a) Metal test frame.

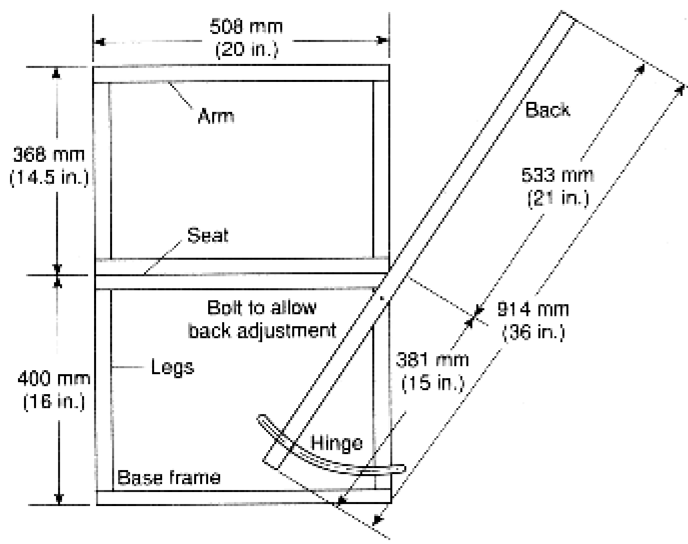

Figure 2-1.4(b) Metal test frame (end view).

2-1.5

Component back, seat, and arm cushions shall be constructed into mock-up designs of the actual article of furniture. Construction shall duplicate all layers found in the actual article of furniture. Cushion construction shall consist of either a manufacturer’s prefabricated cushion of the appropriate size or custom-made cushions. Custom-made cushions shall be constructed by covering all six faces of the filling material with the appropriate interliners and cover fabric.

2-1.6

In the case of mock-up testing, the constructed seat cushion shall be placed horizontally on the seat area of the test frame and pushed against the back of the frame. The constructed back cushion then is placed vertically against the back support of the test frame. The back cushion shall be held in place by wire to prevent it from falling forward.

If arm cushions are used, the constructed arm cushions shall be placed between the seat cushion and the arm supports of the test frame. However, the placement of the seat, back, and arm cushions shall simulate the design features of the completed article of furniture.

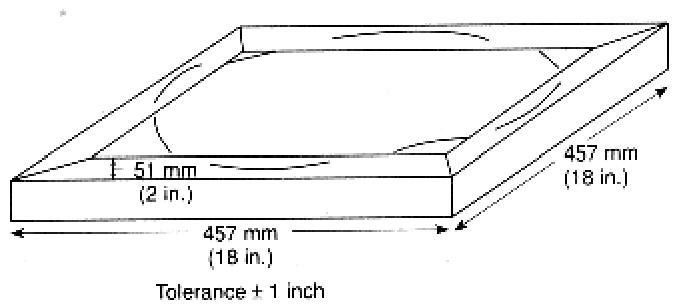

Figure 2-1.6 Back view of constructed cushion.

2-2 Conditioning.

The test specimen shall be conditioned for at least 48 hours prior to testing at 23°C ± 3°C (73°F ± 5°F) and a relative humidity of 50 percent ± 5 percent. Test specimens shall be tested within 10 minutes of removal from such conditions if the test conditions differ from those specified above.

Chapter 3 Test Equipment and Instrumentation

3-1 Ignition Source.

3-1.1

A 250 mm ± 10 mm × 250 mm ± 10 mm (10 in. ± 0.39 in. × 10 in. ± 0.39 in.) burner shall be used as the ignition source in this test method. It shall be constructed in accordance with this section. The burner shall be constructed of 13-mm ± 1 mm (0.5-in. ± 0.039 in.) outside diameter stainless steel tubing with 0.89-mm ± 0.05 mm (0.034-in. ± 0.002 in.) wall thickness [*see Figure 3-1.1(a)*]. The front side shall have 14 holes pointing straight out and spaced 13 mm ± 1 mm (0.5 in. ± 0.039 in.) apart. The right and left sides shall have 6 holes pointing straight out and spaced 13 mm ± 1 mm (0.5 in. ± 0.039 in.) apart, and 4 holes pointing inward at an angle of 45 degrees ± 2 degrees and spaced 50 mm ± 2 mm (2 in. ±0.076 in.) apart. All holes shall be 1 mm ± 0.1 mm (0.039 in. ± 0.0039 in.) in diameter [*see Figure 3-1.1(b)*]. The 1.07-m ± 0.2 m (42-in. ± 7.9 in.) straight arm of the burner shall be welded onto the rear of the front side [*see Figure 3-1.1(c)*] at a 30-degree angle. The burner shall be mounted on an adjustable height pole and shall be balanced by a counterweight or other appropriate mechanism. [*See Figure 3-1.1(d).*]

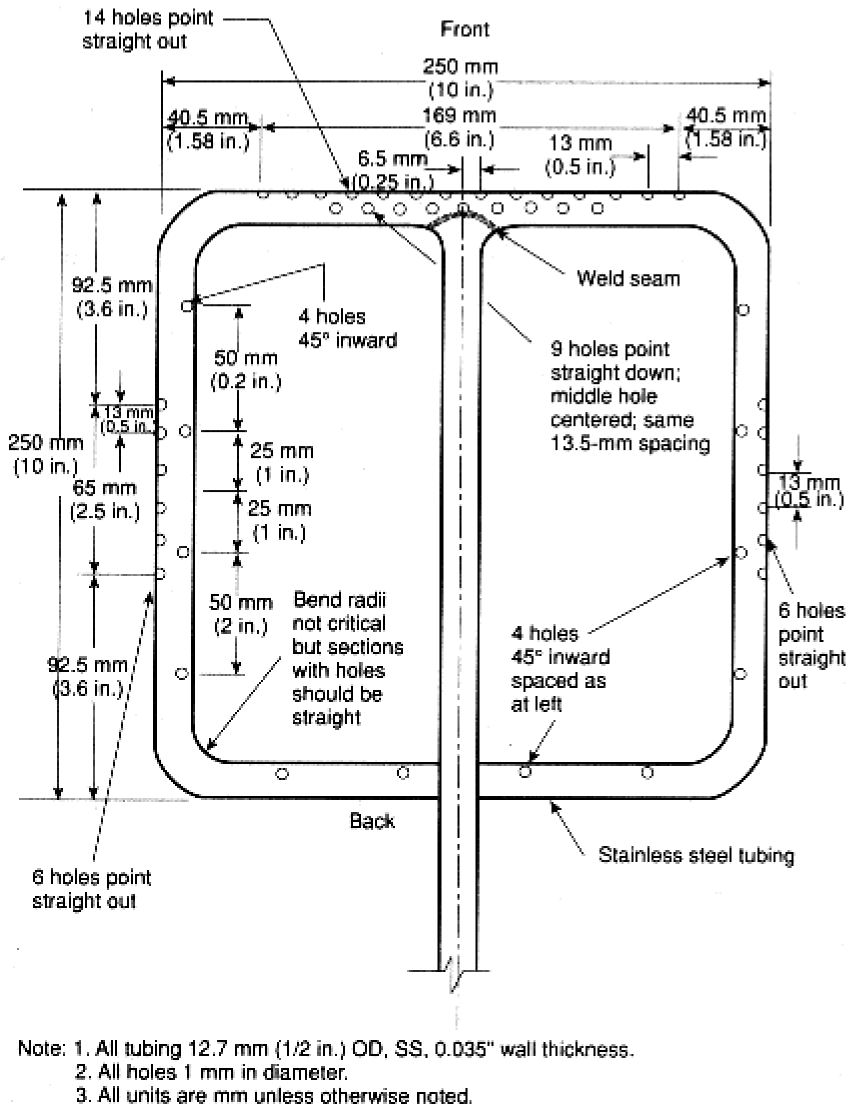

Figure 3-1.1(a) Plan view of square gas burner.

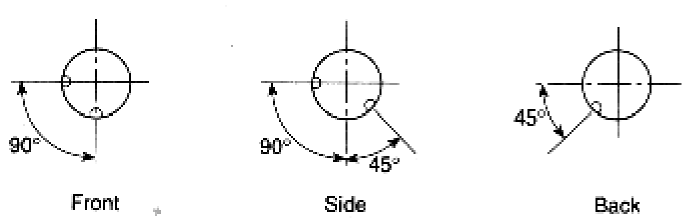

Figure 3-1.1(b) Cross-sectional view of each side of square gas burner.

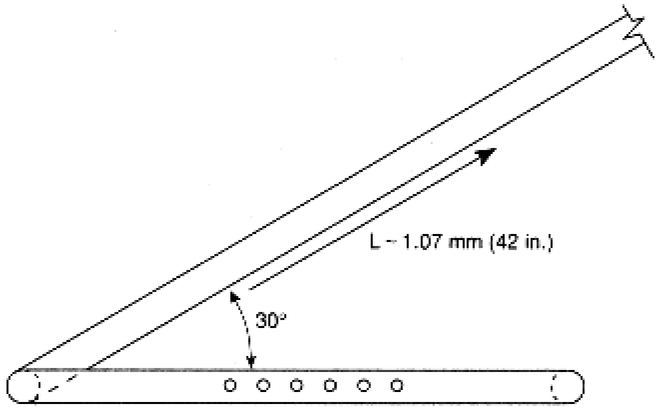

Figure 3-1.1(c) Side view of square gas burner.

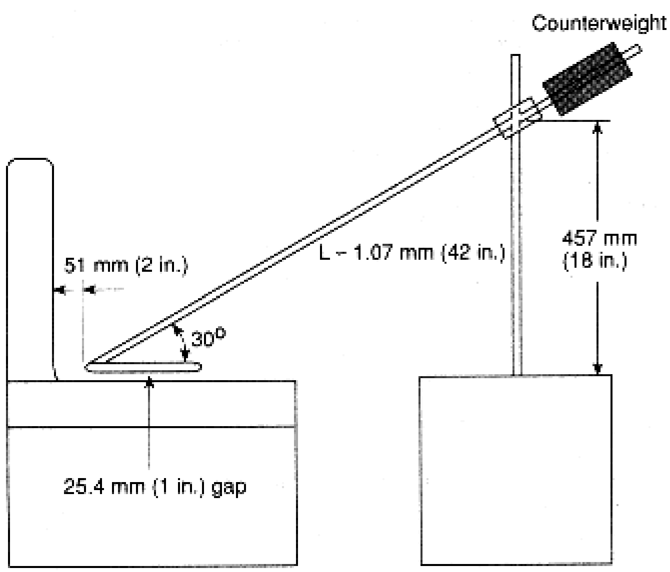

Figure 3-1.1(d) Positioning of square gas burner on the chair.

3-1.2

The gas burner shall utilize commercial-grade propane gas as fuel.

3-2 Collection — Exhaust System.

3-2.1

The hood shall be installed centrally above the weight-measuring system and test specimen. The face dimensions of the hood shall be 2.6 m ± 0.1 m × 2.6 m ± 0.1 m (8.53 ft ± 0.32 ft × 8.53 ft ± 0.32 ft), and the depth shall be 1.1 m ± 0.1 m (3.6 ft ± 0.32 ft). The hood shall exhaust into a plenum having a 0.9 m ± 0.05 m × 0.9 m ± 0.05 m (2.9 ft ± 0.16 ft × 2.9 ft ± 0.16 ft) cross section (*see Figure 3-2.1*). Other hood sizes shall be permitted, provided they produce equivalent test results. The distance between the lower edge of the hood and the weight-measuring system shall be 2.4 m (7.87 ft).

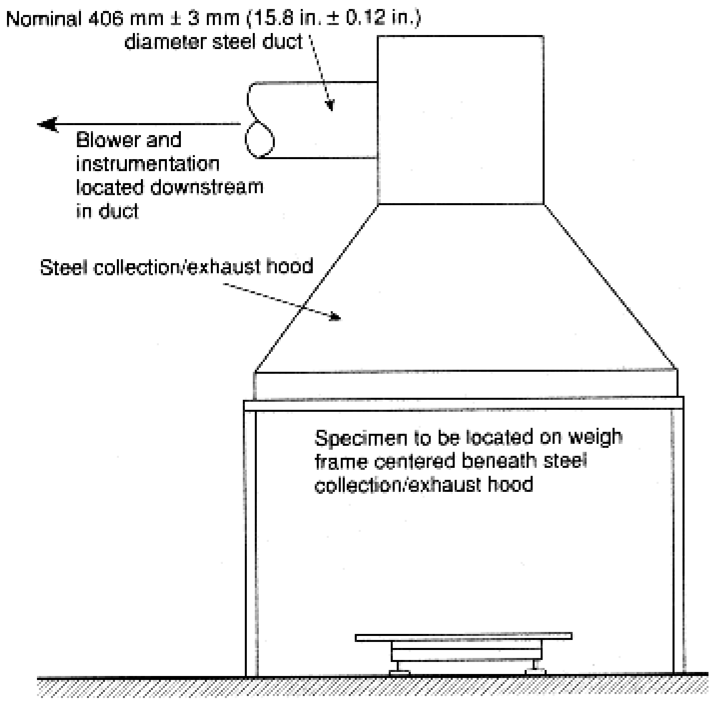

Figure 3-2.1 Collection hood and exhaust duct.

3-2.2*

The exhaust duct connected to the plenum shall be a minimum of 406 mm (15.8 in.) in diameter and shall have a minimum circular aperture of 305 mm (11.9 in.) at its entrance.

3-2.3

The exhaust system shall have sufficient exhaust capacity to collect all products of combustion developed by the burning specimen. The exhaust hood system shall be capable of being operated within a range that varies from a minimum rate of 0.47 m^3/s (16.6 ft^3/s) to a maximum rate of at least 2.4 m^3/s (84.8 ft^3/s).

3-2.4

An alternate exhaust system design shall be permitted to be used if it has been shown to produce equivalent results.

3-3 Velocity Measuring Instruments.

3-3.1

The velocity in the exhaust duct shall be determined by measuring the differential pressure in the flow path with the use of a bidirectional probe, as shown in Figure 3-3.1, connected to an electronic pressure gauge or an equivalent measuring system. The probe shall consist of a stainless steel cylinder with a solid diaphragm in the center that divides it into two chambers. The probe shall measure 44 mm (1.7 in.) long and 22 mm (0.86 in.) inside diameter. The pressure taps on either side of the diaphragm shall support the probe.

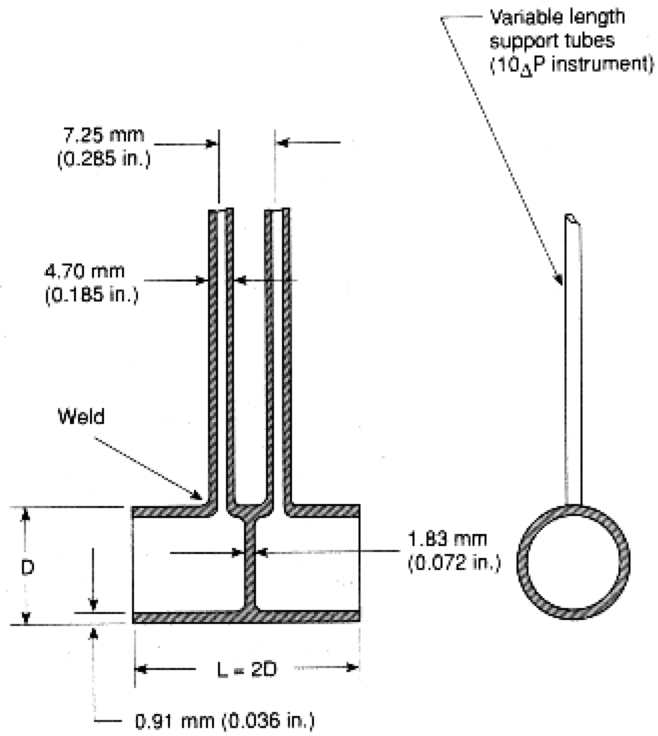

Figure 3-3.1 Bidirectional probe.

3-3.2

The axis of the probe shall be located at the centerline of the duct a minimum of 10 diameters downstream from the last turn in the duct. The taps shall be connected to a pressure transducer with a minimum resolution of 0.25 Pa (0.001 in. H_2O).

3-3.3

The temperature of the exhaust gas shall be measured upstream 152 mm ± 15 mm (5.9 in. ± 0.6 in.) from the probe at the centerline of the duct with a No. 28 AWG (0.08 mm^2), Type K thermocouple with an inconel sheath having a 16-mm (0.62-in.) outside diameter and a 3-mm (0.12-in.) thickness.

3-4 Gas Sampling and Analysis Equipment.

3-4.1*

A stainless steel gas sampling tube shall be located at least 10 diameters downstream from the last turn in the duct to obtain a continuously flowing sample for determining the oxygen concentration of the exhaust gas as a function of time. A suitable filter and cold trap shall be placed in line ahead of the analyzer to remove particulates and water. The oxygen analyzer shall be of the paramagnetic type and shall be capable of measuring the oxygen concentration in a range of from 0 to 21 percent with an accuracy of ± 0.2 percent of full-scale setting. The signal from the oxygen analyzer shall attain 90 percent of the calibration value within 30 seconds after introducing a step change in composition of the gas stream flowing past the inlet to the sampling tube.

3-4.2*

The gas sampling tube shall be located and defined as in 3-4.1. The carbon monoxide analyzer shall be capable of measuring the carbon monoxide in a range of from 0 to 1.0 percent with an accuracy of ± 0.02 percent of full-scale setting. The signal from the analyzer shall attain 90 percent of the calibration value within 30 seconds after introducing a step change in composition of the gas stream flowing past the inlet to the sampling tube.

3-4.3*

The gas sampling tube shall be as located and described in 3-4.1. The carbon dioxide analyzer shall be capable of measuring the carbon dioxide concentration in a range of from 0 to 10 percent with an accuracy of ± 0.2 percent of full-scale setting. The signal from the analyzer shall attain 90 percent of the calibration value within 30 seconds after introducing a step change in composition of the gas stream flowing past the inlet to the sampling tube.

3-5 Smoke Density Measuring Instruments.

3-5.1

The smoke density measuring system shall be a white light system.

3-5.2

The lamp shall be of the incandescent filament type and shall operate at a color temperature of 2900 K ± 100 K. The lamp shall be supplied with stabilized direct current, stable within ± 0.2 percent, including temperature and short-term and long-term stability.

3-5.3

The lens system shall be selected such that the lens shall have a diameter, d, chosen with regard to the focal length, f, so that $d/f \leq 0.04$.

3-5.4

The aperture shall be placed in the focus of the lens.

3-5.5

The detector shall have a spectrally distributed response according to the CIE photopic curve. The detector shall be linear within 5 percent over an output range of at least 3.5 decades. This linearity shall be checked periodically with calibrated optical filters and shall cover the entire range of the instrument.

3-5.6

The system shall be mounted on a horizontal section of duct at a point where it will be preceded by a straight run of duct [at least 12 diameters or 5.2 m (17 ft)] and with the light beam directed upward along the vertical axis of the duct. A photoelectric cell whose output is directly proportional to the amount of light received shall be mounted over the light source and connected to a recording device having an accuracy within ± 1 percent of full scale for indicating changes in the attenuation of incident light resulting from the passage of smoke, particulate, and other effluents. The distance between the light source lens and the photocell lens shall be 914 mm ± 102 mm (35.6 in. ± 3.9 in.). The cylindrical light beam shall pass through 76-mm ± 3 mm (2.9-in. ± 0.12 in.) diameter openings at the top and bottom of the duct, with the resultant light beam centered on the photocell.

3-5.7*

An alternate smoke density measuring system shall be permitted to be used if it has been shown to produce equivalent results.

3-6 Weighing Platform.

3-6.1

Mass loss rate of the burning specimen shall be measured during the test by means of a weight-measuring device.

3-6.2

A weighing platform shall be used to support the test specimen during the test. A reinforced inorganic board having the dimensions 1.2 m ± 0.1 m × 2.4 m ± 0.1 m (3.9 ft ± 0.32 ft × 7.87 ft ± 0.32 ft) shall be located on top of the weighing platform. The weighing platform perimeter shall have a rim extending 0.1 m ± 10 mm (0.32 ft ± 0.38 ft) above the top surface of the inorganic board to prevent spillage of test material.

3-6.3

The weight-measuring device shall be capable of measuring a specimen mass up to at least 90 kg (198.5 lb) with an accuracy of at least ± 150 g (± 0.33 lb). It shall be installed in such a way that the heat from the burning specimen and any eccentricity of the load do not affect the accuracy. Care shall be taken to avoid range shifts during measurements. All parts of the weight-measuring device shall be located below the top level of the slab.

3-6.4

The weighing platform shall support the base of the furniture specimen at a height of 127 mm ± 76 mm (5 in. ± 3 in.) above the floor.

3-6.5

The weighing platform shall be located beneath the collection hood at its geometric center.

3-7 Data Acquisition.

A digital data acquisition system shall be used to collect and record oxygen, carbon monoxide, and carbon dioxide analyzer measurements; pressure gauge measurements; temperatures; smoke measurements; and weight-measuring device measurements. The speed and capacity of the data system shall be sufficient to collect the data every 5 seconds.

3-8 Photographic and Video Equipment.

A camera and video equipment shall be used to record the test specimen performance throughout each test.

Chapter 4 Calibration

4-1 Calibration of Equipment.

4-1.1

The equipment and instrumentation shall be calibrated.

4-1.2

The heat release instrumentation shall be calibrated by burning propane. A gas burner shall be constructed with a 100-mm ± 6 mm (3.9-in. ± 0.23 in.) layer of Ottawa sand to provide the horizontal surface through which the gas is supplied. This type of burner is shown in Figure 4-1.2. The gas supply to the burner shall be of commercial-grade propane and shall have a net heat of combustion of 46.4 MJ/kg ± 0.5 MJ/kg (20,000 Btu/lb ± 200 Btu/lb). The flow rate of propane shall be metered and kept constant throughout the calibration test. A heat release value of 160 kW shall be used for calibration. The test shall be conducted for a period of 10 minutes.

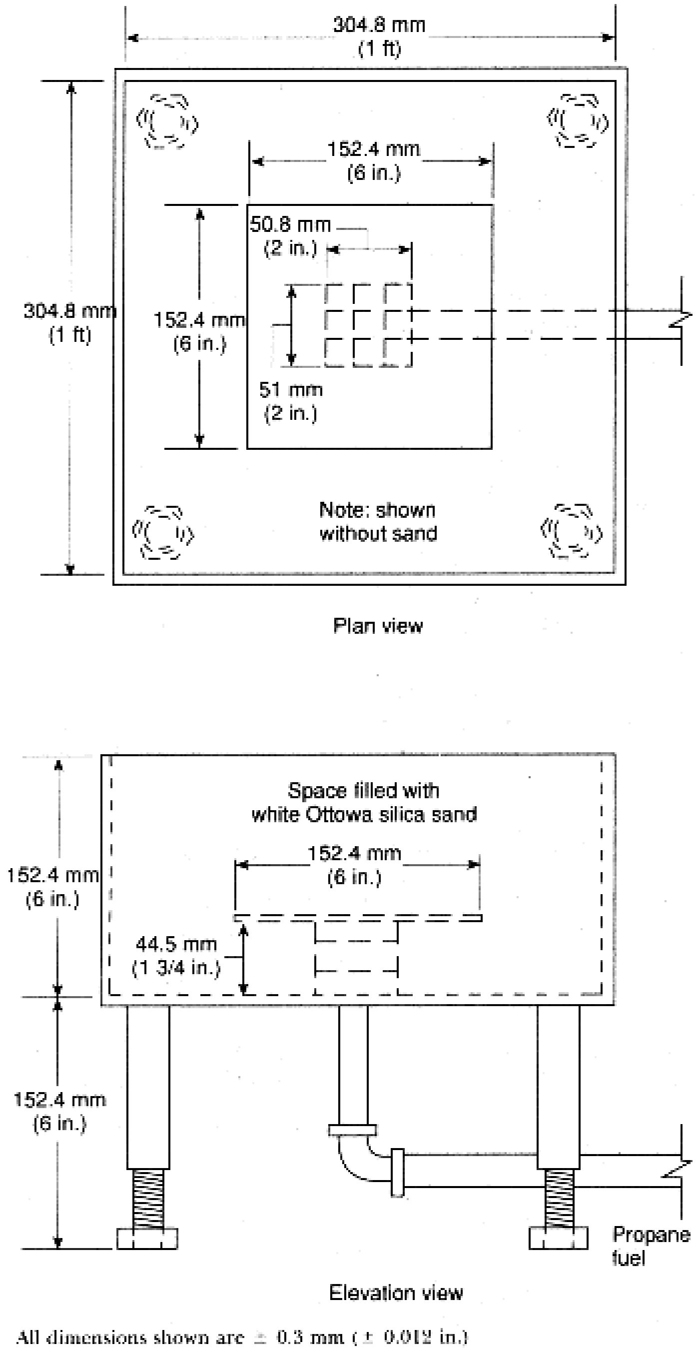

Figure 4-1.2 Calibration gas burner.

4-1.3

A calibration constant, C, shall be obtained as described in Chapter 6. A value for C differing more than 10 percent from the theoretical value shall not be permitted, and the equipment shall be checked. For the exhaust duct configuration described in Section 3-2 and the velocity probe described in Section 3-3, C shall have a theoretical value of 2.8.

4-2 Daily Calibration.

4-2.1

Prior to the start of each day of testing, the equipment calibrations described in 4-2.2 through 4-2.7 shall be performed.

4-2.2

The oxygen analyzer shall be zeroed and spanned. The analyzer shall be zeroed by introducing 100 percent nitrogen gas to the instrument at the same pressure and flow rate as set for the test specimen combustion gases. The analyzer shall be spanned by introducing ambient duct air via the sample probe and adjusting the span to 20.95 percent oxygen. The spanning and zeroing process shall continue until adjustment-free accuracy is obtained.

4-2.3

Following zeroing and spanning, linearity of the oxygen analyzer response curve shall be verified by introducing bottled gas of a known oxygen concentration to the analyzer. The delay time of the analyzer shall be checked by introducing ambient duct air to the analyzer and noting the time at which the analyzer readings reach 90 percent of the final reading.

4-2.4

The CO analyzer and CO_2 analyzer shall be zeroed and spanned in the same manner as the oxygen analyzer. The analyzer shall be zeroed by introducing 100 percent nitrogen gas to the instrument at the same pressure and flow rate as for the test specimen combustion gases. The analyzer shall be spanned by feeding each analyzer with bottled gas containing the selected concentration of span gas and adjusting for the response range of each analyzer.

4-2.5

The delay time of each analyzer shall be determined. The delay time shall be measured by introducing either a calibration span gas (for CO and CO_2) or a zero gas (for O_2) at the sample line just outside the duct and noting the time at which the analyzer readings reach 90 percent of the final reading.

4-2.6

The weight-measuring device shall be calibrated with known weights suitable for the capacity of the equipment and the specimen being tested.

4-2.7

Linearity of the smoke density measuring system shall be verified by interrupting the light beam with multiple calibrated neutral density filters to cover the range of the recording instrument. Transmittance values measured by the photometer, using neutral density filters, shall be within ± 3 percent of the calibrated value for each filter.

Chapter 5 Test Procedure

5-1 Testing Procedure.

5-1.1

The test specimen and weighing platform shall be located as shown in Figure 3-2.1.

5-1.2

The initial exhaust hood flow rate shall be set at a minimum of 0.47 m^3/s (16.6 ft^3/s).

5-1.3

The burner shall be positioned 51 mm ± 3 mm (2 in. ± 0.12 in.) from the back and 25 mm ± 3 mm (0.97 in. ± 0.12 in.) above the seat, with the center of the burner at the centerline of the test specimen.

5-1.4

The data acquisition shall begin in order to monitor test instrumentation.

5-1.5

The gas flow rate to the burner shall be set at a volume flow rate of 13 L/min ± 0.5 L/min (3.4 gal/min ± 0.13 gal/min). Care shall be taken to allow free flow of propane through the burner holes. Periodic cleaning of soot deposits and blowing of pressurized air through the tube shall be required.

5-1.6

The burner shall be ignited.

5-1.7

The exhaust hood flow rate shall be increased as required to collect all products of combustion from the test specimen.

5-1.8

The burner shall be removed from the test specimen after an exposure of 80 seconds ± 2 seconds.

5-1.9

The burner shall be turned off.

5-1.10

Combustion shall be allowed to continue until one or more of the following conditions are reached:

(a) All flaming combustion has ceased;

(b) Thirty minutes have elapsed from the time the burner was ignited.

Chapter 6 Calculations

6-1 Method of Calculation.

The symbols used in this chapter are defined in Appendix C. The equations in this chapter assume that only oxygen is measured. Appropriate equations that shall be used for those cases where additional gas analysis equipment (CO_2, CO, water vapor) is used are provided in Appendix C. If a CO_2 analyzer is used and CO_2 is not removed from the oxygen sampling lines, then the appropriate equations in Appendix C shall be used.

6-2 Calibration Constant Using Propane.

The calibration constant shall be obtained from the following equation:

$$C = \frac{160}{1.10(12.77 \times 10^3)} \times \sqrt{\frac{T_c}{\Delta h}} \times \left[\frac{1.084 - 1.4X_{O_2}}{X^{\circ}_{O_2} - X_{O_2}}\right]$$

where:

160 corresponds to 160 kW propane supplied, 12.77 × 10^3 equals $\Delta h_c/r_o$ for propane, and 1.10 is the ratio of oxygen to air molecular weight.

6-3 Heat Release for Test Specimens.

6-3.1

Prior to performing additional calculations, the oxygen analyzer time shift shall be determined by the following equation:

$$X_{O_2}(t) = X'_{O_2}(t - t_d)$$

6-3.2

The heat release rate then shall be determined by the following equation:

$$\dot{Q}(t) = \left(\frac{\Delta h}{r_o}\right) \times 1.10C \sqrt{\frac{\Delta P}{Tc}} \left[\frac{X^{\circ}_{O_2} - X_{O_2}(t)}{1.084 - 1.4X_{O_2}(t)}\right]$$

6-3.3

The value of $(\Delta h_c/r_o)$ for the test specimen shall be set to equal 13.1 × 10^3 kJ/kg unless a more accurate value is known for the test specimen.

6-3.4

The total heat released during the first 10 minutes of the test shall be determined by the following equation:

$$\dot{q}''_i = \sum_{i=o}^{10} \dot{q}''_i(t)\,\Delta t$$

6-4 Smoke Obscuration.

6-4.1

The extinction coefficient (k) of smoke shall be determined by the following equation:

$$k = \frac{1}{L} \ln\left(\frac{I_o}{I}\right)$$

where:
L = path length in meters.

6-4.2

The smoke release rate (SRR) shall be calculated using the optical density per linear path length and the volumetric flow rate in the duct. The SRR shall be determined by the following equation:

$$SRR = km$$

where:

SRR equals the smoke release rate in m^2/s; k equals the extinction coefficient; and m equals the volumetric flow rate (in m^3/s) referred to 298 K.

Chapter 7 Report of Results

7-1

The following shall be reported for each test specimen:

(a) Test specimen identification or number

(b) Manufacturer or submitter

(c) Date of test

(d) Operator

(e) Composition or generic identification

(f) Details of preparation

(g) Number of replicate test specimens tested

(h) Time to termination of test (seconds)

(i) Maximum mass (kg) loss

(j) Maximum rate of heat release (kW)

(k) Total heat release (MJ) during the first 10 minutes of the test

(l) Maximum smoke release rate (m^2/s)

(m) Maximum carbon monoxide concentration (ppm)

(n) Maximum carbon dioxide concentration (ppm).

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 ASTM Publication.

American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM E1537-93, *Standard Method for Fire Testing of Real Scale Upholstered Furniture Items*.

8-1.2 State of California Publication.

State of California, Department of Consumer Affairs, Bureau of Home Furnishings and Thermal Insulation.

Technical Bulletin 133, *Flammability Test Procedure for Seating Furniture for Use in Public Occupancies*, January 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-1-1.4

For further information on other test environments, see the following publications:

“Furniture Flammability: An Investigation of the California Technical Bulletin 133 Test — Part 1: Measuring the Hazards of Furniture Fires,” by J. Quintiere.

”Furniture Flammability: An Investigation of the California Technical Bulletin 133 Test — Part 2: Characterization of Ignition Source and Comparable Gas Burner,” by J. Ohlemiller and K. Villa.

“Furniture Flammability: An Investigation of the California Technical Bulletin 133 Test — Part 3: Full-Scale Chair Burns,” by W. J. Parker.

A-1-2.4

While using frames or features other than wood or metal, actual articles of furniture (not mock-ups) should be tested.

A-3-2.2

The locations for velocity, temperature, gas analysis, and smoke photometer should be chosen to ensure that the products of combustion are well-mixed and not stratified at the sampling location. The general rule should be for the duct to run a sufficient length (10 diameters) downstream from the last turn in the duct prior to location of instrumentation in order to provide for a fully developed gas flow. Mixing vanes should be used in the duct if concentration gradients are found to exist.

A-3-4.1

One type of oxygen analyzer is a Beckman Instrument Model 755 paramagnetic-type oxygen analyzer. Other equivalent oxygen analyzers may be permitted to be used.

A-3-4.2

One type of carbon monoxide analyzer is a Horiba Instrument Model PIR-2000 analyzer. Other equivalent carbon monoxide analyzers may be permitted to be used.

A-3-4.3

One type of carbon dioxide analyzer is a Horiba Instrument Model PIR-2000 analyzer. Other equivalent carbon dioxide analyzers may be permitted to be used.

A-3-5.7

A laser beam system may be permitted to be used as an alternate system for measuring smoke obscuration.

Appendix B Commentary

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

B-1

This appendix was developed in response to the need to investigate the fire performance of upholstered furniture when exposed to open-flame ignition sources. This performance data has been found to be useful in assessing the fire hazard of upholstered furniture in occupancies that are identified as or considered to be public occupancies.

B-2

In consideration of the statistics that document the involvement of upholstered furniture in fires in public occupancies and in response to the need expressed by fire departments, authorities having jurisdiction, procurement officials, and others, the California Bureau of Home Furnishings and Thermal Insulation (BHFTI) developed Technical Bulletin (TB) 133, *Flammability Test Procedure for Seating Furniture for Use in Public Occupancies*.

B-3

In the development of TB 133, the BHFTI considered such public occupancies as:

(a) Jails, prisons, and penal institutions;

(b) Health care facilities, such as hospitals;

(c) Old-age and convalescent facilities;

(d) Board and care occupancies;

(e) Licensed child care facilities;

(f) Public stadiums and auditoriums;

(g) Public gathering areas of hotels and motels, defined as areas where there are ten or more upholstered seats.

B-4

The TB 133 fire test was initially published in 1984 and consisted of an instrumented test room measuring 3.7 m × 3.0 m (12 ft × 10 ft) with an 2.4-m (8-ft) ceiling and a 0.96 m × 2 m (3 ft 2 in. × 6 ft 9 in.) doorway. The ignition source consisted of five double sheets of loosely crumpled newspaper placed inside a ventilated ignition box that was set on the seating surface of the furniture. The box was designed to contain the flames and direct them onto the sample surface. The sample furniture item weight was monitored by load cells. Test measurements in the TB 133 test included the following:

(a) Temperature increase at several points in the test room;

(b) Smoke opacity at several elevations in the room;

(c) A single point measurement of CO;

(d) Weight loss of the furniture both during and following the test.

B-5

In an actual full-scale fire, research has shown that one of the most significant characteristics of the items involved in a fire is their rate of heat release. The rate of heat release governs the rate of growth and spread of the fire to surrounding objects and the phenomenon of room flashover. In recognition of this fact, fire research of various types of upholstered furniture was conducted at the National Institute of Standards and Technology (NIST) using a full-scale calorimeter. Using this equipment, heat release measurements of furniture were obtained. At Underwriters Laboratories, a test method was developed (UL 1056, *Fire Tests of Upholstered Furniture*) utilizing the calorimeter approach to measurement. The method was intended to investigate the fire growth performance of upholstered furniture for use in public occupancies.

B-6

In consideration of the advance of heat release technology, the BHFTI and NIST undertook a study to expand and modify TB 133 in three areas:

(a) Inclusion of heat measurements;

(b) Development of a gas ignition source to substitute for a newspaper ignition source for increased repeatability and reproducibility;

(c) Development of correlations between the BHFTI test room, the American Society for Testing and Materials (ASTM) Standard Fire Test Room, and the full-scale furniture calorimeter.

B-7

The results of the study were reported in three NIST reports. Based on the findings of the study, TB 133 was modified to include heat release measurement as an optional test procedure. The criteria of acceptance in the January 1991 TB 133 document are provided in B-7.1.

B-7.1

Seating furniture meets the requirements of this test procedure if all of the following criteria are satisfied in a room fire test using the following room instrumentations:

(a) A temperature increase less than 111°C (200°F) at ceiling thermocouple;

(b) A temperature increase less than 28°C (50°F) at the mid-height thermocouple;

(c) An opacity of smoke of 75 percent or less at the (1.2-m) 4-ft smoke density meter;

(d) Carbon monoxide concentration of less than 100 ppm for 5 minutes;

(e) Weight loss of the seating furniture due to combustion of 1.36 kg (3 lb) or less during the first 10 minutes of the test.

B-7.2

Seating furniture meets the requirements of this test procedure if the following criteria are satisfied in a calorimeter test using oxygen consumption calorimetry:

(a) Peak rate of heat release of 80 kW or less;

(b) Total heat release of 25 MJ or less during the first 10 minutes of the test.

B-7.3

TB 133 does not require that upholstered furniture be subjected to both of the test procedures (room test and calorimeter test). Upholstered furniture may be permitted to be tested by either procedure to fulfill the applicable criteria.

B-8

Furniture that meets these criteria reduces the contribution of the furniture to the creation of untenable conditions in a room involved in fire.

B-9

The test method described in this standard provides data useful in evaluating upholstered furniture products in accordance with the January 1991 TB 133 criteria.

B-10

NFPA 101®, *Life Safety Code®*, 31-1.4.3, requires that upholstered furniture shall have limited rates of heat release as follows:

(a) The peak rate of heat release shall not exceed 250 kW unless rooms have approved smoke detectors or approved automatic sprinkler systems.

(b) The peak rate of heat release shall not exceed 500 kW unless rooms have an approved, automatic sprinkler system.

(c) Total energy release during the first 5 minutes of the test shall not exceed 75 MJ unless rooms have an approved, automatic sprinkler system.

B-11

During the past several years, upholstered furniture for public occupancies has been investigated for response to open-flame sources using the TB 133 method and other similar methods such as UL 1056, *Fire Tests of Upholstered Furniture*, and ASTM E1537, *Standard Method for Fire Testing of Real Scale Upholstered Furniture Items*.

Appendix C Heat Release Calculations Using Additional Gas Analysis

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

C-1 Calculation of Heat Release with Additional Gas Analysis.

C-1.1

The equations used to calculate heat release rate in Chapter 6 assume CO_2 is removed from the gas sample in a chemical scrubber before oxygen is measured. Some laboratories are equipped to measure CO_2; in such a case, it is not necessary to remove the CO_2 from the oxygen line. The advantage is that the chemical scrubbing agent, which is costly and needs careful handling, can be avoided.

C-1.2

In this appendix, equations are provided that are to be used when CO_2 is measured but *not* scrubbed out of the sampling lines. Two cases are considered. In the first case, part of the dried and filtered sample stream is diverted into infrared CO_2 and CO analyzers. In the second case, a water-vapor analyzer is also added. To avoid condensation, when measuring water-vapor concentration in the flow of combustion products, a separate sampling system with heated filters, heated sampling lines, and a heated analyzer is needed.

C-2 Symbols.

The following symbols are used in this appendix:

M_a = molecular weight of air (kg/kmol).

M_e = molecular weight of the combustion products (kg/kmol).

$\dot{m}_e$ = exhaust duct mass flow rate (kg/s).

t_d^1 = delay time of the CO_2 analyzer(s).

t_d^2 = delay time of the CO analyzer(s).

t_d^3 = delay time of the water-vapor analyzer(s).

X_{CO2}° = initial CO_2 reading, mole fraction.

X_{CO}° = initial CO reading, mole fraction.

X_{H2O}° = initial water-vapor reading, mole fraction.

X_{O2}^a = ambient oxygen mole fraction.

X_{CO2}^1 = CO_2 reading before delay time correction, mole fraction.

X_{CO}^1 = CO reading before delay time correction, mole fraction.

X_{H2O}^1 = water-vapor reading before delay time correction, mole fraction.

X_{CO2} = CO_2 reading after delay time correction, mole fraction.

X_{CO} = CO reading after delay time correction, mole fraction.

X_{H2O} = water reading after delay time correction,mole fraction.

ϕ= oxygen depletion factor.

C-3 Where CO_2 and CO Are Measured.

C-3.1

As in the case of the oxygen analyzer, measurements of CO_2 and CO should be time-shifted to take transport time in the sampling lines into account as follows:

$$X_{O_2}(t) = X_{O_2}{}^1(t + t_d)$$

$$X_{CO_2}(t) = X_{CO_2}{}^1(t + t_d{}^1)$$

$$X_{CO}(t) = X_{CO}{}^1(t + t_d{}^2)$$

The delay times, $t_d{}^1$ and $t_d{}^2$, for the CO_2 and CO analyzers, respectively, are usually different (smaller) than the delay time, t_d, for the oxygen (O_2) analyzer.

C-3.2

The exhaust duct flow is determined as follows:

$$\dot{m}_e = C\sqrt{\frac{\Delta P}{T_e}}$$

C-3.3

The rate of heat release now can be determined as follows:

$$\dot{q} = 1.10\left(\frac{\Delta h_c}{r_o}\right) X_{O_2}^a \left[\frac{\phi - 0.172(1 - \phi)X_{CO}}{(1 - \phi) + 1.084\phi}\right] \dot{m}_e$$

C-3.4

The oxygen depletion factor, o, is calculated as follows:

$$\phi = \frac{X^{\circ}_{O_2}(1 - X_{CO_2} - X_{CO}) - X_{O_2}(1 - X^{\circ}_{CO_2})}{X^{\circ}_{O_2}(1 - X_{CO_2} - X_{CO} - X_{O_2})}$$

C-3.5

The ambient mole fraction of oxygen (O_2) is determined as follows:

$$X^{a}_{O_2} = (1 - X^{o}_{H_2O})(X^{\circ}_{O_2})$$

C-3.6

The second value in the numerator of the factor in brackets in the equation in C-3.3 is a correction factor for incomplete combustion of some carbon to CO instead of CO_2. In fact, the value for X_{CO} is usually very small, so that it can be disregarded in the equations in C-3.3 and C-3.4. The practical implication of this value is that a CO analyzer will generally not result in a noticeable increase in accuracy of heat release rate measurements. Consequently, the equations in C-3.3 and C-3.4 may be permitted to be used even if no CO analyzer is present by using the setting $X_{CO} = 0$.

C-4 Where Water Vapor Is also Measured.

C-4.1

In an open combustion system, such as that used in this test method, the flow rate of air entering the system cannot be measured directly but is inferred from the flow rate measured in the exhaust duct. An assumption regarding the expansion due to combustion of the fraction of the air that is fully depleted of its oxygen is necessary. This expansion depends on the composition of the fuel and the actual stoichiometry of the combustion. A suitable average value for the volumetric expansion factor is 1.084, which is the factor for propane.

C-4.2

This expansion factor value is already incorporated within the equation in 6-3.2 and the equation in C-3.3 for q. It can be assumed that the exhaust gases consist primarily of nitrogen, oxygen, CO_2, water vapor, and CO; thus, measurements of these gases can be used to determine the actual expansion. (It is assumed that the measurements of oxygen, CO_2, and CO refer to a dry gas stream, while the water-vapor measurement corresponds to total stream flow.) The mass flow rate in the exhaust duct is then more accurately provided by the following equation:

$$M_e = C\sqrt{\frac{\Delta P}{T_c}}\ \sqrt{\frac{M_e}{M_a}}$$

C-4.2.1 The molecular weight, M_e, of the exhaust gases is determined as follows:

$$M_e = \left[4.5 + (1 - X_{H_2O})(2.5 + X_{O_2} + 4X_{CO_2})\right] \times 4$$

C-4.2.2 Using 28.97 as the value for M_a , the heat release rate is determined as follows:

$$\dot{q}(t) = 1.10\left(\frac{\Delta h_c}{r_o}\right)\left(1\text{-}X_{H_2O}\right)\left[\frac{X^{\circ}_{O_2}(1\text{-}X_{O_2} - X_{CO_2}) - X_{O_2}}{1\text{-}X^{\circ}_{O_2} - X_{CO_2}}\right] M_e$$

C-4.3

The water-vapor readings used in the equation in C-4.2.2 are time-shifted in a similar way to those in the equations in C-3.1 for other types of analyzers as follows:

$$X^{\circ}_{H_2O}\ (t) = X^{1}_{H_2O}\ (t + t_d{}^{3})$$

Appendix D Referenced Publications

D-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.

D-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.

D-1.2 Other Publications.

D-1.2.1 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM E602-91, *Method for Sharp-Notch Tension Testing with Cylindrical Specimens.*

ASTM E1537-93, *Standard Method for Fire Testing of Real Scale Upholstered Furniture Items.*

D-1.2.2 NIST Publications. U.S. National Institute of Standards Technology, U.S. Department of Commerce, Technology Administration National Technical Information Service, Springfield, VA 22161.

NIST 4360, "Furniture Flammability: An Investigation of the California Technical Bulletin 133 Test — Part 1: Measuring the Hazards of Furniture Fires," J. Quintiere, July 1990.

NIST 4348, "Furniture Flammability: An Investigation of the California Technical Bulletin 133 Test — Part 2: Characterization of Ignition Source and Comparable Gas Burner," T. Ohlemiller and K. Villa, June 1990.

NIST 4375, "Furniture Flammability: An Investigation of the California Technical Bulletin 133 Test — Part 3: Full-Scale Chair Burns," W. J. Parker, K. M. Tu, S. Nurbakhsh, and G. H. Damant, July 1990.

D-1.2.3 UL Publication. Underwriters Laboratories Inc., 333 Pfingsten Road., Northbrook, IL 60062.

UL 1056-89, *Fire Tests of Upholstered Furniture.*

D-1-2.4 Additional Publications.

Babrauskas, Vytenis, Lawson, Randall J., Walton, W. D., and Twilley, William H., "Upholstered Furniture Heat Release Rates Measured with a Furniture Calorimeter," NMBSIR 82-2604, December 1982.

Damant, Gordon, "Flammability of Soft Furnishings. What's Happening in California?" *Journal of Fire Sciences*, Vol. 18, No. 5, September/October 1990, pp. 313-330.

Nurbakhsh, Said, "Development of Full-Scale Fire Test Facility," Proceedings of the International Conference on Fire Safety, Vol. 15, 1990.

Technical Bulletin 133, *Flammability Test Procedure for Seating Furniture for Use in Public Occupancies*, State of California, Department of Consumer Affairs, Bureau of Home Furnishings and Thermal Insulation, January 1991.

NFPA 267

1994 Edition

Standard Method of Test for Fire Characteristics of Mattresses

1994 Edition

This edition of NFPA 267, *Standard Method of Test for Fire Characteristics of Mattresses and Bedding Assemblies Exposed to Flaming Ignition Source*, was prepared by the Technical Committee on Fire Tests 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 267

NFPA 267 is a new standard that represents the current testing procedures for fire characteristics of mattresses and bedding assemblies exposed to a flaming ignition source. This procedure was developed to provide information that can be used to aid in the selection of mattresses and bedding assemblies that provide for less contribution of heat, flame, smoke, and gases to fire scenarios. This standard was developed by research conducted by the National Institute of Standards and Technology (NIST), Underwriters Laboratories Inc. (UL), and the California Bureau of Home Furnishings and Thermal Insulation (BHFTI).

Technical Committee on Fire Tests

Jesse J. Beitel, *Chair*
Hughes Assoc. Inc., MD

Peter J. Barbadoro, Westinghouse Savannah River Co., SC

April L. Berkol, ITT Sheraton Corp., MA
Rep. American Hotel & Motel Assn.

John A. Blair, The DuPont Co., DE
Rep. Society of the Plastics Industry Inc.

William E. Fitch, Omega Point Laboratories Inc., TX

Thomas W. Fritz, Armstrong World Industries Inc., PA

Robert Gallagher, IBM Corp., NY

Jeffrey E. Gould, Factory Mutual Research Corp., MA

Alfred J. Hogan, Reedy Creek Improvement District, FL
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James R. Lawson, Nat'l Inst. of Standards & Technology, MD

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Sivon C. Reznikoff, Arizona State University, AZ

Howard Stacy, Southwest Research Inst., TX

Herman Stone, General Foam, PA

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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)

Committee Scope: This Committee shall have primary responsibility for documents on fire testing procedures where such documents are not available. The Committee shall 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; and act in a liaison capacity between NFPA and the committees of other organizations writing fire test standards. The Committee shall not be responsible for fire tests that are used to evaluate extinguishing agents, devices, or systems.

NFPA 267
Standard Method of Test for
Fire Characteristics of Mattresses and Bedding Assemblies Exposed to Flaming Ignition Source

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 C.

Chapter 1 General

1-1 Scope.

1-1.1

This test method, using an open calorimeter environment, shall be used to determine heat release, smoke density, weight loss, and generation of carbon monoxide of mattresses and bedding assemblies.

1-1.2*

This test procedure shall be used to determine performance of mattresses and bedding assemblies without bedclothes exposed to a flaming ignition source. This performance data has been found to be useful in assessing the fire hazard of mattresses and bedding assemblies in occupancies that are identified as or considered to be public occupancies. Such occupancies include jails, prisons, nursing care homes, health care facilities, hotels, and motels.

1-1.3

Heat release rate is indicated by measurement of oxygen depletion, and smoke generation is determined by smoke density measurement systems. Weight loss and carbon monoxide (CO) and carbon dioxide (CO_2) evolution are continuously recorded.

1-1.4*

While this test method utilizes a full-scale open calorimeter, research has shown that both ASTM E1537, *Standard Method for Fire Testing of Real Scale Upholstered Furniture Items*, and California Technical Bulletin TB 133, *Flammability Test Procedure for Seating Furniture for Use in Public Occupancies*, provide comparable results for test specimens having heat release rates of 600 kW or less.

1-1.5

With respect to measurement of smoke and CO production, a quantitative relationship has not been established between measurements taken in the duct of the calorimeter exhaust system and measurements taken within the room. Accordingly, results of measurements of CO and smoke taken at different locations in different test environments shall not be considered equivalent.

1-2 Significance and Use.

1-2.1

This test method shall be used to determine the resulting fire performance characteristics of mattresses and bedding assemblies where exposed to a standard flaming ignition source.

1-2.2

The results from this procedure provide information that can be used as an aid in the selection of mattresses and bedding assemblies that provide for less contribution of heat, flame, smoke, and gases to fire scenarios.

1-2.3*

Heat and smoke release rate measurements are sources of useful information for product development that provide a quantitative measure of specific changes in fire performance caused by product modifications.

1-3 Summary of Test Method.

1-3.1

This procedure provides for exposure of full-size specimens to a standard flaming ignition source in an open calorimeter environment.

1-3.2

The standard ignition source shall be a gas burner.

1-3.3

Determinations shall be made and recorded for parameters including density of smoke, concentrations of carbon monoxide and carbon dioxide, weight loss, heat release rate, and total heat release.

Chapter 2 Test Specimens

2-1 Test Specimens.

2-1.1 Size and Preparation.

The test specimen shall consist of the actual mattress or bedding assembly item.

2-1.2 Conditioning.

The test specimen shall be conditioned for at least 48 hours prior to test at 23°C ± 3°C (73°F ± 5°F) and a relative humidity of 50 percent ± 5 percent. Test specimens shall be tested within 10 minutes of removal from such conditions if the test conditions differ from those specified above.

Chapter 3 Test Equipment and Instrumentation

3-1 Ignition Source.

3-1.1

A 205-mm (8.07-in.) long “T” burner shall be constructed of 12 mm ± 1 mm (0.47 in. ± 0.039 in.) outside diameter stainless steel tubing with 0.89 mm ± 0.05 mm (0.034 in. ± 0.0019 in.) wall thickness *(see Figure 3-1.1)*. There shall be 14 holes at 45 degrees above the centerline and spaced 13 mm ± 1 mm (0.5 in. ± 0.039 in.) apart and 9 holes 45 degrees below the centerline and spaced 13 mm ± 1 mm (0.5 in. ± 0.039 in.) apart. All holes shall be 1 mm ± 0.1 mm (0.039 in. ± 0.0039 in.) in diameter *(see Figure 3-1.1)*. The 1.07-m ± 0.2 m (42-in. ± 7.8 in.) straight arm of the burner shall be welded onto the rear of the burner at a 30-degree angle. The burner shall be mounted on an adjustable height pole and shall be balanced by a counterweight or other appropriate mechanism.

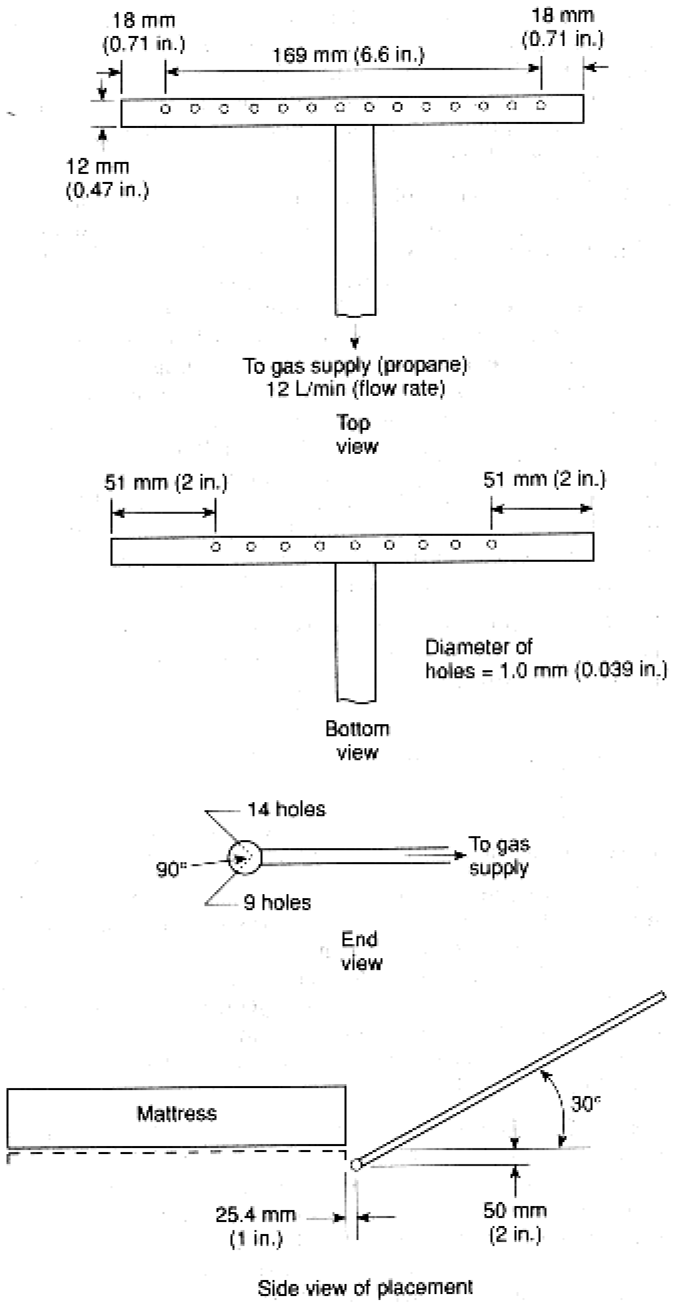

Figure 3-1.1 Propane gas burner.

3-1.2

The gas burner shall utilize commercial-grade propane gas as a fuel.

3-2 Collection — Exhaust System.

3-2.1

The hood shall be installed centrally above the weight-measuring system and test specimen. The face dimensions of the hood shall be 2.6 m ± 0.1 m × 2.6 m ± 0.1 m (8.53 ft ± 0.32 ft × 8.53 ft ± 0.32 ft) and the depth shall be 1.1 m ± 0.1 m (3.6 ft ± 0.32 ft). The hood shall exhaust into a plenum having a 0.9 m ± 0.05 m × 0.9 m ± 0.05 m (2.9 ft ± 0.16 ft × 2.9 ft ± 0.16 ft) cross section (*see Figure 3-2.1*). Other hood sizes shall be permitted, provided they produce equivalent test results. The distance between the lower edge of the hood and the weight-measuring system shall be approximately 2.4 m (7.87 ft).

3-2.2*

The exhaust duct connected to the plenum shall be 406 mm ± 3 mm (16 in. ± 0.12 in.) in diameter and shall have a circular aperture of 305 mm ± 3 mm (11.9 in. ± 0.12 in.) at its entrance.

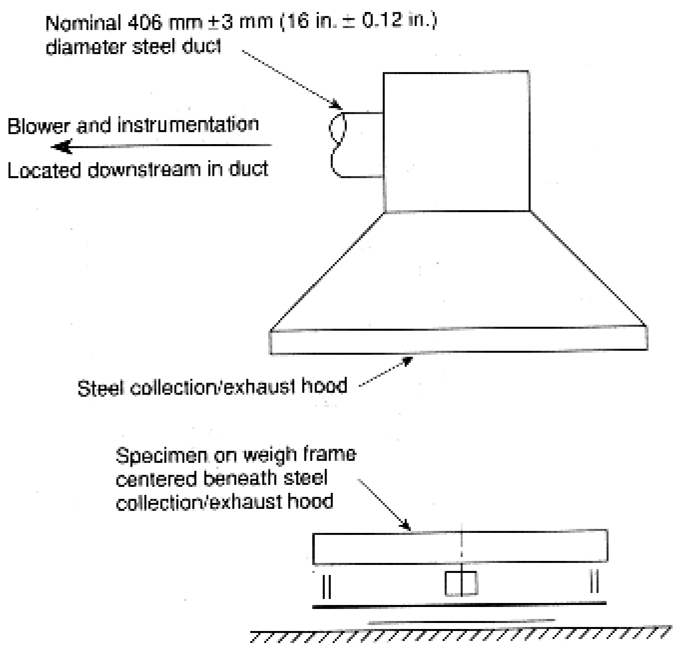

Figure 3-2.1 Collection hood and exhaust duct.

3-2.3

The exhaust system shall have sufficient exhaust capacity to collect all products of combustion developed by the burning specimen. The exhaust hood system shall be capable of being operated within a range that varies from a minimum rate of 0.47 m^3/s (16.6 ft^3/s) to a maximum rate of at least 2.4 m^3/s (84.8 ft^3/s).results.

3-2.4

An alternate exhaust system design shall be permitted to be used if it has been shown to produce equivalent

3-3 Velocity Measuring Instruments.

3-3.1

The velocity in the exhaust duct shall be determined by measuring the differential pressure in the flow path with the use of a bidirectional probe, as shown in Figure 3-3.1, connected to an electronic pressure gauge or an equivalent measuring system. The probe shall consist of a stainless steel cylinder with a solid diaphragm in the center that divides it into two chambers. The probe shall measure 44 mm (1.7 in.) long and 22 mm (0.86 in.) inside diameter. The pressure taps on either side of the diaphragm shall support the probe.

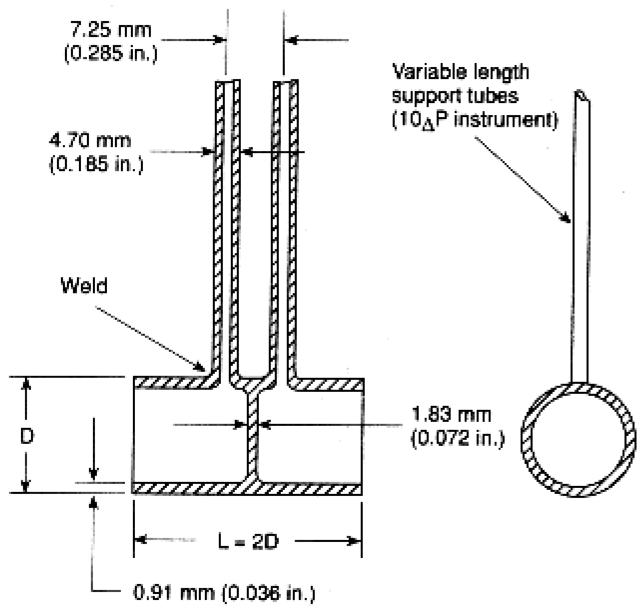

Figure 3-3.1 Bidirectional probe.

3-3.2

The axis of the probe shall be located at the centerline of the duct a minimum of 10 diameters downstream from the last turn in the duct. The taps shall be connected to a pressure transducer with a minimum resolution of 0.25 Pa (0.001 in. H_2O).

3-3.3

The temperature of the exhaust gas shall be measured upstream approximately 152 mm ± 15 mm (5.9 in. ± 0.6 in.) from the probe at the centerline of the duct with a No. 28 AWG (0.08 mm^2), Type K thermocouple with an inconel sheath having a 16-mm (0.62-in.) outside diameter and a 3-mm (0.12-in.) thickness.

3-4 Gas Sampling and Analysis Equipment.

3-4.1*

A stainless steel gas sampling tube shall be located at least 10 diameters downstream from the last turn in the duct to obtain a continuously flowing sample for determining the oxygen concentration of the exhaust gas as a function of time. A suitable filter and cold trap shall be placed in line ahead of the analyzer to remove particulates and water. The oxygen analyzer shall be of the paramagnetic type and shall be capable of measuring the oxygen concentration in the range of from 0 to 21 percent with an accuracy of ± 0.2 percent of full-scale setting. The signal from the oxygen analyzer shall attain 90 percent of the calibration value within 30 seconds after introducing a step change in composition of the gas stream flowing past the inlet to the sampling tube.

3-4.2*

The gas sampling tube shall be located and defined as in 3-4.1. The carbon monoxide analyzer shall be capable of measuring the carbon monoxide in a range of from 0 to 1.0 percent with an accuracy of ± 0.02 percent of full-scale setting. The signal from the analyzer shall attain 90 percent of the calibration value within 30 seconds after introducing a step change in composition of the gas stream flowing past the inlet to the sampling tube.

3-4.3*

The gas sampling tube shall be as located and described in 3-4.1 The carbon dioxide analyzer shall be capable of measuring the carbon dioxide concentration in a range of from 0 to 10 percent with an accuracy of ± 0.2 percent of full-scale setting. The signal from the analyzer shall attain 90 percent of the calibration value within 30 seconds after introducing a step change in composition of the gas stream flowing past the inlet to the sampling tube.

3-5 Smoke Density Measuring Instruments.

3-5.1

The smoke density measuring system shall be a white light system.

3-5.2

The lamp shall be of the incandescent filament type and shall operate at a color temperature of 2900 K ± 100 K. The lamp shall be supplied with stabilized direct current, stable within ± 0.2 percent, including temperature and short-term and long-term stability.

3-5.3

The lens system shall be selected such that the lens, shall have a diameter, d, chosen with regard to the focal length, f, so that $d/f \leq 0.04$.

3-5.4

The aperture shall be placed in the focus of the lens.

3-5.5

The detector shall have a spectrally distributed response according to the CIE photopic curve. The detector shall be linear within 5 percent for an output range of at least 3.5 decades. This linearity shall be checked periodically with calibrated optical filters that shall cover the entire range of the instrument.

3-5.6

The system shall be mounted on a horizontal section of duct at a point where it will be preceded by a straight run of duct [at least 12 diameters or 5.2 m (17 ft)] and with the light beam directed upward along the vertical axis of the duct. A photoelectric cell whose output is directly proportional to the amount of light received shall be mounted over the light source and connected to a recording device having an accuracy within ± 1 percent of full scale for indicating changes in the attenuation of incident light resulting from the passage of smoke, particulate, and other effluents. The distance between the light source lens and the photocell lens shall be 914 mm ± 102 mm (35.6 in. ± 3.9 in.). The cylindrical light beam shall pass through 76-mm ± 3 mm (2.9-in. ± 0.12 in.) diameter openings at the top and bottom of the duct, with the resultant light beam centered on the photocell.

3-5.7

An alternate smoke density measuring system shall be permitted to be used if it has been shown to produce equivalent results.

3-6 Weighing Platform.

3-6.1

Mass loss rate of the burning specimen shall be measured during the test by means of a weight-measuring device.

3-6.2

A weighing platform shall be used to support the test specimen during the test. A reinforced inorganic board having the dimensions 1.2 m ± 0.1 m × 2.4 m ± 0.1 m (3.9 ft ± 0.32 ft × 7.87 ft ± 0.32 ft) shall be located on top of the weighing platform. The weighing platform perimeter shall have a rim extending 0.1 m ± 10 mm (0.32 ft ± 0.39 ft) above the top surface of the inorganic board to prevent spillage of test material.

3-6.3

The weight-measuring device shall be capable of measuring the specimen mass up to at least 90 kg (198.5 lb) with an accuracy of at least ± 150 g (0.33 lb). It shall be installed in such a way that the heat from the burning specimen and any eccentricity of the load do not affect the accuracy. Care shall be taken to avoid range shifts during measurements. All parts of the weight-measuring device shall be located below the top level of the slab.

3-6.4

The weighing platform shall support the base of the furniture specimen 127 mm ± 76 mm (5 in. ± 3 in.) above the floor.

3-6.5

The weighing platform shall be located beneath the collection hood at its geometric center.

3-7 Data Acquisition.

A digital data acquisition system shall be used to collect and record oxygen, carbon monoxide, and carbon dioxide analyzer measurements; pressure gauge measurements; temperatures; smoke measurements; and weight-measuring device measurements. The speed and capacity of the data system shall be sufficient to collect the data every 5 seconds.

3-8 Photographic and Video Equipment.

A camera and video equipment shall be used to record the test specimen performance throughout each test.

Chapter 4 Calibration

4-1 Calibration of Equipment.

4-1.1

The equipment and instrumentation shall be calibrated.

4-1.2

The heat release instrumentation shall be calibrated by burning propane. A gas burner shall be constructed with a 100-mm ± 6 mm (3.9-in. ± 0.23 in.) layer of Ottawa sand to provide the horizontal surface through which the gas is supplied. The gas supply to the burner shall be of commercial-grade propane and shall have a net heat of combustion of 46.4 MJ/kg ± 0.5 MJ/kg (20,000 Btu/lb ± 200 Btu/lb). The flow rate of propane shall be metered and kept constant throughout the calibration test. A heat release value of 160 kW shall be used for calibration. The test shall be conducted for a period of 10 minutes.

4-1.3

A calibration constant, C, shall be obtained as described in Chapter 6. A value for C differing more than 10 percent from the theoretical value shall not be permitted and the equipment shall be checked. For the exhaust duct configuration described in Section 3-2 and the velocity probe described in Section 3-3, C shall have a theoretical value of 2.8.

4-2 Daily Calibration.

4-2.1

Prior to the start of each day of testing, the equipment calibrations described in 4-2.2 through 4-2.7 shall be performed.

4-2.2

The oxygen analyzer shall be zeroed and spanned. The analyzer shall be zeroed by introducing 100 percent nitrogen gas to the instrument at the same pressure and flow rate as set for the test specimen combustion gases. The analyzer shall be spanned by introducing ambient duct air via the sample probe and adjusting the span to 20.95 percent oxygen. The spanning and zeroing process shall continue until adjustment-free accuracy is obtained.

4-2.3

Following zeroing and spanning, linearity of the oxygen analyzer response curve shall be verified by introducing bottled gas of a known oxygen concentration to the analyzer. The delay time of the analyzer shall be checked by introducing ambient duct air to the analyzer and noting the time at which the analyzer readings reach 90 percent of the final reading.

4-2.4

The CO analyzer and CO_2 analyzer shall be zeroed and spanned in the same manner as the oxygen analyzer. The analyzer shall be zeroed by introducing 100 percent nitrogen gas to the instrument at the same pressure and flow rate as for the test specimen combustion gases. The analyzer shall be spanned by feeding each analyzer with bottled gas containing the selected concentration of span gas and adjusting for the response range of each analyzer.

4-2.5

The delay time of each analyzer shall be determined. The delay time shall be measured by introducing either a calibration span gas (for CO and CO_2) or a zero gas (for O_2) at the sample line just outside the duct and noting the time at which the analyzer readings reach 90 percent of the final reading.

4-2.6

The weight-measuring device shall be calibrated with known weights suitable for the capacity of the equipment and the specimen being tested.

4-2.7

Linearity of the smoke density measuring system shall be verified by interrupting the light beam with multiple calibrated neutral density filters to cover the range of the recording instrument. Transmittance values measured by the photometer, using neutral density filters, shall be within ± 3 percent of the calibrated value for each filter.

Chapter 5 Test Procedure

5-1 Testing Procedure.

5-1.1

The test specimen and weighing platform shall be located as shown in Figure 3-2.1.

5-1.2

The initial exhaust hood flow rate shall be set at a minimum of 0.47 m^3/s (16.6 ft^3/s).

5-1.3

The burner shall be positioned 25 mm ± 3 mm (0.97 in. ± 0.12 in.) from the side and 51 mm ± 3 mm (2 in. ± 0.12 in.) below the item with the center of the burner at the centerline of the test specimen.

5-1.4

Data acquisition shall begin in order to monitor test instrumentation.

5-1.5

The gas flow rate to the burner shall be set at a volume flow rate of 13 L/min ± 0.5 L/min (3.4 gal/min ± 0.13 gal/min). Care shall be taken to allow free flow of propane through the burner holes. Periodic cleaning of soot deposits and blowing pressurized air through the tube shall be required.

5-1.6

The burner shall be ignited.

5-1.7

The exhaust hood flow rate shall be increased as required to collect all products of combustion from the test specimen.

5-1.8

The burner shall be removed from the test specimen after an exposure of 80 seconds ± 2 seconds.

5-1.9

The burner shall be turned off.

5-1.10

Combustion shall be allowed to continue until one or more of the following conditions are reached:

(a) All flaming combustion has ceased;

(b) Thirty minutes have elapsed from the time the burner was ignited.

Chapter 6 Calculations

6-1 Method of Calculation.

The symbols used in this chapter are defined in Appendix B. The equations in this chapter assume that only oxygen is measured. Appropriate equations that shall be used for those cases where additional gas analysis equipment (CO_2, CO, water vapor) is used are provided in Appendix B. If a CO_2 analyzer is used and CO_2 is not removed from the oxygen sampling lines, then the appropriate equations in Appendix B shall be used.

6-2 Calibration Constant Using Propane.

The calibration constant shall be obtained from the following equation:

$$C = \frac{160}{1.10(12.77 \times 10^3)} \times \sqrt{\frac{Tc}{\Delta h}} \times \left[\frac{1.084 - 1.4X_{O_2}}{X^{\circ}_{O_2} - X_{O_2}}\right]$$

Where 160 corresponds to 160 kW propane supplied, 12.77×10^3 equals $\Delta h_c/r_o$ for propane, and 1.10 is the ratio of oxygen to air molecular weight.

6-3 Heat Release for Test Specimens.

6-3.1

Prior to performing additional calculations, the oxygen analyzer time shift shall be determined by the following equation:

$$X_{O_2}(t) = X'_{O_2}(t - t_d)$$

6-3.2

The heat release rate then shall be determined by the following equation:

$$\dot{Q}(t) = \frac{\Delta h_c}{r_O} \times 1.10C \sqrt{\frac{\Delta P}{Tc}} \left[\frac{X^{\circ}_{O_2} - X_{O_2}(t)}{1.084 - 1.4X_{O_2}(t)}\right]$$

6-3.3

The value of $(\Delta h_c/r_o)$ for the test specimen shall be set equal to 13.1×10^3 kJ/kg unless a more accurate value is known for the test specimen.

6-3.4

The total heat released during the first 10 minutes of the test shall be determined by the following equation:

$$q''_i = \sum_{i=O}^{10} q''_i(t)\Delta t$$

6-4 Smoke Obscuration.

6-4.1

The extinction coefficient (k) of smoke shall be determined by the following equation:

$$k = \frac{1}{L} \ln \left(\frac{I_o}{I}\right)$$

where:

L = path length in meters.

6-4.2

The smoke release rate (SRR) shall be calculated using the optical density per linear path length and the volumetric flow rate in the duct. The SRR shall be determined by the following equation:

SRR = km

Where:

SRR equals the smoke release rate in m^2/s; k equals the extinction coefficient; and M equals the volumetric flow rate (in m^3/s) referred to 298 K.

Chapter 7 Report of Results

7-1 Report.

7-1.1

The following shall be reported for each test specimen:

(a) Test specimen identification or number

(b) Manufacturer or submitter

(c) Date of test

(d) Operator

(e) Composition or generic identification

(f) Details of preparation

(g) Number of replicate specimens tested

(h) Time to termination of test (seconds)

(i) Maximum mass (kg) loss

(j) Maximum rate of heat release (kW)

(k) Total heat release (MJ) in the first 10 minutes of the test

(l) Maximum smoke release rate (m^2/s)

(m) Maximum carbon monoxide concentration (ppm)

(n) Maximum carbon dioxide concentration (ppm).

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 ASTM Publication.

American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM E1537-93, *Standard Method for Fire Testing of Real Scale Upholstered Furniture Items*.

8-1.2 State of California Publication.

State of California, Department of Consumer Affairs, Bureau of Home Furnishings and Thermal Insulation.

Technical Bulletin 133, *Flammability Test Procedure for Seating Furniture for Use in Public Occupancies*, January 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-1-1.2

This procedure is based on Technical Bulletin (TB) 129, *Flammability Test Procedure for Mattresses for Use in Public Buildings*. This test may not predict changes in performance due to aging or contamination during normal use.

A-1-1.4

For further information on other test environments, see the following publications:

"Furniture Flammability: An Investigation of the California Technical Bulletin 133 Test — Part 1: Measuring the Hazards of Furniture Fires," by J. Quintiere.

"Furniture Flammability: An Investigation of the California Technical Bulletin 133 Test — Part 2: Characterization of Ignition Source and Comparable Gas Burner," by T. Ohlemiller and K. Villa.

"Furniture Flammability: An Investigation of the California Technical Bulletin 133 Test — Part 3: Full-Scale Chair Burns," by W.J. Parker.

A-1-2.3

This procedure is not intended to be used for the evaluation of residential mattresses.

A-3-2.2

The locations for velocity, temperature, gas analysis, and smoke photometer shall be chosen to ensure that the products of combustion are well-mixed and not stratified at the sampling location. The general rule is for the duct to run a sufficient length (10 diameters) downstream from the last turn in the duct prior to location of instrumentation to provide for a fully developed gas flow. Mixing vanes shall be required in the duct if concentration gradients are found to exist.

A-3-4.1

One type of oxygen analyzer is a Beckman Instrument Model 755 paramagnetic-type oxygen analyzer. Other equivalent oxygen analyzers may be permitted to be used.

A-3-4.2

One type of carbon monoxide analyzer is a Horiba Instrument Model PIR-2000 analyzer. Other equivalent carbon monoxide analyzers may be permitted to be used.

A-3-4.3

One type of carbon dioxide analyzer is a Horiba Instrument Model PIR-2000 analyzer. Other equivalent carbon dioxide analyzers may be permitted to be used.

Appendix B Heat Release Calculations Using Additional Gas Analysis

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

B-1 Calculation of Heat Release with Additional Gas Analysis.

B-1.1

The equations used to calculate heat release rate in Chapter 6 assume CO_2 is removed from the gas sample in a chemical scrubber before oxygen is measured. Some laboratories are equipped to measure CO_2; in such a case, it is not necessary to remove the CO_2 from the oxygen line. The advantage is that the chemical scrubbing agent, which is costly and needs careful handling, can be avoided.

B-1.2

In this appendix, equations are provided that should be used when CO_2 is measured but *not* scrubbed out of the sampling lines. Two cases are considered. In the first case, part of the dried and filtered sample stream is diverted into infrared CO_2 and CO analyzers. In the second case, a water-vapor analyzer is also added. To avoid condensation, when measuring water-vapor concentration in the flow of combustion products, a separate sampling system with heated filters, heated sampling lines, and a heated analyzer is needed.

B-2 Symbols.

The following symbols are used in this appendix:

M_a = molecular weight of air (kg/kmol).

M_e = molecular weight of the combustion products (kg/kmol).

$\dot{m}_e$ = exhaust duct mass flow rate (kg/s).

t_d^1 = delay time of the CO_2 analyzer(s).

t_d^2 = delay time of the CO analyzer(s).

t_d^3 = delay time of the water-vapor analyzer(s).

$X_{CO2}°$ = initial CO_2 reading, mole fraction.

$X_{CO}°$ = initial CO reading, mole fraction.

$X_{H2O}°$ = initial water-vapor reading, mole fraction.

X_{O2}^a = ambient oxygen mole fraction.

X_{CO2}^1 = CO_2 reading before delay time correction, mole fraction.

X_{CO}^1 = CO reading before delay time correction, mole fraction.

X_{H2O}^1 = water-vapor reading before delay time correction, mole fraction.

X_{CO2} = CO_2 reading after delay time correction, mole fraction.

X_{CO} = CO reading after delay time correction, mole fraction.

X_{H2O} = water reading after delay time correction, mole fraction.

Ø = oxygen depletion factor.

B-3 Where CO_2 and CO Are Measured.

B-3.1

As in the case of the oxygen analyzer, measurements of CO_2 and CO should be time-shifted to take transport time in the sampling lines into account as follows:

$$X_{O_2}(t) = X_{O_2}{}^{1}(t + t_d)$$

$$X_{CO_2}(t) = X_{CO_2}{}^{1}(t + t_d{}^{1})$$

$$X_{CO}(t) = X_{CO}{}^{1}(t + t_d{}^{2})$$

The delay times, t_d^1 and t_d^2, for the CO_2 and CO analyzers, respectively, are usually different (smaller) than the delay time, t_d, for the oxygen (O_2) analyzer.

B-3.2

The exhaust duct flow is determined as follows:

$$\dot{m}_e = C\sqrt{\frac{\Delta P}{T_e}}$$

B-3.3

The rate of heat release now can be determined as follows:

$$\dot{q} = 1.10\left(\frac{\Delta h_c}{r_O}\right)X^{a}_{O_2}\left[\frac{\phi - 0.172(1-\phi)X_{CO}}{(1-\phi) + 1.084\phi}\right]\dot{m}_e$$

B-3.4

The oxygen depletion factor, Ø , is calculated as follows:

$$\phi = \frac{X^{\circ}_{O_2}(1 - X_{CO_2} - X_{CO}) - X_{O_2}(1 - X_{CO_2}{}^{\circ})}{X^{\circ}_{O_2}(1 - X_{CO_2} - X_{CO} - X_{O_2})}$$

B-3.5

The ambient mole fraction of oxygen (O_2) is determined as follows:

$$X_{O_2}^{3} = (1 - X_{H_2O}{}^{\circ})\ (X_{O_2}{}^{\circ})$$

B-3.6

The second value in the numerator of the factor in brackets in the equation in B-3.3 is a correction factor for incomplete combustion of some carbon to CO instead of CO_2. In fact, X_{CO} is usually very small, so that it can be disregarded in the equations in B-3.3 and B-3.4. The practical implication of this value is that a CO analyzer will generally not result in a noticeable increase in accuracy of heat release rate measurements. Consequently, the equations in B-3.3 and B-3.4 may be permitted to be used even if no CO analyzer is present by using the setting X_{CO} = 0.

B-4 Where Water Vapor Is also Measured.

B-4.1

In an open combustion system, such as that used in this test method, the flow rate of air entering the system cannot be measured directly but is inferred from the flow rate measured in the exhaust duct. An assumption regarding the expansion due to combustion of the fraction of the air that is fully depleted of its oxygen is necessary. This expansion depends on the composition of the fuel and the actual stoichiometry of the combustion. A suitable average value for the volumetric expansion factor is 1.084, which is the factor for propane.

B-4.2

This expansion factor value is already incorporated within the equation in 6-3.2 and the equation in B-3-3 for q. It can be assumed that the exhaust gases consist primarily of nitrogen, oxygen, CO_2, water vapor, and CO; thus, measurements of these gases can be used to determine the actual expansion. (It is assumed that the measurements of oxygen, CO_2, and CO refer to a dry gas stream, while the water-vapor measurement corresponds to total stream flow.) The mass flow rate in the exhaust duct is then more accurately determined by the following equation:

$$M_e = C\sqrt{\frac{\Delta P}{T_e}}\sqrt{\frac{M_e}{M_a}}$$

B-4.2.1 The molecular weight, M_e, of the exhaust gases is determined as follows:

$$M_e = \left[4.5 + (1 - X_{H_2O})\ (2.5 + X_{O_2} + 4X_{CO_2})\right] \times 4$$

B-4.2.2 Using 28.97 as the value for M_a, the heat release rate is determined as follows:

$$q(t) = 1.10 \left(\frac{\Delta h_c}{r_O}\right)(1 - X_{H_2O})\left[\frac{X^{\circ}_{O_2}(1-X_{O_2} - X_{CO_2}) - X_{O_2}}{1-X^{\circ}_{O_2} - X_{CO_2}}\right] M_e$$

B-4.3

The water-vapor readings used in the equation in B-4.2.2 are time-shifted in a similar way to those in the equations in B-3.1 for the other types of analyzers as follows:

$$X^{\circ}_{H_2O}(t) = X^{1}_{H_2O}(t - t^{3}_{d})$$

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 NIST Publications.

U.S. National Institute of Standards Technology, U.S. Department of Commerce, Technology Administration National Technical Information Service, Springfield, VA 22161.

NIST 4360, “Furniture Flammability: An Investigation of the California Technical Bulletin 133 Test — Part 1: Measuring the Hazards of Furniture Fires,” J. Quintiere, July 1990.

NIST 4348, “Furniture Flammability: An Investigation of the California Technical Bulletin 133 Test — Part 2: Characterization of Ignition Source and Comparable Gas Burner,” T. Ohlemiller and K. Villa, June 1990.

NIST 4375, “Furniture Flammability: An Investigation of the California Technical Bulletin 133 Test — Part 3: Full-Scale Chair Burns,” W. J. Parker, K. M. Tu, S. Nurbakhsh, and G. H. Damant, July 1990.

C-1.2 State of California Publications.

State of California Department of Consumer Affairs, Bureau of Home Furnishings and Thermal Insulation.

Technical Bulletin 129, *Flammability Test Procedure for Mattresses for Use in Public Buildings*, October 1992.

Technical Bulletin 133, *Flammability Test Procedure for Seating Furniture for Use in Public Occupancies*, January 1991.

NFPA 268

1996 Edition

Standard Test Method for Determining Ignitibility of Exterior

Wall Assemblies Using a Radiant Heat Energy Source

1996 Edition

This edition of NFPA 268, *Standard Test Method for Determining Ignitibility of Exterior Wall Assemblies Using a Radiant Heat Energy Source*, 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 268 was approved as an American National Standard on February 2, 1996.

Origin and Development of NFPA 268

The 1996 edition represents the first edition for a standard that addresses the determination of ignitibility characteristics of exterior wall assemblies. This test method incorporates a radiant heat energy source. Currently there are no standardized test methods available within the standard writing organizations, and this document will complement the fire test methods available within the NFPA standards. The results of this test can be used to measure and describe properties of materials in controlled laboratory conditions and also can be used as an element of a fire risk assessment.

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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.*

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 268

Standard Test Method for Determining Ignitibility of Exterior Wall Assemblies Using A Radiant Heat Energy Source

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 14 and Appendix C.

Chapter 1 General

1-1 Scope.

1-1.1

This fire test response standard describes a method for determining the propensity of ignition of exterior wall assemblies from exposure to 12.5 kW/m^2 (1.10 Btu/ft^2-sec) radiant heat in the presence of a pilot ignition source.

1-1.2

This test method evaluates the propensity of ignition of an exterior wall assembly where subjected to a minimum radiant heat flux of 12.5 kW/m^2 (1.10 Btu/ft^2-sec). This method determines whether ignition of an exterior wall assembly occurs when the wall is exposed to a specified radiant heat flux, in the presence of a pilot ignition source, during a 20-minute period.

1-1.3

This test method applies to exterior wall assemblies having planar, or nearly planar, external surfaces.

1-1.4

This test shall be used for code and other regulatory purposes, for specification and design purposes, and for research and development activities. (*See Section B-1*.)

1-1.5

This method shall not be used to evaluate the fire endurance of wall assemblies, nor shall it be used to evaluate the effect of fires originating within the building or within the exterior wall assemblies. This method shall not be used to evaluate surface flamespread, nor shall it be used to evaluate the influence of openings for their propensity of ignition.

1-2 Significance and Use.

1-2.1

This fire test response standard measures and describes the properties of materials, products, or assemblies in response to heat and flame under controlled laboratory conditions and shall not be used to describe or appraise the fire hazard or fire risk of materials, products, or assemblies under actual fire conditions. However, results of this test shall be permitted to be used as an element of a fire risk assessment that takes into account all factors that are pertinent to an assessment of the fire hazard of a particular end-use.

1-2.2

This fire test response standard involves hazardous materials, operations, and equipment. This standard does not address all of the safety problems associated with its applications. It is the responsibility of the user of the standard to establish appropriate safety and health practices and to determine the applicability of the regulatory limitations of the standard prior to use. Safety requirements for specific hazards are provided in Chapter 9.

1-2.3

Ignitibility is the propensity of an assembly to ignite and burn with a sustained flame for at least 5 seconds and is further qualified by considering the length of time from time of initial exposure to occurrence of the sustained flaming.

1-2.4

The values stated in SI units shall be considered the required values. The values in parentheses are for information only.

1-2.5

In this procedure, the specimens are subjected to one or more specific sets of laboratory test conditions. If different test conditions are substituted or the end-use conditions are changed, it is not possible for this test to predict all changes in the fire test response characteristics measured. Therefore, the results are valid only for the fire test exposure conditions described in this procedure.

Chapter 2 Terminology and Definitions

2-1 Terminology.

ASTM E 176, *Standard Terminology of Fire Standards*, shall be referenced for definitions of terms used in this test method.

2-2 Definitions.

The terms that follow are defined for the purposes of this standard.

Heat Flux. The incident flux imposed externally on the surface of the specimen by the radiant panel.

Heat Flux Meter. The instrument used to measure the level of radiant heat energy incident on the plane of the specimen surface as specified in this standard.

Ignitibility. The propensity of ignition as measured by the time to sustained flaming.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Sustained Flaming. The visual confirmation of the uninterrupted existence of flame on, or near, the surface of the specimen for at least 5 seconds.

Chapter 3 Summary of Method

3-1 Test Panel Orientation.

This test method utilizes a gas-fired radiant panel to apply a radiant heat flux of 12.5 kW/m^2 (1.10 Btu/ft^2-sec) to a representative sample of an exterior wall assembly while the test specimen is exposed simultaneously to a pilot ignition source. The radiant panel and the test specimen are oriented in a parallel plane configuration, with the geometric centers of the radiant panel and the test specimen concurrent along a line perpendicular to their surfaces. (*See Figure 3-1.*)

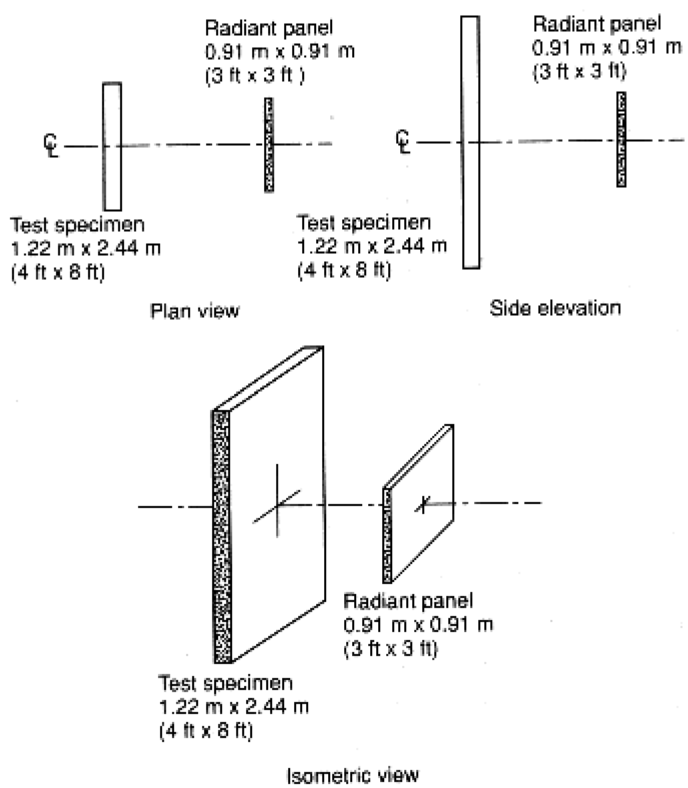

Figure 3-1 Spatial relationship between the test specimen and the radiant panel.

3-2 Test Setup.

This method utilizes a 0.91-m × 0.91-m (3-ft × 3-ft) propane-fired radiant panel and a minimum 1.22-m (4-ft) wide × 2.44-m (8-ft) high test specimen. A spark igniter mounted on the vertical centerline of the test specimen at a point 460 mm (18 in.) above its horizontal centerline and 15.9 mm ($^5/_8$ in.) from its surface serves as the pilot ignition source. A radiation shield isolates the test specimen from the radiant source prior to the start of the test, during which the radiant panel is ignited and brought to a specified steady-state temperature of 871°C ± 27.8°C (1600°F ± 50°F). The specified heat flux value is controlled by the spacing between the radiant panel and the test specimen. The test specimen is exposed to a "square-wave" radiant heat versus time exposure for 20 minutes. The method determines whether the test specimen ignites during the 20-minute test period. When sustained flaming for longer than 5 seconds is observed on, or near, the surface of the test specimen, ignition has occurred.

Chapter 4 Radiant Panel Apparatus and Specimen Mounting System

4-1* Radiant Panel.

The radiant panel shall have minimum face dimensions of 0.91 m × 0.91 m (3 ft × 3 ft) and shall consist of an array of individual burner heads, each measuring not less than 152.4 mm × 152.4 mm (6 in. × 6 in.). The individual burner heads shall consist of a porous ceramic plate covered by an Inconel mesh, or equivalent, radiant panel burners. The burner heads shall be fired by a premixed propane-air fuel mixture. The gas supply to the burner heads shall be separated into three zones. Each zone shall consist of two horizontal rows of six burner heads. The zone arrangement shall allow the surface of the 0.91 m × 0.91 m (3 ft × 3 ft) radiator to be controlled to produce a relatively uniform temperature. The temperature of each zone of burner heads shall be established by controlling the propane-air fuel mixture pressure supplied to each zone. Automatic controls shall be provided to ignite the radiant panel and to shut off the propane gas fuel flow in the event of a misfire. The burner heads and the associated propane and air plumbing and control equipment shall be mounted on a steel platform. [*See Figures 4-1(a) and (b).*]

Exception: Alternate radiant panels shall be permitted, provided the calibration criteria of 7-3(a) and (b) are met.

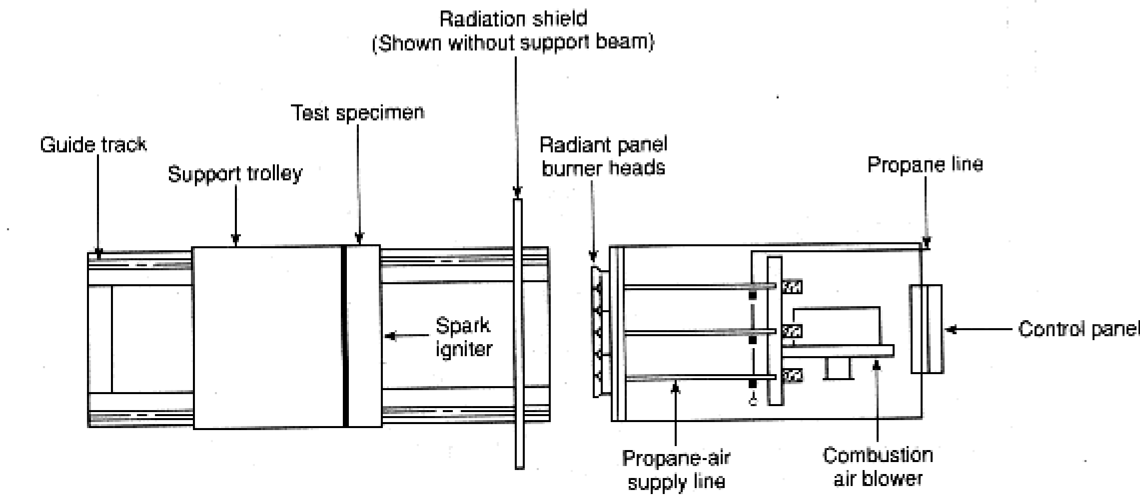

Figure 4-1(a) Plan view of the test apparatus.

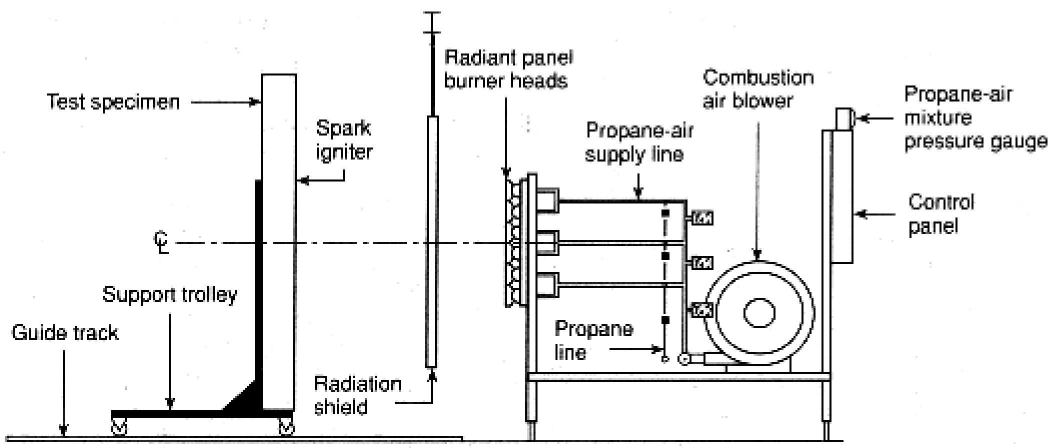

Figure 4-1(b) Side elevation of the test apparatus.

4-2 Test Specimen.

A minimum 1.22-m (4-ft) wide × 2.44-m (8-ft) high test specimen shall be mounted on a steel frame trolley assembly (*see Figure 4-2*) or equivalent support system. The mounting frame shall hold the test specimen securely in a vertical orientation and shall allow for the spacing between the test specimen and the radiant panel to be adjusted. The specimen trolley shall consist of a 1.22-m × 1.22-m (4-ft × 4-ft) steel base mounted on steel V-groove wheels or an equivalent arrangement. The V-groove wheels shall travel on angle-iron tracks that are mounted securely to the laboratory floor and that incorporate leveling adjusters. A means shall be provided to prevent the trolley from overturning.

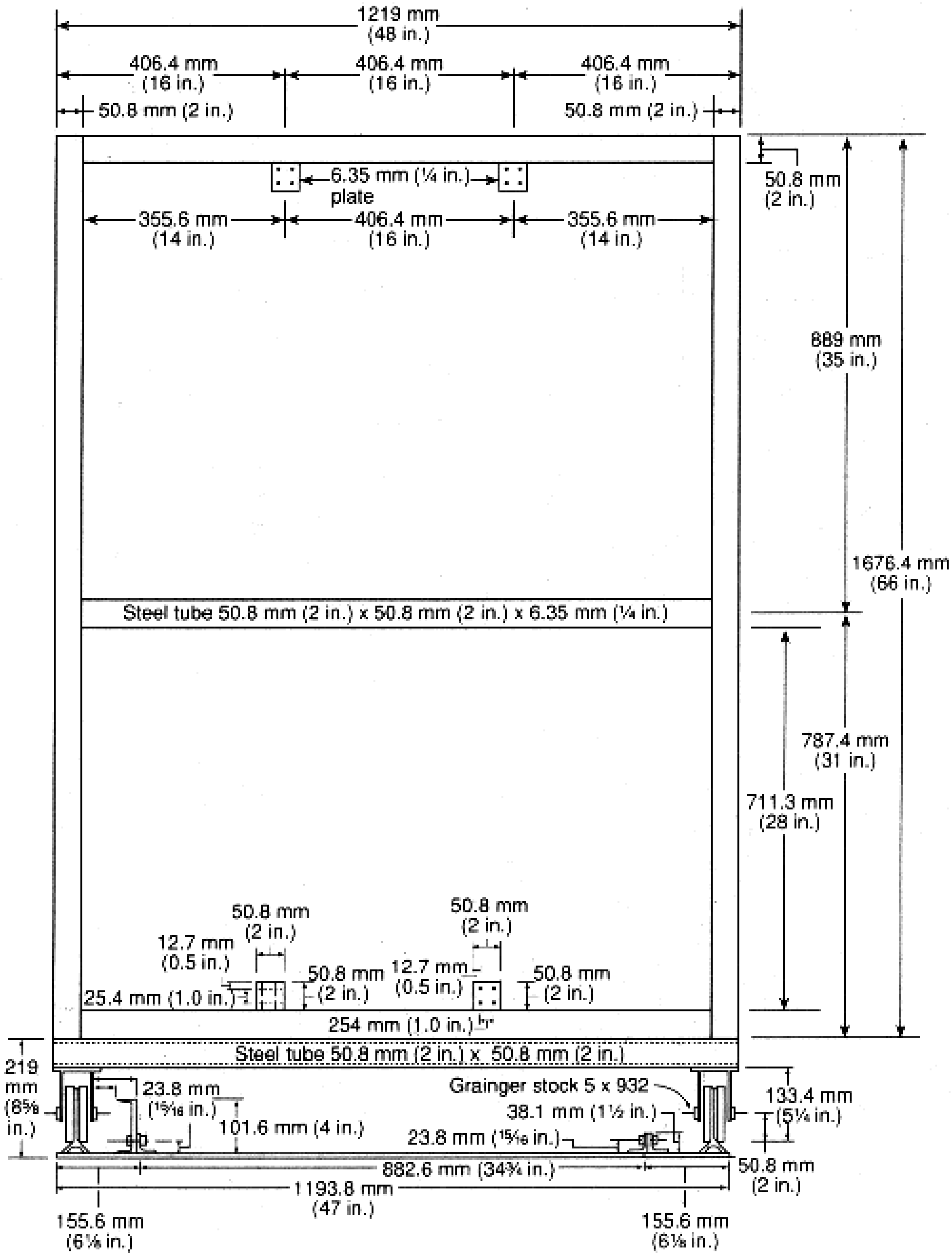

Figure 4-2 Front elevation of the specimen trolley and frame.

4-3 Radiation Shield.

4-3.1

A radiation shield shall be used to isolate the test specimen from the radiant panel both before and after the test period. The radiation shield shall consist of a water-cooled panel (*see Figure*

4-3.1 for one possible arrangement) or other construction that has been shown to have no effect on the specimen or radiator.

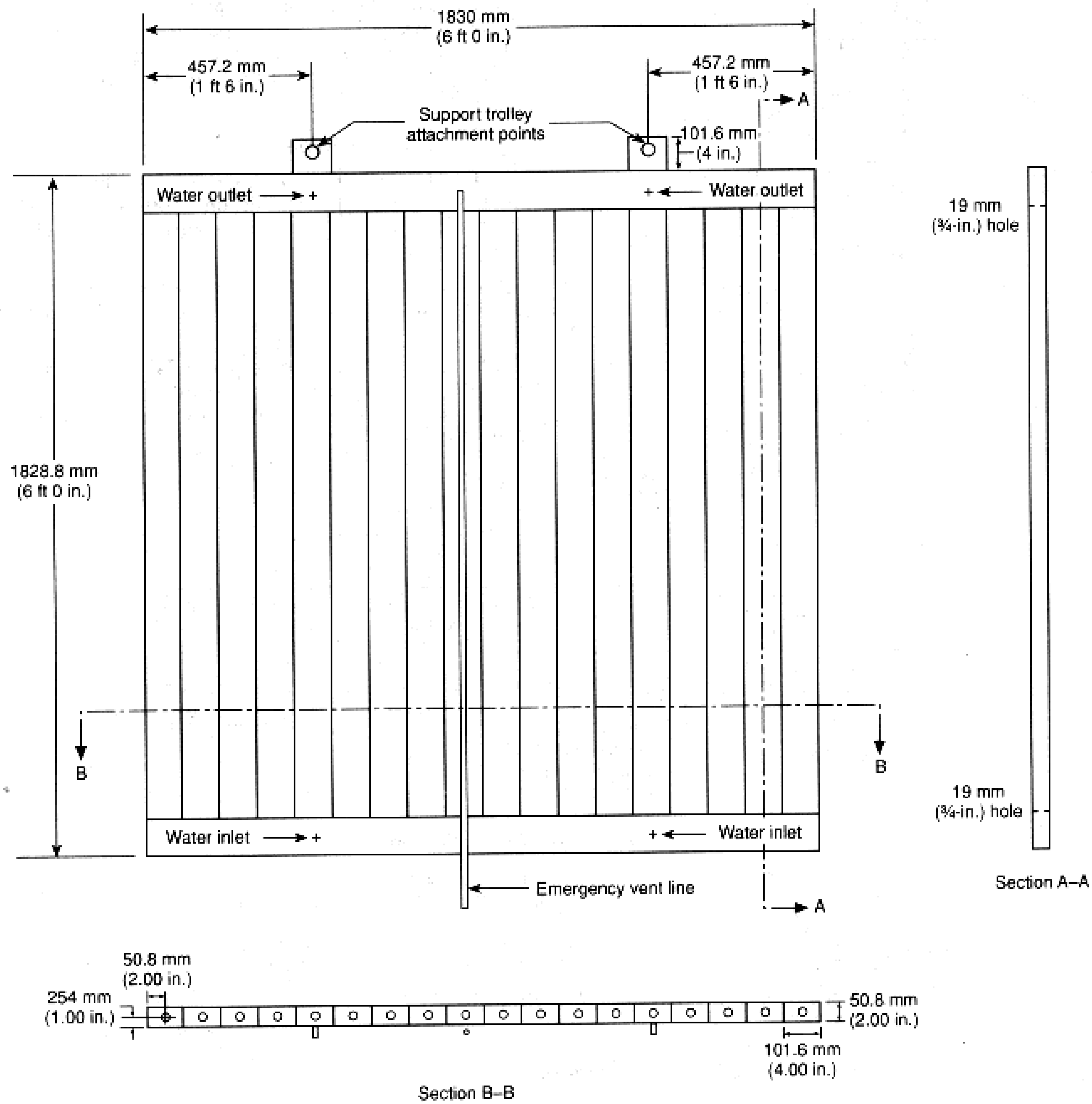

Figure 4-3.1 Radiation shield.

4-3.2

Where a water-cooled shield is used, dual waterflow connections shall supply coolant water to the bottom of the radiation shield. The coolant water shall exit along the top edge of the radiation shield. The water coolant flow shall be either a closed loop or open loop system, depending on the conditions and preference of the individual laboratory. The radiation shield shall be fitted with a pressure gauge and, in closed loop systems, a pressure relief valve. The outlet of the pressure relief valve shall be piped to an area that prevents injury to test personnel in the event of the release of coolant or steam. A thermocouple shall be mounted in the coolant discharge to monitor temperature increase in the coolant during tests. Increases in coolant temperature during tests shall not exceed 56°C (100°F).

4-3.3

The radiation shield shall be mounted so that it can be removed quickly or inserted (*see Figure 4-3.3 for one possible arrangement).* Prior to the start of the test, the radiation shield shall be inserted between the radiant panel and the test specimen to prevent exposure of the test specimen until the start of the 20-minute exposure. Once the radiant panel has attained its specified steady-state temperature, the radiation shield shall be removed in order to begin the radiant heat exposure period.

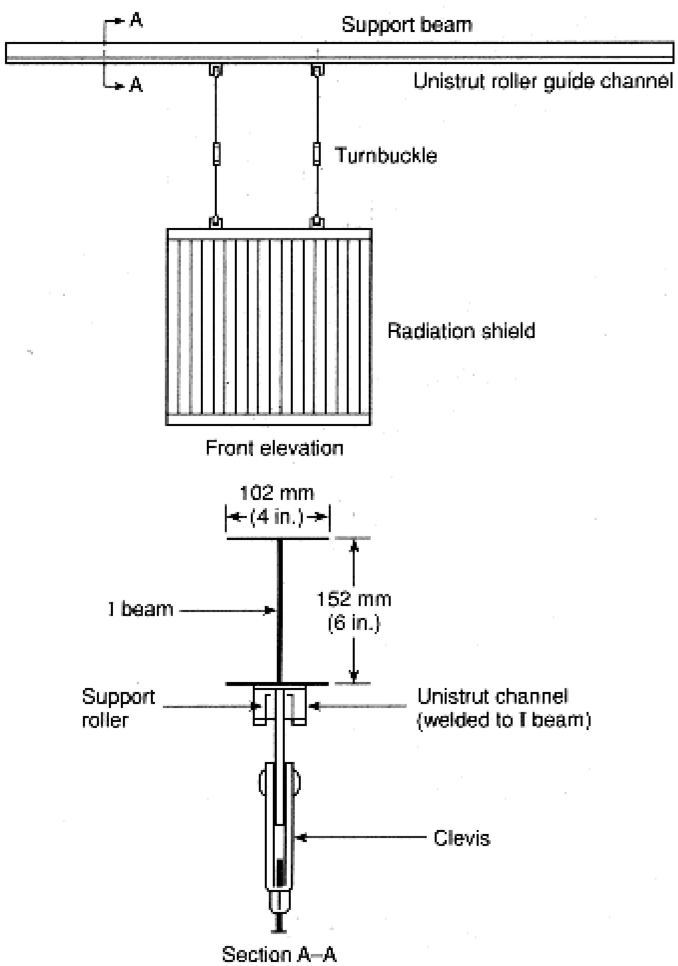

Figure 4-3.3 Radiation shield support trolley.

4-4 Spark Igniter.

The spark igniter shall consist of two electrodes connected to a nominal 6000-volt energy source. The spark igniter electrodes shall extend horizontally from the edge of the test specimen and shall be positioned so that the center of the spark gap is located along the vertical centerline of the test specimen at a location 460 mm ± 3.2 mm (18 in. ± $^1/_8$ in.) above the horizontal centerline of the test specimen [*see Figures 4-4(a) and (b).*] The center of the spark gap also shall be located 15.9 mm ± 1.6 mm ($^5/_8$ in. ± $^1/_{16}$ in.) away from the surface of the test specimen.

The spark igniter electrodes shall be designed and mounted so that the 15.9-mm ± 1.6 mm ($^5/_8$-in. ± $^1/_{16}$ in.) spacing is maintained throughout the test period by a spring tensioner or equivalent arrangement. The spacing shall be maintained even if the test specimen surface deforms. The spark igniter electrodes and support structure shall be designed so that the entire cross-sectional area of the design is contained within a 9.5-mm ($^3/_8$-in.) projected width.

The spark igniter shall be operated so that the duration of the “off” portion of the cycle is no greater than 2 seconds, and the duration of the “on” portion of the cycle is at least 5 seconds.

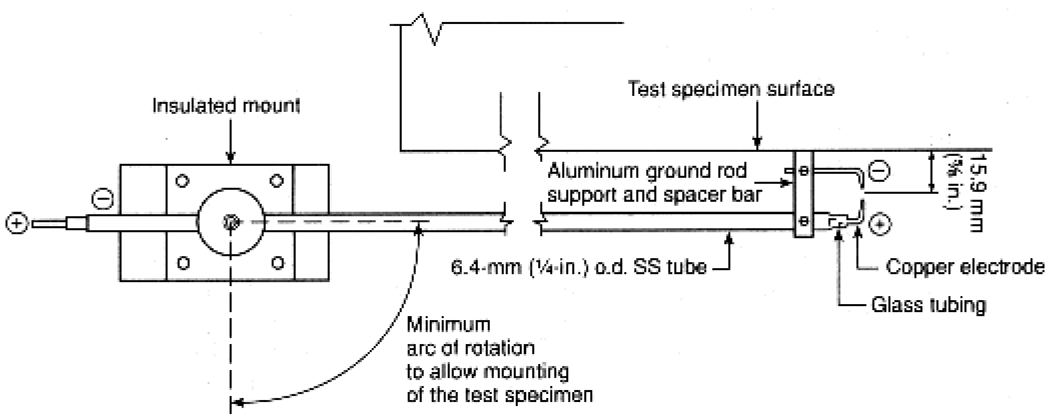

Figure 4-4(a) Plan view of the spark igniter.

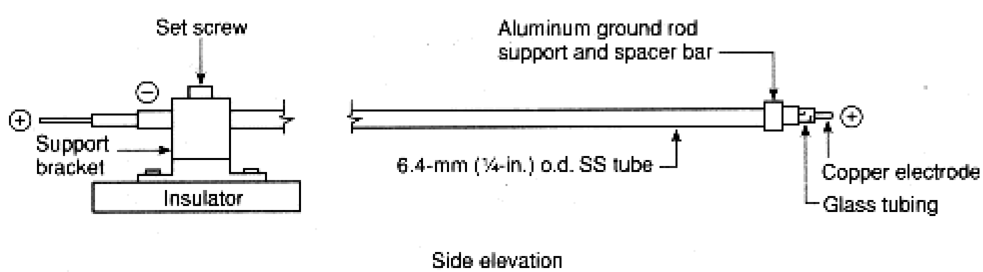

Figure 4-4(b) Side elevation of the spark igniter.

4-5 Ambient Conditions.

4-5.1

The test shall be conducted within a building vented to discharge combustion products and to intake fresh air so that oxygen-deficient air is not introduced during a test.

4-5.2

Ambient air temperature at the start of the ignitibility test and the calibration test shall be 10°C to 32°C (50°F to 90°F).

4-5.3

The radiant panel apparatus shall be located in a draft-free environment so that volatiles evolving during the course of a test rise vertically adjacent to the surface of the test specimen.

Chapter 5 Instrumentation and Documentation

5-1 Heat Flux Meter.

5-1.1 Locations During Calibration and Product Tests.

A heat flux meter for reference use shall be located within 127 mm (5 in.) of the vertical edge of the test specimen on a line along the horizontal centerline of the test specimen (*see Figure 5-1.1*). The exact distance of the heat flux meter from the vertical edge of the test specimen shall be the same as that used for the calibration test. The front face of the heat flux meter shall be in the same plane as the exposed face of the test specimen and shall be parallel to the face of the radiant panel.

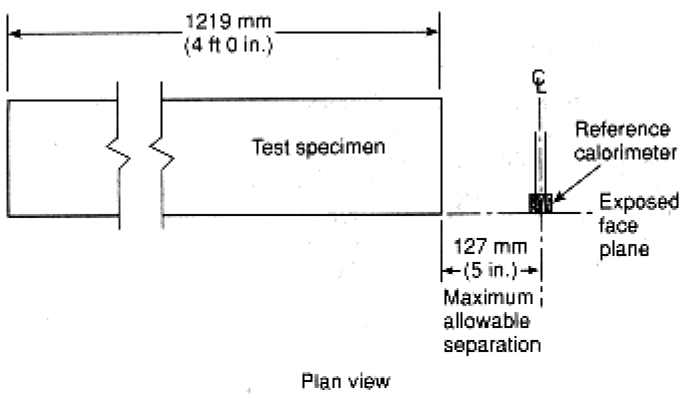

Figure 5-1.1 Reference calorimeter location.

5-1.2

Heat flux meters shall be located in the calibration panel at the five locations specified in Figure 5-1.2.

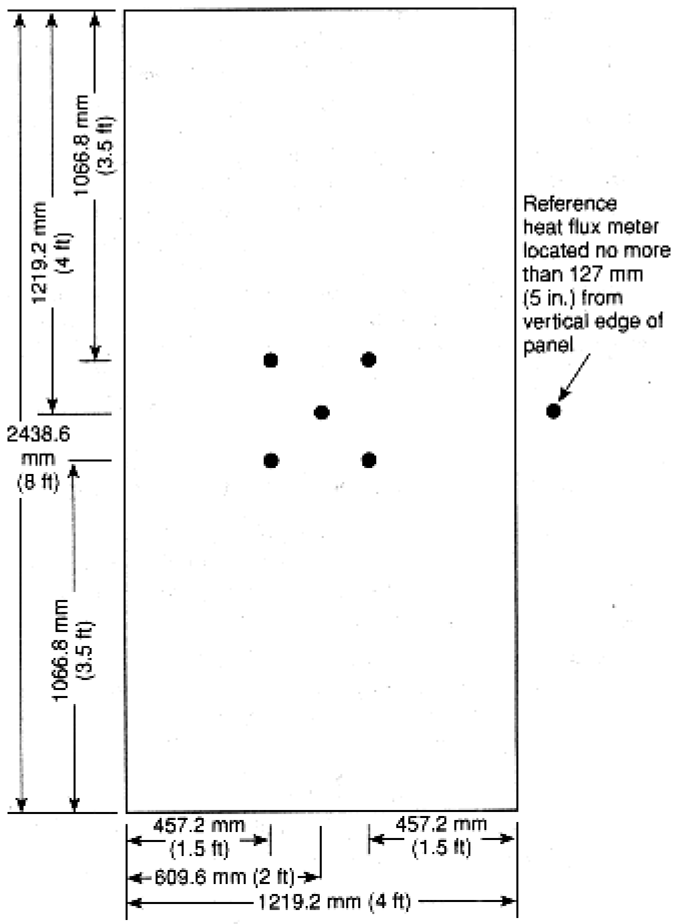

Figure 5-1.2 Calibration panel heat flux meter locations.

5-1.3 Specification.

The heat flux meters shall be of the Gardon or Schmidt-Boelter type with a flat black surface and a nominal 180-degree view angle. The heat flux meters shall be operated at the manufacturer's recommended coolant temperature, and the flow rate for the flux levels shall be measured in accordance with ASTM E 511, *Standard Test Method for Measuring Heat Flux Using a Copper-Constantan, Circular Foil, Heat-Flux Gage*. For Schmidt-Boelter heat flux meters, the zero off-set of the heat flux meters at ambient temperature, due to the temperature of the coolant water, shall be added to or subtracted from the heat flux data collected during the calibration tests and the product tests before calculations are made to determine compliance with this test method.

5-2 Thermocouples.

5-2.1 Locations.

A minimum of eight thermocouples shall be installed on the face of the radiant panel with the termination bead of each thermocouple mounted so that the bead is in contact with the burner screen at the locations specified in Figure 5-2.1.

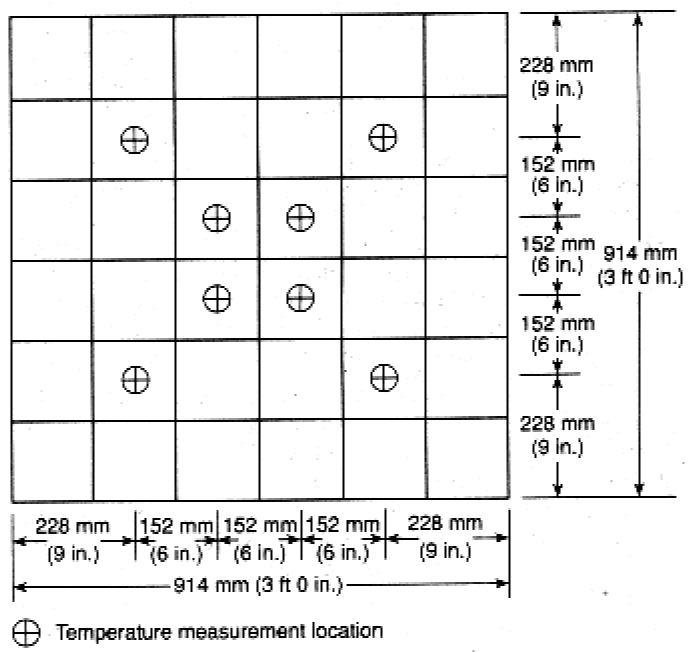

Figure 5-2.1 Temperature measurement locations on the face of the radiant panel.

5-2.2 Specifications.

The thermocouples shall be Type K, no smaller than No. 24 AWG, and no larger than No. 14 AWG. The thermocouples shall be insulated and capable of continuous operation at a temperature of at least 982°C (1800°F.)

5-3 Photographic Documentation.

Photographic or video equipment shall be used to record the performance of the test specimen throughout the test period. The exterior surface of the test specimen shall be marked clearly with a 0.3-m × 0.3-m (1-ft × 1-ft) grid using a contrasting color. A clock or other suitable timing device shall be used for photographic records. This clock or timing device shall be synchronized accurately with all other measurements, or other provision shall be made to correlate the photo record with time. Color photographs shall be taken at regular intervals for the duration of the test, or a continuous video or film recording shall be made. The camera view area shall include the entire 1.22-m × 2.44-m (4-ft × 8-ft) specimen.

Chapter 6 Test Specimen and Mounting

6-1 Specimen Detail.

Test specimens shall be a minimum of 1.22 m × 2.44 m (4 ft × 8 ft) and shall be representative of the overall wall system construction, including finish details, joints, if any, attachments, and support structure.

6-2 Mounting.

Test specimens shall be mounted securely on the trolley assembly with their 2.44-m (8-ft) dimension in a vertical orientation. The exterior face of the test specimen shall be parallel to the face of the radiant panel and the geometric center of the test specimen, and the geometric center of the radiant panel shall be concurrent with respect to a line drawn perpendicular to the faces of the test specimen and the radiant panel.

Chapter 7 Calibration of the Test Equipment

7-1* Calibration.

A successful calibration test shall have been performed prior to and within 30 days of any ignitibility test. The calibration test shall last for 20 minutes and shall use the radiant panel to expose a standard calibration panel as detailed in Figure 5-1.2. The calibration panel shall consist of two layers having a total thickness of 31.8 mm ($1^1/_4$ in.). A 12.7-mm ($^1/_2$-in.) low density, rigid thermal insulation board (fiberfrax Duraboard or equivalent) having a nominal density of 0.23 g/cm^3 to 0.28 g/cm^3 (15 lb/ft^3 to 18 lb/ft^3) shall be mounted to the test frame and covered with one layer of 19.1-mm ($^3/_4$-in.), 0.74-g/cm^3 (44-lb/ft^3) nominal density calcium silicate insulating material with a thermal conductivity at 177°C (350°F) of 0.128 W/m•K (0.89 Btu•in./h•ft^2•°F). The data specified in Section 7-1(a) through (d) shall be recorded at intervals no greater than 15 seconds as follows:

(a) The heat flux versus the time curve at each of the five specified heat flux meter locations on the calibration panel surface and the reference heat flux meter at the side-mounted locations (*see Figure 5-1.2*);

(b) The heat flux versus the time curve obtained by averaging the four heat flux meters located at the corners of the central square foot of the calibration panel;

(c) The temperatures versus the time on the surface of the radiant panel at the specified locations (*see Figure 5-2.1*);

(d) The average of the temperatures on the surface of the radiant panel at each of the specified locations.

7-2 Spacing.

The spacing between the exposed face of the calibration panel and the face of the radiant panel shall be recorded.

7-3 Validation.

The calibration test shall be considered valid, provided the values specified in Section 7-3(a) through (c) are as follows:

(a) The heat flux obtained by averaging the four heat flux meters located at the corners of the central square foot of the calibration panel shall be 12.5 kW/m^2 ± 5 percent (1.10 Btu/ft^2-sec ± 5 percent).

(b) The heat flux at the center of the calibration panel shall not exceed 15/kW/m^2 (1.32

Btu/ft^2-sec) or shall not be less than 12.5 kW/m^2 (1.10 Btu/ft^2-sec).

(c) The average surface temperature of the radiant panel shall be 871°C ± 27.8°C (1600°F ± 50°F) for each thermocouple.

Chapter 8 Test Specimen Conditioning

8-1 Conditioning.

Specimens shall be conditioned to a constant weight at 21.1°C ± 5.6°C (70°F ± 10°F) and a relative humidity of 50 percent ± 10 percent. The constant weight shall be considered to have been achieved where less than a 0.1 percent change in the measured weight of the test specimen undergoing conditioning is recorded for each of three successive measurements taken three days apart, prior to testing.

Chapter 9 Safety Precautions

9-1 Gas Hazard.

The possibility of a gas-air fuel explosion in the test apparatus shall be recognized. Suitable safeguards consistent with sound engineering practice shall be installed in the panel fuel supply system. These safeguards shall include one or more of the following, as appropriate:

(a) A gas feed cutoff that activates when the air supply fails;

(b) A fire sensor directed at the panel surface that stops fuel flow when the panel flame goes out;

(c) A commercial gas water heater or gas-fired furnace pilot burner control thermostatic shutoff that activates when the gas supply fails, or other suitable and approved device;

(d) A manual reset for any safeguard system used.

9-2 High Temperature and Pressure.

The possibility of excess pressure and high temperatures involving the fluid (water) of the heat exchanger used as a radiation shield (*see Section 4-3*) shall be recognized. Pressure relief valves piped to a safe location shall be provided. The design and operation of the radiation shield shall be consistent with sound engineering practice.

9-3 Products of Combustion.

In view of the potential hazard from products of combustion, other laboratory equipment shall be protected from smoke and gas. Laboratory operators shall be instructed to minimize exposure to combustion products by following sound safety practice (e.g., wearing appropriate protective clothing, using insulated gloves).

Chapter 10 Test Procedure

10-1 Conditioning.

The specimen shall be tested within 1 hour from the time the specimen is removed from the conditioning room.

10-2 Specimen and Test Equipment.

Prior to the start of the test, the status of the following items shall be verified:

(a) The test specimen shall be mounted securely to the trolley assembly and properly oriented with respect to the radiant panel.

(b) The trolley assembly shall be moved to the proper location to provide the required separation distance between the face of the test specimen and the face of the radiant panel, as determined from the most recent calibration test.

(c) The side-mounted reference heat flux meter shall be mounted in its proper orientation and shall be operated at the manufacturer's recommended coolant temperature and flow rate for the flux levels shall be measured in accordance with ASTM E 511, *Standard Test Method for Measuring Heat Flux Using a Copper-Constantan, Circular Foil, Heat-Flux Gage*. The coolant temperature shall be set high enough to prevent condensation on the sensor prior to the start of the test.

(d) The spark igniter shall be in place and operational.

(e) The radiation shield shall be in place and shall be operated at the proper waterflow rate.

(f) The propane gas supply to the radiant panel shall be of sufficient quantity for the test duration and shall be connected properly.

10-3 Radiant Panel Preheat.

Ten minutes prior to the start of the test period, the radiant panel shall be ignited. During the 10-minute warm-up period, the radiant panel shall function properly, and its average surface temperature shall be 871°C ± 27.8°C (1600°F ± 50°F). Data shall be recorded for the surface temperature of the radiant panel and the reference heat flux meter beginning 1 minute prior to the start of the test and shall be continued until the end of the test period. Thirty seconds prior to the test, the spark igniter shall be turned on and videotaping or photographing of the test assembly shall commence and continue for the test period.

10-4 Specimen Exposure.

At time zero, the radiation shield shall be removed and the radiant heat exposure of the test specimen shall begin. The test shall be continued for 20 minutes unless sustained flaming (ignition) of the test specimen occurs. If sustained flaming (ignition) of the test specimen occurs, the test shall be terminated by inserting the radiation shield between the radiant panel and the test specimen, turning off the spark igniter, extinguishing the test specimen, and interrupting the flow of gas to the radiant panel. If the specimen does not ignite, the test shall be terminated after 20 minutes by inserting the radiant shield between the radiant panel and the test specimen, turning off the spark igniter, and interrupting the flow of gas to the radiant panel.

10-5 Heat Flux Variation.

During a test, if the heat flux measured by the reference heat flux meter varies more than ± 2.5 percent from the average value recorded during the most recent calibration test, the results shall be invalid.

Chapter 11 Report

11-1 Information.

The report shall include the information specified in Section 11-1(a) through (k) as follows:

(a) The name, thickness, density, and size of all materials used in the wall construction, along with any other identifying characteristics or labels that are significant in order to identify the construction completely;

(b) The construction of the full wall assembly, including finish details, joints, if any, attachments, support structure, and any other details necessary to fully describe the test assembly;

(c) A description of the material conditioning;

(d) The relative humidity and temperature of the test building prior to and during both the test and the most recent calibration test;

(e) The time histories of the eight individual thermocouples mounted on the surface of the radiant panel and the average of the eight thermocouples;

(f) The time history of the reference heat flux meter;

(g) The distance from the edge of the test specimen to the centerline of the side-mounted reference heat flux meter during both the test and the most recent calibration test;

(h) The separation distance between the exposed face of the test specimen and the face of the radiant panel both in the calibration test and the product test;

(i) A transcript of the visual observations recorded during the test;

(j) A statement regarding flaming or ignition of the specimen, or both, that includes the following:

1. The time to sustained flaming, if any;
2. Observations and the time of occurrence of any transient flaming on or near the surface of the specimen; and
3. If appropriate, a statement indicating that no ignition (sustained flaming) occurred during the 20-minute test period.

(k) The average heat flux value recorded at the reference heat flux meter during both the test and the most recent calibration test.

Chapter 12 Precision and Bias

12-1* Applicability.

This standard does not address either the precision or bias of this test method.

Chapter 13 Calibration

13-1 Heat Flux Meters.

13-1.1*

Heat flux meters shall be calibrated at least annually by a method that is traceable to NIST.

13-1.2

Each laboratory shall be permitted to use a dedicated calibrated reference heat flux meter for the calibration of heat flux meters.

Chapter 14 Referenced Publications

14-1

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.

14-1.1 ASTM Publications.

American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM E 176, *Standard Terminology of Fire Standards*, 1993.

ASTM E 511, *Standard Test Method for Measuring Heat Flux Using a Copper-Constantan, Circular Foil, Heat-Flux Gage*, 1989.

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-4-1

Eclipse Infra-Glo or equivalent radiant panel burners manufactured by Eclipse Combustion, Rockford, IL, are considered to be satisfactory.

A-7-1

Fiberflax Duraboard or equivalent can be considered acceptable for low density rigid thermal insulation board.

A-12-1

Due to the fact that results are not being expressed numerically, a precision and bias statement is not applicable.

A-13-1.1

For additional information, see ASTM E 511, *Standard Test Method for Measuring Heat Flux Using a Copper-Constantan Circular Foil, Heat Flux Gage.*

Appendix B Commentary on Radiant Ignition Test

This Appendix is not a part of the requirements of this NFPA document but is included for

informational purposes only.

B-1 Introduction.

B-1.1

Historically, the exterior walls of buildings of large area or multistory buildings have been constructed using noncombustible materials. In recent years, the model building codes of the United States have been revised to recognize the use of limited quantities of combustible materials in the exterior walls of buildings traditionally required to use noncombustible materials. The use of combustible materials in exterior walls has raised concerns regarding the possibility of fire spreading from building to building by radiant heat transfer and ignition of the exterior facades.

B-1.2

Model codes contain fire resistance ratings and opening limitations for the exterior walls of buildings, based upon the concept of limiting radiant heat transfer to adjacent buildings. The commonly accepted threshold for piloted ignition of wood is 12.5 kW/m^2 (1.10 Btu/ft^2-sec). The exterior walls of a building should be designed to limit the radiant heat transfer to adjacent structures to 12.5 kW/m^2 (1.10 Btu/ft^2-sec) or less. The basis of the concept is that radiant heat transfer should be limited to values that do not ignite combustible architectural trim, veneer, or exterior facades on adjacent buildings.

B-2 U.S. Model Building Codes.

The BOCA *National Building Code* and the SBCCI *Standard Building Code* regulate building facades based on ignitibility characteristics. Exterior facades are regulated as a function of the distance to the property line and on the basis of the radiant heat flux necessary to cause ignition of the facade under “piloted” conditions.

Both the *Standard Building Code* and the *National Building Code* provide summarized descriptions for conducting ignitibility evaluations for exterior wall assemblies. However, no standardized test method for the determination of the ignitibility characteristics of exterior building facades under radiant heat exposure currently exists within the model building codes or ASTM.

B-3 Ignitibility Research.

B-3.1

A research project, sponsored by the Exterior Insulation Manufacturers Association, was conducted to develop a laboratory-scale, radiant heat ignitibility test procedure. The research program consisted of two phases. In the first phase, large-scale tests were run at the Southwest Research Institute to develop a database to be used to judge the reliability of data from laboratory-scale tests of similar specimens.

Large-scale tests used 2.44-m × 3.66-m (8-ft × 12-ft) exterior wall panels that were exposed to radiant heat from a 1.83-m × 2.44-m (6-ft × 8-ft) radiant panel.[1] The radiator and product sizes are believed to be adequate to predict product behavior in actual fires. However, large-scale testing can be needlessly expensive if laboratory-scale or bench-scale tests are shown to be capable of producing data that correlate with large-scale testing.

Specimens similar to those tested in the large-scale apparatus were tested in a laboratory-scale procedure at the University of California at Richmond Field Test Station by Fisher Research and Development, Inc.[2] Specimens for the laboratory-scale tests measured 1.22 m × 2.44 m (4 ft × 8 ft) and were exposed to a 0.91-m × 0.91-m (3-ft × 3-ft) gas-fired radiant panel. To achieve an exposure of 12.5 kW/m^2 (1.10 Btu/ft^2-sec), the specimen was separated from the radiant panel by a distance of 1.08 m to 1.10 m (43 in. to 44 in.). The data from the laboratory-scale tests and the large-scale tests are provided in Table B-3.1. The laboratory-scale test procedure developed by Fisher Research and Development, Inc., has been used as the basis for the NFPA 268 standard.

Table B-3.1 Summary of the Radiant Heat Exposure Test Results

Description of the Wall Construction	Exposure Heat Flux (kW/m^2)	Time to Ignition (sec) Cone Calorimeter	Lab Scale	Full Scale
EIFS (thin coat, mineral wool core)	12.5	No	322	No
EIFS (thin coat, mineral wool core)	20	199	150	163
EIFS (thin coat, 2 in. expanded P.S.)	12.5	No	No	No
EIFS (thin coat, 2 in. expanded P.S.)	20	140	134	139
EIFS (thin coat, 2 in. expanded P.S.)	12.5	No test	No	No
EIFS (thin coat, 2 in. expanded P.S.)	12.5	No test	No	270
EIFS (thin coat, 2 in. expanded P.S.)	20	No test	117	135
EIFS (thin coat, 2 in. expanded P.S.)	12.5	No	235	280
EIFS (thin coat, 2 in. expanded P.S.)	20	218	83	85
EIFS (thin coat, 1 in. expanded P.S.)	12.5	No	No	No
EIFS (thin coat, 1 in. expanded P.S.)	20	209	185	140
EIFS (thin coat, 1 in. expanded P.S.)	12.5	No	No	No
EIFS (thin coat, 1 in. expanded P.S.)	20	186	130	116
EIFS (thick coat, 2 in. extruded P.S.)	12.5	No	No	No
EIFS (thick coat, 2 in. extruded P.S.)	20	No	No	771
EIFS (thick coat, 2 in. extruded P.S.)	12.5	No	No	No
EIFS (thick coat, 2 in. extruded P.S.)	20	No	Malfunc.	570
EIFS (thin coat, 4 in. expanded P.S.)	12.5	No	250	No
EIFS (thin coat, 4 in. expanded P.S.)	20	158	89	86
EIFS (thin coat, 1 in. isocyanurate)	12.5	355	200	222
EIFS (thin coat, 1 in. isocyanurate)	20	138	Ramped	105

EIFS (thin coat, no insulation)	12.5	No	No	No
EIFS (thin coat, no insulation)	20	137	80	99
$^{5}/_{8}$-in. × 4-in. thick exterior gypsum board	12.5	No	No	No
$^{5}/_{8}$-in. × 4-in. thick exterior gypsum board	20	No test	No test	1336
$^{5}/_{8}$-in. × 4-in. thick T1-11 plywood	12.5	No	1100	819
$^{5}/_{8}$-in. × 4-in. thick T1-11 plywood	20	197	333	191

For SI units: 1 in. = 25.4 mm; 1 kW/m^2 = 5.28 Btu/ft^2-sec

B-3.2

Table B-3.1 shows that the performance of exterior wall systems tested in accordance with the NFPA 268 standard correlates well with full-scale test results. The 0.91-m × 0.91-m (3-ft × 3-ft) radiant panel and 1.22-m × 2.44-m (4-ft × 8-ft) specimen are sufficient to reproduce full-scale behavior.

B-3.3

The NFPA 268 standard uses a conservative approach by evaluating the ignitibility of specimens under "piloted" conditions. A spark igniter is located at the upper boundary of the specimen area that is subjected to the specified radiant heat exposure. The spark is located in the flow of volatiles that travel up the face of the specimen in the region where the greatest concentration of volatiles has been observed.

B-3.4

This method prescribes the testing of full assemblies. Tests of individual wall components might not be indicative of the behavior of the final assembly.

B-3.5

Use of a bench-scale apparatus might not produce results that correlate with the full-scale behavior of wall assemblies because of "scale effects."[3] For example, many insulated exterior wall systems use expanded polystyrene (thermoplastic) foam insulation. Thermoplastic insulation can shrink away from the fire exposure, thereby changing test geometry and exposure conditions. Changes in exposure conditions can be magnified in bench-scale tests, as compared to full-scale tests. Furthermore, there could be a minimum test specimen area (larger than bench scale) that needs to be exposed in order for some specimens to produce sufficient volatiles to reach a flammable mixture with air.

B-3.6

This test method carefully prescribes radiant panel size and operating conditions. Radiant panel specifications are set to standardize the "flux map" on the face of test specimens. This method could be used for regulatory purposes, and, consequently, it is important that exposure conditions from apparatus to apparatus be standardized. Significantly changing the size or shape of the radiant panel, for example, results in a different flux profile over the face of the test specimen and can produce varying results. Similarly, a change in the operating temperature of the radiant panel, which, in turn, would necessitate a change in the separation of the radiant panel and the test specimen, results in a change in the configuration factor. The change in configuration factor produces a different flux profile.

B-3.7

To respond to the needs of the U.S. model building codes, this apparatus has been standardized to operate at a single exposure condition: 12.5 kW/m^2 (1.10 Btu/ft^2-sec). The apparatus could be recalibrated for different exposure conditions. However, such changes would necessitate additional research. For example, an apparatus has been developed to evaluate the performance of wall assemblies under radiant heat exposure. Sufficient separation of the radiant panel and the test specimen need to be maintained to avoid convective heat transfer. Avoidance of convective heat transfer establishes a limit for exposures in this apparatus. The limits of the exposure conditions possible with this apparatus have not been determined.

---

[1]Beitel, Jesse J., "Large-Scale Radiant Heat Exposure Tests of Exterior Insulated Finish Systems," Final Report SwRI Project No. O1-3528, June 1991.

[2]Fisher, P. E., Fred L. and Fleishmann, Charles M., "Radiant Heat Exposure of Exterior Walls," Final Report, Project No. FRD8933, October 1992.

[3]Grand, Ph.D., Arthur F. and Valys, Anthony J., "Report on Cone Calorimeter Time to Ignition Test," Final Report, SwRI Project No. 01-3782-022, September 20, 1991.

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 BOCA Publication.

Building Officials and Code Administrators International, Inc., 4051 West Flossmoor Road, Country Club Hill, IL 60477.

National Building Code, 1993.

C-1.2 SBCCI Publication.

Southern Building Code Congress International, Inc., 900 Montclair Road, Birmingham, AL 35213.

Standard Building Code, 1994.

NFPA 269

1996 Edition

Standard Test Method for Developing Toxic Potency Data for

Use in Fire Hazard Modeling

1996 Edition

This edition of NFPA 269, *Standard Test Method for Developing Toxic Potency Data for Use in Fire Hazard Modeling*, 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 269 was approved as an American National Standard on February 2, 1996.

Origin and Development of NFPA 269

This is the first edition of NFPA 269. It was desirable to establish a standard test method for the development of data for use in toxic hazard modeling. The basis of this standard is derived from much work completed by the National Institute of Standards and Technology.

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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.

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 269

Standard Test Method for Developing Toxic Potency Data for Use in Fire Hazard Modeling

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 Footnotes to Appendix B and Appendix C.

Chapter 1 Introduction

1-1 General.

The pyrolysis or combustion of every combustible material or product produces smoke that is toxic. A standard test method for the development of data for use in toxic hazard modeling is valuable. Such data include quantification of the toxicity of the smoke. It also is desirable to ascertain whether or not the observed toxicity can be attributed to the major common toxicants.

Chapter 2 General

2-1 Scope.

2-1.1

This method is intended to provide a means for assessing the lethal toxic potency of combustion products produced from a material or product ignited when exposed to a radiant flux.

2-1.2

This method has been designed to generate toxic potency data on materials and products (including composites) for use in fire hazard analysis. It also can be used to assist in the research and development of materials and products.

2-1.3

Lethal toxic potency values associated with 30-minute exposures are predicted using calculations that employ combustion atmosphere analytical data for carbon monoxide, carbon dioxide, oxygen (vitiation) and, if present, hydrogen cyanide, hydrogen chloride, and hydrogen bromide. The calculation method is, therefore, limited to those materials and products whose smoke toxicity can be attributed to these toxicants.

2-1.4

Specimens shall be exposed to a radiant heating flux with an electric spark ignition.

2-1.5

Specimens tested shall be representative of finished products, including composite and combination systems.

2-1.6

This standard is not intended to address all safety issues associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and to determine the applicability of regulatory limitations (especially with regard to the institutional care and use of experimental test animals) prior to use. For specific hazard requirements, see Section 7-1.

Chapter 3 Purpose

3-1 Significance and Use.

3-1.1

This test method is intended to provide data for the mathematical modeling of fire hazard as a means for the evaluation of materials and products.

3-1.2

This test method shall be used to predict, *and subsequently confirm*, the lethal toxic potency of smoke produced upon exposure of a material or product to specific fire test conditions. Confirmation determines whether certain major gaseous toxicants account for the observed toxic effects as well as the lethal toxic potency. If a predicted lethal toxic potency value is not adequately confirmed, indicating the potential for unusual or unexplained toxicity due to other components, the lethal toxic potency shall be investigated using other methodology, such as conducting an experimental determination of the LC_{50} using the apparatus described. (*See B-3.1 and B-3.2*.)

3-1.3

This test method produces lethal toxic potency data that shall be considered appropriate for use in modeling the hazard of both pre-flashover and post-flashover fires. Most fire deaths due to smoke inhalation in the U.S. occur in areas other than the room of fire origin and are caused by fires that have proceeded beyond the room of fire origin. It is assumed that these fires typically are flashover fires. Therefore, the principal emphasis is placed on evaluating toxic hazard under these conditions. In post-flashover fires, large concentrations of carbon monoxide result from a reduced air supply to the fire plume. Bench-scale tests do not have the capability to simulate this phenomenon. Therefore, the lethal toxic potencies determined in this test method shall require adjustment for use in modeling the hazard from post-flashover conditions (*see Section 12-2.3*). For pre-flashover conditions, the LC_{50} values derived from this method shall be permitted to be used as toxic potency data without adjustment.

3-1.4

Lethal toxic potency values determined in this test method exhibit a degree of uncertainty where used to predict real-scale toxic potencies. (*See B-4.2*.)

3-1.5

Tests shall be conducted on small-size specimens that are representative of the materials, products, or composites in their intended end-use.

3-1.6

This test method does not attempt to address the toxicological significance of changes in particulate/aerosol size, smoke transport, distribution, or deposition or changes in the concentration of any smoke constituent as a function of time that occurs in an actual fire.

3-1.7

The propensity for smoke from any material tested for its effects on a rat to have the same effects on a human in fire situations shall be inferred only to the extent that a rat can be correlated with a human biologically. (*See B-2.5*.)

3-1.8

This test method shall not be used to assess incapacitation. Incapacitation shall be inferred from lethal toxic potency values.

3-1.9

The effects of sensory irritation are not addressed by this test method.

Chapter 4 Definitions

4-1 Definitions of Terms Specific to this Measurement Method.

Carboxyhemoglobin Saturation. The percent of blood hemoglobin converted to carboxyhemoglobin due to reaction with inhaled carbon monoxide.

Concentration-Time Curve. A plot of the concentration of a gaseous toxicant (ppm) as a function of time.

Ct Product. The concentration-time product (in ppm• min) obtained by the integration of the area under a concentration-time curve.

Fractional Effective Dose (FED). The ratio of the Ct product for a gaseous toxicant produced in a given test to that Ct product of the toxicant that has been statistically determined from independent experimental data to produce lethality in 50 percent of test animals within a specified exposure and post-exposure time. Since time values in this ratio numerically cancel, the FED is also the ratio of the average concentration of a gaseous toxicant to its LC_{50} value for the same exposure time. Where not used with reference to a specific toxicant, FED represents the sum of FEDs for individual toxicants in a combustion atmosphere.

LC_{50}. A measure of lethal toxic potency; the concentration of gas or smoke statistically calculated from concentration response data to produce lethality in 50 percent of test animals within a specified exposure and post-exposure time. LC50 is measured in units of g•m-3.

Mass Loss Concentration. The mass loss of a test specimen per unit exposure chamber volume ($g•m^{-3}$).

Post-flashover. The stage of a room fire during which average air temperature in the upper half of the room exceeds 600°C.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Chapter 5 Test Method

5-1 Summary of Test Method.

This method shall subject a 76-mm × 127-mm or smaller test specimen to ignition while exposed to 50 kW/m^2 of radiant heat for 15 minutes. The smoke produced shall be collected for 30 minutes within a 200-L chamber to which the combustion assembly is joined through a connecting chimney. Concentrations of the major gaseous toxicants shall be monitored over the 30-minute period, with Ct products for each determined from the integration of the areas under the respective concentration time plots. The Ct product data, along with the mass loss of the test specimen during the test, then shall be used in calculations to predict the 30-minute LC_{50} of the test specimen. The predicted LC_{50} then shall be confirmed in comparable tests by exposing six rats, restrained for head-only exposure, for 30 minutes to the smoke produced from that mass of the test specimen whose mass loss concentration during the 30-minute period is approximately equivalent to 70 percent ±10 percent and equivalent to 130 percent of its estimated LC_{50}. If no more than one rat dies during the 30-minute exposure, or within 14 days post-exposure, to the mass loss concentration corresponding to 70 percent of the LC_{50}, and at least five rats die during the 30-minute exposure, or within 14 days post-exposure, to the mass loss concentration corresponding to 130 percent of the LC_{50}, the predicted LC_{50} shall be considered to be validated. This confirmation ensures that the monitored toxicants account for the observed toxic effects. For data representing post-flashover fires, a correction shall be made for the excess CO generated by ventilation-limited fires.

The normal radiant heat flux is 50 kW/m^2. However, other levels of flux shall be permitted to be used for specific evaluations of other fire scenarios, provided the variation is properly recorded and reported.

The test method also allows for measurements of the time to ignition and the rate of mass loss of the test specimens.

Chapter 6 Test Apparatus

6-1 Animal Exposure Chamber.

The animal exposure chamber, shown in Figures 6-1(a) and (b), shall be of a transparent polycarbonate or polymethylmethacrylate with a nominal volume of 0.2 m^3. Its inside dimensions shall be 1220 mm × 370 mm × 450 mm. The six animal ports, intended for head-only exposure, shall be located in a horizontal row, approximately halfway from the bottom to the top of the chamber, in the front wall. A plastic bag with a volume of 0.05 m^3 shall be attached to a port at the end of the chamber to provide for gas expansion. The exposure box shall be equipped with a gas sampling port at the animal nose level in the geometric center of the exposure chamber and with a port for returning gases in the end wall closest to the gas analyzers. A thermocouple shall be provided to monitor the temperature at the level of the animal ports. There shall be two doors in the exposure chamber, one in the front wall near the connection to the combustion cell and one in the end wall nearest the animal ports. The purpose of the doors is to allow for cleaning and maintenance of the chamber, the chimney, and the smoke shutter and to provide fresh air during the calibration of the heat lamps and immediately prior to testing.

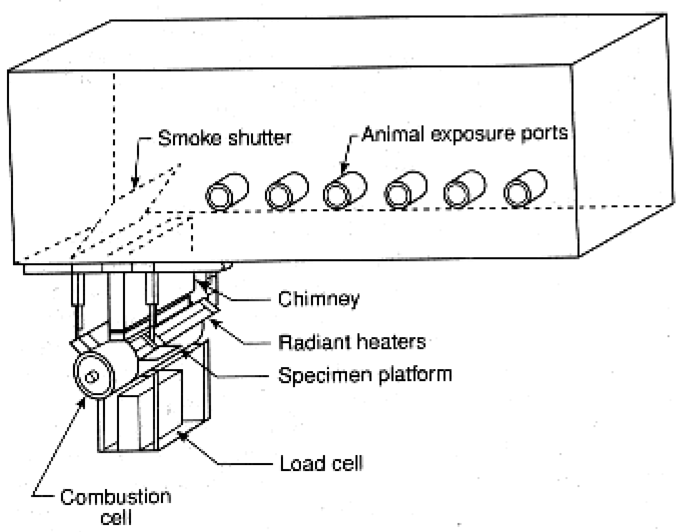


Figure 6-1(a) General view of radiant heat apparatus.

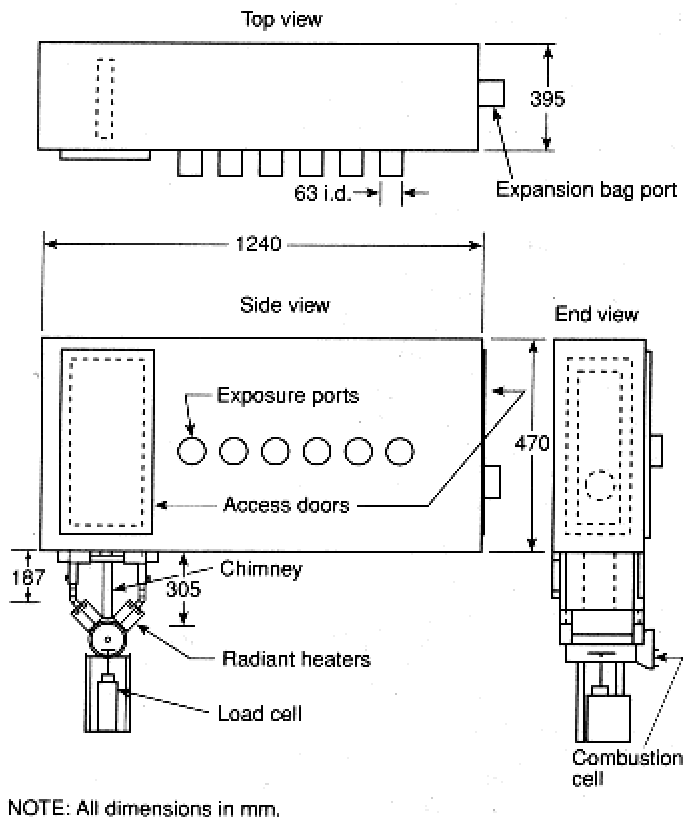
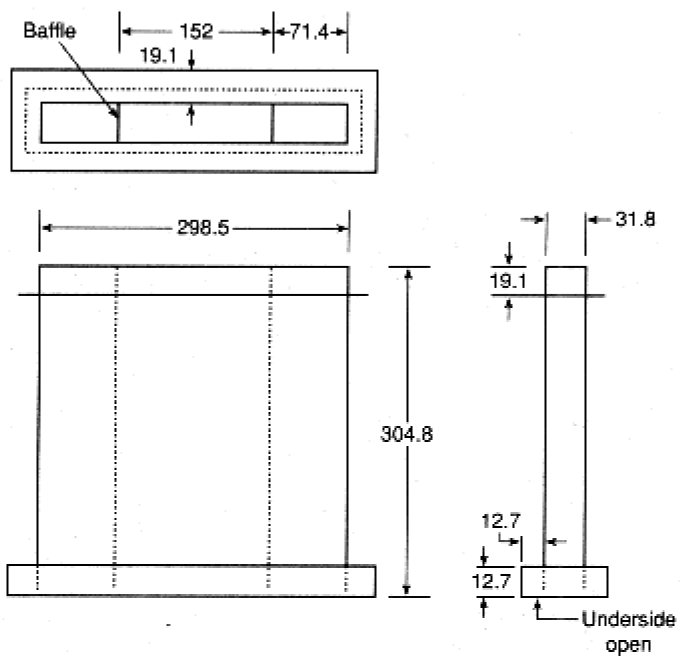


Figure 6-1(b) Main dimensions of the apparatus.

6-2 Chimney.

The chimney (*see Figure 6-2*) shall be a stainless steel assembly approximately 30 mm × 300 mm, inside dimensions, and approximately 300 mm wide. It shall connect the combustion cell to the animal exposure chamber. The chimney shall be divided into three channels by stainless steel dividers. The center channel shall be approximately 150 mm wide. The purpose of the dividers shall be to induce smoke to travel up through the center portion of the chimney, while air from the animal exposure chamber is drawn down through the outside channels to provide air to the combustion cell. The chimney shall be connected to the underside of the animal exposure chamber by clamps, allowing its removal for cleaning. It shall be sealed to the animal chamber by low-density ceramic fiber insulation of approximately 65 kg/m^3. The other end of the chimney shall be sealed to the combustion cell by an H-shaped trough with a small quantity of the same fiber insulation in the trough.



NOTE 1: All dimensions in mm, inside measure where applicable.
NOTE 2: Material is 1.6 mm stainless steel.

Figure 6-2 Chimney.

6-3 Smoke Shutter.

The smoke shutter shall be made of stainless steel plate and shall be situated inside the animal exposure chamber. It shall be positioned so that it closes over the chimney opening. It shall be hinged and provided with a positive locking mechanism. The purpose of the shutter shall be to seal the combustion chamber and chimney from the exposure chamber at the end of irradiation. A wire attached to the shutter and a simple push rod shall be provided to allow the shutter to be closed gently. A wire attached to a clamp shall lock the shutter in place. To produce a gastight seal, the underside of the shutter shall be covered with a 12-mm thick blanket of low-density ceramic fiber insulation of approximately 65 kg/m^3, which shall be covered further with stainless steel foil.

6-4 Combustion Cell.

6-4.1

The combustion cell [*see Figures 6-4.1(a), (b), and (c)*] shall be a horizontal quartz tube with a 127-mm inside diameter and a length of approximately 320 mm. It shall be sealed at one end and shall have a large standard taper outer joint located at the other end. A sealed inner joint shall serve as a removable plug for the open end [*see Figure 6-4.1(c)*]. The combustion cell shall have a rectangular opening on the top that is parallel to the axis of the cylinder with a “collar” that allows it to fit securely into the chimney. The bottom of the cell shall have a hole for the rod connecting the specimen support platform and the load cell. The sealed end of the combustion cell shall be fitted with a standard tapered glass joint for the electric sparker.

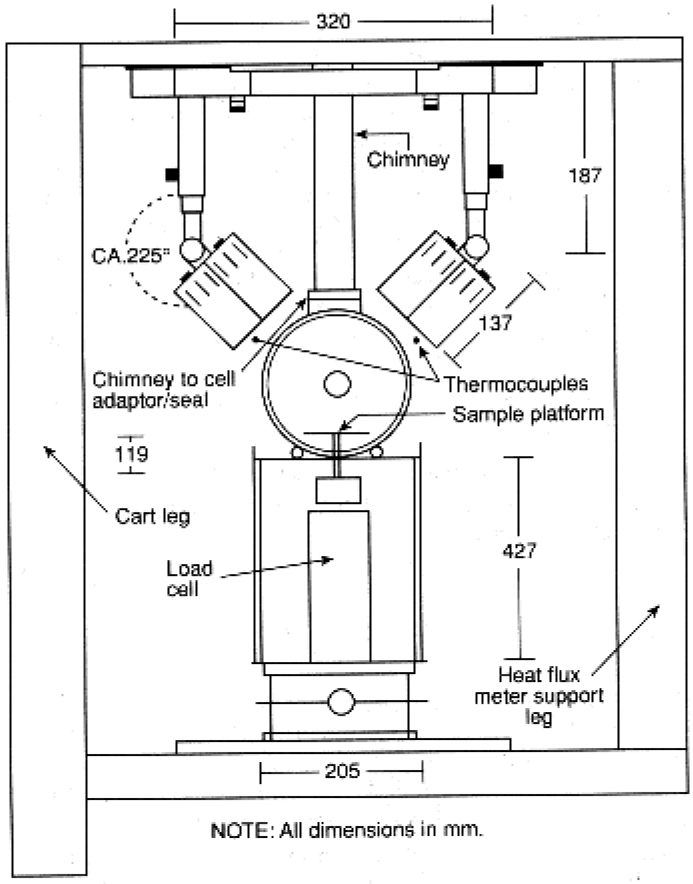


Figure 6-4.1(a) End view showing dimensions pertinent to combustion cell and heaters.

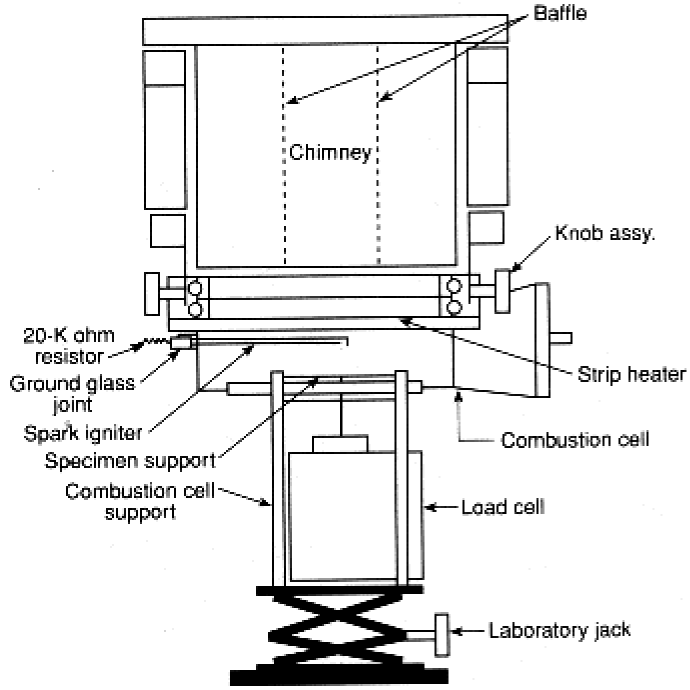


Figure 6-4.1(b) Side view of combustion cell.

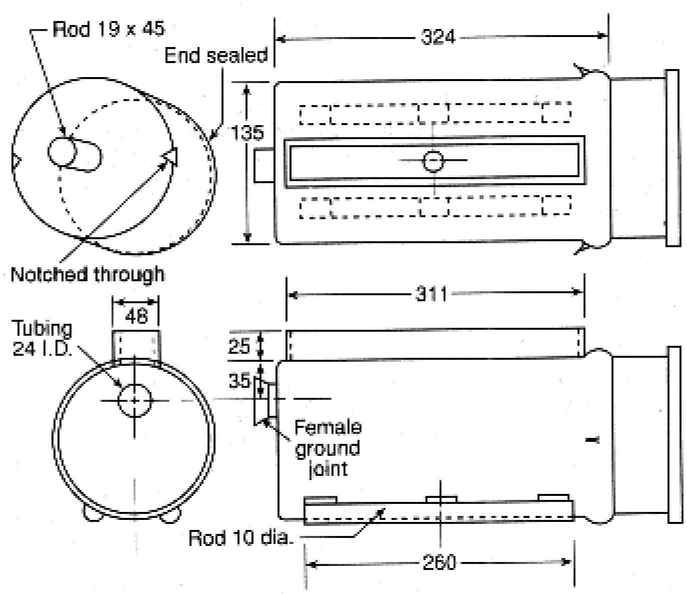


Figure 6-4.1(c) Construction details for the combustion cell.

6-4.2

The combustion cell shall be supported by a metal frame that also holds the load cell [*see Figures 6-4.1(a) and (b)*] that monitors mass loss rate. The entire frame shall be supported by a laboratory jack that holds the combustion cell tightly to the chimney during experimentation and allows the cell to be lowered for removal and cleaning. The load cell shall be located at a fixed distance from the combustion cell.

6-5 Radiant Heaters.

6-5.1

The active element of the heater shall consist of four quartz infrared lamps (with tungsten filaments) rated at 2000 W at 240 V. The lamps (two on each side) shall be encased in water-cooled holders with parabolic reflectors. These holders [*see Figure 6-4.1(a)*] shall be attached to adjustable metal frames that allow the lamps to be moved vertically and laterally and to be rotated in such a way as to give a uniform flux field across the sample surface. To keep the lamps from overheating, cooling water shall be circulated through their respective holders.

6-5.2

The irradiance of the lamps shall be held at a preset level. This shall be accomplished by using a temperature controller and two type K thermocouples placed between the lamps and the combustion cell and wired in parallel.

6-5.3

The irradiance from the lamps shall be uniform within the central area of the sample holder to within ± 10 percent. Figure 6-5.3 shows the calibration holder used in determining the uniformity of the radiant field from the lamps. If the field is found to be inadequately uniform, the lamp holders shall be repositioned, as necessary.

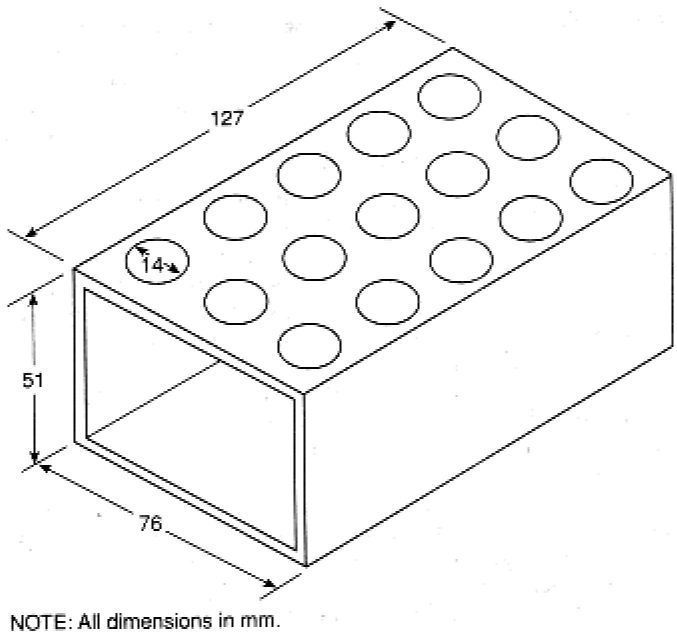


Figure 6-5.3 Calibration jig used for checking the uniformity of irradiance.

6-6 Temperature Controller.

Where a temperature controller is used for maintaining the required radiant flux, the output of the quartz lamps shall be controlled by a thermocouple signal to the temperature controller. The outputs from the two type K thermocouples shall be averaged by means of a parallel-wired connection, and this average value shall be used as the input to the controller. The temperature controller shall be a three-term type and shall provide an output signal suitable for driving the power controller. If necessary, the temperature controller also shall incorporate a means for setting the maximum output to prevent the power controller from being driven wide open. The power controller shall be selected to be compatible with the radiant heat lamps used.

6-7 Heat Flux Meter.

6-7.1

The total heat flux meter shall be of the Schmidt-Boelter (thermopile) type, or equivalent, with a design range of at least 75 kW/m^2. The target receiving radiation shall be flat, circular, approximately 12.5 mm in diameter, and coated with durable matte-black finish. The target shall be water-cooled. The flux meter shall have an accuracy of within ± 3 percent and a repeatability within 0.5 percent.

6-7.2

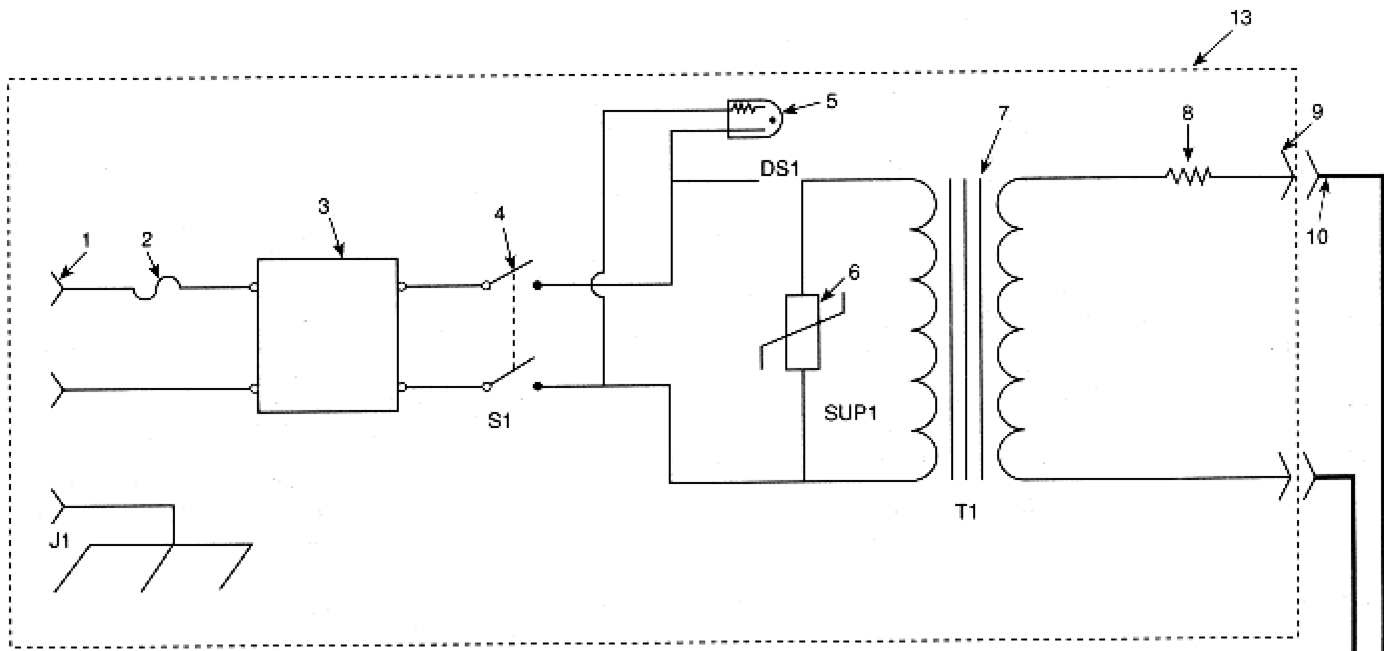
The calibration of the heat flux meter shall be checked periodically. This shall be accomplished most easily by having two flux meters, one used for routine testing and another used only for calibration purposes.

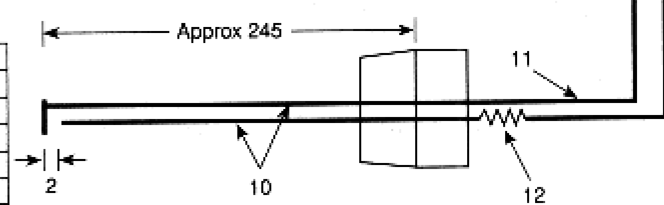
6-7.3

The flux meter shall be used to calibrate the radiant heaters. It shall be positioned firmly in a rigid support device to ensure repeatable readings. The surface of the heat flux meter shall be located in a position corresponding to the center of the specimen face. Figure 6-5.3 shows a calibration bracket suitable for this purpose.

6-8 Igniter.

A spark igniter shall be constructed of two 3.2-mm stainless steel rods. One of these two rods shall be bent at 90 degrees, flattened on the end and positioned to have the appearance of the tip of an automotive-type spark plug. The gap between the two rods shall be about 2 mm ± 0.5 mm. These two rods shall be connected to a high voltage spark system that uses a 10-kV transformer (*see Figure 6-8*). To reduce the propagation of radio frequency that could interfere with the instrumentation, a 20,000 Ω, 5-W resistor shall be connected in series with one of the electrodes. The spark gap shall be positioned approximately 25 mm above the center of the top surface of the specimen, inside the combustion cell. In one method of operation, the rods comprising the spark igniter shall pass through a 29/42 male ground glass stopper, forming a gastight seal with a mating joint in place of the collar on the combustion cell [*see Figure 6-4.1(c)*]. Otherwise, the electrical leads shall be sealed in the glass collar in a gastight manner.





13	1	Cabinet	Bud futura md-1962
12	1	Resistor 20k ohm	STD
11		Wire corona res hv	Dearborn 391845
10	2	3.2 dia. SS rods	STD
9	1	Receptacle ceramic 10kv	Part of 10kV transformer
8	1	Resistor pwr 10k 225w	Ohmite L225J10K
7	1	Transformer 10kV 22ma	Donegan modle LJH-90-A
6	1	Surge suppressor	G.E. mov V130LA20B
5	1	Panel indicator light red	Dialight 249-7866-0931-514
4	1	Toggle switch dpst	Cutler-hammer 7590K6
3	1	Power line filter	Corcom 3EP1
2	1	Fuse holder & fuse 3AG 2A	Littlefuse 342058A
1	1	Power receptacle	Belden 17253

NOTE: All dimensions in mm.

Figure 6-8 Power supply for spark ignition.

6-9 Specimen Holder.

The specimen holder shall be a stainless steel assembly approximately 76 mm × 127 mm, inside dimensions, and 50 mm deep (*see Figure 6-9*). The specimen shall be backed by a layer of ceramic fiber blanket of nominal 65 kg•m^3 density. The specimen holder shall be positioned for testing on the specimen platform, inside the combustion cell.

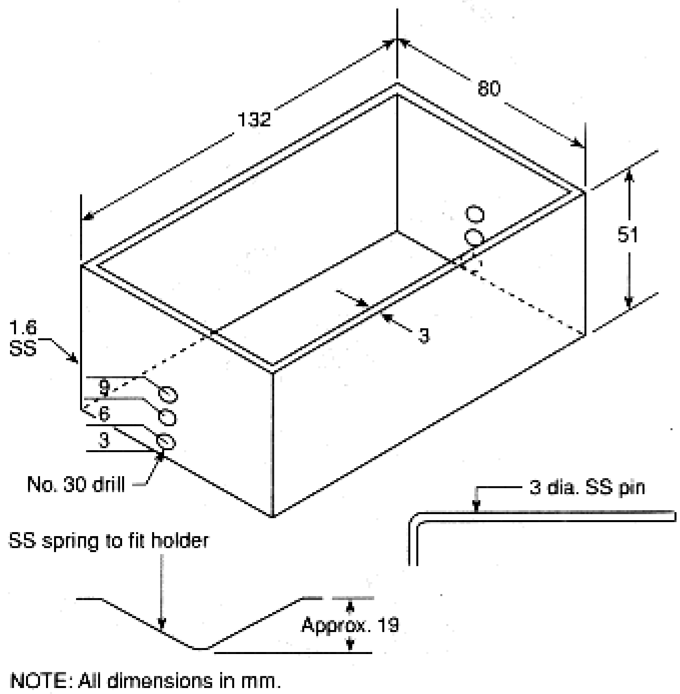


Figure 6-9 Specimen holder.

6-10 Load Cell.

The general arrangement of the load cell and specimen holder is illustrated in Figure 6-4.1(b). The load cell shall be installed under the combustion cell and shall be insulated against the heating effects of the radiant heaters. The specimen and holder shall be located on a support plate and a rigid rod. The load cell shall have an accuracy of 0.01 g, and it shall have a measuring range of at least 100 g.

6-11 Gas Sampling.

6-11.1

A suitable gas sampling arrangement shall include a pump, a glass wool filter at the sampling port, a cold trap to remove soot and moisture, and a pressure relief valve that shall return all flow required by the CO, CO_2, and O_2 gas analyzers. The flow to these analyzers also shall be returned to the animal exposure chamber through separate return lines (*see Figure 6-11.1*). The return lines shall be closed during the calibration of the instruments to prevent the accumulation of calibration gases in the animal exposure chamber. Since this is a closed system, gases that are removed for chemical analysis and that can be recirculated to the animal exposure chamber are allowed to be returned.

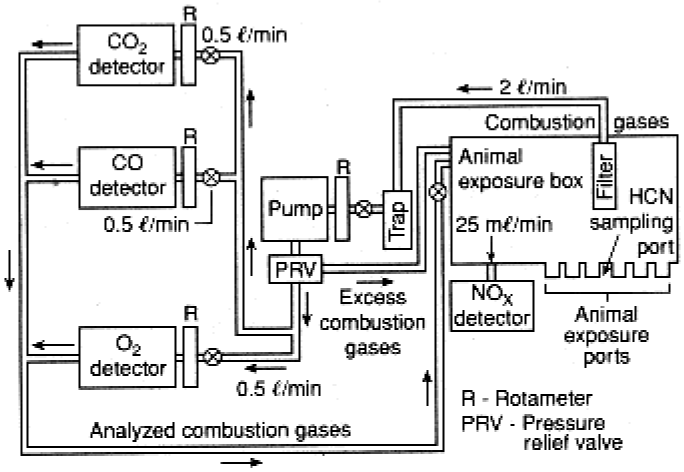


Figure 6-11.1 Gas sampling system.

6-11.2

The gas analyzers shall have the following ranges and resolutions:

(a) Carbon monoxide — 0 to ≥ 10,000 ppm; 10 ppm;

(b) Carbon dioxide — 0 to ≥ 10 percent; 0.1 percent (vol./vol. percent);

(c) Oxygen — 0 to 21 percent; 0.01 percent (vol./vol. percent).

6-11.3

Gas analysis for HCN, HCL, and HBr shall be performed as required by Section 12-1.

6-12 Data Collection.

The data collection system shall be capable of recording the output from the gases monitored by the gas analyzer, the thermocouple(s) in the chamber, and the load cell and shall have an accuracy corresponding to 0.01 percent of full-scale instrument output.

6-13 Animal Restrainers.

Animal restrainers that are made of aluminum and designed to allow exposure of only the heads of the animals shall be used. A detailed illustration of one animal restrainer meeting this requirement is shown in Figure 6-13.

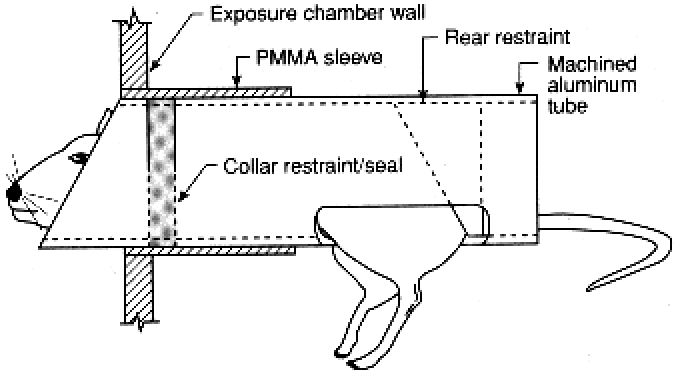


Figure 6-13 Animal restrainer.

Chapter 7 Hazards

7-1 Safety Precautions.

7-1.1

The test procedure involves high temperature and combustion processes. Therefore, precautions shall be exercised against hazards from burns, eye injuries, ignition of extraneous objects, and inhalation of combustion products. To avoid accidental leakage of toxic combustion products into the surrounding atmosphere, the entire exposure system shall be placed into a chemical hood or under a canopy hood. If under a canopy hood, an accessory exhaust trunk for any combustion gases escaping through the load cell hole on the bottom of the combustion cell shall be required. An exhaust line to evacuate the exposure box at the end of a test shall be recommended. The operator shall use safety tongs for the removal of the specimen holder. The combustion cell, while hot, shall be handled only with protective gloves. Due to the intense light from the infrared lamps used, dark safety glasses shall be worn by the operator, or a darkened polymethylmethacrylate or polycarbonate shield shall be placed in front of the combustion cell.

7-1.2

The venting system for the exposure chamber shall be checked for proper operation before testing and shall discharge into an exhaust system with adequate capacity.

Chapter 8 Material Test Specimens

8-1 Test Specimens.

8-1.1

Test specimens shall be cut to an appropriate area and thickness (to be determined by the procedure described in Section 11-1), no larger than 76 mm × 127 mm and no more than 50 mm thick, representing the end-use product. Raw materials (e.g., paints, adhesives, and wall coverings) shall be tested on the substrate to which they are normally applied. For testing, the specimens shall be wrapped on all sides with either aluminum or stainless steel foil.

Exception: The top faces of the specimens shall not be required to be wrapped.

8-1.2

Test specimens shall be conditioned to moisture equilibrium (constant weight) at an ambient temperature of 23°C ± 3°C and a relative humidity of 50 percent ± 10 percent.

Chapter 9 Test Animals

9-1 Test Animal Specifications.

The test animals shall be inbred 3-month to 4-month-old male rats, weighing 225 g to 350 g. The rats shall be obtained from a reputable supplier that certifies that the animals are free of major respiratory pathogens.

9-1.1

The maintenance and care of the animals shall be performed by qualified trained personnel in accordance with the guidelines of the National Institute of Health Guide for the Care and Use of Laboratory Animals. The animal housing facilities shall be suitable for studies of this type.

9-1.2

Upon receipt, the animals shall be identified, weighed, and housed in a separate quarantine area for a minimum of 7 days prior to testing. During the quarantine period, animals shall be observed and weighed daily. Animals that are unsuitable by reason of health or other criteria shall not be used. Cage assignments shall be made according to a randomization routine. Health criteria for eliminating animals from a study shall include any animal weighing outside ± 20 percent of the body weight specified in Section 9-1.

9-1.3

The animals shall be housed one animal to a cage. The environment shall have proper ventilation and shall be controlled at a temperature of 23°C ± 3°C and a relative humidity of 50 percent ± 15 percent. The animal room shall have a 12-hour light/dark cycle.

9-1.4

Each animal shall be weighed when received, prior to test, and surviving animals shall be weighed at 7 and 14 days post-exposure.

9-1.5

Prior to exposure, the animals shall be weighed and secured in individual restrainers for placement in the animal exposure chamber.

9-1.6

After testing, surviving animals shall be housed in an animal room separate from the pre-test animal room for the post-exposure observation period.

Chapter 10 Equipment Calibration

10-1 Calibration of the Apparatus.

The following parts of the test apparatus shall require calibration:

(a) The radiant heaters;

(b) The gas analyzers;

(c) The load cell;

(d) The temperature controller (if used).

10-2 Heat Flux Calibration.

10-2.1

For heat flux calibration, the heat flux meter shall be secured in the proper position. The target surface of the flux meter shall be centered at the location corresponding, both horizontally and vertically, to that of the top of the specimen when the specimen holder is in place on the platform. (The igniter shall be removed from its position during this procedure.) The temperature controller, if used, shall be set to the desired flux temperature and the radiant heat lamps shall be turned on, adjusting the temperature controller until the desired irradiance (i.e., 50 kW/m^2 ± 10 percent) is achieved. If manual control of the heat lamps is used, the calibration curve of the heater controller setting as a function of the time needed to maintain the desired flux level shall be developed.

10-2.2

The orientation of the radiant heat lamps shall be checked whenever the heaters have been moved or a lamp has been replaced, using the following procedure:

(a) The heat flux calibration jig shown in Figure 6-5.3 shall be installed.

(b) The top face of the calibration jig shall be positioned at the same height at which the top of a test specimen is placed.

(c) A power setting for the lamps shall be estimated that produces the desired level (i.e., 50 kW/m^2) at the center hole.

(d) The power shall be adjusted and at least 5 minutes shall be allowed for equilibration.

(e) The orientation of the radiant heat lamps shall be adjusted so that no measurement at seven locations across the face of the specimen (*see Figure 6-5.3*) deviates by more than 10 percent from the average.

10-3 Gas Analyzer Calibration.

10-3.1

At the beginning of each series of tests, the O_2, CO_2, and CO analyzers shall be calibrated by using nitrogen gas for “zeroing” and an appropriate gas mixture with a full-scale reading that is near to, but less than, that of the analyzer. For all calibrations, the gas shall be set to flow at the same rate and pressure as the sample gas. For calibrating the O_2 analyzer, ambient air (20.9 percent O_2) shall be used, while, for the CO_2 and CO analyzers, bottled gases containing CO_2 and CO at known concentrations shall be required to be used. A single mixture containing both CO and CO_2 shall be permitted to be used. *During the calibration procedure, the gas return* *lines shall be diverted into the exhaust and not into the exposure chamber to prevent the inadvertent accumulation of CO and CO_2.*

10-3.2

The calibration of apparatus for analysis of optional gases (e.g., HCN, HCl, HBr, and NO_2) shall be performed.

10-4 Load Cell Calibration.

10-4.1

The load cell shall be calibrated with standard weights corresponding to the range of test specimens on a regular basis, and when first setting up the apparatus or after making adjustments for sensitivity and range.

10-4.2

Before each test, the load cell shall be checked routinely using at least two analytical quality weights for the full effective range of measurement. Any deviation of the load cell output, as compared to these weights, shall be recorded, and appropriate compensation shall be made for the specimen mass loss readings.

10-5 Calibration of the Temperature Controller.

To set up the controller, the flux meter first shall be inserted into its holder so that the sensing surface is at the exact center of where the top of the specimen is placed during normal testing. The lamp shall have been adjusted to obtain a uniform flux field over the sample. The output of the heat flux meter then shall be connected to a strip chart recorder running at a trace speed that is still fast enough to detect any changes in the flux. Using the output from the heat flux meter, the instructions of the controller manufacturer for adjusting the controller shall be followed in order to obtain, as closely as possible, a square wave output from the heat flux meter when the lamps are turned on and then turned off. Because the lamps respond quickly, while the temperature at the thermocouples rises more slowly, it is important to avoid a significant overshoot, which can occur if the controller is not tuned optimally. It is also important to avoid using settings that result in an unstable, oscillating output. If such a problem is noted, the solution shall be to limit the maximum output from the slave controller. This can be done either by using the “load line out” function of the temperature controller, if so equipped, or by installing a voltage divider at the output of the temperature controller. When setting up the controller for this function, the thermocouples always shall read room air temperature only. Using the correct adjustment of the temperature controller, 90 percent of the desired flux can be reached within 2 seconds, with 100 percent flux reached within 20 seconds, and a deviation of within ± 5 percent reached for the remainder of the test duration.

Chapter 11 Procedures

11-1 General.

Test procedures for smoke toxicity data initially shall be followed *without* the exposure of test animals in order to produce analytical data for CO, O_2, CO_2, and, if present, HCN, HCl, and HBr. The choice of specimen size for the initial tests shall be made with consideration of anticipated toxicant yields so that total FEDs of 0.5 to 1.5 shall be obtained (*see Section 12-1*). In the absence of appropriate information for such choices, an area equal to $^1/_4$ of a maximum area of 96.5 cm^2 shall be selected initially. Analytical data from at least two initial tests shall be used for estimation of an average LC_{50} for the test specimen. (*See Section 12-1.*)

Comparable tests then shall be conducted, but *with* the exposure of six rats to the smoke produced from that quantity of the test material whose mass loss concentration during the 30-minute exposure is approximately equivalent to 70 percent (± 10 percent) and to 130 percent of its average estimated LC_{50}. If no more than one rat dies during the 30-minute exposure, or within 14 days post-exposure, to the mass loss concentration corresponding to 70 percent of the LC_{50} and at least five rats die during the 30-minute exposure, or within 14 days post-exposure, to the mass loss concentration corresponding to 130 percent of the LC_{50}, the estimated LC_{50} shall be considered to be validated. If the validation is not successful, or if unexplained or unusual toxicity is suspected, other test methods shall be employed, or further research will be needed to determine experimentally the lethal toxic potency of the test material. (*See B-3.1 and B-3.2.*)

11-2 Preparation for Tests.

11-2.1

Coolant water for the heat flux meter (at least 750 ml/min) and for the tungsten lamps (at least 600 ml/min) shall be turned on.

11-2.2

Verification that all lines, filters, and traps for the gas analyzers have been serviced and that flow rates are satisfactory shall be made.

11-2.2.1 The moisture trap in the gas analyzer stream shall be checked. The trap shall be dried, and the glass wool shall be replaced. The normal operating temperature of the moisture trap is 0°C.

11-2.2.2 A wool filter shall be placed before the gas sampling port.

11-2.3

Operation of the spark ignition circuit shall be verified.

11-2.4

The required calibration procedures specified in Chapter 10 shall be performed. The specimen shall be weighed on a laboratory balance with an accuracy of ± 0.01 g. The specimen shall be wrapped in either aluminum or stainless steel foil, leaving the top surface exposed, and the combined weight of the specimen with the foil and after mounting in the specimen holder shall be determined. The correspondence of the load cell readout to the appropriate weight of the specimen plus the holder shall be verified.

11-3 Test Procedure.

11-3.1

If animals are to be exposed, they shall be weighed and placed in their restrainers.

11-3.2

The specimen, mounted in the specimen holder, shall be inserted into the combustion cell, and the standard taper plug shall be replaced (no grease or sealant shall be used on the ground glass). The plug shall be secured with wire or springs. Immediately prior to beginning the test, the animals shall be placed into the ports in the exposure chamber. All exposure chamber doors and ports shall be closed if not used for animals. It shall be ascertained that the smoke shutter is open.

11-3.3

The spark igniter shall be turned on. The power to the radiant heat lamps shall be activated simultaneously with the start of the data collection.

11-3.4

The time at which ignition of the specimen occurs shall be recorded and the spark igniter shall be turned off. The time of flameout shall be recorded. For specimens that have the tendency to self-extinguish soon after ignition, the sparker igniter shall be left on until flaming ceases.

11-3.5

At the end of 15 minutes, the power to the radiant heat lamps shall be switched off, and the smoke shutter shall be closed.

11-3.6

Data shall be collected for a total of 30 minutes from the initiation of the test.

11-3.7

At the end of 30 minutes, data collection shall cease. If animals were exposed, they shall be removed from the exposure chamber. The exposure chamber shall be vented with a high capacity exhaust system.

11-3.8

In tests where animals are exposed, blood samples shall be taken from any dead animals and analyzed for carboxyhemoglobin saturation. Blood sampling and analyses shall be conducted in accordance with generally accepted methodologies.

11-3.9

In tests where animals are exposed, those surviving shall be checked daily for any signs of toxic effects (e.g., difficulty in breathing, convulsions), exploratory behavior, and eye and righting reflexes. The status and weights (at 7 and 14 days) of the animals shall be followed for a 14-day post-exposure period. Any deaths during this period shall be recorded.

11-3.10

The sample holder shall be removed from the combustion chamber and cooled to an ambient temperature in an exhaust hood. After the specimen has cooled, the specimen holder shall be disassembled and the weight of the aluminum foil and the residue shall be determined.

11-3.11

The combustion chamber and the chimney shall be removed and cleaned after each test. The exposure chamber shall be cleaned after each test. Ethyl alcohol shall be considered a satisfactory solvent. There shall be no residue on the inside of any of the pieces of the apparatus.

Chapter 12 Calculation

12-1 General.

The lethal toxic potency (LC_{50}) of the test specimen shall be predicted from the combustion atmosphere analytical data for CO, CO_2, O_2, and, if present, HCN, HC1, and HBr (*see B-2.7*). This shall be determined for a given specimen mass loss by first calculating the total FED for the test. The LC_{50} then shall be calculated as that specimen mass loss that would yield a total FED = 1.1 within a chamber volume of 1 m^3. Although the theoretical value of the FED associated with 50 percent lethality is 1.0, a median value of 1.1 has been determined experimentally.

12-2 Equations.

12-2.1

The total 30-minute FED for a given specimen mass loss shall be determined from the following equation:

$$FED = \frac{m\,[CO]}{[CO_2]-b} + \frac{21 - [O_2]}{21 - LC_{50}O_2} + \frac{[HCN]}{LC_{50}HCN} + \frac{[HC1]}{LC_{50}HC1} + \frac{[Hbr]}{LC_{50}HBr}$$

$$= \frac{m\,[CO]}{[CO_2]-b} + \frac{21 - [O_2]}{21 - 5.4\%} + \frac{[HCN]}{150\text{ ppm}} + \frac{[HC1]}{3700\text{ ppm}} + \frac{[HBr]}{3000\text{ ppm}}$$

Where the values of all gas concentrations are the integrated Ct product values under their respective concentration time curves taken over the 30-minute test period divided by 30. All values are in ppm, except O_2, which is expressed as a percentage. The values for m and b depend on the concentration of CO_2. If $[CO_2] < 5\%$, m = -18 and b = 122,000. If $[CO_2] > 5\%$, m = 23 and b = -38,600. For each individual toxicant, the LC_{50} values shown have been statistically determined from independent experimental data to produce lethality in 50 percent of test animals (rats) within a 30-minute exposure plus 14 days post-exposure.

12-2.2

The 30-minute LC_{50} for the test specimen shall be determined from the following equation:

$$LC_{50} = \frac{\text{specimen mass loss}}{\text{FED} \times \text{chamber volume}}$$

Where the specimen mass loss is in g and the chamber volume is 0.2 m^3, the resulting LC_{50} = $g \cdot m^{-3}$.

12-2.3*

To calculate toxic hazard data for smoke from a post-flashover fire, a value of the LC_{50} corrected for the expected post-flashover yield of CO is needed. The adjusted value shall be determined from the following formula:

$$LC_{50}(corr) = \frac{1}{\frac{1}{LC_{50}(raw)} + 44 \times 10^{-3} - 5.0 \times 10^{-5} \frac{[CO]}{m}}$$

where LC_{50}(raw) is the value of the LC_{50} determined from the equation in 12-2.1, m is the mass of specimen loss during the test at the FED = 1.1 condition, and [CO] is the concentration of CO at the FED = 1.1 condition (ppm).

Chapter 13 Analysis

13-1 Report.

The report shall include the following information for all tests:

(a) Laboratory identification;

(b) Test identification and date;

(c) Laboratory ambient conditions (temperature and humidity);

(d) Description of specimen;

(e) Specimen dimensions;

(f) Irradiation time and heat flux conditions;

(g) Maximum exposure chamber temperature and time when attained (*see B-2.6*);

(h) Initial specimen mass and mass loss during test in $g \cdot m^{-3}$ of chamber volume (*see B-3.3*);

(i) Time to ignition and flameout;

(j) Observations of specimen;

(k) Observations that shall be required include the times to smoke evolution, ignition, and flameout. Other observations shall include melting, char formation, spalling, unusually vigorous burning, and reignition.

13-2 Gas Analysis Data.

The required exposure chamber data shall include integrated Ct product values during the 30-minute test for CO, O_2, HCN, HCl, and HBr; minimum O_2 concentration and maximum CO_2 concentration; and times to reach minimum O_2 and maximum CO_2. The methods used for analyses shall be identified.

13-3 Calculations.

The following data shall be calculated for all tests:

(a) Ct product for each analyzed toxicant;

(b) FED;

(c) Predicted LC_{50}.

13-4 Best Overall Predicted LC_{50} Value.

A least squares regression analysis of FED versus mass loss values for all tests shall be used to determine the best overall predicted LC_{50} value.

13-4.1

The LC_{50} value shall be corrected for high post-flashover CO yield.

13-4.2

Plots of individual toxicant concentrations, specimen mass loss, and temperature as functions of time shall be considered optional.

13-5 Report.

The report shall include the following information for each test using the exposure of animals:

(a) Strain of rat and identity of supplier;

(b) Weight of each animal when received, prior to test, and of surviving animals at 7 and 14 days post-exposure;

(c) Number of animals that die during the test (including up to 10 minutes post-test), and number of animals that die up to 14 days post-test;

(d) Blood carboxyhemoglobin saturation values for animals that die during the test;

(e) Animal observations, (e.g., unusual behavior during test); immediate post-test observations of live animals, such as tremors, convulsions, difficulty in breathing, and severe eye irritation.

Chapter 14 Precision and Bias

14-1 Precision.

The precision of this test method has not yet been established. A precision statement will be prepared and included in the test method after completion of an interlaboratory test series.

14-2 Bias.

The bias of this test method has not been measured, since there is no accepted reference material for use in making such measurements.

14-2.1

Comparison of the LC_{50} (corrected) values derived using this method (*see B-4.2*) have been shown to reproduce the LC_{50} values from real-scale, post-flashover fires to within a factor of three. Therefore, product LC_{50} values differing by less than a factor of three are indistinguishable from each other.

14-2.2

The accuracy of the bench-scale data for pre-flashover fires has not been established experimentally. However, the combustion conditions in the apparatus are quite similar to real pre-flashover fires, although the mass burning rate is higher at the 50 kW/m^2 irradiance.

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-12-2.3

If real-scale, post-flashover fire test data are available for a particular product/occupancy combination, the measured CO yield should be used in the equation in 12-2.1, and the correction in the equation in 12-2.3 should not be made.

Appendix B Commentary

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

B-1 Introduction.

This appendix provides insight into the development of the test method, to describe the rationale for the unique features of the method, and to describe the proper use of the resulting data. For a more comprehensive treatment, along with presentation of data and results obtained on typical materials, see NIST Special Publication 827.[1]

B-2 Development of the Method.

A test method to assess the acute inhalation toxicity of combustion products has three basic components: a combustion system, a chemical analysis system and an animal exposure system.[2] Additionally, there should be a rational and accepted strategy for the incorporation of raw experimental data into a quantified expression for toxic potency.

B-2.1

This test method employs the combustion system that was developed at Southwest Research Institute (SwRI) for the National Institute of Building Sciences (NIBS).[3] Representing a significant improvement over an earlier radiant heat device first used at the Weyerhaeuser Company,[2] the combustion system was adopted jointly by the National Institute of Standards and Technology (NIST) and SwRI for the development of this test method.[4] Its main feature is that of providing for combustion of a test specimen under the realistic conditions of radiant heat within an apparatus especially designed for ruggedness and ease of operation.

B-2.2

For a small, developing fire, the bench-scale specimen in the radiant apparatus provides a reasonable representation of a full-scale fire. The thermal boundary conditions are appropriate, being radiative and emanating from only one face. A small fire imposes about 35 kW/m^2 on an adjacent unburned surface, although a value of approximately 48 kW/m^2 is common, and values over 100 kW/m^2 can be measured.[5,6] Thus, while an irradiance of 50 kW/m^2 for a pre-flashover test might be somewhat high, it is by no means unusual. If a specific scenario involves a heating flux other than 50 kW/m^2, it can be readily accommodated in the test method.

B-2.3

In a real-scale fire, the combustion products generally contain contributions from portions of the burning product that are burning near the front surface, those that are partially burned through, and those produced from nearly burned out portions of the burning product. Thus, a bench-scale test should represent this mixture of gases as closely as possible. The physical constraints of the test method are a maximum specimen thickness of 51 mm and a radiant heating time of 15 minutes. The actual thickness of nonlayered products should be selected so that thermal decomposition is complete when 15 minutes has elapsed and the shutter is closed. This should be determined by examination of the generation of CO, which should have ceased before the shutter is closed. A preliminary trial run where neither animals nor gas analyzers need to be used should suffice. Homogeneous products then can be prepared for actual testing by cutting to the appropriate thickness. Layered composites also generally might be reduced in thickness, as necessary. If the two face materials are not identical, however, then separate tests should be performed, with each face being exposed in separate testing.

B-2.4

The chemical analysis system used in the test method employs methodology commonly accepted by those skilled in such procedures and as presented in ASTM E 800, *Standard Guide for Measurement of Gases Present or Generated During Fires* and in ISO/TR 9122, *Toxicity Testing of Fire Effluents*, Part 3.

B-2.5

The use of rats as an acceptable model for human exposure has, within the scope and significance of this test method, been well documented in ISO/TR 9122, *Toxicity Testing of Fire Effluents*, Part 5.

B-2.6

The animal exposure system is that employed in the NBS Cup Furnace method.[7] It has been widely used in a number of laboratories and has been found to be highly satisfactory. An important consideration in conducting animal exposures is that the biological effects on the animals' condition during a test should be adversely affected as little as possible by causes other than specimen toxicity. Such adverse affects can be minimized by:

(a) Providing an animal exposure chamber of sufficient size so that the animals' exhaled CO_2 does not affect them adversely;

(b) Making certain that heating conditions from specimen heaters do not create an excessive heat burden to the animals; and

(c) Providing a restraint system that does not cause undue physical stress. Judgment regarding exposure chamber temperatures excursions above 40°C should be exercised. Generally, such excursions have not been regarded as detrimental to the resulting test data. However, there could be exceptions in extreme cases.

B-2.7

The strategy employed in this method for quantification of smoke toxicity represents utilization of the latest in state of the art understanding of the prediction of the toxic effects of fire effluents as reported in ISO/TR 9122, *Toxicity Testing of Fire Effluents*, Part 5. It employs a methodology for the calculation of toxic potencies from combustion product analysis data without the exposure of experimental animals. The basis for such methodology comes from extensive experimentation using the exposure of rats to the common fire gases, both singly and in combinations, which showed the additivity of fractional exposure doses (FEDs) of the individual toxicants. [8-18] Expressed mathematically, the principle is shown in the following equation:

$$FED = \sum_{i=1}^{n} \int_{0}^{t} \frac{C_i}{(Ct)_i} dt$$

where C_i is the concentration of the toxic component, i, and $(Ct)_i$ is the specific exposure dose required to produce the toxicological effect.[19] Where the FED = 1, it is expected that the mixture of gaseous toxicants would be lethal to 50 percent of exposed animals. Use of the principle in the form given in this test method has been termed the "N-Gas Model" by NIST. The N-Gas Model also takes into account the effect of CO_2 on the toxicity of CO, as expressed empirically from studies conducted at NIST.[8] Examination of a series of pure gaseous toxicant experiments in which various percentages of animals die indicates that the mean FED value using the N-Gas calculation was 1.07, with 95 percent ± 0.20 percent confidence limits.[11]

B-3 Limitations on Materials and Products.

B-3.1

All products should be tested using the calculation method described. However, the lethal toxic potency of the smoke from certain products cannot be attributed to the common toxic gases analyzed. These products might need to be tested according to conventional animal exposure methodology that requires the experimental determination of an LC_{50} value. Otherwise, further research is necessary in order to explain why the lethal toxic potency cannot be estimated from the concentrations of the common toxic gases. For certain materials or products containing perfluorinated polymers, this test method could be inappropriate, because a number of highly specialized combustion and toxicological phenomena can arise that make the creation of proper bench-scale conditions that represent real-scale toxicity difficult.[20]

B-3.2

The research for the N-gas Model did not include the combustion gases likely to be produced when materials or products that contain elements such as sulfur, bromine, or fluorine are burned. Therefore, the calculations might not fully account for the smoke toxicity in such cases.

B-3.3

Certain ash-producing materials (e.g., silicones) necessitate the use of appropriate procedures to measure the quantity of sample burned, since the load cell readings are compromised by the deposit of ash resulting from the burning of the material.

B-4 Test Method Data.

This test method has been designed to provide data for the mathematical modeling of fire hazard as a means for the evaluation of materials and products and to assist in their research and development.

B-4.1

Studies at NIST[4] have demonstrated that a bench-scale toxic potency test can adequately represent many aspects of a post-flashover fire. One exception is the generation of carbon monoxide, which can, in some cases, be governed more by the available air supply in an actual full-scale fire than by the nature of the material burned. This cannot be simulated in a practical bench-scale test method. It was found in a few limited studies that post-flashover fires exhibited a yield of approximately 0.2 kg of CO per kg of specimen mass lost. Based on this finding, LC_{50} values to be used in appraising post-flashover toxic fire hazard should be adjusted according to 12-2.3.

B-4.2

Data from this method have been compared directly to real-scale, post-flashover fires of the same materials (i.e., douglas fir, rigid polyurethane foam, and PVC).[21] Wall cork, particle board, and a laminated melamine/vermiculite composite also have been studied, producing much the same result.[22] These materials challenge the method with an extremely diverse set of test cases as follows:

(a) Natural cellulosics and man-made plastics;

(b) Solid and foam plastics;

(c) Materials where CO (along with CO_2 and low O_2) is the only toxicant; and

(d) Those that produce significant amounts of HCl and HCN.

The results showed agreement of the post-flashover LC_{50} data and the bench-scale data to within a factor of 3.

B-4.3

It is possible to demonstrate the regime of LC_{50} values where performance differentiation is, and is not, scientifically proper. The LC_{50} of CO_2-potentiated CO is about 5 $g•m^{-3}$, and the yield of CO is about 0.2 g/g of fuel burned. Some variation in this latter value has been observed. This value is the best representation, given current knowledge. Research to improve this knowledge is in progress. Therefore, the LC_{50} of post-flashover smoke is about 25 $g • m^{-3}$using this test method. Combining this with the accuracy of the method, the result is that post-flashover smoke with LC_{50} (corr) values between 8 $g • m^{-3}$ (i.e., 25/3) and 25 $g • m^{-3}$ are indistinguishable from each other using this test method. LC_{50} values > 25 $g • m^{-3}$ are not possible for post-flashover smoke, since the high CO is characteristic of these fires. Thus, it is more indicative of the state of the art that LC_{50} values greater than 8 $g • m^{-3}$ are indistinguishable from each other using this test method. Most common building and furnishing materials have LC_{50} values substantially higher than 8 $g • m^{-3}$. Thus, the lethal toxicity potency of the smoke most often is determined by the fire ventilation. For pre-flashover and post-flashover fires, this method identifies products that produce smoke of extreme toxic potency.

B-4.4

In the event that time to ignition and mass burning rate data are desired but not readily available from other test methods, they should be obtained using a modification of this test procedure. Test specimens should be cut to the maximum size of 76 mm × 127 mm and blackened with a thin coating of carbon black or sprayed with a flat black coating having a heat energy absorptivity factor of 0.96 (Krylon® ultra flat spray paint may be permitted to be used for this application). Specimens then should be conditioned at an ambient temperature of 23°C ± 3°C and relative humidity of 50 percent ± 10 percent for at least 24 hours prior to testing. A specimen, mounted in the specimen holder, should be inserted into the combustion cell, which then should be sealed with the standard taper plug. The plug should be secured with wire or springs and the door closed at the front of the exposure chamber (nearest the chimney). The portholes and the end door should be left open. The apparatus should be located directly under an exhaust hood. (CAUTION: Substantial quantities of smoke could be produced by a full-scale specimen, as in this test. The hood should be of adequate capacity to accommodate the smoke evolution.) The spark igniter should be turned on and the power activated to the radiant heat lamps. Data should be collected from the load cell and oxygen analyzer only. The time of ignition should be noted, and the spark igniter should be turned off. (For samples that have the tendency to self-extinguish immediately, the spark igniter should be left on until flaming ceases.) Data should be collected for 15 minutes. After cooling to ambient temperature, the specimen should be reweighed. The mass loss rate (MLR) per unit area should be calculated from the following equation:

$$MLR = \frac{m_{90} - m_{10}}{A\,(t_{90} - t_{10})}$$

where:

A = exposed face area of the specimen (m2)

M_{ch} = mass of the specimen (g) before the test

m_{100} = mass of the specimen consumed (g)

m_{10} = 10% of consumed mass (g)

m_{90} = 90% of consumed mass (g)

t_{10} = time at which 10% mass loss of the consumed mass occurred (g)

t_{90} = time at which 90% mass loss of the consumed mass occurred (g).

Footnotes to Appendix B

[1] Babrauskas, V., Levin, B. C., Gann, R. G., Paabo, M., Harris, Jr., R. H., Peacock, R. D., and Yusa, S., “Toxic Potency Measurement for Fire Hazard Analysis,” NIST Special Publication 827, National Institute of Standards and Technology, Gaithersburg, MD (1991).

[2] Kaplan, H. L., Grand, A. F., and Hartzell, G. E., *Combustion Toxicology: Principles and Test Methods*, Technomic Publishing Co., Inc., Lancaster, PA (1983).

[3] Grand, A. F., “Development of a Product Performance Smoke Toxicity Test,” Southwest Research Institute Project No. 01-1744, Final Report to National Institute of Building Sciences, Washington, DC (1990).

[4] Babrauskas, V. R., Harris, Jr., R. H., Braun, E., Levin, B. C., Paabo, M., and Gann, R. G., “The Role of Bench-Scale Test Data in Assessing Full-Scale Fire Toxicity,” NIST Tech. Note 1284, National Institute of Standards and Technology, Gaithersburg, MD (1991).

[5] Babrauskas, V. and Krasny, J. F., “Fire Behavior of Upholstered Furniture,” NBS Monograph 173, U.S. Natl. Bur. Stand. (1985).

[6] Ohlemiller, T. J. and Villa, K., “Furniture Flammability: An Investigation of the California Bulletin 133 Test — Part II: Characterization of the Ignition Source and a Comparable Gas Burner,” NISTIR 4348, National Institute of Standards and Technology, Gaithersburg, MD (1990).

[7] Levin, B. C., Fowell, A. J., Birky, M. M., Paabo, M., Stolte, A., and Malek, D., “Further Development of a Test Method for the Assessment of the Acute Inhalation Toxicology of Combustion Products,” NBSIR 82-2532, U.S. Natl. Bur. Stand. (1982).

[8] Levin, B. C., Paabo, M., Bailey, C., Harris, S. E., and Gurman, J. L., “Toxicological Effects of the Interactions of Fire Gases and Their Use in a Toxic Hazard Assessment Computer Model,” *The Toxicologist*, Vol. 5, p. 127 (1985).

[9] Babrauskas, V., Levin, B. C., and Gann, R. G., “A New Approach to Fire Toxicity Data for Hazard Evaluation,” *Fire J*., Vol. 81, No. 2, pp. 22-71 (1987). Also in *ASTM Stand. News*, Vol. 14, pp. 28-33 (1986).

[10] Levin, B. C., Paabo, M., Gurman, J. L., and Harris, S. E., “Effects of Exposure to Single or Multiple Combinations of the Predominant Toxic Gases and Low Oxygen Atmospheres Products in Fires,” *Fund. Appl. Tox*., Vol. 9, pp. 236-250 (1987).

[11] Levin, B. C., Paabo, M., Gurman, J. L., Clark, H. M., and Yoklavich, M. F., “Further Studies of the Toxicological Effects of Different Time Exposures to the Individual and Combined Fire Gases: Carbon Monoxide, Hydrogen Cyanide, Carbon Dioxide, and Reduced Oxygen,” pp. 249-252 in *Polyurethane ’88, Proceedings of the 31st Society of Plastics Meeting*, Technomic Publishing Co., Lancaster, PA (1988).

[12] Levin, B. C. and Gann, R. G., “Toxic Potency of Fire Smoke: Measurement and Use,” pp. 3-11 in *Fire and Polymers: Hazards Identification and Prevention*, ACS Symp. Series 425, G. L. Nelson, ed., Amer. Chem. Soc., Washington, DC (1990).

[13] Hartzell, G. E., Priest, D. N., and Switzer, W. G., “Modeling of Toxicological of Fire Gases: II. Mathematical Modeling of Intoxication of Rats by Carbon Monoxide and Hydrogen Cyanide,” *J. Fire Sciences*, Vol. 3, No. 2, pp. 115-128 (1985).

[14] Hartzell, G. E., Packham, S. C., Grand, A. F., and Switzer, W. G., “Modeling of Toxicological of Fire Gases: III. Quantification of Post-Exposure Lethality of Rats from Exposure to HCl Atmospheres,” *J. Fire Sciences*, Vol. 3, No. 3, pp. 195-207 (1985).

[15] Hartzell, G. E., Stacy, H. W., Switzer, W. G., and Priest, D. N., “Modeling of Toxicological of Fire Gases: V. Mathematical Modeling of Intoxication of Rats by Combined Carbon Monoxide and Hydrogen Cyanide Atmospheres,” *J. Fire Sciences*, Vol. 3, No. 5, pp. 330-342

(1985).

[16] Hartzell, G. E. Grand, A. F., and Switzer, W. G., "Modeling of Toxicological of Fire Gases: VI. Further Studies on the Toxicity of Smoke Containing Hydrogen Chloride," *J. Fire Sciences*, Vol. 5, No. 6, pp. 368-391 (1987).

[17] Hartzell, G. E., Grand, A. F., and Switzer, W. G., "Modeling of Toxicological of Fire Gases: VII. Studies on Evaluation of Animal Models in Combustion Toxicology," *J. Fire Sciences*, Vol. 6, No. 6, pp. 411-431 (1988).

[18] Hartzell, G. E., Grand, A. F., and Switzer, W. G., "Studies on the Toxicity of Smoke Containing Hydrogen Chloride," Symposium on Fire and Polymers, American Chemical Society Meeting, Dallas, TX, April 10, 1989.

[19] Hartzell, G. E. and Emmons, H. W., "The Fractional Effective Dose Model for Assessment of Hazards Due to Smoke from Materials," *J. Fire Sciences*, Vol. 6, No. 5, pp. 356-362 (1988).

[20] Clarke, F. B., van Kuijk, H., Valentine, R., Makovec, G. T., Seidel, W. C., Baker, B. B., Kasprzak, D. J., Bonesteel, J. K., Janssens, M., and Herpol, C. H., "The Toxicity of Smoke from Fires Involving Perfluoropolymers: Full-Scale Fire Studies," *J. Fire Sciences*, Vol. 10, No. 6, pp. 488-527 (1992).

[21] Braun, E., Gann, R. G., Levin, B. C., and Paabo, M., "Combustion Product Toxic Potency Measurements: Comparison of a Small-Scale Test and 'Real-World' Fire," *J. Fire Sciences*, Vol. 8, No. 1, pp. 63-79 (1990).

[22] Brown, E., "Additional Real Scale Data for Smoke Toxicity Analysis," National Institute of Standards and Technology, Gaithersburg, MD (1994).

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 ASTM Publication.

American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM E 800, *Standard Guide for Measurement of Gases Present or Generated During Fires*, 1995.

C-1.2 ISO Publication.

American National Standards Institute, 11 West 42nd Street, New York, NY 10036.

ISO/TR 9122 (Parts 1-5) *Toxicity Testing of Fire Effluents*, Part 1, 1989; Part 2, 1990; Parts 3-5, 1993.

NFPA 291

1995 Edition

Recommended Practice for Fire Flow Testing and Marking of Hydrants

1995 Edition

This edition of NFPA 291, *Recommended Practice for Fire Flow Testing and Marking of Hydrants*, was prepared by the Technical Committee on Private Water Supply Piping Systems 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 291 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 291

The NFPA Committee on Public Water Supplies for Private Fire Protection presented the idea of indicating the relative available fire service water supply from hydrants in its 1934 report. The Committee felt then and feels now that such an indication is of substantial value to water and fire departments. The following recommendations were initially adopted in 1935. The Committee agreed that tests of individual hydrants did not give as complete and satisfactory results as group testing but expressed the opinion that tests of individual hydrants did have sufficient value to make the following recommendations worthy of adoption. This was reconfirmed with minor editorial changes in 1974.

The 1977 edition was completely rewritten and a chapter on the flow testing of hydrants was added.

The 1982 edition had been reconfirmed by the committee. The 1988 edition of the document noted several changed which clarified and reinforced certain recommendations. Specific guidance was added on the correct method of utilizing a Pitot tube to gain accurate test results.

The 1995 edition incorporated several changes in an attempt to make the document more user friendly. Changes were also incorporated with regard to the layout of hydrant and water flow tests.

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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.

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 private piping systems supplying water for fire protection and for hydrants, hose houses, and valves. The Committee is also responsible for documents on fire flow testing and marking of hydrants.

NFPA 291

Recommended Practice for Fire Flow Testing and Marking of Hydrants

1995 Edition

Chapter 1 General Information

1-1 Introduction.

Fire flow tests are conducted on water distribution systems to determine the rate of flow available at various locations for fire-fighting purposes. A certain residual pressure in the mains is specified at which the rate of flow should be available. Additional benefit is derived from fire flow tests by the indication of possible deficiencies (such as tuberculation of piping or closed valves or both) which could be corrected to ensure adequate fire flows as needed.

1-2 Definitions.

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.

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.

Rated Capacity. The flow available from a hydrant at the designated residual pressure (rated pressure), either measured or calculated.

Residual Pressure. The pressure that exists in the distribution system, measured at the residual hydrant at the time the flow readings are taken at the flow hydrants.

Should. Indicates a recommendation or that which is advised but not required.

Static Pressure. The pressure that exists at a given point under normal distribution system conditions measured at the residual hydrant with no hydrants flowing.

1-3 Units.

Metric units of measurement in this standard are 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 1-3 with conversion factors.

Table 1-3

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
bar	bar	1 bar = 10^5 Pa

For additional conversions and information, see ASTM E380-1989, *Standard for Metric Practice*.

1-3.1

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

Chapter 2 Flow Testing

2-1 Rating Pressure.

For the purpose of uniform marking of fire hydrants, the ratings should be based on a residual pressure of 20 psi (1.4 bar) for all hydrants having a static pressure in excess of 40 psi (2.8 bar). Hydrants having a static pressure of less than 40 psi (2.8 bar) should be rated at one-half of the static pressure.

It is generally recommended that a minimum residual pressure of 20 psi (1.4 bar) be maintained at hydrants when delivering the fire flow. Fire department pumpers can be operated where hydrant pressures are less, but with difficulty. Where hydrants are well distributed and of the proper size and type (so that friction losses in the hydrant and suction line are not excessive), it might be possible to set a lesser pressure as the minimum pressure. A primary concern should be the ability to maintain sufficient residual pressure to prevent developing a negative pressure at any point in the street mains, which could result in the collapse of the mains or other water system components or back-siphonage of polluted water from some other interconnected source. It should be noted that the use of residual pressures of less than 20 psi (1.4 bar) is not permitted by many state health departments.

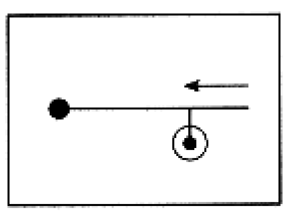
2-2 Procedure.

Tests should be made during a period of ordinary demand. The procedure consists of discharging water at a measured rate of flow from the system at a given location and observing the corresponding pressure drop in the mains.

2-3 Layout of Test.

After the location where the test is to be run has been determined, a group of test hydrants in the vicinity is selected. Once selected, due consideration should be given to potential interference with traffic flow patterns, damage to surroundings (e.g., roadways, sidewalks, landscapes, vehicles, and pedestrians), and potential flooding problems both local and remote from the test site. One hydrant, designated the residual hydrant, is chosen to be the hydrant where the normal static pressure will be observed with the other hydrants in the group closed, and where the residual pressure will be observed with the other hydrants flowing. This hydrant is chosen so it will be located between the hydrant to be flowed and the large mains that constitute the immediate sources of water supply in the area. In Figure 2-3, a test layout is indicated, showing the residual hydrant by means of a circle.

The number of hydrants to be used in any test depends upon the strength of the distribution system in the vicinity of the test location. To obtain satisfactory test results of theoretical calculation of expected flows or rated capacities, sufficient discharge should be achieved to cause a drop in pressure at the residual hydrant of at least 25 percent, or to flow the total demand necessary for fire-fighting purposes. If the mains are small and the system weak, only one or two hydrants need to be flowed. If, on the other hand, the mains are large and the system strong, it may be necessary to flow as many as seven or eight hydrants.
It is preferable to flow water past the residual hydrant.



Note: Circles drawn about residual hydrant.
Arrow denotes flow direction in main.

Suggested test layout for hydrants.

(Copyright, Insurance Services Office, 1963)

2-4 Equipment.

The equipment necessary for field work consists of a single 200-psi (14-bar) bourdon pressure gauge with 1-psi (0.0689 bar) graduations, a number of Pitot tubes, hydrant wrenches, 50- or

60-psi (3.5- or 4.0-bar) bourdon pressure gauges with $^1/_2$-psi (0.03445 bar) graduations, and scales with $^1/_{16}$-in. (1.6-mm) graduations (one Pitot tube, a 50- or 60-psi [3.5- or 4.0-bar] gauge, a hydrant wrench, and a scale for each hydrant to be flowed), and a special hydrant cap tapped with a hole into which a short length of $^1/_4$-in. (6.35-mm) brass pipe is fitted. This pipe is provided with a T connection for the 200-psi (14-bar) gauge and a cock at the end for relieving air pressure. All pressure gauges should be calibrated at least every 12 months, or more frequently depending on use. When more than one hydrant is flowed, it may be desirable and necessary to use portable radios to facilitate communication between team members.

It is preferred to use an Underwriter's Playpipe, or other stream straightener, when testing hydrants due to a more streamlined flow and more accurate pitot reading.

2-5 Test Procedure.

In a typical test, the 200-psi (14 bar) gauge is attached to one of the $2^1/_2$-in. (6.4-cm) outlets of the residual hydrant using the special cap, the cock on the gauge piping is opened, and the hydrant valve is opened full. As soon as the air is exhausted from the barrel, the cock is closed. A reading (static pressure) is taken when the needle comes to rest. At a given signal each of the other hydrants is opened in succession, with discharge taking place directly from the open hydrant butts. Hydrants should be opened one at a time. With all hydrants flowing, water should be allowed to flow for a sufficient time to clear all debris and foreign substances from the stream(s). At that time, a signal is given to the people at the hydrants to read the Pitot pressure of the streams simultaneously while the residual pressure is being read. The final magnitude of the pressure drop can be controlled by the number of hydrants used and the number of outlets opened on each.

After the readings have been taken, hydrants should be shut down slowly, one at a time, to prevent undue surges in the system.

2-6 Pitot Readings.

When measuring discharge from open hydrant butts, it is always preferable from the standpoint of accuracy to use $2^1/_2$-in. (6.4-cm) outlets rather than pumper outlets. In practically all cases, the $2^1/_2$-in. (6.4-cm) outlets are filled across the entire cross section during flow, while in the case of the larger outlets there is very frequently a void near the bottom. When measuring the Pitot pressure of a stream of practically uniform velocity, the orifice in the Pitot tube is held downstream approximately one-half the diameter of the hydrant outlet or nozzle opening, and in the center of the stream. The center line of the orifice should be at right angles to the plane of the face of the hydrant outlet. The air chamber on the Pitot tube should be kept elevated. Pitot readings of less than 10 psi (.7 bar) and more than 30 psi (2.0 bar) should be avoided, if possible. Opening additional hydrant outlets will aid in controlling the Pitot reading. With dry barrel hydrants, the hydrant valve should be wide open. This minimizes problems with underground drain valves. With wet barrel hydrants, the valve for the flowing outlet should be wide open. This gives a more streamlined flow and a more accurate Pitot reading. (*See Figure 2-6.*)

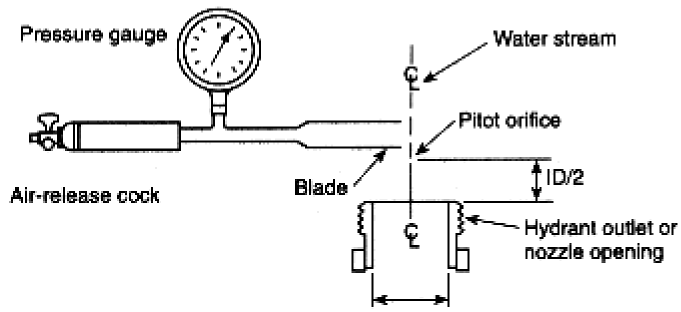


Figure 2-6 Pitot tube position.

2-7 Determination of Discharge.

At the hydrants used for flow during the test, the discharges from the open butts are determined from measurements of the diameter of the outlets flowed, the pitot pressure (velocity head) of the streams as indicated by the Pitot gauge readings, and the coefficient of the outlet being flowed as determined from Figure 2-7. If flow tubes (stream straighteners) are being utilized, a coefficient of 0.95 is suggested unless the coefficient of the tube is known.

The formula used to compute the discharge, Q, in gpm from these measurements is:

$$Q = 29.83\, cd^2\sqrt{P} \qquad \text{(a)}$$

where c is the coefficient of discharge (*see Figure 2-7*),

d the diameter of the outlet in inches, and

p the pitot pressure (velocity head) in psi.

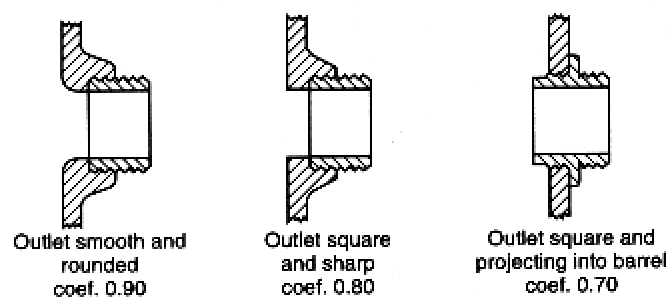


Figure 2-7 Three general types of hydrant outlets and their coefficients of discharge.

2-8 Use of Pumper Outlets.

If it is necessary to use a pumper outlet, and flow tubes (stream straighteners) are not available, the best results are obtained with the pitot pressure (velocity head) maintained between 5 psi and 10 psi (.3 bar and .7 bar). For pumper outlets, the approximate discharge can be computed from equation (a) using the pitot pressure (velocity head) at the center of the stream and multiplying the result by one of the coefficients in Table 2-8, depending upon the pitot pressure (velocity head). These coefficients are applied in addition to the coefficient in equation (a) and are for average type hydrants.

Table 2-8 Pumper Outlet Coefficients

Pitot Pressure (Velocity Head)	Coefficient
2 psi (0.14 bar)	0.97
3 psi (0.21 bar)	0.92
4 psi (0.28 bar)	0.89
5 psi (0.35 bar)	0.86
6 psi (0.41 bar)	0.84
7 psi (0.48 bar) and over	0.83

2-9 Determination of Discharge Without a Pitot.

If a Pitot tube is not available for use to measure the hydrant discharge, a 50- or 60-psi (3.5 or 4.0 bar) gauge tapped into a hydrant cap may be used. The hydrant cap with gauge attached is placed on one outlet, and the flow is allowed to take place through the other outlet at the same elevation. The readings obtained from a gauge so located, and the readings obtained from a gauge on a Pitot tube held in the stream, are approximately the same.

2-10 Calculation Results.

2-10.1

The discharge in gpm (L/min) for each outlet flowed is obtained from the discharge tables in 2-10.1 or by the use of formula (a). If more than one outlet is used, the discharges from all are added to obtain the total discharge.

The formula which is generally used to compute the discharge at the specified residual pressure or for any desired pressure drop is formula (b):

$$Q_R = Q_F \times \frac{h_r^{0.54}}{h_f^{0.54}} \qquad \text{(b)}$$

Q_R = flow predicted at desired residual pressure

Q_F = total flow measured during test

h_r = pressure drop to desired residual pressure

h_f = pressure drop measured during test

In this equation, any units of discharge or pressure drop may be used as long as the same units are used for each value of the same variable. In other words, if Q_R is expressed in gpm, Q_F must be in gpm, and if h_r is expressed in psi, h_f must be expressed in psi. These are the units which are normally used in applying formula (b) to fire flow test computations.

Pitot Pressure psi[1] (kPa)	Feet[2] (m)	Velocity Discharge, ft/sec (m/s)	2 (51)	2¼ (57)	2⅜ (60)	2½ (64)	2⅝ (67)	2¾ (70)	3 (76)	3¼ (83)	3½ (89)	3¾ (95)	4 (101)	4½ (114)
1 (6.89)	2.31 (0.70)	12.20 (3.72)	119 (451)	151 (571)	168 (637)	187 (705)	206 (778)	226 (854)	269 (1020)	315 (1190)	366 (1390)	420 (1590)	478 (1810)	604 (2290)
2 (13.8)	4.61 (1.41)	17.25 (5.26)	169 (639)	214 (808)	238 (900)	264 (1000)	291 (1100)	319 (1210)	380 (1440)	446 (1690)	517 (1960)	594 (2250)	676 (2560)	854 (3230)
3 (20.7)	6.92 (2.11)	21.13 (6.44)	207 (782)	262 (990)	292 (1100)	323 (1220)	356 (1350)	391 (1480)	465 (1760)	546 (2070)	633 (2400)	727 (2750)	827 (3130)	1045 (3960)
4 (27.6)	9.23 (2.81)	24.39 (7.43)	239 (930)	302 (1140)	337 (1280)	373 (1410)	411 (1560)	452 (1710)	537 (2030)	631 (2390)	731 (2770)	840 (3180)	955 (3610)	1210 (4570)
5 (34.5)	11.54 (3.52)	27.26 (8.31)	267 (1010)	338 (1280)	376 (1420)	417 (1580)	460 (1740)	505 (1910)	601 (2270)	705 (2670)	817 (3090)	938 (3550)	1068 (4040)	1350 (5110)
6 (41.4)	13.84 (4.22)	29.87 (9.10)	292 (1110)	370 (1400)	412 (1560)	457 (1730)	504 (1910)	553 (2090)	658 (2490)	772 (2920)	896 (3390)	1028 (3890)	1170 (4420)	1480 (5600)
7 (48.3)	16.15 (4.92)	32.26 (9.83)	316 (1190)	400 (1510)	445 (1680)	494 (1870)	544 (2060)	597 (2260)	711 (2690)	834 (3160)	967 (3660)	1111 (4210)	1263 (4780)	1600 (6050)
8 (55.2)	18.46 (5.63)	34.49 (10.51)	338 (1280)	427 (1620)	476 (1800)	528 (2000)	582 (2200)	638 (2410)	760 (2880)	892 (3380)	1034 (3910)	1187 (4490)	1351 (5110)	1710 (6470)
9 (62.0)	20.76 (6.33)	36.58 (11.15)	358 (1360)	453 (1710)	505 (1910)	560 (2120)	617 (2340)	677 (2560)	806 (3050)	946 (3580)	1097 (4150)	1259 (4770)	1433 (5420)	1815 (6860)
10 (68.9)	23.07 (7.03)	38.56 (11.75)	378 (1430)	478 (1810)	532 (2010)	590 (2230)	650 (2460)	714 (2700)	850 (3220)	997 (3770)	1156 (4380)	1327 (5020)	1510 (5710)	1910 (7230)
11 (75.8)	25.38 (7.73)	40.45 (12.33)	396 (1500)	501 (1900)	553 (2110)	619 (2340)	682 (2580)	759 (2830)	891 (3370)	1046 (3960)	1213 (4590)	1392 (5270)	1584 (5990)	2010 (7580
12 (82.7)	27.68 (8.44)	42.24 (12.87)	414 (1560)	524 (1980)	583 (2210)	646 (2450)	712 (2690)	782 (2960)	931 (3520)	1092 (4130)	1267 (4800)	1454 (5500)	1655 (6260)	2100 (7920
13 (89.6)	29.99 (9.14)	43.97 (13.40)	431 (1630)	545 (2060)	607 (2300)	673 (2550)	741 (2800)	814 (3080)	969 (3670)	1137 (4300)	1318 (4990)	1515 (5730)	1722 (6520)	2180 (8240
14 (96.5)	32.30 (9.84)	45.63 (13.91)	447 (1690)	566 (2140)	630 (2380)	698 (2640)	769 (2910)	845 (3200)	1005 (3800)	1180 (4470)	1368 (5180)	1572 (5950)	1787 (6760)	2260 (8550
15 (103)	34.61 (10.55)	47.22 (14.39)	463 (1750)	586 (2220)	652 (2470)	722 (2730)	796 (3010)	874 (3310)	1040 (3940)	1221 (4620)	1416 (5360)	1626 (6150)	1849 (7000)	2340 (8850
16 (110)	36.91 (11.25)	48.78 (14.87)	478 (1810)	605 (2290)	673 (2550)	746 (2820)	822 (3110)	903 (3420)	1075 (4070)	1261 (4770)	1463 (5540)	1679 (6360)	1910 (7230)	2420 (9140
17 (117)	39.22 (11.95)	50.28 (15.33)	493 (1870)	623 (2360)	694 (2630)	769 (2910)	848 (3210)	931 (3520)	1108 (4190)	1300 (4920)	1508 (5710)	1731 (6550)	1969 (7540)	2500 (9430
18 (124)	41.53 (12.66)	51.73 (15.77)	507 (1920)	642 (2430)	714 (2700)	791 (2990)	872 (3300)	958 (3630)	1140 (4310)	1338 (5060)	1551 (5870)	1781 (6740)	2026 (7670)	2570 (9700
19 (131)	43.83 (13.36)	53.15 (16.20)	521 (1970)	659 (2490)	733 (2770)	813 (3080)	896 (3390)	984 (3720)	1171 (4430)	1374 (5200)	1594 (6030)	1830 (6920)	2082 (7870)	2640 (9970
20 (138)	46.14 (14.06)	54.54 (16.62)	534 (2020)	676 (2560)	753 (2850)	834 (3160)	920 (3480)	1010 (3820)	1201 (4540)	1410 (5330)	1635 (6180)	1877 (7100)	2136 (8080)	2710 (10200
22 (152)	50.75 (15.47)	57.19 (17.43)	560 (2120)	709 (2680)	789 (2990)	875 (3310)	964 (3650)	1059 (4000)	1260 (4770)	1479 (5590)	1715 (6490)	1969 (7540)	2240 (8470)	2840 (10700
24 (165)	55.37 (16.88)	59.74 (18.21)	585 (2210)	741 (2800)	824 (3120)	914 (3460)	1007 (3810)	1106 (4180)	1316 (4980)	1545 (5840)	1791 (6770)	2056 (7780)	2340 (8850)	2970 (1120
26 (179)	59.98 (18.28)	62.18 (18.95)	609 (2300)	771 (2910)	858 (3250)	951 (3600)	1048 (3970)	1151 (4350)	1370 (5180)	1608 (6080)	1864 (7050)	2140 (8100)	2435 (9210)	3090 (1170
28 (193)	64.60 (19.69)	64.52 (19.67)	632 (2390)	800 (3020)	890 (3370)	987 (3730)	1088 (4120)	1194 (4520)	1422 (5380)	1668 (6310)	1935 (7320)	2221 (8400)	2527 (9560)	3210 (1210
30 (207)	69.21 (21.10)	66.79 (20.36)	654 (2470)	828 (3130)	922 (3490)	1022 (3860)	1126 (4260)	1236 (4680)	1472 (5570)	1727 (6530)	2003 (7570)	2299 (8700)	2616 (9890)	3320 (1250
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2702 (10200)	3430 (1290
34 (234)	78.44 (23.91)	71.10 (21.67)	697 (2640)	882 (3340)	981 (3710)	[illegible] (4120)	[illegible] (4540)	[illegible] (4980)	[illegible] (5930)	[illegible] (6960)	[illegible] (8070)	[illegible] (9270)	2785 (10540)	3540 (1330
36 (248)	83.05 (25.31)	73.16 (22.30)	717 (2710)	908 (3440)	1010 (3820)	1119 (4240)	1233 (4670)	1354 (5120)	1612 (6100)	1892 (7160)	2194 (8300)	2519 (9530)	2866 (10850)	3640 (1380

Pitot Pressure psi[1] (kPa)	Feet[2] (m)	Velocity Discharge, ft/sec (m/s)	2 (51)	2¼ (57)	2⅜ (60)	2½ (64)	2⅝ (67)	2¾ (70)	3 (76)	3¼ (83)	3½ (89)	3¾ (95)	4 (101)	4½ (114)
38 (262)	87.67 (26.72)	75.17 (22.91)	736 (2790)	932 (3530)	1037 (3930)	1150 (4350)	1267 (4800)	1392 (5270)	1656 (6270)	1944 (7360)	2254 (8530)	2588 (9800)	2944 (11140)	3740 (14100)
40 (276)	92.28 (28.13)	77.11 (23.50)	755 (2860)	956 (3620)	1064 (4030)	1180 (4470)	1300 (4920)	1428 (5400)	1699 (6430)	1994 (7550)	2313 (8750)	2655 (10050)	3021 (11430)	3840 (14500)
42 (290)	96.89 (29.53)	79.03 (24.09)	774 (2930)	980 (3710)	1091 (4130)	1209 (4580)	1332 (5040)	1463 (5540)	1741 (6590)	2043 (7730)	2370 (8970)	2721 (10300)	3095 (11710)	3935 (14800)
44 (303)	101.51 (30.94)	80.88 (24.65)	792 (3000)	1003 (3800)	1116 (4220)	1237 (4680)	1364 (5160)	1497 (5670)	1782 (6740)	2091 (7910)	2426 (9180)	2785 (10540)	3168 (11990)	4030 (15200)
46 (317)	106.12 (32.35)	82.70 (25.21)	810 (3070)	1025 (3880)	1141 (4320)	1265 (4790)	1394 (5280)	1531 (5790)	1822 (6900)	2138 (8090)	2480 (9390)	2847 (10780)	3239 (12260)	4120 (15500)
48 (331)	110.74 (33.75)	84.48 (25.75)	828 (3130)	1047 (3960)	1166 (4410)	1293 (4890)	1424 (5390)	1564 (5920)	1861 (7040)	2184 (8270)	2533 (9587)	2908 (11010)	3309 (12520)	4205 (15800)
50 (345)	115.35 (35.16)	86.22 (26.28)	845 (3200)	1069 (4050)	1190 (4500)	1319 (4990)	1454 (5500)	1596 (6040)	1900 (7190)	2229 (8440)	2586 (9790)	2968 (11230)	3377 (12780)	4290 (16200)
52 (358)	119.96 (36.57)	87.93 (26.80)	861 (3260)	1091 (4130)	1213 (4590)	1345 (5090)	1482 (5610)	1628 (6160)	1937 (7330)	2274 (8610)	2637 (9980)	3027 (11460)	3444 (13040)	4375 (16500)
54 (372)	124.58 (37.97)	89.61 (27.31)	878 (3320)	1111 (4200)	1237 (4680)	1371 (5190)	1511 (5720)	1659 (6280)	1974 (7470)	2317 (8770)	2687 (10170)	3085 (11680)	3510 (13290)	4460 (16800)
56 (386)	129.19 (39.38)	91.20 (27.80)	894 (3380)	1132 (4280)	1259 (4770)	1396 (5280)	1538 (5820)	1689 (6390)	2010 (7610)	2359 (8930)	2736 (10360)	3141 (11890)	3574 (13530)	4540 (17100)
58 (400)	133.81 (40.78)	92.87 (28.31)	909 (3440)	1152 (4350)	1282 (4850)	1421 (5370)	1566 (5920)	1719 (6500)	2046 (7740)	2401 (9080)	2785 (10530)	3197 (12090)	3637 (13760)	4620 (17400)
60 (414)	138.42 (42.19)	94.45 (28.79)	925 (3500)	1171 (4430)	1303 (4930)	1445 (5460)	1592 (6030)	1749 (6610)	2081 (7870)	2442 (9240)	2832 (10710)	3252 (12300)	3700 (13990)	4700 (17700)
62 (427)	143.03 (43.60)	96.01 (29.26)	941 (3560)	1191 (4500)	1325 (5010)	1470 (5560)	1619 (6130)	1777 (6720)	2115 (8000)	2483 (9390)	2879 (10890)	3305 (12500)	3761 (14220)	4775 (18000)
64 (441)	147.65 (45.00)	97.55 (29.73)	956 (3610)	1210 (4570)	1346 (5090)	1493 (5640)	1645 (6220)	1806 (6830)	2149 (8130)	2522 (9540)	2925 (11060)	3358 (12700)	3821 (14450)	4850 (18300)
66 (455)	152.26 (46.41)	99.07 (30.20)	971 (3670)	1228 (4640)	1367 (5170)	1516 (5730)	1670 (6320)	1834 (6940)	2183 (8260)	2561 (9690)	2971 (11240)	3410 (12900)	3880 (14680)	4925 (18600)
68 (469)	156.88 (47.82)	100.55 (30.65)	985 (3720)	1247 (4710)	1388 (5250)	1539 (5820)	1695 (6420)	1862 (7040)	2215 (8380)	2600 (9830)	3015 (11400)	3462 (13090)	3938 (14900)	5000 (18900)
70 (483)	161.49 (49.22)	102.03 (31.10)	999 (3780)	1265 (4780)	1408 (5330)	1561 (5900)	1720 (6510)	1889 (7140)	2248 (8500)	2638 (9980)	3059 (11570)	3512 (13280)	3996 (15110)	5075 (19100)
72 (496)	166.10 (50.63)	103.47 (31.54)	1014 (3830)	1283 (4850)	1428 (5400)	1583 (5990)	1745 (6600)	1916 (7250)	2280 (8620)	2675 (10120)	3103 (11730)	3562 (13470)	4053 (15330)	5140 (19400)
74 (510)	170.72 (52.03)	104.90 (31.97)	1028 (3880)	1301 (4920)	1448 (5480)	1605 (6070)	1769 (6690)	1942 (7350)	2311 (8740)	2712 (10260)	3146 (11900)	3611 (13660)	4109 (15540)	5200 (19700)
76 (524)	175.33 (53.44)	106.30 (32.71)	1041 (3940)	1318 (4980)	1467 (5550)	1627 (6150)	1792 (6780)	1968 (7440)	2342 (8860)	2749 (10400)	3188 (12060)	3660 (13840)	4164 (15750)	5265 (19900)
78 (538)	179.95 (54.85)	107.69 (32.82)	1055 (3990)	1335 (5050)	1486 (5620)	1648 (6230)	1816 (6870)	1994 (7540)	2373 (8970)	2785 (10530)	3230 (12210)	3708 (14020)	4218 (15950)	5340 (20200)
80 (552)	184.56 (56.25)	109.08 (33.25)	1068 (4040)	1352 (5110)	1505 (5690)	1669 (6310)	1839 (6960)	2019 (7640)	2403 (9090)	2820 (10670)	3271 (12370)	3755 (14200)	4272 (16160)	5405 (20400)
82 (565)	189.17 (57.66)	110.42 (33.66)	1082 (4090)	1369 (5180)	1524 (5770)	1689 (6390)	1862 (7040)	2044 (7730)	2433 (9200)	2855 (10800)	3311 (12520)	3801 (14380)	4325 (16360)	5470 (20700)
84 (579)	193.79 (59.07)	111.76 (34.06)	1095 (4140)	1386 (5240)	1542 (5840)	1710 (6466)	1884 (7130)	2069 (7830)	2462 (9310)	2890 (10930)	3351 (12670)	3847 (14550)	4377 (16560)	5535 (21000)
86 (593)	198.40 (60.47)	113.08 (34.47)	1170 (4190)	1402 (5300)	1561 (5900)	1730 (6540)	1907 (7210)	2094 (7920)	2491 (9420)	2924 (11070)	3391 (12820)	3893 (14720)	4429 (16750)	5600 (21200)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4480 (16950)	5665 (21400)
[illegible] (620)	[illegible] (63.29)	[illegible] (35.26)	[illegible] (4280)	[illegible] (5420)	[illegible] (6040)	[illegible] (6690)	[illegible] (7380)	[illegible] (8100)	[illegible] (9640)	[illegible] (11310)	[illegible] (13120)	[illegible] (15060)	4531 (17140)	5730 (21700)
92 (634)	212.24 (64.69)	116.96 (35.65)	1146 (4330)	1450 (5480)	1614 (6110)	1789 (6770)	1972 (7460)	2165 (8190)	2577 (9750)	3024 (11440)	3507 (13260)	4027 (15230)	4581 (17330)	5795 (21900)

Table 2-10.1 Theoretical Discharge Through Circular Orifices (United States Gallons of Water per Minute) (See Notes)

Pitot Pressure psi[1] (kPa)	Feet[2] (m)	Velocity Discharge, ft/sec (m/s)	2 (51)	2 1/4 (57)	2 3/8 (60)	2 1/2 (64)	2 5/8 (67)	2 3/4 (70)	3 (76)	3 1/4 (83)	3 1/2 (89)	3 3/4 (95)	4 (101)	4 1/2 (114)
94	216.86	118.23	1158	1466	1632	1809	1993	2189	2605	3057	3545	4070	4631	5865
(648)	(66.10)	(36.04)	(4380)	(5540)	(6170)	(6840)	(7540)	(8280)	(9850)	(11560)	(13410)	(15390)	(17510)	(22200
96	221.47	119.48	1170	1481	1649	1828	2014	2212	2632	3089	3583	4113	4680	5925
(662)	(67.50)	(36.42)	(4420)	(5600)	(6240)	(6910)	(7620)	(8370)	(9960)	(11680)	(13550)	(15560)	(17700)	(22400
98	226.09	120.71	1182	1497	1666	1847	2035	2235	2660	3121	3620	4156	4728	5985
(676)	(68.91)	(36.79)	(4470)	(5660)	(6300)	(6980)	(7700)	(8450)	(10060)	(11810)	(13690)	(15720)	(17880)	(22600
100	230.70	121.94	1194	1512	1683	1866	2056	2258	2687	3153	3657	4198	4776	6045
(689)	(70.32)	(37.17)	(4520)	(5720)	(6370)	(7050)	(7780)	(8540)	(10160)	(11930)	(13830)	(15880)	(18060)	(22900
102	235.31	123.15	1206	1527	1699	1884	2076	2280	2713	3184	3693	4240	4824	6100
(703)	(71.72)	(37.54)	(4560)	(5770)	(6430)	(7130)	(7860)	(8620)	(10260)	(12040)	(13970)	(16040)	(18240)	(23100
104	239.93	124.35	1218	1542	1716	1903	2097	2302	2740	3215	3729	4281	4871	6150
(717)	(73.13)	(37.90)	(4610)	(5830)	(6490)	(7190)	(7930)	(8710)	(10360)	(12160)	(14100)	(16190)	(18420)	(23300
106	244.54	125.55	1230	1556	1733	1921	2117	2324	2766	3246	3765	4322	4917	6200
(731)	(74.54)	(38.27)	(4650)	(5890)	(6560)	(7260)	(8010)	(8790)	(10460)	(12280)	(14240)	(16350)	(18600)	(23500)
108	249.16	126.73	1241	1571	1749	1939	2137	2346	2792	3277	3800	4363	4963	6260
(745)	(75.94)	(38.63)	(4690)	(5940)	(6620)	(7330)	(8080)	(8870)	(10560)	(12390)	(14370)	(16500)	(18770)	(23800)
110	253.77	127.89	1253	1586	1765	1957	2156	2368	2818	3307	3835	4403	5009	6320
(758)	(77.35)	(38.98)	(4640)	(6000)	(6680)	(7400)	(8160)	(8960)	(10660)	(12510)	(14500)	(16650)	(18950)	(24000)
112	258.38	129.05	1264	1600	1781	1974	2176	2389	2843	3337	3870	4443	5054	6380
(772)	(78.76)	(39.33)	(4780)	(6050)	(6740)	(7470)	(8230)	(9040)	(10750)	(12620)	(14640)	(16800)	(19120)	(24200)
114	263.00	130.20	1275	1614	1797	1992	2195	2410	2869	3367	3904	4482	5099	6440
(786)	(80.16)	(39.68)	(4820)	(6100)	(6800)	(7530)	(8310)	(9120)	(10850)	(12730)	(14770)	(16950)	(19290)	(24400)
116	267.61	131.33	1286	1628	1812	2009	2214	2431	2894	3396	3938	4521	5144	6500
(800)	(81.57)	(40.03)	(4860)	(6160)	(6860)	(7600)	(8380)	(9200)	(10940)	(12840)	(14890)	(17100)	(19460)	(24600)
118	272.23	132.46	1297	1642	1828	2027	2233	2452	2918	3425	3972	4560	5188	6560
(813)	(82.97)	(40.37)	(4910)	(6210)	(6920)	(7660)	(8450)	(9280)	(11040)	(12950)	(15020)	(17250)	(19620)	(24800)
120	276.84	133.57	1308	1656	1843	2044	2252	2473	2943	3454	4006	4599	5232	6620
(827)	(84.38)	(40.71)	(4950)	(6260)	(6970)	(7730)	(8520)	(9350)	(11130)	(13060)	(15150)	(17390)	(19790)	(25000)
122	281.45	134.69	1319	1670	1859	2061	2271	2494	2967	3483	4039	4637	5275	6680
(841)	(85.79)	(41.05)	(4990)	(6310)	(7030)	(7790)	(8590)	(9430)	(11220)	(13170)	(15270)	(17540)	(19950)	(25300)
124	286.07	135.79	1330	1684	1874	2077	2289	2514	2992	3511	4072	4675	5318	6740
(855)	(87.19)	(41.39)	(5030)	(6370)	(7090)	(7860)	(8660)	(9510)	(11320)	(13280)	(15400)	(17680)	(20120)	(25500)
126	290.68	136.88	1341	1697	1889	2094	2308	2534	3016	3539	4105	4712	5361	6800
(869)	(88.60)	(41.72)	(5070)	(6420)	(7150)	(7920)	(8730)	(9580)	(11410)	(13390)	(15520)	(17820)	(20280)	(25700)
128	295.30	137.96	1351	1711	1904	2111	2326	2554	3040	3567	4137	4749	5403	6850
(882)	(90.01)	(42.05)	(5110)	(6470)	(7200)	(7980)	(8800)	(9660)	(11500)	(13490)	(15650)	(17960)	(20440)	(25900)
130	299.91	139.03	1362	1724	1919	2127	2344	2574	3063	3595	4169	4786	5445	6900
(896)	(91.41)	(42.38)	(5150)	(6520)	(7260)	(8040)	(8870)	(9740)	(11590)	(13600)	(15770)	(18100)	(20600)	(26100)
132	304.52	140.10	1372	1736	1933	2144	2362	2594	3087	3623	4201	4823	5487	6950
(910)	(92.82)	(42.70)	(5190)	(6570)	(7320)	(8110)	(8940)	(9810)	(11670)	(13700)	(15890)	(18240)	(20750)	(26300)
134	309.14	141.16	1382	1749	1948	2160	2380	2613	3110	3650	4233	4860	5529	7000
(924)	(94.23)	(43.03)	(5230)	(6620)	(7370)	(8170)	(9010)	(9880)	(11760)	(13800)	(16010)	(18380)	(20910)	(26500)
136	313.75	142.21	1392	1762	1962	2176	2398	2633	3133	3677	4625	4896	5570	7050
(938)	(95.63)	(43.35)	(5270)	(6670)	(7430)	(8230)	(9070)	(9960)	(11850)	(13910)	(16130)	(18520)	(21070)	(26700)

* 1 psi—2.307 ft of water. 1 kPa—0.102 m of water. For pressure in bars, multiply by 0.01.

Notes to Table 2-10.1

Note 1. This corresponds to velocity head.

Note 2. This table is computed from the formula $Q = 29.83cd^2\sqrt{p}$ ($Q_m = 0.0666cd^2\sqrt{p_m}$) with $c = 1.00$. The theoretical discharge of sea water, as from fire-boat nozzles, can be found by subtracting 1 percent from the figures in the following table, or from the formula $Q = 29.83cd^2\sqrt{p}$ ($Q_m = 0.065cd^2m\ p_m$).

Appropriate coefficient should be applied where it is read from hydrant outlet. Where more accurate results are required, a coefficient appropriate on the particular nozzle must be selected and applied to the figures of the table.

tity discharged under

Pitot Pressure psi[1] (kPa)	Feet[2] (m)	Velocity Discharge, ft/sec (m/s)	2 (51)	2 1/4 (57)	2 3/8 (60)	2 1/2 (64)	2 5/8 (67)	2 3/4 (70)	3 (76)	3 (
1 (6.89)	2.31 (0.70)	12.20 (3.72)	119 (451)	151 (571)	168 (637)	187 (705)	206 (778)	226 (854)	269 (1020)	315
2 (13.8)	4.61 (1.41)	17.25 (5.26)	169 (639)	214 (808)	238 (900)	264 (1000)	291 (1100)	319 (1210)	380 (1440)	446
3 (20.7)	6.92 (2.11)	21.13 (6.44)	207 (782)	262 (990)	292 (1100)	323 (1220)	356 (1350)	391 (1480)	465 (1760)	546
4 (27.6)	9.23 (2.81)	24.39 (7.43)	239 (930)	302 (1140)	337 (1280)	373 (1410)	411 (1560)	452 (1710)	537 (2030)	631
5 (34.5)	11.54 (3.52)	27.26 (8.31)	267 (1010)	338 (1280)	376 (1420)	417 (1580)	460 (1740)	505 (1910)	601 (2270)	705
6 (41.4)	13.84 (4.22)	29.87 (9.10)	292 (1110)	370 (1400)	412 (1560)	457 (1730)	504 (1910)	553 (2090)	658 (2490)	772
7 (48.3)	16.15 (4.92)	32.26 (9.83)	316 (1190)	400 (1510)	445 (1680)	494 (1870)	544 (2060)	597 (2260)	711 (2690)	834
8 (55.2)	18.46 (5.63)	34.49 (10.51)	338 (1280)	427 (1620)	476 (1800)	528 (2000)	582 (2200)	638 (2410)	760 (2880)	892
9 (62.0)	20.76 (6.33)	36.58 (11.15)	358 (1360)	453 (1710)	505 (1910)	560 (2120)	617 (2340)	677 (2560)	806 (3050)	946
10 (68.9)	23.07 (7.03)	38.56 (11.75)	378 (1430)	478 (1810)	532 (2010)	590 (2230)	650 (2460)	714 (2700)	850 (3220)	997
11 (75.8)	25.38 (7.73)	40.45 (12.33)	396 (1500)	501 (1900)	553 (2110)	619 (2340)	682 (2580)	759 (2830)	891 (3370)	1 (3
12 (82.7)	27.68 (8.44)	42.24 (12.87)	414 (1560)	524 (1980)	583 (2210)	646 (2450)	712 (2690)	782 (2960)	931 (3520)	1092
13 (89.6)	29.99 (9.14)	43.97 (13.40)	431 (1630)	545 (2060)	607 (2300)	673 (2550)	741 (2800)	814 (3080)	969 (3670)	1 (4
14 (96.5)	32.30 (9.84)	45.63 (13.91)	447 (1690)	566 (2140)	630 (2380)	698 (2640)	769 (2910)	845 (3200)	1005 (3800)	1180
15 (103)	34.61 (10.55)	47.22 (14.39)	463 (1750)	586 (2220)	652 (2470)	722 (2730)	796 (3010)	874 (3310)	1040 (3940)	1 (4
16 (110)	36.91 (11.25)	48.78 (14.87)	478 (1810)	605 (2290)	673 (2550)	746 (2820)	822 (3110)	903 (3420)	1075 (4070)	1261
17 (117)	39.22 (11.95)	50.28 (15.33)	493 (1870)	623 (2360)	694 (2630)	769 (2910)	848 (3210)	931 (3520)	1108 (4190)	1 (4
18 (124)	41.53 (12.66)	51.73 (15.77)	507 (1920)	642 (2430)	714 (2700)	791 (2990)	872 (3300)	958 (3630)	1140 (4310)	1338
19 (131)	43.83 (13.36)	53.15 (16.20)	521 (1970)	659 (2490)	733 (2770)	813 (3080)	896 (3390)	984 (3720)	1171 (4430)	1 (5
20 (138)	46.14 (14.06)	54.54 (16.62)	534 (2020)	676 (2560)	753 (2850)	834 (3160)	920 (3480)	1010 (3820)	1201 (4540)	1410
22 (152)	50.75 (15.47)	57.19 (17.43)	560 (2120)	709 (2680)	789 (2990)	875 (3310)	964 (3650)	1059 (4000)	1260 (4770)	1 (5
24 (165)	55.37 (16.88)	59.74 (18.21)	585 (2210)	741 (2800)	824 (3120)	914 (3460)	1007 (3810)	1106 (4180)	1316 (4980)	1545

26 (179) 28 (193)	59.98 (18.28) 64.60 (19.69)	62.18 (18.95) 64.52 (19.67)	609 (2300) 632 (2390)	771 (2910) 800 (3020)	858 (3250) 890 (3370)	951 (3600) 987 (3730)	1048 (3970) 1088 (4120)	1151 (4350) 1194 (4520)	1370 (5180) 1422 (5380)	1 (6 1668
30 (207) 32 (221)	69.21 (21.10) 73.82 (22.50)	66.79 (20.36) 68.98 (21.03)	654 (2470) 676 (2550)	828 (3130) 856 (3230)	922 (3490) 952 (3600)	1022 (3860) 1055 (3990)	1126 (4260) 1163 (4400)	1236 (4680) 1277 (4830)	1472 (5570) 1520 (5750)	1 (6 1784
34 (234) 36 (248)	78.44 (23.91) 83.05 (25.31)	71.10 (21.67) 73.16 (22.30)	697 (2640) 717 (2710)	882 (3340) 908 (3440)	981 (3710) 1010 (3820)	1088 (4120) 1119 (4240)	1199 (4540) 1233 (4670)	1316 (4980) 1354 (5120)	1566 (5930) 1612 (6100)	1 (6 1892
38 (262) 40 (276)	87.67 (26.72) 92.28 (28.13)	75.17 (22.91) 77.11 (23.50)	736 (2790) 755 (2860)	932 (3530) 956 (3620)	1037 (3930) 1064 (4030)	1150 (4350) 1180 (4470)	1267 (4800) 1300 (4920)	1392 (5270) 1428 (5400)	1656 (6270) 1699 (6430)	1 (7 1994
42 (290) 44 (303)	96.89 (29.53) 101.51 (30.94)	79.03 (24.09) 80.88 (24.65)	774 (2930) 792 (3000)	980 (3710) 1003 (3800)	1091 (4130) 1116 (4220)	1209 (4580) 1237 (4680)	1332 (5040) 1364 (5160)	1463 (5540) 1497 (5670)	1741 (6590) 1782 (6740)	2 (7 2091
46 (317) 48 (331)	106.12 (32.35) 110.74 (33.75)	82.70 (25.21) 84.48 (25.75)	810 (3070) 828 (3130)	1025 (3880) 1047 (3960)	1141 (4320) 1166 (4410)	1265 (4790) 1293 (4890)	1394 (5280) 1424 (5390)	1531 (5790) 1564 (5920)	1822 (6900) 1861 (7040)	2 (8 2184
50 (345) 52 (358)	115.35 (35.16) 119.96 (36.57)	86.22 (26.28) 87.93 (26.80)	845 (3200) 861 (3260)	1069 (4050) 1091 (4130)	1190 (4500) 1213 (4590)	1319 (4990) 1345 (5090)	1454 (5500) 1482 (5610)	1596 (6040) 1628 (6160)	1900 (7190) 1937 (7330)	2 (8 2274
54 (372) 56 4540 (386)	124.58 (37.97) 129.19 (39.38)	89.61 (27.31) 91.20 (27.80)	878 (3320) 894 (3380)	1111 (4200) 1132 (4280)	1237 (4680) 1259 (4770)	1371 (5190) 1396 (5280)	1511 (5720) (5820)	1659 (6280) 1538	1974 (7470) 1689 (6390)	2 (8 20
58 (400) 60 4700 (414)	133.81 (40.78) 138.42 (42.19)	92.87 (28.31) 94.45 (28.79)	909 (3440) 925 (3500)	1152 (4350) 1171 (4430)	1282 (4850) 1303 (4930)	1421 (5370) 1445 (5460)	1566 (5920) (6030)	1719 (6500) 1592	2046 (7740) 1749 (6610)	2 (9 208
62 (427) 64 4850 (441)	143.03 (43.60) 147.65 (45.00)	96.01 (29.26) 97.55 (29.73)	941 (3560) 956 (3610)	1191 (4500) 1210 (4570)	1325 (5010) 1346 (5090)	1470 (5560) 1493 (5640)	1619 (6130) (6220)	1777 (6720) 1645	2115 (8000) 1806 (6830)	2 (9 214

66	152.26	99.07	971 (3670)	1228	1367	1516	1670	1834	2183	2
(455)	(46.41)	(30.20)	985 (3720)	(4640)	(5170)	(5730)	(6320)	(6940)	(8260)	(9
68	156.88	100.55		1247 (4710)	1388 (5250)	1539 (5820)		1695	1862 (7040)	22
5000										
(469)	(47.82)	(30.65)					(6420)			
70	161.49	102.03 (31.10)	999 (3780)	1265	1408	1561	1720	1889	2248	2
(483)	(49.22)	103.47 (31.54)	1014 (3830)	(4780)	(5330)	(5900)	(6510)	(7140)	(8500)	(9
72	166.10			1283 (4850)	1428 (5400)	1583 (5990)		1745	1916 (7250)	228
(496)	(50.63)						(6600)			(10
74	170.72	104.90 (31.97)	1028	1301	1448	1605	1769	1942	2311	2
(510)	(52.03)	106.30 (32.71)	(3880)	(4920)	(5480)	(6070)	(6690)	(7350)	(8740)	(10
76	175.33		1041 (3940)	1318 (4980)	1467 (5550)		1627 (6150)	1792	1968 (7440)	234
(524)	(53.44)						(6780)			(10
78	179.95	107.69 (32.82)	1055	1335	1486	1648	1816	1994	2373	2
(538)	(54.85)	109.08 (33.25)	(3990)	(5050)	(5620)	(6230)	(6870)	(7540)	(8970)	(10
80	184.56		1068 (4040)	1352 (5110)	1505 (5690)		1669 (6310)	1839	2019 (7640)	24
(552)	(56.25)						(6960)			(10
82	189.17	110.42 (33.66)	1082	1369	1524	1689	1862	2044	2433	2
(565)	(57.66)	111.76 (34.06)	(4090)	(5180)	(5770)	(6390)	(7040)	(7730)	(9200)	(10
84	193.79		1095 (4140)	1386 (5240)	1542 (5840)		1710 (6466)	1884	2069 (7830)	24
(579)	(59.07)						(7130)			(10
86	198.40	113.08 (34.47)	1170	1402	1561	1730	1907	2094	2491	2
(593)	(60.47)	114.39 (34.87)	(4190)	(5300)	(5900)	(6540)	(7210)	(7920)	(9420)	(11
88	203.02		1120 (4240)	1419 (5360)	1579 (5970)		1750 (6620)	1929	2118 (8010)	25
(607)	(61.88)						(7300)			(11
90	207.63	115.68 (35.26)	1133	1434	1596	1770	1950	2142	2549	2
(620)	(63.29)	116.96 (35.65)	(4280)	(5420)	(6040)	(6690)	(7380)	(8100)	(9640)	(11
92	212.24		1146 (4330)	1450 (5480)	1614 (6110)		1789 (6770)	1972	2165 (8190)	25
(634)	(64.69)						(7460)			(11
94	216.86	118.23 (36.04)	1158	1466	1632	1809	1993	2189	2605	3
(648)	(66.10)	119.48 (36.42)	(4380)	(5540)	(6170)	(6840)	(7540)	(8280)	(9850)	(11
96	221.47		1170 (4420)	1481 (5600)	1649 (6240)		1828 (6910)	2014	2212 (8370)	26
(662)	(67.50)						(7620)			(11
98	226.09	120.71 (36.79)	1182	1497	1666	1847	2035	2235	2660	3
(676)	(68.91)	121.94 (37.17)	(4470)	(5660)	(6300)	(6980)	(7700)	(8450)	(10060)	(11
100	230.70		1194 (4520)	1512 (5720)	1683 (6370)		1866 (7050)	2056	2258 (8540)	2
(689)	(70.32)						(7780)		(10160)	(11
102	235.31	123.15 (37.54)	1206	1527	1699	1884	2076	2280	2713	3
(703)	(71.72)	124.35 (37.90)	(4560)	(5770)	(6430)	(7130)	(7860)	(8620)	(10260)	(12

104 (717)	239.93 (73.13)		1218 (4610)	1542 (5830)	1716 (6490)		1903 (7190) (7930)	2097	2302 (8710) (10360)	2 (12
106 (731)	244.54 (74.54)	125.55 (38.27) 126.73 (38.63)	1230 (4650)	1556 (5890)	1733 (6560)	1921 (7260)	2117 (8010)	2324 (8790)	2766 (10460)	3 (12
108 (745)	249.16 (75.94)		1241 (4690)	1571 (5940)	1749 (6620)		1939 (7330) (8080)	2137	2346 (8870) (10560)	2 (12
110 (758)	253.77 (77.35)	127.89 (38.98) 129.05 (39.33)	1253 (4640)	1586 (6000)	1765 (6680)	1957 (7400)	2156 (8160)	2368 (8960)	2818 (10660)	3 (12
112 (772)	258.38 (78.76)		1264 (4780)	1600 (6050)	1781 (6740)		1974 (7470) (8230)	2176	2389 (9040) (10750)	2 (12
114 (786)	263.00 (80.16)	130.20 (39.68) 131.33 (40.03)	1275 (4820)	1614 (6100)	1797 (6800)	1992 (7530)	2195 (8310)	2410 (9120)	2869 (10850)	3 (12
116 (800)	267.61 (81.57)		1286 (4860)	1628 (6160)	1812 (6860)		2009 (7600) (8380)	2214	2431 (9200) (10940)	2 (12
118 (813)	272.23 (82.97)	132.46 (40.37) 133.57 (40.71)	1297 (4910)	1642 (6210)	1828 (6920)	2027 (7660)	2233 (8450)	2452 (9280)	2918 (11040)	3 (12
120 (827)	276.84 (84.38)		1308 (4950)	1656 (6260)	1843 (6970)		2044 (7730) (8520)	2252	2473 (9350) (11130)	2 (13
122 (841)	281.45 (85.79)	134.69 (41.05) 135.79 (41.39)	1319 (4990)	1670 (6310)	1859 (7030)	2061 (7790)	2271 (8590)	2494 (9430)	2967 (11220)	3 (13
124 (855)	286.07 (87.19)		1330 (5030)	1684 (6370)	1874 (7090)		2077 (7860) (8660)	2289	2514 (9510) (11320)	2 (13
126 (869)	290.68 (88.60)	136.88 (41.72) 137.96 (42.05)	1341 (5070)	1697 (6420)	1889 (7150)	2094 (7920)	2308 (8730)	2534 (9580)	3016 (11410)	3 (13
128 (882)	295.30 (90.01)		1351 (5110)	1711 (6470)	1904 (7200)		2111 (7980) (8800)	2326	2554 (9660) (11500)	3 (13
130 (896)	299.91 (91.41)	139.03 (42.38) 140.10 (42.70)	1362 (5150)	1724 (6520)	1919 (7260)	2127 (8040)	2344 (8870)	2574 (9740)	3063 (11590)	3 (13
132 (910)	304.52 (92.82)		1372 (5190)	1736 (6570)	1933 (7320)		2144 (8110) (8940)	2362	2594 (9810) (11670)	3 (13
134 (924)	309.14 (94.23)	141.16 (43.03) 142.21 (43.35)	1382 (5230)	1749 (6620)	1948 (7370)	2160 (8170)	2380 (9010)	2613 (9880)	3110 (11760)	3 (13
136 (938)	313.75 (95.63)		1392 (5270)	1762 (6670)	1962 (7430)		2176 (8230) (9070)	2398	2633 (9960) (11850)	3 (13

* 1 psi 2.307 ft of water, 1 kPa 0.102 m of water. For pressure in bars, multiply by 0.01.
Notes to Table 2-10.1
Note 1. This corresponds to velocity head.

Note 2. This table is computed from the formula $Q = 29.83cd^2\sqrt{P}(Q_m = 0.0666cd^2\sqrt{P_m})$ with c = 1.00. The theoretical discharge of sea water, as from fireboat nozzles, can be found by subtracting 1 percent from the figures in the following table, or from the formula $Q = 29.83cd^2\sqrt{P}(Q_m = 0.065cd^2m\ p_m)$.

Appropriate coefficient should be applied where it is read from hydrant outlet. Where more accurate results are required, a coefficient appropriate on the particular nozzle must be selected and applied to the figures of the table.

The discharge from circular openings of sizes other than those in the table can readily be computed by applying the principle that quantity discharged under a given head varies as the square of the diameter of the opening.

2-10.2 Discharge Calculations from Table.

One means of solving this equation without the use of logarithms is by using Table 2-10.2. This table gives the values of the 0.54 power of the numbers from 1 to 175. Knowing the values of h_f, h_r, and Q_F, the values of $h_f^{0.54}$ and $h_r^{0.54}$ can be read from the table and formula (b) solved for Q_R. Results are usually carried to the nearest 100 gpm (380 L/min) for discharges of 1,000 gpm (3,800 L/min) or more, and to the nearest 50 gpm (190 L/min) for smaller discharges, which is as close as can be justified by the degree of accuracy of the field observations.

Table 2-10.2 Values of "h" to the 0.54 Power

h	$h^{0.54}$	h	$h^{0.54}$	h	$h^{0.54}$	h	$h^{0.54}$	h	$h^{0.54}$
1	1.00	36	6.93	71	9.99	106	12.41	141	14.47
2	1.45	37	7.03	72	10.07	107	12.47	142	14.53
3	1.81	38	7.13	73	10.14	108	12.53	143	14.58
4	2.11	39	7.23	74	10.22	109	12.60	144	14.64
5	2.39	40	7.33	75	10.29	110	12.66	145	14.69
6	2.63	41	7.43	76	10.37	111	12.72	146	14.75
7	2.86	42	7.53	77	10.44	112	12.78	147	14.80
8	3.07	43	7.62	78	10.51	113	12.84	148	14.86
9	3.28	44	7.72	79	10.59	114	12.90	149	14.91
10	3.47	45	7.81	80	10.66	115	12.96	150	14.97
11	3.65	46	7.91	81	10.73	116	13.03	151	15.02
12	3.83	47	8.00	82	10.80	117	13.09	152	15.07
13	4.00	48	8.09	83	10.87	118	13.15	153	15.13
14	4.16	49	8.18	84	10.94	119	13.21	154	15.18
15	4.32	50	8.27	85	11.01	120	13.27	155	15.23
16	4.48	51	8.36	86	11.08	121	13.33	156	15.29
17	4.62	52	8.44	87	11.15	122	13.39	157	15.34

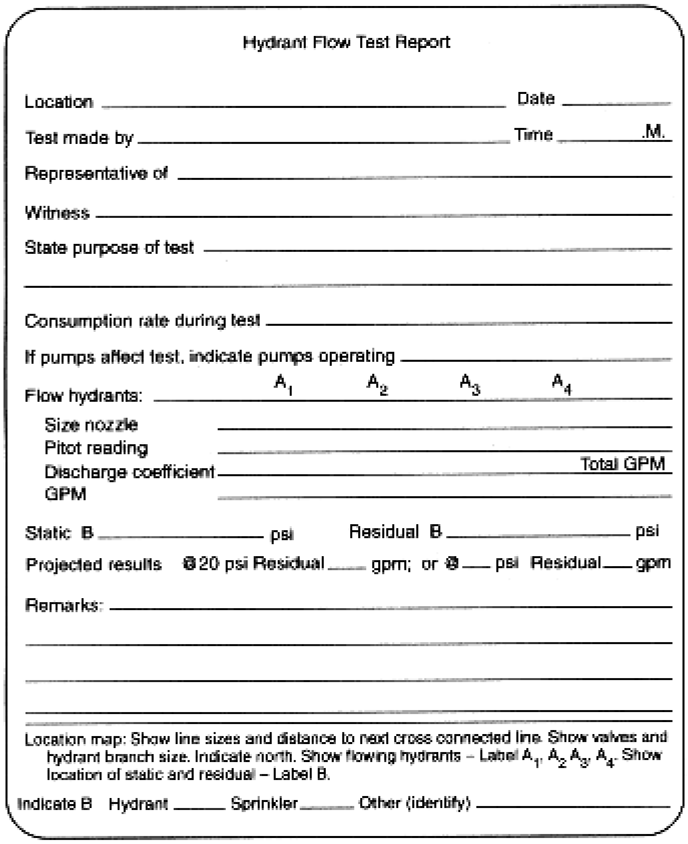
18	4.76	53	8.53	88	11.22	123	13.44	158	15.39
19	4.90	54	8.62	89	11.29	124	13.50	159	15.44
20	5.04	55	8.71	90	11.36	125	13.56	160	15.50
21	5.18	56	8.79	91	11.43	126	13.62	161	15.55
22	5.31	57	8.88	92	11.49	127	13.68	162	15.60
23	5.44	58	8.96	93	11.56	128	13.74	163	15.65
24	5.56	59	9.04	94	11.63	129	13.80	164	15.70
25	5.69	60	9.12	95	11.69	130	13.85	165	15.76
26	5.81	61	9.21	96	11.76	131	13.91	166	15.81
27	5.93	62	9.29	97	11.83	132	13.97	167	15.86
28	6.05	63	9.37	98	11.89	133	14.02	168	15.91
29	6.16	64	9.45	99	11.96	134	14.08	169	15.96
30	6.28	65	9.53	100	12.02	135	14.14	170	16.01
31	6.39	66	9.61	101	12.09	136	14.19	171	16.06
32	6.50	67	9.69	102	12.15	137	14.25	172	16.11
33	6.61	68	9.76	103	12.22	138	14.31	173	16.16
34	6.71	69	9.84	104	12.28	139	14.36	174	16.21
35	6.82	70	9.92	105	12.34	140	14.42	175	16.26

Method of Use

Insert in formula (b) the values of $h_r^{0.54}$ and $h_f^{0.54}$ determined from the table and the value of Q_F, and solve the equation of Q_R.

2-11 Data Sheet.

The data secured during the testing of hydrants for uniform marking can be valuable for other purposes. With this in mind, it is suggested that the form shown in Figure 2-11 be used to record information that is taken. The back of the form should include a location sketch. When the tests are complete, the forms should be filed for future reference by interested parties.



Hydrant Flow Test Report

Location ______________________ Date ________

Test made by ______________________ Time ________ .M.

Representative of ______________________

Witness ______________________

State purpose of test ______________________

Consumption rate during test ______________________

If pumps affect test, indicate pumps operating ______________________

Flow hydrants: A_1 A_2 A_3 A_4

Size nozzle

Pitot reading

Discharge coefficient ______________________ Total GPM

GPM

Static B ________ psi Residual B ________ psi

Projected results @ 20 psi Residual ____ gpm; or @ ____ psi Residual ____ gpm

Remarks: ______________________

Location map: Show line sizes and distance to next cross connected line. Show valves and hydrant branch size. Indicate north. Show flowing hydrants – Label A_1, A_2, A_3, A_4. Show location of static and residual – Label B.

Indicate B Hydrant ____ Sprinkler ____ Other (identify) ______________________

Figure 2-11 Sample hydrant flow test report.

2-12 System Corrections.

It must be remembered that flow test results show the strength of the distribution system and do not necessarily indicate the degree of adequacy of the entire water works system. Consider a system supplied by pumps at one location and having no elevated storage. If the pressure at the pump station drops during the test, it is an indication that the distribution system is capable of delivering more than the pumps can deliver at their normal operating pressure. It is necessary to use a value for the drop in pressure for the test which is equal to the actual drop obtained in the field during the test, minus the drop in discharge pressure at the pumping station. If sufficient pumping capacity is available at the station and the discharge pressure could be maintained by operating additional pumps, the water system as a whole could deliver the computed quantity. If, however, additional pumping units are not available, the distribution system would be capable of delivering the computed quantity, but the water system as a whole would be limited by the pumping capacity. The portion of the pressure drop for which a correction can be made for tests on systems with storage is generally estimated upon the basis of a study of all the tests made and the pressure drops observed on the recording gauge at the station for each. The corrections may vary from very substantial portions of the observed pressure drops for tests near the pumping station, to zero for tests remote from the station.

Chapter 3 Marking of Hydrants

3-1 Classification of Hydrants.

Hydrants should be classified in accordance with their rated capacities (at 20 psi [1.4 bar] residual pressure or other designated value) as follows:

Class AA — Rated capacity of 1,500 gpm or greater (5,680 L/min)

Class A — Rated capacity of 1,000-1,499 gpm (3,785-5,675 L/min)

Class B — Rated capacity of 500-999 gpm (1,900- 3,780 L/min)

Class C — Rated capacity of less than 500 gpm (1,900 L/min)

3-2 Marking of Hydrants.

3-2.1 Public Hydrants.

All barrels are to be chrome yellow except in cases where another color has already been adopted. The tops and nozzle caps should be painted with the following capacity-indicating color scheme to provide simplicity and consistency with colors used in signal work for safety, danger, and intermediate condition:

Class AA — Light blue

Class A — Green

Class B — Orange

Class C — Red

For rapid identification at night, it is recommended that the capacity colors be of a reflective-type paint.

Hydrants rated at less than 20 psi (1.4 bar) should have the rated pressure stenciled in black on the hydrant top.

In addition to the painted top and nozzle caps, it may be advantageous to stencil the rated capacity of high volume hydrants on the top.

The classification and marking of hydrants provided for in this chapter anticipate determination based on individual flow test. Where a group of hydrants can be used at the time of a fire, some special marking designating group-flow capacity may be desirable.

3-2.2 Flush Hydrants.

Location markers for flush hydrants should carry the same color background as stated above for class indication, with such other data stenciled thereon as deemed necessary.

3-2.3 Private Hydrants.

Marking on private hydrants within private enclosures is to be at the owner's discretion. When private hydrants are located on public streets, they should be painted red, or some other color, to distinguish them from public hydrants.

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Standard for Wildfire Control

1991 Edition

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The 1991 edition of this document has been approved by the American National Standards Institute.

Origin and Development of NFPA 295

This complete rewrite of NFPA 295 was prepared by the Committee on Forest and Rural Fire Protection. This edition replaces the previous edition (1985) and succeeds the 1978 edition as well as other editions that bore the titles: *Wildfire Control and Environmental Improvement* (1972); *Forest, Grass and Brush Fire Control* (1965); *Community Organization and Equipment for Fighting Forest, Grass and Brush Fires* (1956); and the original NFPA 295, *Community Forest Fire Equipment*, adopted by NFPA in 1934.

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Chapter 1 Introduction

1-1 Scope.

This standard presents fundamental information to fire departments on the control of wildfire burning in natural and other vegetative fuels. This standard recognizes that protection of structures in the wildland areas may require modification of strategy and tactics to allow for protection of those structures. It includes necessary and useful information on safe procedures and practices, as well as other topics that are essential for the safe and successful control of wildfires.

1-2* Purpose.

The purpose of this standard is to identify organizational practices and management policies and to specify requirements on safe procedures, equipment, and apparatus to ensure the successful control of vegetation fires and exterior protection of structures and improvements. This standard does not apply to interior structural fire fighting operations.

1-3 Definitions.

For the purposes of this standard the following terms have the meanings shown below:

Apparatus. Motor-driven vehicles specially designed or modified for fire fighting or other emergency service, or a collective group of such vehicles, such as pumpers or engines, tankers, ladder trucks, rescue squads, etc.

Brush. Shrubs and scrub vegetation or other growth heavier than grass but not full tree size.

Company. An organized group of fire fighters under the leadership of a company officer or other designated official. Companies are often assigned to specific apparatus or stations. Also see “Crew.”

Company Officer. The officer in charge of a fire department company or station or any other position of comparable responsibility in the department.

Control. When an adequate line has been established completely around the perimeter of the fire and it nolonger has a potential for additional destruction or for escaping under forseeable conditions. The fire has reached the phase in which mop-up and patrol are the only activities required to extinguish the fire. “Control” is also used as an inclusive term for any and all actions taken to halt, confine, and totally extinguish a fire, including detection, mobilization, size-up, attack, mop-up, and patrol.

Crew. An organized group of fire fighters under the leadership of a crew leader or other designated official. Also see “Company.”

Crew Leader. A supervisory person in charge of a group of fire fighters and responsible for their leadership, performance, safety, and welfare for the duration of their assignment; sometimes called a crew foreman, crew boss, or crew supervisor.

Forest Fire. Any uncontrolled, unwanted fire in a forested area.

Grass Fire. Any uncontrolled, unwanted fire involving dried grass.

Incident Commander. The person responsible for all suppression and service activities on a wildfire. Primary responsibilities are to develop control plans and organize and direct the fire suppression organization in such a manner that the fire is completely and efficiently controlled. The incident commander may carry out all responsibilities alone or assign prescribed line and staff duties to subordinates.

Incident Management System. A system that provides structure and coordination to the management of emergency incident operation in order to provide for the safety and health of fire department members and other persons involved in those activities. (*See* NFPA 1561, *Standard on Fire Department Incident Management System*.)

Prevention. That part of fire protection activities designed to prevent ignition of unwanted fires and to minimize loss if fire does occur. Such activities, including public education, personal contact, law enforcement, engineering, and reduction of fuel hazards, are directed at reducing or eliminating the number of fires that start.

Rural. Any area wherein residences and other developments are scattered and intermingled with forest, range, or farmland and native vegetation or cultivated crops.

Wildfire. An unplanned and unwanted fire requiring suppression action; an uncontrolled fire, usually spreading through vegetative fuels and often threatening structures.

Figure 1-3 Wildfire.

Wildland/Urban Interface. An area where development and wildland fuels meet at a well-defined boundary.

Wildland/Urban Intermix. An area where development and wildland fuels meet with no clearly defined boundary.

Chapter 2 Organization and Management

2-1* Organization.

2-1.1* Purpose.

The fire department shall be organized to perform fire prevention and control in order to protect life and property from fire. Other services demanded of the fire department, because the fire department force is available and has specialized training, shall be undertaken only to the extent that they do not interfere with the department's basic purpose and that they are activities justifiably related to it.

2-1.2 Goal.

The fire department's goals shall be to protect life and property; to minimize fire losses through fire prevention; to take quick, aggressive initial action to prevent the small fire from becoming large; and to control the large fire as soon as possible with the minimum cost.

2-2* Command.

2-2.1 Fire Chief.

The fire department shall have a fire chief who shall be in overall command of the department at all times.

2-2.2 Incident Commander.

On every fire or emergency incident one individual or individuals (in a unified command structure) must be recognized as incident commander.

When the department responds to a fire or other emergency, the first officer to arrive shall assume command of the incident until specifically relieved by someone with higher authority.

2-2.3 Succession.

A formal chain of command or succession shall be followed as described in NFPA 1561, *Standard on Fire Department Incident Management System*.

2-2.4 Company Officers.

Each fire company or crew shall operate under the command of a designated officer, crew leader, or incident commander. Each company shall have enough officers to provide a leader to command the company at the time of any response.

2-3 Responsibilities.

2-3.1 Fire Chief.

The fire chief shall be responsible for the administration, management, and operation of the fire department. Duties shall specifically include:

(a) Act as the principal spokesperson for and represent the fire department before the public and the governing legal authority.

(b) Establish the operational procedures of the department through the issuance of regulations and orders.

(c) Direct operations at a fire or emergency incident.

(d) Ensure that the department is adequately trained and staffed.

(e) Ensure that a training plan is developed and implemented and that all members are knowledgeable in the basic measures for attaining fast, safe, and effective fire suppression.

(f) Prepare a departmental budget.

(g) Be familiar with all laws and ordinances that apply to the operation of the fire department.

(h) Investigate all fires for cause, origin, and circumstances.

(i) Ensure compliance by the department with all sections of this standard and all applicable local laws and ordinances.

(j) Develop and implement a fire prevention program for the entire year.

(k) Be responsible for department equipment and the safety and welfare of all fire department members engaged in departmental operations.

2-3.2 Officers.

Company officers or supervisors shall have the following duties and responsibilities:

(a) Ensure the safety and welfare of their company or crew members.

(b) Act as leader of a crew of individuals.

(c) Respond to alarms to which the unit is assigned and direct operations of the units.

(d) Have sufficient knowledge of fire strategy to be able, in the absence of a chief officer, to make a proper size-up or appraisal of the emergency and assume initial command until formally relieved.

(e) Be familiar with the area protected by the department.

(f) Ensure the care, maintenance, and fire readiness of assigned apparatus and equipment.

2-3.3 Members.

All fire department members shall be responsible for the following:

(a) Be familiar with the rules and regulations governing the operation of the fire department.

(b) Keep themselves in good physical condition in accordance with the fire department's established fitness standards.

(c) Be familiar with and knowledgeable of the entire area protected by the department.

(d) Be knowledgeable in the methods of fire suppression, the safe use of tools and fire fighting equipment, and the procedures for safe and effective response to incidents.

(e) Be familiar with the fire laws and regulations of the local jurisdiction and state or province.

(f) Operate through established lines of responsibility and authority.

(g) Respond to incidents when notified.

(h) Protect themselves and others in the hazardous task of fire fighting through compliance with all safety standards, regulations, and procedures.

2-4 Emergency Response and Notification.

Members shall be trained to achieve safe and effective response to incidents.

2-4.1

When an incident occurs, members of the fire department shall be immediately notified so they can respond with apparatus and equipment.

2-4.2

Provisions shall be made for immediate notification of fire department members. This may be accomplished through activation of a siren, use of radio pagers or alert monitors, or a telephone chain.

2-5* Pre-Incident Planning.

2-5.1 Plan Required.

A written plan shall be prepared. A plan in outline form is acceptable. The plan shall be revised and updated annually or sooner if required by changing conditions.

2-5.2 Elements.

The plan shall contain the following information as a minimum:

(a) Fire department organization and personnel roster with contact information.

(b) A listing of cooperating agencies and contacting procedures.

(c) Additional available resources of personnel, equipment, supplies, and facilities, and contracting or ordering procedures.

(d) Up-to-date map of protection area, including boundaries, roads and other means of access; heliports, airports, aviation hazards, water sources, special hazards; and dangerous fire risks.

(e) Mutual aid agreements, automatic response agreements, and other protection agreements.

2-6 Mutual Aid.

Whenever possible, mutual aid, automatic response, and cooperative agreements for mutual assistance with adjacent fire departments or other agencies shall be negotiated and implemented. Such agreements shall include provisions to ensure clearly established command authorities and responsibilities.

2-7* Fire Prevention Program.

2-7.1* Plan Required.

A fire prevention plan shall be developed and implemented each year.

2-7.2 Elements.

The fire prevention plan shall contain an analysis of fire causes, special fire hazards and risks, an assessment of interface fire protection problems, and proposed measures to reduce fire occurrence and decrease fire damage. It shall also include provisions for cooperative efforts with all other neighboring fire protection agencies.

Chapter 3 Safety and Training

3-1 Safety.

3-1.1* Personnel.

The safety and welfare of personnel shall be the first and foremost consideration in all incident operations and decisions.

3-1.2* Protective Clothing and Equipment.

The officer in charge shall require that appropriate personal protective clothing and equipment be worn by all fire department personnel while engaged in any incident.

3-1.2.1 As a minimum, fire fighters engaged in wildfire suppression shall have and use a safety hard hat or fire helmet equipped with chin strap, leather boots at least 6 in. (15.24 cm) high, goggles, and gloves. Synthetic polyester clothing, tennis shoes, sneakers, or low-quarter shoes shall not be worn on the fireline. Fire department members shall wear cotton or wool clothing with cuffless trousers and long-sleeved shirts or lightweight flame resistant clothing, specially designed for wildfire fire fighting. Individual states or provinces may have more restrictive personnel protective clothing requirements. To ensure compliance with such regulations, the fire department shall check with its state or provincial occupational safety and health agency.

3-1.2.2 Structural fire fighting personal protection clothing and equipment (turnouts and rubber boots) are not appropriate for wildland fire suppression activities, and wildland fire suppression personal protective equipment shall not be utilized for interior attacks on structures.

3-1.3* Physical Examination.

Prospective members of the fire department shall undergo and pass a physical examination before admission to the department as an active member. The medical examiner shall certify the applicant's physical ability to perform fire fighting duties.

3-1.4 First Aid.

3-1.4.1* Fire department members shall be trained and certified in first aid and cardiopulmonary resuscitation (CPR).

3-1.4.2 First Aid Kits. First aid kits for fireline use shall be readily available on all emergency responses.

3-1.5 Fire Apparatus.

3-1.5.1 All apparatus shall be equipped and operated as described in NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, and NFPA 1901, *Standard for Pumper Fire Apparatus*.

3-1.5.2 Vehicles on the fireline shall be parked so they face in the direction of the escape route.

3-1.5.3 Fire apparatus shall be driven and operated only by trained and qualified personnel. Apparatus shall be driven in a safe and sane manner. All applicable laws and departmental regulations regarding the response of emergency vehicles shall be obeyed.

3-1.6 Tractor Plows, Dozers, and Fire Plows

3-1.6.1 Fire fighters shall not work directly above or below tractor plows, dozers, or fire plows where they may slide beneath the machine or be struck by rolling material.

3-1.6.2 Fire fighters shall not approach a tractor plow, dozer, or fire plow until it has stopped and the operator has signaled it is safe to approach.

3-1.6.3 Fire fighters shall avoid being immediately in front of or in back of a tractor plow, dozer, or fire plow in operation.

3-1.6.4 Fire fighters shall not get on or off moving equipment.

3-1.6.5 Fire fighters shall not sit or bed down near a tractor plow, dozer, or fire plow.

3-1.6.6 Tractor plows, dozers, and fire plows shall be operated only by trained, experienced operators.

3-1.6.7 Fire fighers shall not ride on tractor plows, dozers, or fire plows.

3-1.7 Power Saws.

3-1.7.1 Power saws shall be operated only by trained, experienced personnel.

3-1.7.2 Power saw operators shall wear safety hard hats, protective chaps, ear and eye protection, and gloves.

3-1.7.3 The motor shall be stopped whenever a power saw is to be carried more than 10 ft (3.0 m) unless equipped with a chain break. The motor shall be stopped whenever the saw is to be carried more than 30 ft (9.0 m).

3-1.7.4 The motor shall be stopped for all cleaning, adjustments, and repairs.

3-1.7.5 The motor shall be stopped and the exhaust allowed to cool prior to refueling. Refueling shall be done on bare ground and spilled fuel wiped off the motor. The saw shall not be started within 10 ft (3.0 m) of the refueling area.

3-1.7.6 Whenever using a power saw, nearby there shall be either a portable fire extinguisher, or a backpack pump filled with water, or a shovel for extinguishing fires that may be started by the power saw.

3-1.8 Hand Tools.

3-1.8.1 All hand tools shall be maintained in good condition, with tight handles, properly sharpened, and all sharp edges guarded when not in use.

3-1.8.2 Hand tools shall not be carried on the shoulder. Hand tools shall be carried by the balance point on the downhill side with the cutting edge away from the body. A distance of at least 6 ft (2.0 m) shall be maintained between individuals when carrying hand tools. When using tools, a distance of at least 10 ft (3.0 m) shall be maintained between individuals. Except in an emergency, fire fighters shall not run while carrying hand tools.

Figure 3-1 A fire crew building a fireline. Note the safety helmets, canteens, and the spacing between crew members.

3-1.9* Aircraft.

If the department has occasion to work with fire fighting aircraft, members shall be trained in safety procedures regarding fixed wing and rotary wing aircraft. An air operations safety briefing shall be conducted.

3-2* Training.

3-2.1

To ensure safety and effectiveness, every fire department member shall receive basic wildland fire training prior to responding to a wildland fire.

3-2.2

The content and length of the training program shall be determined by the fire chief. As a minimum, the content shall include courses in fireline safety, fire behavior, suppression methods, the 10 standard fire fighting orders, and the 18 situations that shout “Watch Out.”

Chapter 4 Equipment and Apparatus

4-1 Equipment.

4-1.1* Hand Tools.

4-1.1.1 The organization shall have sufficient hand tools for wildland fire suppression.

4-1.1.2 All hand tools shall be for use in emergencies only and shall be distinctly labeled for emergency use.

4-1.2* Power Saws.

4-1.2.1 Power saws shall be carefully maintained and serviced in accordance with manufacturer's recommendations. Manufacturer's operating and safety instructions shall be followed.

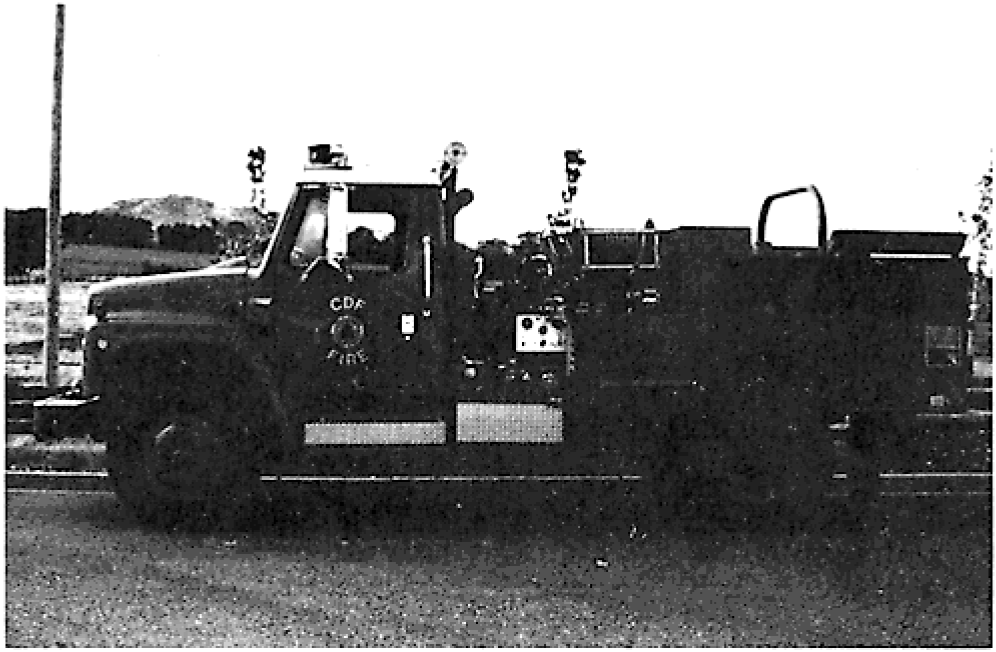
4-1.2.2 Power saws shall be equipped with approved spark arresters.

4-1.3 Fire Hose.

Fire hose shall be maintained in good condition and cared for properly. It shall not be used for other than fire fighting unless such use is approved by the fire chief. (*See* NFPA 1962, *Standard for the Care, Use, and Maintenance of Fire Hose Including Couplings and Nozzles*).

4-2* Tractor Plows and Dozers.

All tractor plows and dozers shall have protective canopies, adequate lights for night operations, and if not turbocharged, shall be equipped with approved spark arresters.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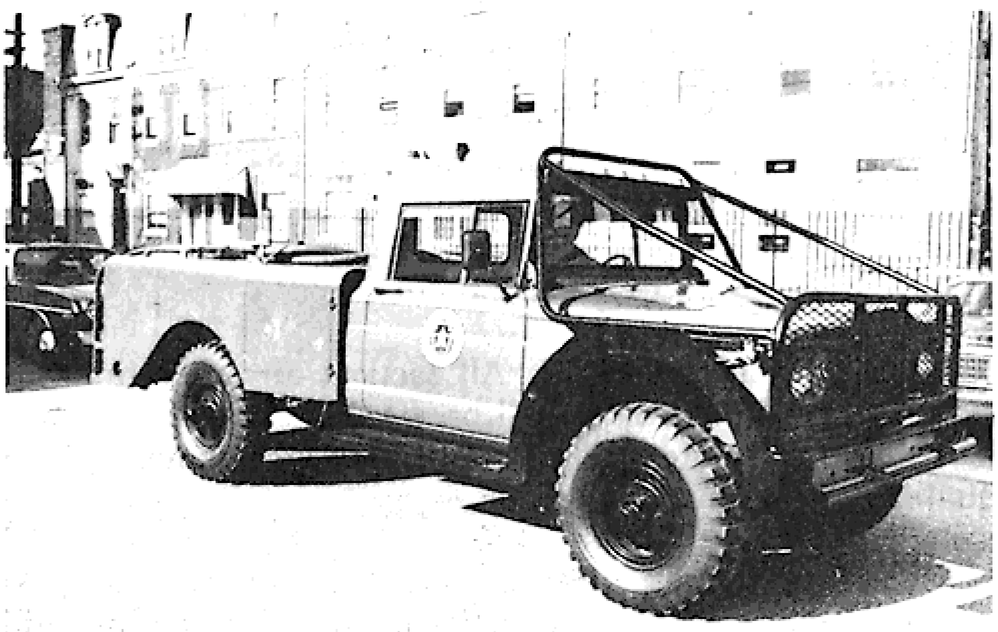
FIRE



Figures 3-1.5(a), (b), and (c) Apparatus used in wildfire suppression exist in a variety of configurations. The top photograph pictures a fire engine specifically designed for wildfire suppression. It includes an integral 300-gpm pump and a 500-gal water tank. The center photograph depicts a unit that was converted for wildfire suppression from a surplus military vehicle. The bottom photograph is a slip-on unit, including fire pump and water tank, designed to be placed on a 12,000-lb GVW truck whenever it is needed.

Chapter 5 General

5-1* Retardants and Suppressants.

These items shall not be used without a thorough knowledge of the particular precautions to be followed and the hazards associated with their use. Wildland fire foams shall meet NFPA 298 requirements. Wetting agents shall meet NFPA 18 requirements.

5-2 Communications.

5-2.1* Communications System.

A wildland fire communications system plan shall be established by all fire departments and shall be incorporated into the fire department's/agency's everyday operational procedures.

As a minimum, a wildland fire communications system plan shall address the following:

(a) Communications between the public and the fire department/agency

(b) Communications procedures within the fire department/agency

(c) Communications between the fire department/agency and other public safety related agencies.

5-2.2 Emergency Telephone.

An emergency telephone number shall be established for receiving reports of fires or other emergencies. This emergency telephone number shall be widely publicized in the response area and published in the local telephone directory.

5-2.3 Alerting Systems.

The fire department shall have an alerting system by which it can summon personnel at any time of the day or night.

5-2.4* Incident Radio Communications Plan.

The fire department/agency shall have established procedures for determining incident radio system needs; methods for allocating frequencies and priorities; and support equipment assignment and accountability.

5-3 Fire Reporting and Investigation.

5-3.1* Fire Reporting.

A fire report shall be completed and filed with the appropriate state or federal agency for every incident to which the fire department responds.

5-3.2* Fire Investigation.

Every fire responded to by the fire department shall be investigated for fire cause, and an investigation report shall be completed. Significant wildland fires may require investigation by a specially trained wildland fire investigator.

The fire department shall contact its state forester, state fire marshal, or other equivalent officer to request assistance and determine required fire reporting and investigation procedures and report contents.

5-4 Air Operations Plan.

All tactical air operations in support of wildland fire shall be conducted in accordance with an appropriate air operations plan and managed by a qualified air operations officer.

5-5 Wildland/Urban Interface Operations.

Where jurisdiction or mutual aid and assistance agreements include wildland/urban interface areas, training shall be provided in basic wildland and structural fire, safety, and exposure protection.

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 18, *Standard on Wetting Agents*, 1990 edition

NFPA 298, *Foam Chemicals for Wildland Fire Control*, 1989 edition

NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, 1987 edition

NFPA 1561, *Standard on Fire Department Incident Management System*, 1990 edition

NFPA 1901, *Standard for Pumper Fire Apparatus*, 1991 edition

NFPA 1962, *Standard for the Care, Use, and Maintenance of Fire Hose Including Couplings and Nozzles*, 1988 edition

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

The current text is designed to help the thousands of small community organizations existing in the rural and forested areas of North America. Many of these communities are exposed to the dangers of a large fire involving many acres of natural fuels, such as forest, grass, or brush. To prepare effectively for such emergencies, the responsive fire protection organizations and individuals must be informed of the most recent and useful wildland fire control techniques, equipment, training, and operations.

Additional information on large equipment, heavy power tools, specialized wildfire fire fighting equipment, and techniques is available in other publications. This standard includes a list of mandatory requirements that must be met if fire fighters are to be safe and effective in the prevention and suppression of wildfires.

It is suggested that fire organizations consider the adoption of this standard through a vote by the fire department members or by citizens of the protected area. Legal counsel should be consulted to explain how the adoption of this standard affects the department and its members.

In many rural and wildland areas, forest, grass, crop, and brush fires are a continual problem. These fires, if not controlled, can endanger human life and cause serious damage to property, natural resources, and the environment. Careful evaluation of wildfires in the United States and Canada for many years has shown that fire damage can be prevented or minimized if such fires are aggressively attacked by trained fire fighters in the early stages of fire development.

A-2-1 Organization and Management.

In order to provide fire prevention and control and to protect life and property from wildfire, a community should establish the following:

(a) An officially designated formal organization headed by a fire chief or fire warden charged with the responsibility of prevention and suppression of wildland fires. The chief is in charge of the entire departmental operation. The chief should be appointed by the governing body, if one exists, or elected by the membership on the basis of merit and ability. The chief may be a paid professional, part-time paid, or volunteer.

(b) A well-organized, equipped, and trained fire company or crew who will operate under the authority of the chief, fire warden, or subordinate officer. Most small wildfires can be handled by a well-trained squad or company of two to five fighters if attacked quickly. Large or rapidly spreading fires require more fire fighters, more equipment, expert supervision, and extensive radio and telephone communications.

(c) Three or four small companies or squads of five or six fire fighters, with leaders, may be grouped together under the command of a crew leader or company officer. This leader may be one of several crew leaders commanding similar groups, and all personnel under his command, and others concerned, should know who the crew leader is and the scope of the leader's authority. The crews or companies may be assigned to action only on a designated portion of the main fire. This designated portion of the fire is commonly called a sector or division.

A-2-1.1

For more information see NFPA 1201, *Recommendations for Developing Fire Protection Services for the Public*.

A-2-2 Command.

The first responsible authority ranger, warden, company officer or crew leader, or other officer who arrives at the emergency is the incident commander until someone with higher authority specifically assumes command. Whenever a new incident commander assumes command, all officers, crew leaders, and others on the incident should be notified immediately. The incident commander is responsible for planning and directing the fire control efforts; assembling crews of fire companies and telling them where and how to work; making the best use of personnel; arranging for communications, rest periods, and relief crews; making the best use of equipment and tools; obtaining supplies; and ensuring that the fire is completely extinguished before the last crews are released from the scene. In other words, the incident commander is responsible for all activities and operations at an emergency incident. The incident commander delegates more and more responsibility to assistants as the organization needed grows, but the incident commander is always the final authority and bears total responsibility.

A-2-5 Pre-Incident Planning.

Written fire suppression mobilization plans are important even if prepared only in outline form. They should list all preplanned decisions and attack plans and outline other information needed for planned action. Such fire control plans allow a subordinate to take emergency action in the absence of the fire chief or other key individuals. Copies of the plans with necessary maps should be distributed to key fire officers. Plans must be updated at least annually and at any other time when required by changing conditions.

A. Fire Department Organizational Chart

1. Line of Succession Names—how to contact.

2. Personnel Roster Names—how to contact.

B. Cooperating Agencies Names—how to contact.

C. Resources

1. Reserve personnel—how to contact.
2. List of available equipment—type, locations, how to contact and procure.
3. List of available supplies and suppliers—types, locations, how to contact and procure.
4. List of other available facilities—types, locations, who to contact.

D. Map of Protected Area. Include such items as:

1. Boundary of protected area and adjacent jurisdictions.
2. Roads and other means of access: heliports and airports.
3. Locations of manpower, equipment, and facilities’ resources.
4. Water sources.
5. Areas of concern.
   (a) Hazards—mapped areas of hazardous fuels.
   (b) High risk ignition sources: dumps, sawmills, logging operations, recreation areas, etc.

E. Fire Weather Information

1. Source of information.
2. Methods of notifying the public.

F. Pre-Attack Plans

A-2-7 Fire Prevention.

A major responsibility of every fire protection organization is to keep the community informed of the methods and need for sound fire prevention. Prevention of wildfire is a continual job. Fire is an ever-present danger, and, to be effective, fire prevention must be constantly practiced. Fire prevention is often said to be the most important function of a fire protection organization. A fire prevention program must include plans for the entire year. The program should analyze the common causes of fire, identify significant fire hazards and risks existing in the protection area, and propose measures to reduce the occurrence of fire and fire damages. The following is an example of a systematic wildland fire prevention planning process.

A-2-7.1 Wildfire Prevention Planning.

In order to implement a wildfire prevention program as an integrated element of the fire management program, wildfire prevention must be focused. Wildfire prevention efforts must focus upon ignitions that pose the greatest threat to cause unacceptable damage or losses. Utilizing wildfire prevention as a selected strategy based on the threat of the ignition integrates it into the fire management program. Other strategies within the fire management program that may be employed include suppression, fuels management, prescribed fire, etc.

To focus wildfire prevention programs it is important to identify problems or potential problems accurately. Any wildfire prevention planning process that does not accurately assess or identify wildfire prevention problems is doomed to fail. Identification of priority wildfire prevention programs must look at a number of variables. These variables include:

1. Risks. Risks are defined as those uses or human activities that have the potential to result in wildfire ignition. When assessing the risk of a given area, only the RISK should be examined. The potential for a fire to spread or burn will be looked at separately; these two items should not be confused. Wherever there are concentrations of people or activity, the potential for a human-caused ignition exists. After assessing the risks within an area it may be helpful to look at historical fires to validate the risk assessment. Historical fires alone, however, are not an accurate reflection of the risks within a given area. The objective of this effort is to determine the degree of risk within given areas of an administrative unit.
2. Hazards. Hazards are defined as the fuels and topography of an area. The objective in examining risks is to determine the potential for a large fire to result from an ignition. This could be more simply put as determining the degree of difficulty in suppressing a fire once it is ignited. Again, it is important to examine hazards without regard to anything else.
3. Values. Values are defined as natural or developed areas whose loss or destruction by wildfire would be considered unacceptable. The objective of this process is to rate values based upon the need to protect them from wildfire.

Once risks, hazards, and values have been evaluated, it will be possible to determine when, where, and how to implement effective fire prevention programs. By comparing an area’s potential to have an ignition (risks) with its potential to burn after ignited (hazards), and the values threatened by a wildfire, an effective fire prevention plan can be written. This plan can focus on the highest priority wildfire prevention problems within an administrative unit. It may not be necessary to have an extensive fire prevention effort in an area with a number of risks where the hazard is minimal and there are no real values at risk. In contrast, it will be important to have a comprehensive effort in an area where there are substantial risks, a high hazard, and high values threatened.

The wildfire prevention plan should address what needs to be done in each area based upon the type of activities and uses. It should clearly define what actions will take place, when, and who is responsible. Wildfire prevention activities generally fall within one of three broad categories. These categories include:

1. Education. Education is aimed at changing people’s behavior by informing them. Informing people can be done through printed materials, mass media (radio, television, etc.), one-on-one

contacts, or group presentations. Information can also be delivered through signs, displays, fairs, parades, etc.

2. Engineering. Engineering is an activity designed to shield an ignition source (e.g., spark arrester) or remove the fuel that would ignite from a spark (clearance around a home).

3. Enforcement. Enforcement is used to gain compliance with fire codes and ordinances.

The wildfire prevention plan should select the most cost-effective mix of activities to mitigate potential fire problems within each priority area. Annually, the wildfire prevention plan should be evaluated. If ignitions are occurring in an area where an active fire prevention program is implemented, perhaps the fire prevention activities should be reviewed. This review may result in a change of activities within the area. If the plan is working, there will be no need to make any changes.

A-3-1.1 Personnel.

Fire fighting requires fast action, sustained effort, and greater energy than most other work. Fire fighting is always potentially hazardous. In the United States, fire fighting has one of the highest accident rates of any occupation. Wildfire control can be particularly hazardous unless the necessary safety procedures and principles are constantly practiced and obeyed. Most accidents can be prevented by careful procedures and training before emergencies. The safety and welfare of the entire fire fighting organization are the responsibility of the incident commander. All persons in authority are likewise responsible for the safety of the personnel under their direction.

A-3-1.2 Protective Clothing.

A safety hard hat with chin strap must be worn on the fireline. A standard fire fighter’s helmet may be worn as an alternative. Hard hats greatly reduce the number of serious injuries. Lightweight “bump” hats are unacceptable as they do not provide adequate protection in wildfire control.

Footwear should be leather lace-up boots. It is recommended that boots be without steel toes except for those used by chain saw operators. The boots should have slip-resistant soles, such as a hard rubber lug-type or tractor tread. This allows for maximum traction and prevents melting when exposed to normal fireline conditions. Soles should not be made of composition rubber or plastic, which have low melting points. This does not preclude the use of boots with smooth, hard rubber soles or those with a well-defined tread. However, the disadvantage of these soles is their tendency to slip on smooth rock, logs, dry grass, and pine needle surfaces that are often encountered on wildfires. The height of boot tops should be a minimum of 6 in. (15.2 cm), with at least 8 in. (20.3 cm) or greater preferred. Low-quarter boots or shoes should not be worn as they do not provide ankle support or keep out sparks and dirt. Pull-on type boots, such as structural fire fighting rubber boots, cowboy boots, or engineering boots are not recommended because they do not provide adequate ankle support, do not keep out sparks and dirt, and are loose-fitting and may cause blisters.

If available, flame-resistant clothing specially designed for wildfire fighting should be worn. If flame-resistant clothing is not available, fire fighters should wear loose, cuffless trousers and shirts made of cotton or wool. Loose-fitting clothing reduces chafing and affords more protection. Neck-buttoning collars should be worn to protect the arms and neck from heat, burns, scratches, and insects.

Fire shelters should be worn by all fire fighters engaged in suppression activities if available.

Gloves should be worn to protect hands and make hand work easier. Fire fighters should have goggles for eye protection when encountering excessively smoky or dusty environments.

An NFPA standard on personal protective clothing and equipment for wildland fire fighters is currently being developed.

A-3-1.3 Physical Examination.

Members of the fire department must be in good physical condition. Suppression operations often demand long hours of vigorous activity. Wildfires in particular require much climbing, carrying, and use of tools and equipment in uneven terrain, often for several days and nights. Persons unable to pass a rigid physical examination may be used within their abilities in nonfireline activities, such as dispatching, or other capacities.

Anyone selected as an active member of the fire department should undergo a physical examination by a physician. The fire department may establish standards for physical examinations and for physical fitness. These standards may be used for evaluation through testing procedures as well as guidance for physicians evaluating members. The U.S. federal wildfire control agencies and a number of states use a “step test” for evaluating the physical condition of new and experienced personnel. Information on the step test may be obtained from respective state forester’s offices or the local federal wildlife management agency.

Medical files should be established to maintain a history of accidents or disabilities that the fire fighter receives in service. One of the first acts in the newly formed fire control organization should be to establish its membership requirements in accordance with the applicable provisions of state or provincial legislation. This would include provisions for workmen’s compensation or other insurance for fire fighters. Requirements for professional fire fighters are included in NFPA 1001, *Fire Fighter Professional Qualifications*.

A-3-1.4.1 First Aid. All fire department members must be trained and certified in first aid and cardiopulmonary resuscitation (CPR). As a minimum, the training should consist of the American Red Cross’s First Responder standard first aid course and the American Heart Association’s First Responder cardiopulmonary resuscitation (CPR) course, or equivalent medically certified courses. It is highly recommended that fire department members be trained and certified beyond these courses to the more advanced First Responder First Aid training or Emergency Medical Technician (EMT) level.

A-3-1.9 Aircraft Safety—Fixed Wing Aircraft.

The use of fire retardants dropped from aircraft is a modern, sophisticated attack tool in wildfire control. It is likely that members of fire departments may become involved in the use of airtankers; therefore, they must be cognizant of the safety rules regarding airtanker operations.

Ground forces should be warned when drops will be made in their area. Often the airtanker pilot will make a dry run or high pass over the portion of the fire where the drop will be made. This usually indicates the drop will be made within 1 to 3 min. If drops have already been made in the area, there usually will be no dry runs.

Figure A-3-1.9(a) An airtanker makes a drop of fire retardant on a wildfire. If a drop is coming toward you, take cover and follow the safety procedures.

If unable to retreat to a safe place when an airdrop is imminent, follow these safety procedures:

(a) Lie face down with head toward oncoming aircraft and hard hat in place. If possible, grab something solid and get behind it to prevent being carried or rolled about by the drop. Spread feet apart for better body stability and to assist digging in.

(b) Hold tools firmly out to the side and away from the body. Flying tools or equipment can cause injury.

(c) Do not run unless escape is assured. Never stand up in the path of an air drop.

(d) Stay away from large old trees and snags. Tops, limbs, or entire trees may break and fall, causing injury.

After the retardant drop has been made, there is a follow-up advantage on the fire. However, these factors must be considered after the drop:

(a) Most retardants are slippery; therefore, be careful of footing and wipe off all hand tools, especially the handles.

(b) Heavy application of retardant on surfaced roads can be hazardous and should be washed down as soon as possible.

(c) Retardant should be washed from equipment and structures as soon as possible to prevent damage to finishes.

(d) Retardant may also damage agricultural or ornamental vegetation, and actions should be taken to minimize such damage.

Figure A-3-1.9(b) The use of helicopters has become a common occurrence in wildfire suppression. This helicopter is being used to make water drops on a wildfire.

Rotary Wing Aircraft (Helicopters). The use of helicopters has become a key part of wildfire protection; however, as with any other piece of fire fighting equipment, there are definite rules for safety when using or operating around a helicopter. The following safety procedures apply to helicopter operations.

Approach and Departure.

(a) Get the pilot's attention and permission before approaching the helicopter.

(b) Always approach in full view of the pilot. Never approach from the rear of the helicopter.

(c) Always approach or depart in a crouched position. Gusts of wind can cause the rotor blades to drop dangerously low to the ground.

(d) Safety helmets must be held securely to prevent their being blown away or blown up into the rotors by the rotor blast.

(e) Never approach or depart a helicopter from ground that is upslope from the main rotor. Rotors are almost invisible when turning at high speed or under poor lighting conditions.

(f) Keep clear of the main and tail rotors at all times. Do not walk to the rear of the helicopter when entering or exiting.

(g) Carry all long-handled tools in such a manner that the handles will not be inadvertently raised into the rotor path.

Working Around Heliports.

(a) Stay at least 100 ft (30 m) away from helicopters at all times unless you have a specific job that requires otherwise. Your presence can cause confusion and disrupt the pilot's concentration.

(b) Do not face a landing helicopter unless wearing goggles.

(c) Do not remain in an area that is consistently under the flight path of any helicopter.

(d) Do not smoke within 50 ft (15 m) of any helicopter or fueling area.

In-flight Safety.

(a) Do not smoke in the helicopter.

(b) Use the seatbelt and keep it secured until the pilot instructs you to leave the helicopter.

(c) Ensure that all loose gear and helmets, maps, papers, etc., are securely held to prevent their being blown about the helicopter or out the windows.

(d) Do not let any gear get in the way of the pilot or the pilot's controls.

(e) Never throw anything out of a helicopter.

(f) Do not talk to the pilot unless necessary, particularly during takeoff and landing.

(g) Be alert for hazards such as other aircraft and especially telephone and power lines.

(h) Never slam the doors of a helicopter. The doors do not have spring-loaded locks, so the handles must be physically turned to secure the door.

A-3-2 Training.

All personnel should receive frequent training in first aid, fireline safety, fire behavior, and techniques and methods of wildfire suppression. This should include periodic hands-on training with hand tools and equipment, as well as crew and fireline organization. Crew leaders and company officers need specialized training in fire control tactics to assure their competence when directing fire suppression operations. It is recommended that cooperative training with other wildfire control organizations be conducted. Federal, state, and provincial forest fire officers have technical training materials and are usually available to assist.

Many states and provinces have established programs through which fire fighters can receive training in structural fire fighting. Special training in wildfire tactics and techniques can be obtained from state, provincial, or federal wildfire protection agencies, which frequently conduct special fire schools, seminars, and other forms of instruction. A number of publications dealing with wildfire control are available from state forester's offices or the National Wildfire Coordinating Group's Publication Management System. (*See Appendix C.*)

The 10 standard fire fighting orders and 18 situations that shout "Watch Out" are used as the basic safety instructions for wildland fire suppression activities and should be included in all wildland fire suppression training.

Ten Standard Fire Fighting Orders

1. Fight fire aggressively but provide for safety first.
2. Initiate all actions based on the current and expected fire behavior.
3. Recognize current weather conditions and obtain forecasts.

4. Ensure instructions are given and understood.
5. Obtain current information on fire status.
6. Remain in communication with crew members, your supervisor, and adjoining forces.
7. Determine safety zones and escape routes.
8. Establish lookouts in potentially hazardous situations.
9. Retain control at all times.
10. Stay alert, keep calm, think clearly, act decisively.

18 Situations That Shout Watch Out

1. The fire is not scouted and sized up.
2. You're in country not seen in daylight.
3. Your safety zones and escape routes aren't identified.
4. You're unfamiliar with weather and local factors influencing fire behavior.
5. You're uninformed on strategy, tactics, and hazards.
6. Instructions and assignments are not clear.
7. You have no communication link with crew members and supervisors.
8. You're constructing a line without a safe anchor point.
9. You're building a fireline downhill with fire below.
10. You're attempting a frontal assault on the fire.
11. There is unburned fuel between you and the fire.
12. You cannot see the main fire, and you're not in contact with anyone who can.
13. You're on a hillside where rolling material can ignite fuel below.
14. The weather is getting hotter and drier.
15. Wind increases and/or changes direction.
16. You're getting frequent spot fires across the fire line.
17. Terrain and fuels make escape to safety zones difficut.
18. You feel like taking a nap near the fireline.

A-4-1.1 Hand Tools.

Tools needed will vary by sections of the country due to differences in fuels, soil, and topography. All equipment selected for fire control work should be dependable, properly maintained, and used for the type of work for which it was designed. Many national standards and specifications are available to help fire department organizations purchase the proper equipment. Assistance in selecting appropriate tools can be obtained from federal, state, or provincial wildfire fighting agencies.

A-4-1.2 Power Saws.

It is not necessary that fire suppression organizations own power saws; they are frequently available from woods operators, the same operators that communities may often rely on for additional fire fighting manpower.

Information on power saws can be secured from the manufacturers as well as from operators who have used the various makes and types. Because fire suppression may require carrying saws long distances over rough terrain, an important consideration is weight.

Saws must be equipped with adequate spark arresters to minimize the possibility of igniting nearby fuels by hot exhaust particles. References for information on approved spark arresters for power saws are found in Appendix C.

A-4-2 Tractor Plows and Dozers.

Tractor plows and dozers are costly compared to hand tools or the majority of power tools used in line construction and mop-up work. Most fire departments will not find it economical to own tractors or bulldozers but should make a careful evaluation to determine use possibilities under existing conditions of terrain, fuels, and rates of fire spread. Heavy tractor equipment is frequently available from construction and logging operators, whose names and telephone numbers should be included in the fire plan. Any tractors or bulldozers used for wildfire suppression should be equipped with protective canopies, winches, and adequate lights for operating at night. Unless turbo-charged, bulldozers or tractors should also be equipped with approved and effective spark arresters. References for information on approved spark arresters for tractor plows and dozers are found in Appendix C.

Figure A-4-2(a) Dozers are a valuable tool for wildfire suppression. This one is properly equipped with protective canopy, lights, brush guards, and a winch.

Figure A-4-2(b) Tractor plows are often used in suitable terrain to build firelines along the flanks and rear of a wildfire.

A-5-1 Retardants and Suppressant Applications.

In wildland fire suppression and fire management including prescribed burning, these items fall into two categories:

Long-Term Retardant. (Depends upon chemicals that alter the combustion process—effective for long period of time.)

Suppressants. (Depends upon availability to retain moisture—usually effective from just a few minutes to up to one hour or so under optimum conditions.)

Long-Term Retardant

1. Long-term retardants contain true fire-retarding salts, ammonium sulfate, ammonium phosphate, or a combination of each that alters the combustion process.

2. Used for:

Direct attacks: may or may not be used in support of fire crews.

Short-term protection of items such as improvements, log decks, and forest fuels adjacent to a fireline.

Prescribed burning and backfiring.

Mop-up.

3. Methods of application:

Fixed wing airtankers.

Helicopters with buckets or fixed tanks.

Fire engines.

Portable pumps.

Back pumps.

Suppressant

1. Suppressants are water with additives such as polymers or foam concentrate. They depend upon the water and moisture retention for effectiveness. When the water dries out, the effectiveness disappears.

2. Used for:

Direct attack: in support of on-the-line fire crews.

Short-term protection of items such as improvements, log decks, and forest fuels adjacent to a fire- line.

Prescribed burning and backfiring.

Mop-up.

3. Methods of application:

Fixed wing airtankers.

Helicopters with buckets or fixed tanks.

Fire engines.

Back pumps.

4. Basic principles for the creation of foam for Class A fuels:

Foam solution is a homogeneous mixture of water and foam concentrate. Foam is the aerated solution created by forcing or entraining air into a foam solution by means of suitably designed equipment or by cascading it through the air at a high velocity.

Very small amounts of Class A foam concentrate are needed, usually between 0.1 percent and 1.0 percent by volume of water.

The viscosity and density, or consistency, of foam is described by drain time and expansion ratio. A WET foam has a rapid drain time and a low expansion ratio. A DRY foam is characterized by long drain times and high expansion ratios. A DRIPPING foam has properties of both WET and DRY foams.

The consistency of foam is a function of the inputs of air, water, and concentrate, and the generation method. Changes in any of these variables will change the foam. Aerial and ground foam delivery systems are designed to allow changing inputs in order to create the most effective foam for the situation.

WET and DRIPPING foams are excellent for suppression, mop-up, and as a wetting treatment under a DRY foam creating a fire barrier.

DRY foam is most effective as a barrier for short-term protection of structures, improvements, and forest fuels.

Aspirating nozzles with water/air expansion rates of ±10 to ±100 are available.

For mop-up, regular fire hose nozzles and aspirating nozzles with low water/air expansion rates are the most effective.

The thickest, driest foams are made by using compressed air foam systems (CAFS).

Class A foams are chemically derived wetting agent foams. As such, they have the ability to form an insulating blanket on the surface of fuels, as well as increasing the efficiency of water by increased penetration into fuels and reducing the amount of water that runs off onto the ground.

References for information on retardants and suppressants are found in Appendix C.

A-5-2.1 Communication System.

A communication system by which fires and emergencies may be reported to the fire organization is essential. There must be telephone communications to some central location that serves as a dispatch center. An emergency telephone number, widely publicized in the response area and published in the local telephone directory, must be established. It is essential that all persons in the community and surrounding area be notified of how and where to report a fire or other emergency. It is also essential that the fire department have an alerting system by which its personnel can be summoned at any time of the day or night. There are a number of ways to do this, including radio-activated pagers and monitors, sirens, and telephone chain systems.

Communications between officers, apparatus, and the dispatch center are also important. This is usually accomplished through the use of 2-way radios and cellular telephones.

Additional detailed information on fire department communications can be found in NFPA 1221, *Standard for the Installation, Maintenance, and Use of Public Fire Service Communication Systems*.

System Elements. There are four basic elements in the communications requirements of a fire protection agency:

(a) Communications between the public and the fire agency.

(b) Communications within the fire agency under both emergency and nonemergency conditions.

(c) Communications among fire agencies.

(d) Communications between the fire agency and other agencies.

Each plays an essential part, enabling the fire agency to meet its protection responsibility. The particular method used must provide for each in order to be effective.

Radio, telephone, and other electronic equipment, operating procedures, and personnel training must allow messages to be conveyed as quickly and reliably as the situation requires. Messages must be sent and received correctly with no delay. Time delay and the number of messages to be handled are strongly interrelated with service. Systems and equipment must be provided so that the public may notify the fire agency of fires or other emergencies. Attention must be given to message types, the number and length of messages, the equipment capabilities, radio frequencies, and system organization. Effective operating practices must be developed, and training must be provided to meet the needs of each agency. The measure of adequate service is the ability of the system to handle emergency situations as well as the normal daily activities of the agency. A major conflagration, or multiple fires, generate a much greater need for communications than do normal daily activities.

Communications Between the Public and the Fire Agency. Communications between citizens and the fire agency revolve around several areas:

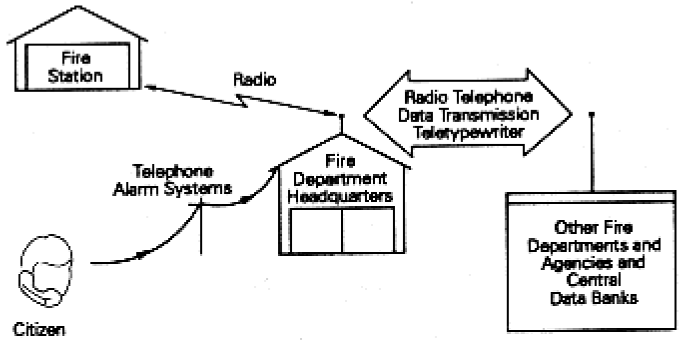


Figure A-5-2.1(a) Fire communications.

(a) Calls from citizens for emergency assistance or for reporting fires.

(b) Calls from citizens giving information to, or requesting information from, the fire agency.

(c) Calls from the fire agency to citizens.

Calls from citizens, usually received through the telephone system, giving or requesting information, may be of an emergency nature. Whether or not such a call is an emergency is decided by the individual answering the telephone. Many fire agencies maintain different administrative and emergency telephone numbers to keep the two types of communications separate. Calls from the fire agency to citizens usually are of an administrative nature. Reporting using "911" (universal emergency telephone number) has become common. It is most easily accomplished in rural areas rather than urban areas.

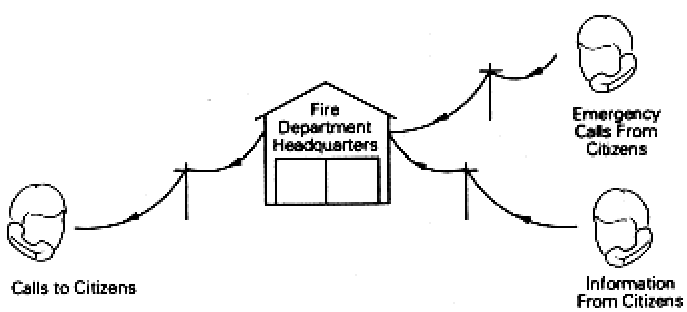


Figure A-5-2.1(b) Typical fire department communications with the public.

Communications with the Fire Agency. Communications between members of the fire agency include emergency and nonemergency messages. Most of these are accomplished by radio and may involve the dispatcher, radio-equipped vehicles (land, water, or air), personnel equipped with two-way radios, or personnel at outlying stations in a variety of emergency situations. Examples of such communications are:

(a) The radio dispatcher gives information to the fire stations and mobile equipment.

(b) Personnel report location and work status to the dispatcher for emergency assignment.

(c) The dispatcher gives coordination information and status to personnel and equipment responding to an emergency.

(d) Field commanders give instructions to ground or air mobile units and to fireline personnel under their command in a tactical situation.

(e) Communications between equipment units of personnel at a fire or other emergency.

(f) The field commander requests information or assistance, and the dispatcher advises status.

(g) Reports of fire are transmitted from lookouts or aircraft to dispatch centers.

(h) Information on status of personnel and equipment, fire danger rating, fire weather forecasts, and legal burning is transmitted between fixed stations, mobile units, and the radio dispatcher.

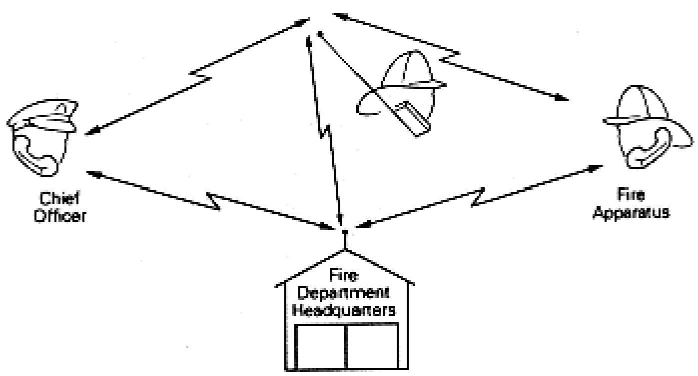


Figure A-5-2.1(c) Base-mobile radio communications.

Communications Among Fire Agencies. Many fire agencies supply their neighbors with requested information. Such communications are necessary because many small agencies depend on mutual aid agreements, and wildland fires are likely to cover more than the jurisdiction of a single agency. In addition, many fire agencies have common information needs.

Interchange may be divided into two kinds of communications—directed and incidental. Directed communication is the conveying of information from one agency to one or more specifically selected agencies. Incidental communication is the exchange of information among agencies that is a by-product of the primary purpose of the communications.

An example of directed communication is the exchange of information regarding burning permits or other smokes of interest to stations of other agencies, or the transmittal of a fire danger rating or fire weather information. It may also be advice regarding equipment in adjoining stations where first attack arrangements exist.

Incidental or nondirected communication among agencies occurs whenever one agency monitors the transmissions of another, although the information is not specifically intended for interagency distribution. Most of this kind of communication is by radio, especially among agencies that share a radio channel. (When agencies have a choice of channels on which to operate, they must weigh the advantages of mutual monitoring by all system users against the disadvantages of greater message traffic and the resulting problems of channel loading.) This kind of communication is no less important than directed communication, for it allows one agency to be aware of situations in another community or area that may “spill over” or involve it directly in a short time.

Monitoring of nearby fire departments’ or fire agencies’ transmissions helps the listener to anticipate the need for mutual aid and to be aware of the level of emergency activity in an area larger than the department’s or agency’s own boundaries. If two fire service agencies anticipate a need for mutual aid or cooperation, they frequently monitor each other’s calls even when not on the same radio channel. Monitor-receivers at the dispatcher positions are generally used.

Special mutual aid radio frequencies or channels for mobile use only have been licensed so that fire agencies from adjacent jurisdictions can communicate directly with each other. Such a channel can assist normal day-to-day interagency communication needs and emergency communication during widespread disasters. The channels may serve as command channels for interagency communication. Although these are helpful, there are also problems with them. The frequencies may become overloaded very quickly. The multichannel synthesizer mobile radio allows all radio traffic to be conducted on the “Agency in Charge” radio system, starting with initial attack on through large fire operations.

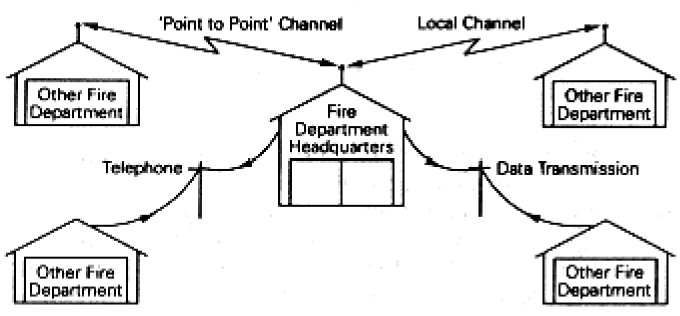


Figure A-5-2.1(d) Interdepartmental communications.

Communications Between the Fire Agency and Other Agencies. Another function of a communications system is to pass messages between the fire agency and public safety oriented agencies, such as public works, highway maintenance departments and utilities, hospitals and ambulance services, towing and wrecker services, law enforcement agencies, civil defense units, forest industries, and fire weather forecasters.

Fire agencies exchange a large variety of information with nonfire agencies or cooperators. Perhaps the information most widely exchanged in the rural and mountain areas is the local fire danger rating or fire weather information, reports of road conditions, flooding, fallen trees, and similar useful data. Reports of vehicle accidents are often made to the fire agency by police agencies where a fire department or rescue company response is required. Since many of these companies are radio equipped, they can be of assistance during large fires or other major incidents.

One of the greatest demands for communications with other agencies can occur during major emergencies. The ability to meet this problem requires planning for message volumes and possible language barriers. Telecommunications for a fire department or forest agency must include contingency plans for emergency situations. An emergency is no time to set up new communications links. The volume of messages that must be handled is likely to exceed mostestimates, so plans must include means for handling the volume of message traffic to prevent system breakdown due to overloading. Concerned citizens and news media can rapidly overload a telephone system. Nonfire agencies may not understand the standard language of fire radio. Therefore, liaison personnel familiar with the radio language of the fire service and the assisting organizations are needed to maintain effective communications. The National Interagency Incident Management System (NIIMS), which is being adopted by many fire agencies, includes two important communications concepts that should improve communications effectiveness during major emergencies. These are:

(a) Common Terminology—using “clear text” or “plain language” radio and established standard terms and phrases.

(b) Integrated Incident Communications—intends the best possible use of all participating agency radio systems including frequency sharing agreements.

The new synthesizer mobile radios can also be very useful here. Police, fire, and other public safety agencies can now converse with each other “at the scene” and not depend on time-consuming relays through dispatchers.

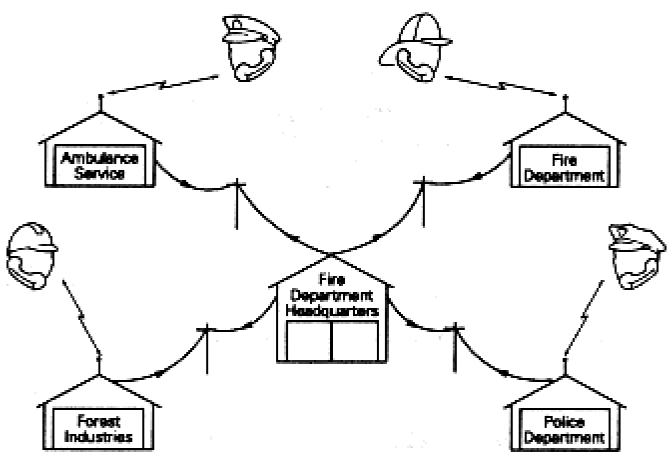


Figure A-5-2.1(e) Communications with other agencies.

A-5-2.4 Incident Radio Communications Plan.

An incident radio communications plan should be prepared in direct support of the objectives and control operations established by the incident commander. This incident radio communications plan is usually a single-page form that outlines the general radio system needs and allocations, frequency assignments and priorities (ground to ground, ground to air, and air to air), communication equipment accountability, and specific remarks to meet the control and management objectives for the incident. Initially, incident radio communications planning is the responsibility of the incident commander until a logistics chief and communications unit leader is assigned to the more complex incidents.

Table A-5-2.4 Sample incident radio communications plan.

INCIDENT RADIO COMMUNICATIONS PLAN		1. Incident Name Butte		2. Date/Time Prepared 8-20-89 2100 Hr	3. Operational Period Date/Time 8-21-89 0600–1800 Hr
			4. Basic Radio Channel Utilization		
System/Cache	**Channel**	**Function**	**Frequency**	**Assignment**	**Remarks**
Fire Department "A"	1	Command Net	170.450	IC, Generic and Command Staff, Air Ops., Div Supv., and Group Supv.	1. Command and support net repeaters are located at DP-2 on Cleghorn Truck Trail 2. Command/Gen Staff, Air Ops. Helibase Mgr, Division Supervisors, & Group Leaders, all monitor the command net. When not using another net, keep radios on command net. 3. Communication Centers are to monitor the command support, tactical, support, and air to ground nets. 4. Turn in all radios at the end of each shift.
Fire Department "A"	2	Tactical Net	170.000	Division A	
Fire Department "A"	3	Tactical Net	170.250	Division B	
Fire Department "B"	1	Tactical Net Structure Protection	154.250	Engine Strike Teams: 1801 1802 1930	
Emergency Fire Cache (White)	1	Air to Ground	168.075	Air Ops, Helibase Manager, Helicopters, Airtankers, Division Sup.	
Emergency Fire Cache (White)	2	Logistics Net	168.250	Support Functions and in-camp communications tankers, Division Sup.	
205	ICS 8-78	5. Prepared By (Communications Unit)			

See Figure A-5-3.1 for a sample reporting form modified to include wildland fires.

A-5-3.1 Fire Reporting.

The reporting of fires is an important function of the fire department. Fire reports provide a realistic and factual basis for fire prevention planning, support for funding requests, and aid in organizational development. They may also be significant documents in insurance claim adjustment cases. A report must be completed on every fire or false alarm responded to by the fire department. It is important to compile information when it is fresh in the mind of the reporting officer.

To maintain uniformity in fire reporting, the NFPA Technical Committee on Fire Reporting has developed NFPA 901, *Uniform Coding for Fire Protection*. This standard establishes basic definitions and terminology for use in fire reporting and a means of classifying data so that they can be aggregated either manually or automatically. NFPA 901 provides the common language used by nearly all large-scale (e.g., state, national) data bases in the United States and many others around the world.

The U.S. Fire Administration (USFA) has developed the National Fire Incident Reporting System (NFIRS), which is the automated system based on the work of the NFPA Fire Reporting Committee as published in NFPA 901. The system now has been installed in approximately 40 states, the District of Columbia, and a number of larger fire departments.

At the state level, NFIRS provides for the collection of written reports on incidents to which local communities responded. At the national level, NFIRS provides data bases from individual states to form the national data base. The USFA analyzes this data base and publishes the analysis.

The National Wildfire Coordinating Group (NWCG) has established a standard information content for wildfire reporting. This standardized content is now used by all U.S. Federal Wildfire Control Agencies and many states.

Telephone Number Where You Can Be Contacted ( ) ____
Area Code

NFIRS 1

INCIDENT REPORT

1 ☐ DELETE
2 ☐ CHANGE

FILL IN THIS REPORT IN YOUR OWN WORDS ____ FIRE DEPARTMENT

COMPLETE FOR ALL INCIDENTS

10	A	FDID | INCIDENT NO. | EXP. NO. | MO. | DAY | YEAR | DAY OF WEEK | ALARM TIME | ARRIVAL TIME | TIME IN SERVICE
	B	TYPE OF SITUATION FOUND | TYPE OF ACTION TAKEN | MUTUAL AID 1 ☐ REC'D 2 ☐ GIVEN
	C	FIXED PROPERTY USE | IGNITION FACTOR
	D	CORRECT ADDRESS | ZIP CODE | CENSUS TRACT
11	E	OCCUPANT NAME (LAST, FIRST, MI) | TELEPHONE | ROOM OR APT.
12	F	OWNER NAME (LAST, FIRST, MI) | ADDRESS | TELEPHONE
13	G	METHOD OF ALARM FROM PUBLIC | DISTRICT | SHIFT | NO. ALARMS
	H	NUMBER FIRE SERVICE PERSONNEL RESPONDED | NUMBER ENGINES RESPONDED | NUMBER AERIAL APPARATUS RESPONDED | NUMBER OTHER VEHICLES RESPONDED

COMPLETE IF CASUALTY

20	I	NUMBER OF INJURIES: FIRE SERVICE | OTHER | NUMBER OF FATALITIES: FIRE SERVICE | OTHER

COMPLETE FOR ALL FIRES

	J	COMPLEX | MOBILE PROPERTY TYPE
	K	AREA OF FIRE ORIGIN | EQUIPMENT INVOLVED IN IGNITION
	L	FORM OF HEAT OF IGNITION | TYPE OF MATERIAL IGNITED | FORM OF MATERIAL IGNITED
	M	METHOD OF EXTINGUISHMENT | LEVEL OF FIRE ORIGIN | ESTIMATED LOSS (DOLLARS ONLY)

COMPLETE IF STRUCTURE FIRE

	N	NUMBER OF STORIES | CONSTRUCTION TYPE
	O	EXTENT OF FLAME DAMAGE | EXTENT OF SMOKE DAMAGE
	P	DETECTOR PERFORMANCE | SPRINKLER PERFORMANCE
	Q	IF SMOKE SPREAD BEYOND ROOM OF ORIGIN: TYPE OF MATERIAL GENERATING MOST SMOKE | AVENUE OF SMOKE TRAVEL
	R	FORM OF MATERIAL GENERATING MOST SMOKE

30	S	IF MOBILE PROPERTY | YEAR | MAKE | MODEL | SERIAL NO. | LICENSE NO.
40	T	IF EQUIPMENT INVOLVED IN IGNITION | YEAR | MAKE | MODEL | SERIAL NO.

☐ CHECK IF COMMENTS ON REVERSE SIDE

U	OFFICER IN CHARGE (NAME, POSITION, ASSIGNMENT) | DATE
	MEMBER MAKING REPORT (IF DIFFERENT FROM ABOVE) | DATE

COMPLETE ON GRASS AND WILDLAND FIRES

	W	FIRE DANGER | SLOPE | ASPECT | RESISTANCE TO CONTROL | SPREAD RATE
	X	SIZE CLASS ACRES | TOTAL ACRES BURNED | ACRES GRASSLAND | ACRES FORESTLAND
	Y	FEDERAL ACRES BURNED | STATE ACRES BURNED | PRIVATE ACRES BURNED
	Z	SUPPRESSION COST | DAMAGE CLASS VALUE | VALUE CLASS

Entries contained in this report are intended for the sole use of the State Fire Marshal. Estimations and evaluations made herein represent "most likely" and "most probable" cause and effect. Any representation as to the validity or accuracy of reported conditions outside the State Fire Marshal's office, is neither intended nor implied.

2	Wind Direction | Velocity | Humidity | General Description
3	Exit Drill in the Home Practiced | Was it Used

Figure A-5-3.1.

A-5-3.2 Fire Investigation.

The effectiveness of future fire prevention efforts may depend on the thoroughness of fire investigation; therefore, every fire should be investigated for cause as soon as possible. Investigation can be performed simultaneously with the fire suppression operation. Crew members must be trained to protect the fire's area of origin and to protect any evidence at the fire scene. It is important that the fire's area of origin be as undisturbed as possible and that anything that might be evidence not be moved unless absolutely necessary to prevent it from being destroyed.

All fire fighters have responsibilities in fire investigation. When responding to a fire they should note anyone or anything that could relate to the starting of the fire; they should observe vehicles in the fire area and those moving away from it; they should record license numbers, vehicle descriptions, personal descriptions, number of people, and locations or directions of travel.

At the fire scene fire fighters should be alert for evidence on how the fire started and who started it. They should preserve and protect any evidence found, recording the time and place where each item was located. It may be necessary to assign one of the crew members to this task while the rest of the crew takes suppression action. All information obtained should be recorded, including the names of witnesses or anyone else contacted, and summaries of any conversations with them. If an official investigator arrives, that investigator should receive full cooperation from all fire fighters and all obtained information should be turned over to the investigator.

Additional detailed information on wildland fire investigation can be found in Wildfire *Cause and Determination Handbook*, National Wildfire Coordinating Group Handbook 1. (*See Appendix C*.)

Appendix B Air Operations for Forest, Brush, and Grass Fires

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

B-1 Introduction.

B-1-1 Scope.

This guide presents fundamental information for agencies desiring to use aircraft for any and all aspects of wildland fire prevention, detection, and suppression. It presents necessary and useful information on procedures, practices, organization, management, and even suggested policy.

B-1-2 Purpose.

The primary purpose of this guide is to present the information necessary to plan, organize, and manage safe, cost-effective aircraft operations. The guide focuses on aircraft under the control of agencies responsible for wildland fire prevention, detection, and suppression.

B-1-3 General.

Many agencies in different countries use aircraft for reconnaissance, fire detection, fire suppression, fuel management, and coordination of ground control forces.

B-1-4 Definitions of Aeronautical and Air Operations Terminology.

Abort. An order to terminate a preplanned aircraft maneuver, e.g., abort takeoff, abort run.

ADF. Automatic Direction Finder is a radio navigational receiver operating in the low frequency bands; found in many aircraft.

Advisory Service. Advice and information provided by a facility to assist pilots in the safe conduct of flight and aircraft movements.

AGL. Above Ground Level.

Air Attack. An operation involving the use of aircraft as part of the fire suppression action.

Air Attack Supervisor (AAS). The officer, normally airborne, in tactical command of all aircraft operating at an incident.

Air Traffic. Aircraft operating in the air or on an airport surface, exclusive of loading ramps and parking areas. (FAR.1.1)

Aircraft Footprint. That area on the surface of the earth, runway, or ramp that is covered by the tread of the aircraft tires while the aircraft is in a motionless condition.

Airport Advisory Area. The area within 10 miles (16.1 km) of an uncontrolled airport on which is located a flight service station.

Airport Advisory Service. A terminal service provided by a flight service station located at an airport where a control tower is not in operation.

Airport Information Desk. A local airport facility designed for pilot self-service, weather briefing, flight planning, and filing of flight plans.

Airport Traffic Area. Unless otherwise specifically designated in FAR Part 93, that airspace within a horizontal radius of 5 statute miles (8 km) from the geographical center of any airport at which a control tower is operating, extending from the surface up to, but not including, an altitude of 3,000 ft (914 m) above the elevation of an airport.

Airspeed. The speed of an aircraft relative to its surrounding air mass. The unqualified term “airspeed” means one of the following:
1. Indicated Airspeed—The speed shown on the aircraft airspeed indicator. This is the speed used in pilot/controller communications under the general term “airspeed.” (Refer to FAR Part 1.)
2. True Airspeed—The airspeed of an aircraft relative to undisturbed air. Used primarily in flight planning and en route portion of flight. When used in pilot/controller communications, it is referred to as “true airspeed” and not shortened to “airspeed.”

Airtanker. A fixed wing aircraft equipped to drop fire retardants or fire suppressants.

Airtanker Coordinator, Birddog Pilot, Lead Plane Pilot. The pilot of the control aircraft, working under supervision of the Air Attack Supervisor (AAS), who designates targets of retardant drops and coordinates the movement of airtankers.

Airtanker Mandatory Requirements. Those requirements set forth by the Interagency Airtanker

Board.

Alert Area. Airspace that may contain high volume pilot training activities or an unusual type of aerial activity.

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.

Armed. A term used in connection with the safety device that prevents accidental opening of retardant tank doors. When the door actuating system is "armed," the controls are operative.

Artificial Horizon Attitude Indicator. An instrument that indicates attitude with respect to the true horizon. A substitute for the natural horizon.

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."

Autorotation. This is a nonpowered flight condition with the rotor system maintaining the required flight rpm at a given forward airspeed, due to the relative wind upward through the rotors, caused by the weight, forward speed, and descent of the helicopter.

Avigation. Aerial navigation.

Base/Rear/Heel. The side of the fire having the slowest rate of speed.

Birddog/Air Attack (Aircraft). The aircraft carrying the officer or individual in charge of air attack operations over a fire.

Bomb Away/ or "Now." The voice command that signals the moment for actuating the controls that open the retardant doors.

Break/Left or Right. Means turn left or right. Applies to aircraft in flight, usually on a retardant drop run, and when given as a command to the pilot, implies a prompt compliance.

Bullseye. Term indicating that a load was placed exactly where requested.

Called Shot. The drop technique wherein the control aircraft triggers the load by voice signal to the pilot. (*See "Countdown*.")

Candling or Torching. The burning of the foliage of a single tree, or a small group of trees, from the bottom up.

Canopy. The uppermost layer of tree foliage.

Ceiling. The height, from the earth's surface, of the lowest layer of clouds or obscuring phenomena that is reported as "broken," "overcast," or "obstruction" and not classified as "thin" or partial.

Countdown. A ten down to one reverse count on a called shot starting approximately one-half mile (0.8 km) from the target. (*See "Called Shot*.")

Course. The intended direction of flight in the horizontal plane.

Crosswind Component. The wind component measured in knots at 90 degrees to the longitudinal axis of the flight path.

Crown Fire. Fire traveling in the upper foliage of standing timber.

Cruising Altitude. A flight level determined by the vertical measurement from mean sea level. (MSL.)

Density Altitude. Pressure altitude for ambient temperature. In standard (ICAO) atmosphere, density and pressure altitude are equal. For a given pressure altitude, the higher the temperature, the higher the density altitude.

Direct Attack. A drop with the main portion of retardant or suppressant falling on the flame front.

Discrete Frequency. A frequency assigned to a particular function.

DME. Distance Measuring Equipment.

Down Loading. The reduction in aircraft gross weight made to compensate for loss of performance due to increase in density altitude.

Dozer Line. A physical fire break made by dozers or tractor plows.

Drift. The effect of wind on smoke or retardant/suppressant drop.

Drop Accuracy. The assessment of a drop made by the air attack supervisor or a fireline supervisor, i.e., where a load lands in relation to target.

Drop Sequence. The order and method in which the tanks are released.

Dummy Run/Dry Run. A simulated retardant or suppressant run made on a target by the birddog/leadplane or airtanker. Used to indicate approach and target to airtanker and to check for flight hazards.

DZ. Drop Zone or target area.

Early or Short. Landing before the target. Retardant/suppressant dropped before reaching target.

Elevation. The elevation of the lead plane/birddog when over the target on a dry run.

ELT. Emergency Locator Transmitter. A radio transmitter attached to the aircraft structure, which operates from its own power source on 121.5 MHz and 243 MHz, transmitting a distinctive downward swept audio tone for homing purposes, and is designed to function without human action after an accident.

End of Load. The last portion of retardant/suppressant to be released from an airtanker.

ETA. Estimated Time of Arrival.

ETD. Estimated Time of Departure.

ETE. Estimated Time Enroute.

FAA. Federal Aviation Administration.

FAR. Federal Aviation Regulations.

Final. That portion of the flight path that is aligned with the retardant/suppressant drop line.

Fire Fighter's Certificate. A method of carding fire fighters so overhead can determine their qualifications prior to assigning them a position.

Fix. A geographical position determined by visual reference to the surface, by reference to one or more radio navaids, by celestial plotting, or by any other navigational device.

Flank. Side of a fire joining base or rear to head.

Flight Path. The route an aircraft flies on any approach to and from a target.

Flight Plan. Specified information relating to the intended flight of an aircraft that is filed orally or in writing with an air traffic control facility.

Flight Time. The time from the moment the aircraft first moves under its own power for the purpose of flight until the moment it comes to rest at the next point of landing.

Flight Visibility. The average forward horizontal distance from the cockpit of an aircraft in flight at which prominent unlighted objects may be seen and identified by sight.

Front or Start of Load. The early end of the load.

FSS. Flight Service Station. A facility operated by the FAA to provide flight assistance service.

Gallons per Hour Concept. An initial and supporting attack on a fire based on a continuous delivery of retardant/suppressants by airtankers or helicopters until complete control of the fire is achieved by ground personnel.

Ground Effect. Reaction of the wing or rotor downwash against ground surface forming a "ground cushion" that increases lifting capability of that section of air.

Ground Fire. Fire in duff, ground debris, or low growing vegetation.

Ground Speed. The speed with which an aircraft transverses the ground over which it flies.

Ground Visibility. Prevailing horizontal visibility near the earth's surface as reported by the U.S. National Weather Service or an accredited observer.

Head. The side of the fire having the fastest rate of spread.

Heading. The compass direction in which the longitudinal axis of an aircraft points.

Helibase. Location within the general area of an incident for parking, fueling, and maintenance of helicopters.

Helibase Manager. Manages resources/supplies at a helibase (heliport/helispot).

Helibucket. A specially designed bucket carried by the helicopter like a sling load and used to drop retardant or suppressants.

Helicopter Coordinator. Works for the air attack supervisor. With instructions from air attack supervisor, is primarily responsible for coordinating tactical or logistical mission(s) by helicopters assigned to an incident.

Heliport. A designated landing area that is accessible by road and large enough to accommodate, at a minimum, two helicopters. It should have fueling facilities, wind indicator, fire extinguishers, surfaced pads, tie downs, parking areas, water source, telephone and radio communications, officers for base personnel, pilots' rest areas, and lights.

Helipumper. A portable pump unit developed for transport by helicopter.

Helispot. Location where a helicopter can land and take off.

Helitack. The initial attack phase of fire suppression using helicopters and trained airborne teams to achieve immediate control of wildfire in a safe and economical manner.

Helitack Crew Member. A fire fighter trained in use of helicopter accessories and techniques to attack and suppress wildfire.

Helitack Manager. The person directly in charge of a helitack crew.

Helitank. A tank attached to a helicopter to carry liquids such as suppressants or retardants.

HF. High Frequency.

High Drop. A drop well above the canopy to give a soft falling, well-dispersed pattern. Used mainly to give a light retardant or suppressant coating that will reduce fire intensity.

Hold. Do not drop. An order to hold a load and go around. It should be followed by an explanation and new directions from the air attack supervisor, usually a change in attack plan or a ground crew in the way.

Hole. Weak or missed area in retardant or suppressant drop.

Hot Spot. A particularly active part of a fire within or along the fire boundary.

ICS. The incident command system or qualifying and organizing personnel to manage wildfires or other incidents.

Incident Commander. The chief of an incident management team under the ICS.

Identification Run. A pass over the target area by the airtanker coordinator, birddog, or lead aircraft to indicate the flight path and target while the airtanker pilot is observing.

IFR. Instrument Flight Rules.

IGE. In-Ground Effect. Using the high density ground cushion to hover the helicopter.

Initial Attack. The first action taken to suppress a fire, whether it be ground or air attack.

Inspection Run. Run over target area to check for wind and smoke conditions and other hazards.

Knot. Nautical mile per hour.

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.

Late Drop. Retardant or suppressant landing beyond the target.

Lay-Up. Connecting a drop to the rearward part of a previous drop.

Lead In. Lead plane/birddog flies the target run in front of the tanker on final approach to target.

LF. Low Frequency—in 30-300 KYz band.

Line. A stretch of retardant or suppressant laid by aircraft to support constructed line or suppressant or to retard fire spread.

Line Length. The distance actually covered on the ground by a single retardant or suppressant drop at a given coverage level.

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.

Lone-Wolf Action. Initial attack by a single airtanker operating without direction from an airtanker coordinator (lead plane pilot/birddog officer).

Long-Term Retardant. One having a chemical retarding action on fire even after water content has evaporated.

Low Drop. A drop lower than recommended minimum drop height.

Magnetic Bearing. Angle to an object measured from magnetic north in a clockwise direction.

Magnetic Course. The angle that the longitudinal axis of the aircraft makes with magnetic north.

Magnetic Variation. The angle between true north and magnetic north, measured east or west.

Maneuvering Speed. The maneuvering speed is the greatest safe speed for abrupt maneuvers or for very rough air. Upon encountering severe gusts, the pilot should reduce airspeed to maneuvering speed. For airplanes in which the maneuvering speed is not specified, it can be safely computed as 70 percent greater than normal stalling speed. (Stalling speed $\times 1.7$ = maneuvering speed.)

MOT. Canadian Ministry of Transport.

MSL. Mean Sea Level. The base commonly used in measuring altitudes.

NAVAID. Air Navigation Facility. Any structure, equipment, or device used in air navigation or air traffic control and considered a part of the national airways system.

Night. The time between the end of evening civil twilight and the beginning of morning civil twilight, as published in the "American Air Almanac," converted to local time.

NOTAM. Notice to Airmen. A notice identified either as a Notam or Airmen Advisory, containing information concerning the establishment, condition, or change in any component of, or hazard in, the National Airspace System, the timely knowledge of which is essential to personnel concerned with flight operations.

OAT. Outside Air Temperature.

One Strike/One Shot Concept. An initial attack on a fire based on enough long-term retardant or suppressant arriving to finish the action and control the fire without the airtankers having to make a second trip.

Orbit. Circular holding pattern an aircraft makes over one specific spot or area.

Parallel Attack. An outside (indirect) attack parallel to and removed from the fire's edge. Usually only effective with long-term retardants in an air attack operation.

Pass. A run by the target without making a retardant drop.

Pilotage. Navigation by visual reference to landmarks.

Pilot-in-Command. The pilot responsible for the operation and safety of an aircraft during flight time.

Pull Up. The act of executing a sharp maneuver to indicate the target area.

Radial. A magnetic bearing extending from a VOR, VORTAC, or TACAN.

Radio Fix. The determining of position by one or more radio navigational aids.

Restricted Area. Special use airspace of defined dimensions identified by an area on the surface of the earth within which the flight of aircraft, while not wholly prohibited, is subject to restrictions.

Retardant. A chemical having a retarding action on fire.

Retardant Support Base. A base set up to support the operations of retardant/suppressant aircraft.

Return and Hold. An order to a pilot denoting mission completed and further loads not required. He returns to base and waits for further instructions.

Rheologic Properties. Cohesiveness or the ability of a material to hold together during a drop.

Rising Ground. Terrain of increasing elevation ahead or on either side.

Salvo. The dropping of the entire retardant or suppressant load at one time.

Should. Indicates a recommendation or that which is advised but not required.

Slurry Base. The same as retardant support base.

Snag/Chicot. Any dead or living tree rising above the forest canopy.

Special Use Airspace. Defined airspace within which flight is prohibited or restricted, or in which special hazards exist to flight.

Split Load. A drop sequence wherein the load is dropped in increments.

Spot Fire. A fire ahead of, or outside, the main fire boundary.

STOL Aircraft. Short Takeoff and Landing Aircraft. An aircraft that has the capability of operating from a STOL runway, in accordance with applicable airworthiness and operating regulations.

Suppressants. Agents used to extinguish the flaming and glowing phases of combustion by direct application to burning fuels, i.e., water or foam.

Tag-On. Connecting a drop to the forward part of a previous drop.

Temporary Flight Restriction (TFR). Special use airspace obtained under FAR Part 91.137 for the use of air attack or other incident aircraft.

Touchdown Area (Pad). That part of the landing and takeoff area where the helicopter alights.

Tower. Airport traffic control tower. A facility providing airport traffic control service.

Track. The flight path of an aircraft over the surface of the earth.

Traffic Pattern. The traffic flow that is prescribed for aircraft landing at, taxiing on, and taking off from an airport. The usual components of a traffic pattern are upwind leg, crosswind leg, base leg, and final approach.

Trail Drop. To drop retardant from separate compartments in rapid succession to give an extended pattern on the ground. Normally used to build a retardant line or barrier along the fireline.

True Bearing. A bearing by true north rather than magnetic north.

Turn-the-Corner. Connecting a drop to a previous drop at an angle toward the head of the fire.

Uncontrolled Airport. An airport not having an operating control tower.

Unicom. Frequencies authorized for aeronautical advisory services to private aircraft.

Vector. A heading issued to an aircraft to provide navigational guidance by radar.

VFR Conditions. Basic weather conditions prescribed for flight under visual flight rules.

VFT (Special). Aircraft operating in accordance with clearances within control zones in weather conditions less than the basic VFR weather minima.

VHF. Very High Frequency.

Viscosity. The thickness of a solution or suspension. A measure of the relative ability of a fluid to resist flow. Heavy syrup has a high viscosity; gasoline has a low viscosity. Viscosity is usually measured in centipoise.

VOR. VHF Omnidirectional Range. Provides pictorial guidance on any selected magnetic course to or from the radio facility. It is limited to line of sight reception. There is some “spillover,” however, and reception at an altitude of 1,000 ft (305 m) is about 40 to 45 miles (64 km to 72 km). This distance increases with altitude.

VTOL Aircraft. Vertical Takeoff and Landing Aircraft. An aircraft that has the capability of vertical takeoff and landing. These aircraft include, but are not limited to, helicopters.

Weather Advisory. In aviation forecast practice, an expression of hazardous weather conditions not predicted in the area forecast, as they affect the operation of air traffic and as prepared by the National Weather Service.

Wetting Agent. Chemical added to water to reduce surface tension.

Wing Span. The distance in feet (meters) and inches (centimeters) from wing tip to wing tip of an airplane.

B-2 Aircraft and Equipment Suitability and Selection.

B-2-1 Aircraft—Fixed Wing.

B-2-1.1 Detection, Reconnaissance, and Survey.

Small airplanes (single and multiengine) are used for detection, reconnaissance, and surveys. Airplanes for fire reconnaissance are used in combination with ground detection systems in areas of high fire occurrence. The use of aircraft for checking areas not visible from ground detection units is an accepted practice. Reconnaissance flights are usually scheduled following lightning storms. Flights to check “going” fires and controlled fires from previous days provide the latest information on conditions and progress.

Recently, heat sensing (FLIR) systems have been developed for use with small aircraft. These systems are economically feasible, and simplicity of operation warrants their consideration for detection and reconnaissance activities. With further development the detection could be computerized.

Table B-2-1.1 Thermal (IR)
Indicator Correspondence to Scan Angle

Altitude	Swath Width	Speed
500 ft	1730 ft	100 mph
1000 ft	3460 ft	200 mph

1500 ft	5200 ft	300 mph
2000 ft	6920 ft	400 mph

Surveys of an area before and after a burn can provide a detailed review and study of an area that might otherwise be expensive and time-consuming. Many times the measurement of burn areas can be accomplished with a minimal amount of flying time.

Small airplanes can be made available for other jobs in connection with wildland fire protection. It is standard practice for agencies that do not own their own aircraft to contract with a local fixed base operator (FBO) to provide the aircraft and pilot.

B-2-1.2 Paracargo and Freight.

Numerous types of small, medium, and large airplanes are used for transporting freight and dropping paracargo to fire camps or isolated crews. Not all airplanes are suitable for freight activities, and relatively few can be modified into good paracargo aircraft. Most civilian airplanes now being used were designed and built for carrying passengers and require special modifications to adapt them for freight or paracargo work.

Desirable features for air-freight and paracargo airplanes are: sufficient capacity, smooth floors, inherent stability, moderate or low stalling and landing speeds, suitable paracargo discharge aperture, ample reserve power at near gross weight (multiengine), easy control under marginal flying conditions, good visibility, stripped utility interior, cargo tiedown facilities, and approved seats, seatbelts, and shoulder harness.

B-2-1.3 Special Equipment.

Cargo tiedown facilities are necessary in all airplanes used to transport air-freight or cargo. Special equipment must be installed to prevent any malfunctions. Most special equipment must have FAA approval before use.

B-2-1.4 Amphibious Operations.

Amphibious or float equipped aircraft can be more versatile and serve more functions than land based aircraft. In Alaska, and some parts of Canada and the contiguous United States where suitable lakes and rivers are numerous, and in the coastal area, this type of aircraft is used extensively.

As long as adequate water depth and an unobstructed water surface area are maintained, little or no preparation other than suitable docking or ramp facilities is required for a water-base operation. If no safe natural docking or beaching site is available, temporary docks can be constructed to facilitate loading and unloading, to avoid damage to the aircraft.

Many amphibious aircraft are equipped to drop suppressants such as foam.

B-2-1.5 Detection, Reconnaissance, and Survey Aircraft.

Airplanes that are available and suitable for detection, reconnaissance, and surveys can be divided into three basic types: (1) light high-wing, single engine airplanes, (2) light low-wing, single engine airplanes, and (3) light twin engine airplanes. The light high-wing single engine type of airplane is usually the most suitable.

Figure B-2-1.5Detection, reconnaissance, and survey aircraft.

Light airplanes are usually more economical and efficient than helicopters for detection, reconnaissance, and survey flights; however, the helicopter, because of its versatility, is especially useful for intensive-type missions that require landing for ground inspections and low level slow flight.

Some factors to consider in selecting aircraft for these assignments are:

(a) Number of persons necessary to carry out the assignment.

(b) Performance characteristics of the airplane; landings and takeoffs from airfields at high elevations, with short unsurfaced runways; adequate cruising range; visibility (maximum forward and lateral visibility is essential); cabin space; aircraft instruments and properly installed radio equipment.

(c) Suitability for infrared scanning and mapping.

B-2-1.6 Airtankers.

Aircraft selection for wildfire suppression and related uses involves certain problems. The performance characteristics must be such that safe and efficient operations can be conducted over typical terrain and at necessary elevations. The aircraft integrity should be such that atmospheric conditions will not present a structural problem.

Tank capacity, drop speed, cruise speed, and other characteristics of the various makes and models of airtankers are listed in Table B-2-1.6.

Light airtankers can be operated efficiently and economically as initial attack aircraft on wildfires where the fires are within 30 miles (48.3 km) of the air attack base. These aircraft are also capable of support action and accurate low volume drops in confined areas.

Medium and larger airtankers with 2,000 plus gal (7600 L) capacities are more efficient on a cost-per-gallon mile basis for high volume cascading on fires and retardant fireline construction. This should not preclude use of large airtankers at short range because many times fires are contained or controlled by several high volume cascading actions.

With the development of the MAFFS concept (Modular Airborne Fire Fighting System), military and civil cargo aircraft can be converted for airtanker use provided the aircraft is equipped with a tail loading door and can carry the weight of the system.

Figure B-2-1.6 Lockheed C-130 (MAFFS) Airtanker.

Table B-2-1.6 Fixed Wing Airtankers Specifications Chart

Airtanker	Min Runway Required Feet (Meters)	No. of Engines	No. of Crews	A/C Loaded Speed Drop	Knots Cruise	No. of Doors	Minin U.S
LIGHT up to & including 800 gallons (3028 liters)							
Aero Commander Snow	2000(610)	1	1	61	96	1	30
DeHavilland Otter	2500(762)	1	1	70	100	2	108
DeHavilland DHC-6 Twin Otter	2500(762)	2	1	59	150	2	27
Grumman AG-Cat N3N Stearman	2000(610)	1	1	61	87	1-2	30
Grumman S2F Tracker	3500(1067)	2	1	104	161	2	20
FLZ M18 Dromader	1000(305)	1	1	78	118	1	66
MEDIUM—800 gallons up to 2000 gallons (3028 liters) (7570 liters)							
Douglas B-26 STOL	4000(1220)	2	1	122	190	4	25
Consolidated PBY5A Canso	5000(1525)	2	2	87	104	2	40

Consolidated Super PBY 5	4200(1281)	2	2	87	148	2	624
Canadair CL-215	4000(1220)	2	2	96	152	2	588
Lockheed PV2	4000(1220)	2	2	113	180	2	437
Douglas DC-4	4000(1220)	4	2	126	170	4-8	207
SP2H	4000(1220)	2	2	120	216	2	500
HEAVY—2000 gallons plus (7570 liters)							
Convair Super PB4Y-2	4000(1220)	4	2	113	190	8	275
Douglas Super DC-4	3600(1098)	4	2	126	190	8	275
Douglas DC-6	5000(1525)	4	2	126	216	8	250
Douglas DC-7	4500(1373)	4	2	130	230	8	250
Lockheed P2V	4000(1220)	4	2	126	216	8	408
Lockheed P-3A	4000(1220)	4	2	130	300	8	250
Lockheed C-130A	4000(1220)	4	3	130	256	8	375
Lockheed C-130 (MAFFS)	4500(1373)	4	5	130	256	8	300

*Individual airplanes on this list are sometimes modified for local needs.

B-2-1.6.1 Suitability Factors for Airtankers. To select suitable airtankers, consider the tank capacities, performance capabilities, and general flight characteristics listed in Table B-2-1.6, in relation to the following factors:

(a) Airport. Airtankers using an airport at high elevations, above standard temperatures or with a gradient of 1 percent or above, will require more runway length for safe efficient operation than they would at sea level airports.

To help evaluate airport capability versus airtanker performance for safety during maximum load takeoff purposes, the 80 percent takeoff concept (4-engine) or the accelerated stop concept two engine should be used. If either of these two concepts fails to meet the runway length, the cleared area concept may be used.

(b) Airtanker Loading. It may be necessary to reduce the load to obtain safe performance in response to certain variables such as density altitude, runway lengths, gradient, runway surface, and obstructions.

(c) Cruising Speed. Generally, high cruising speed is desired, especially for initial attack operation.

(d) Drop Speed. The speed at which the aircraft flies during retardant/suppressant drops (slower than cruising speed).

B-2-1.6.2 Special Appliances for Airtankers. Each airtanker should have the following equipment: FAA and agency approved installation of tanks, discharge gates, emergency dump mechanism, shoulder harness, parking brake, rotating beacon, emergency locator transmitter, warning sound device, strobe light, suitable radio equipment, camlock or quick connect fittings for loading tanks, and accurate tank gauge to control loading.

B-2-1.6.3 Tanks, Venting, Drop Gates. The criteria (requirements) for performance of these items are established in the Interagency Airtanker Board, Aircraft-Tank, and Gating Systems.

B-2-1.6.4 Application Variation. For maximum flexibility and efficiency, the retardant/suppressant application rate should be variable, to fit the fire situation. This can be done by sequencing various combinations of multiple doors or using a variable flow rate system.

B-2-1.6.5 Quantity (Splitting the Load). A means of varying the quantity dropped should be provided on airtankers having capacities larger than 500 gal (1893 L). This may be accomplished by:

(a) Tank with separate compartments, each with its own door.

(b) One tank with controllable doors.

(c) A main tank with one door that can be filled from other tanks in the aircraft.

B-2-1.6.6 Discharge Rate. A means of varying the discharge rate is necessary for effective application. The amount of variation possible will depend on the aircraft and tank door arrangement. The maximum discharge rate should be as high as practicable, and the lowest rate should achieve minimum coverage levels. The discharge rate is measured with the airplane in level flight altitude, all doors open, dropping water in the amount equal to the chemical capacity.

B-2-1.6.7 Acquisition. Arrangements for obtaining airtankers must be based upon the most practical and economically feasible method—contract, lease, or outright ownership.

B-2-1.7 Smokejumping Aircraft.

Civil aircraft are not designed specifically for smokejumping use, and certain approved installations and modifications must be made to the properly selected aircraft. These modifications will include a static line anchor cable (installation will vary with the aircraft), door safety strap, safety handrails, doorstep, cargo parachute static line anchor, cargo dropping harness anchor cable, and cargo tiedown facilities. All sharp corners and projections near the door and step, along the fuselage, and under the belly that snag parachutes or cargo must be removed or shielded. (Smokejumper aircraft equipment drawings and specifications may be obtained from the U.S. Forest Service.)

B-2-2 Aircraft—Rotary Wing.

The helicopter has become a familiar multiuse fire fighting aircraft in wildland fire suppression. This aircraft has become as necessary in today's fire suppression as hand tools, crews, tractors, smokejumpers, engines, and airtankers (*see Table B-2-2*).

Table B-2-2 Helicopter Model Specifications

Helicopter Make/Model	Diam. in ft (meters)	Type Landing Gear	Fuel Type	U.S./IMP Fuel Capacity	Wkg. Hrs	Cruise Speed Knots	Hover IGE in ft (meters)	Pass. Seats	Int. Pay-load in lb (kg)	Ext. Pay-load in lb (kg)	R
LIGHT											
Bell 47B3B-1	37′2″ (11.3)	Skid	100 Octavgas	57/46	2	70	15,000 (4575)	2	600 (272.4)	650 (295.1)	U al
Bell 47G38-2	37′2″ (11.3)	Skid	100 Octavgas	57/46	2	70	15,000 (4575)	2	600 (272.4)	650 (295.1)	Sa lo
Soloy Bell 47G	37′2″ (11.3)	Skid	Jet Fuel	57/46	2	83	16,500 (5032.5)	2	1100 (499.4)	1100 (499.4)	G
Bell 206BII	33′4″ (10)	Skid	Jet Fuel	76/43	3	109	10,000 (3050)	4	973 (441.7)	1200 (544.8)	Sa pe
Bell 206BIII	33′4″ (10)	Skid	Jet Fuel	76/63	2	109	10,500 (3202.5)	4	973 (441.7)	1200 (441.7)	Sa pe
Bell 206 L1 or L3	37′0″ (11.28)	Skid	Jet Fuel	110/100	6	109	16,500 (5030)	5	1900 (870)	2000 (907)	V fi
Hiller 12E	35′5″ (10.82)	Skid	100 Octavgas	46/39	2	61	8,500 (2592.5)	2	580 (263.3)	700 (319.8)	G
Hiller 12-53/5	35′5″ (10.82)	Skid	Jet Fuel	46/39	1¾	78	13,500 (4117.5)	3	1100 (499.4)	1100 (499.4)	G w
Hughes 500 C	26′4″ (8.05)	Skid	Jet Fuel	64/54	2½	100	11,000 (3355)	4	582 (309.6)	782 (355)	S g
Aerospatiale	33′6″ (10.24)	Skid	Jet Fuel	149/124	4	78	5,200 (1586)	4	600 (272.4)	900 (408.6)	L n
Aerospatiale Alouette Lama	36′2″ (11.03)	Skid	Jet Fuel	149/124	2½	96	20,000 (6100)	4	980 (444.9)	1442 (6544.7)	E n n
Aerospatiale Alouettte SA-341	34′6″ (11.33)	Skid	Jet Fuel	120/110	3½	130	10,500 (3202.5)	2	833 (378)	1600 (454)	L c
Aerospatiale Aster AS-350	35′0″ (10.67)	Skid	Jet Fuel	140/116	3	121	9,000 (2775)	5	900 (408.6)	1600 (454)	G sp
Aerospatiale Twinstar AS-350	35′0″ (10.67)	Skid	Jet Fuel	140/116	3	121	9,000 (2775)	5	840 (381.4)	1540 (699.2)	S
MEDIUM											
Aerospatiale SA-365N	38′4″ (11.7)	Wheel	Jet Fuel	210/180	2½	148	6,700 (2043.5)	13	2800 (1271.2)	2300 (1044.2)	E
Bell 204B	49′0″ (14.64)	Skid	Jet Fuel	165/137	2	100	9,000 (2745)	9	3575 (1623.1)	3000 (1362)	E p
Bell 205A-1	48′0″ (14.63)	Skid	Jet Fuel	220/183	2½	104	11,000 (3355)	14	2593 (1177.2)	3100 (1407.4)	E p
Bell 212	48′0″ (14.63)	Skid	Jet Fuel	225/187	2	113	11,200 (3416)	14	2295 (1041.9)	3000 (1362)	I
Bell 412	46′0″ (14.02)	Skid	Jet Fuel	214/180	2	121	11,600 (3538)	14	2700 (1225.8)	3400 (1543.6)	
Vought	36′2″ (11.03)	Wheel	Jet Fuel	148/124	2½	95	10,000 (3050)	6	1000 (454)	1200 (544.8)	E t
Sikorsky S55T	53′0″ (16.15)	Wheel	Jet Fuel	186/153	3	78	10,000 (3050)	10	1520 (690.1)	1650 (749.1)	T p

Helicopter Make/Model	Diam. in ft (meters)	Type Landing Gear	Fuel Type	U.S./IMP Fuel Capacity	Wkg. Hrs	Cruise Speed Knots	Hover IGE in ft (meters)	Pass. Seats	Int. Pay-load in lb (kg)	Ext. Pay-load in lb (kg)	Re
MEDIUM (continued)											
Sikorsky S58	56′0″ (17.06)	Wheel	100	158/133	2	87	5,000 (1525)	15	3500 (1589)	4000 (1916)	Go
Sikorsky S58T	56′0″ (17.06)	Wheel	Jet Fuel	274/228	21/1	87	8,000 (2440)	15	3717 (1679.8)	4500 (2065.7)	Tw go
Bell 214	50′0″ (15.2)	Skid	Jet Fuel	204/176	11/2	139	17,800 (5429)	14	3300 (1498.2)	6000 (2860.2)	Ex
Bell 214SAT	52′0″ (15.8)	Skid	Jet Fuel	412/342	2	121	12,500 (3812.5)	19	4500 (2043)	6000 (2724)	Sa
HEAVY											
Aerospatiale SA330 Puma	49′5″ (15.1)	Wheel	Jet Fuel	408/330	3	130	11,500 (3507.5)	18	5200 (2360.8)	7500 (3405)	Ex
Aerospatiale AS332C	51′5″ (14.7)	Wheel	Jet Fuel	408/339	21/2	148	14,800 (4514)	18	6200 (2814.8)	9500 (4313)	Ex
Aerospatiale AS332L	51′2″ (15.6)	Wheel	Jet Fuel	536/429	31/2	148	14,800 (4514)	22	6200 (2724)	9500 (4313)	Ex
Sikorsky S61	62′0″ (18.9)	Wheel	Jet Fuel	410/341	2	104	6,700 (2043.5)	26	4000 (1816)	6000 (2724)	Tw tu
Sikorsky Sky Crane	72′0″ (21.9)	Wheel	Jet Fuel	1700/1396	3	87	6,000 (1830)			10526 (4778.8)	La
Boeing-Vertol	50′0″ (15.2)	Wheel	Jet Fuel	350/292	11/2	113	7,300 (2226.5)	26	4795 (2176.9)	5700 (2587.8)	La an
Boeing-Vertol 114 (CH47A)	60′0″ (18.3)	Wheel	Jet Fuel	630/515	11/2	113	13,000 (3965)	34	6500 (2951)	6500 (2951)	La pe
Boeing-Vertol 234	60′0″ (18.3)	Wheel	Jet Fuel	2090/1700	31/2	139	14,500 (4422.5)	44	24000 (10896)	28000 (12712)	Co

B-2-2.1 Retardant and Suppressant Dropping.

The versatility and maneuvering capabilities of the helicopter make this aircraft an important initial attack tool. Helicopters with capacities for dropping 80-2000 gal (303-7600 L) of suppressant or retardants are principal weapons in the helitack phase of wildland fire suppression. Helicopters generally utilize two methods of dropping (*see Table B-2-2.1*).

Table B-2-2.1 Helicopter Fire Fighting Bucket Specification

Make and Model No.	Collapsible Diam. × H Inches	H_2O Level Adjustment Gallons Pop-out Plug	Injection Pump	Flotation Ring	Overall Dimensions		Unit Complete Weight lb		Door Ope	
					Diam. × H Inches	Cubic Vol. Ft	Empty	Full/H_2O 8.5 lb	No.	T
Chadwick C-140	No	50-70-90 110-140	Yes	Yes	45 × 39	35.8	90	1,280	1	V
Chadwick C-450	No	170-230-300 380-450	Yes	Yes	45 × 51	46.9	300	4,125	3	V
Hawkins & Powers 200[1]	42 × 4½	70-100 Zipper	No	No	42 × 24	19.2	101	1,036	2	B
Hawkins & Powers 200[2]	48 × 4½	125-200 Zipper	No	No	48 × 24	25.1	104	1,804	2	B
Hawkins & Powers 300[2]	48 × 4½	200-300 Zipper	No	No	48 × 38	39.7	108	2,658	2	B
Hawkins & Powers 400[2]	48 × 4½	300-400 Zipper	No	No	48 × 50	52.3	111	3,511	2	B
Sims PTF-50[1]	No	50	Yes	Yes	32 × 22½	11.8	50	475	1	V
Sims PTF-100	No	50-70-100	Yes	Yes	46 × 33	31.7	81	931	1	V
Sims PTF-150	No	50-70-90 110-140-150	Yes	Yes	47 × 39	39.1	86	1,361	1	V
Sims PTF-300[2]	58 × 21	None	Yes	Yes	59 × 36½	71.1	300	2,850	2	B
Sims PT-450	No	200-250-300 350-450	Yes	Yes	64 × 57½	106.9	252	4,077	2	B
Sims PT-1000	No	500-600-700 800-1000	Yes	Yes	84 × 74	237.2	625	9,125	2	B
Griffith 140[1]	34 × 24	Variable Adjustment	No	Yes	34 × 43½	22.8	84	1,357	1	V
Griffith 140[2]	50 × 30	Variable Adjustment	No	Yes	51 × 55	64.9	225	3,625	1	V
Bambi	Variable		Available	No	Variable		Variable		1	D
Griffith 2000	80 × 34	Variable Adjustment	No	Yes	96 × 82	474.4	900	17,900	1	V
Sims PT-250	45 × 25	None	Yes	Yes	45 × 45	41.4	180	2,305	1	V
Sims SF-2000	No	1500 1700	Yes	No	98 × 79	344.8	700	17,000	1	B
Griffith 50	24 × 20	+35	No	Yes	24 × 30	7.9	94	470	1	V
Griffith 100	30 × 18	+70	No	Yes	31½ × 38½	17.4	106	956	1	V
Griffith 250	45 × 26	+193	No	Yes	42 × 44	35.3	198	2,323	1	V
Griffith 600	50 × 30	+400	No	Yes	58 × 58	88.7	350	3,325	1	V
Griffith 1000	50 × 35	+400	No	Yes	65 × 84	161.3	575	9,075	1	V

All above buckets are sling mounted to helicopter with open top.
Material: Hawkins and Powers—Canvas/Steel Frame.
Griffith—Made of Polyurethane.
The rest are fiberglass.

[1]Can be carried on small helicopter cargo rack.
[2]Will fit in cabin or passenger compartment of a 205.
+All Griffith Buckets can be ordered with adjustment plugs.

For SI Units: 1 in. = 2.54 cm; 1 gallon = 3.78 liters

Guide to Drop Patterns:

Size Bucket Gallon	Pattern	Coverage Gal/per 100 sq ft
150	20–25 × 200–250	1.4-2
200–450	35 × 330	3.7
500–1000	50 × 850	2.2

(a) A bucket slung underneath the helicopter.

(b) A fixed external tank.

B-2-2.2 Initial Attack Transport.

Helitack functions are designed to transport trained personnel to the fire as quickly as possible. Small crews, trained and properly equipped, can gain control of most incipient wildland fire situations if they can make fast initial attack. This can be accomplished by landing or rappelling near the fire.

B-2-2.3 Reconnaissance and Scouting.

Performance characteristics of the helicopter make it an excellent reconnaissance and scouting aircraft. The slow speed and ability to operate in areas that could not be observed from fixed wing aircraft, plus its usefulness in providing terrain and fire intelligence that otherwise may not be obtainable, are obvious benefits. The helicopters provide an ideal platform for using heat sensing and mapping systems. The systems range from hand-held units to permanently mounted units.

B-2-2.4 Shuttling Equipment and Personnel.

Equipment can be moved to other fire areas, heliport to heliport, or by paracargo or sling load methods, where landings cannot be safely accomplished. Personnel (fire crews, helitack personnel, and others) can be airlifted as conditions warrant. Food and water can be delivered to line crews, and spike camps can be supported in this manner.

B-2-2.5 Rescue.

Helicopters are an essential part of many rescue operations. Some uses are: airlifting medical aid crew personnel to care for and move the injured persons to medical aid sites or hospitals; scouting and directing rescue crews and servicing isolated parties until rescue can be accomplished.

Weather and performance limitations of the aircraft may, at times, prevent their use in rescue operations.

B-2-2.6 Night Operations.

Under tightly controlled conditions, night vision aids for piloting helicopters can extend the safe use of many daytime helicopter operations in the wildland environment into night.

Night operations have several tactical advantages: cooler temperatures, higher humidity, low density altitude, and more stable air are usually present after dark. Atmospheric conditions contribute to better flying conditions at times that suppression measures can be more effective.

Also, helicopter services will not be in competition with airspace requirements of airtankers, smokejumpers, and cargo planes.

B-2-2.7 Other Uses.

Helicopters may also be used for aerial ignition operations such as helitorch, ping pong dispensor, and other similar devices; repelling of trained crews; retrieving smokejumpers; and for detection and prevention activities.

B-2-2.8 Criteria for Selecting Landing Sites.

Consideration should be given to the following in selecting a site for a helibase or helispot.

(a) Proximity to Fire

1. Close enough to minimize flight time.

2. Out of the path of the fire.

(b) Topography of the Site

1. Recommended size of takeoff and landing area (safety circle).
a. Light helicopters 75 ft in diameter (23 m)
b. Medium helicopters 90 ft in diameter (27 m)
c. Large helicopters 100 ft in diameter (33 m)

NOTE: There should not be any obstacles other than 2-ft (.6-m) high brush maximum in the safety circle. All other vegetation and obstacles should be removed (trees, large rocks, etc.).

2. Slope of landing/parking area 6 degrees maximum recommended.

3. Touchdown, taxiway, and parking surfaces.
a. Maximum height of brush is 2 ft (.6 m). (Caution: Dry grass can be a fire hazard around helicopters.)
b. Sufficiently free of large rocks so as to ensure a stable landing.
c. Minimum foreign object damage potential.

(i) Secure or eliminate all loose objects in the vicinity, such as twigs, branches, and trash.

(ii) Dust abatement: Dust can do severe damage to a helicopter's rotating components, especially the engine. Dust abatement will also minimize the rotor-wash generated dust cloud that could dangerously restrict a pilot's visibility.

d. Compacted enough to support the following weights:

(i) Light helicopters 7,000 lb (3178 kg)

(ii) Medium helicopters 15,000 lb (6810 kg)

(iii) Large helicopters 60,000 lb (27,240 kg).

e. The touchdown/parking pad (on which the landing gear will physically sit) should be a minimum of the following:

(i) Light helicopters 15 ft × 15 ft (4.6 m × 4.6 m)

(ii) Medium helicopters 20 ft × 20 ft (6.1 m × 6.1 m)

(iii) Large helicopters 30 ft × 30 ft (9.1 m × 9.1 m).

f. Soft surfaces, such as tundra or boggs, may require a log pad.

g. Recommended minimum obstacle clearance for touchdown, taxiway, and parking areas is 10 ft (3 m) from the tip of the main and tail rotor. If, during planning, the turning radius of the helicopter is not known, utilize the radius of the appropriate safety circle outlined in 1.b above, to determine the minimum distance that an obstacle (including other helicopters) should be from the touchdown/parking pad or centerline of the taxiway.

4. Approach and departure capability in several directions if possible. This will allow the pilots to utilize the wind to their best advantage.

5. Bare, open pinnacles, ridgelines, and meadows make the best helispots and helibases. Due to the potential volume of traffic at a helibase, a more level, open, and preferably improved area should be sought, along with stricter adherence to the guidelines.

6. Although helicopters are capable of operating out of areas in which the safety circle is surrounded by tall trees (hover hole), it is not necessarily safe to do so. Every effort should be made to allow the helicopter to make shallow approaches and departures.

If operating from a hover hole is the only alternative, ensure that the approach and departure paths to the hover hole meet the minimum criteria outlined in (c) below.

(c) The recommended criteria for approach and departure paths:

1. Preferably, the approach and departure paths should not be the same. In fact, several approach and departure paths should be developed if possible. This will allow pilots to adjust to changing meteorological conditions.

2. The minimum width of approach and departure paths should be the same as the diameter of the corresponding safety circle. Safety would be enhanced if the paths could be widened by 10 degrees on either side of the centerline as they leave the circle (20-degree spread).

3. Curving paths are permissable in order to avoid major obstacles.

4. The paths should have a minimum 8:1 slope, measured from the edge of the safety circle.

5. No obstacle should penetrate that slope during the 20-degree spread for:
a. Approach path 150 ft (48 m)
b. Departure path 300 ft (96 m).

6. Areas suitable for landing the helicopter in the event of an emergency would be desirable along the paths.

7. The paths may generally be aligned with the prevailing wind but not always. Pilots will utilize such variables as velocity of the wind, turbulence, updrafts, and downdrafts in deciding the direction of their approach and departure; hence the importance of having several approach and departure paths available.

(d) Establish flight routes in order to ensure the following:

1. Separation between helicopters.

2. Separation between other aircraft on the fire.

3. Flight following check points.

4. Aircraft performance—try not to have a heavily loaded helicopter climb steep terrain.

(e) Pilots. The most important factor to consider when establishing these sites is the advice of the pilots flying in and out of them. This test offers only general guidelines for selecting helibases and helispots. The pilots will make the final decision on all proposed site selections.

B-2-2.9 Helicopter Accessories.

The versatility of the helicopter permits utilization of a variety of helitack accessories. It is essential that helitack crews be able to use these accessories properly and that fire overhead personnel understand their tactical use.

(a) Cargo Hook. A cargo hook or cargo adapter assembly is required with helicopter accessories. The cargo hook or adapter assembly serves as a standard suspension hard point for attaching external helicopter accessories. With the cargo hook installed, the helicopter can take sling-type helitanks or any load suspended by a cable or cables.

(b) Swivels. Swivels are required for sling loads of supplies and for using drum lifters. A swivel permits sling loads to rotate freely and eliminates the possibility of lead line breakage due to oscillation.

(c) Lead Line. The cable that joins the cargo hook or swivel to the sling load. Regardless of the type of lead line material or length used, the following points should be considered:

1. Tensile strength
2. Condition of material
3. Length of line.

(d) Cargo Nets. Cargo nets are designed for transporting freight suspended beneath helicopters. A suspended load beneath the aircraft permits delivery of freight without landing and is considered the most efficient method for heliborne freight movement.

(e) Helicopter—Buckets and Tanks. These are used to drop retardants/suppressants on fires.

The key to effective use of the bucket is to have a water or chemical source as close as possible to the fire site. Hoverfilling (filling the bucket while the helicopter hovers) maximizes the turnaround and delivery capability since it is not necessary to land and load water or chemicals by pumping.

The helicopter buckets vary in capacity from 80 through 2000 gal (303-7600 L) and are designed for use with various makes and models of helicopters.

The helicopter fixed tank is made of metal (usually aluminum) and usually has a capacity of 200-360 gal (757-1363 L). These are filled by a hose from an engine, portable pump, or through an internal snorkel from a dip tanker or other water source.

(f) Cargo Racks. A variety of helicopter cargo carriers are in use—flat racks, basket-types (Stokes litter), etc. General requirements applicable to cargo racks must be observed. Litters can be mounted internally and externally.

(g) Loading Platforms. An elevated landing ramp or loading pit may be required for heavy or bulky loads that must be stacked as close to the sling release as possible.

(h) Firing Devices. At least two proven firing devices can be effectively used for “firing out” operations on wildland wildfires and for igniting prescribed burns.

The helitorch consists of a 35–200-gal (132–757-L) drum mounted on a sled platform, pump, discharge line, and an electronically activated glow plug. As the thickened fuel passes through the glow plug, the fuel ignites and free flows to the ground. The fuel consists of unleaded gasoline and a gelling agent. When properly mixed, the fuel thickens to a jello-like substance.

The Aerial Ignition Device System (AIDS) mounts within the helicopter’s passenger doorway. “Ping pong balls,” containing potassium permanganate, are fed through the device injecting each ball with ethylene glycol causing the ball to ignite within 20–40 sec after it exits the discharge tube.

(i) Forward Looking Infrared (FLIR). Units can be internally and externally mounted on helicopters for detection and reconnaissance. The images are recorded on videotape and can simultaneously be viewed on a screen within the helicopter. Hand-held infrared units can be operated effectively from within the helicopter. Tapes can then be cropped or delivered to fire camp where they can be used for tactical planning.

B-2-3 Effects of Increased Density Altitude on Aircraft Performance.

With increased density altitude, lift and engine horsepower decrease; rotor blades and propellers lose efficiency; and ground speed increases for any given indicated airspeed. This increases takeoff distance and radius of turn, decreases rate of climb of fixed-wing aircraft, and reduces the performance of rotorcraft [*see Tables B-2-3(a)* and *B-2-3(b)*].

Table B-2-3(a) The ICAO Standard Atmosphere Table

	Altitude	**Temperature**		**Speed of Sound**	**Pressure**
	Meters (Ft)	**°C**	**°F**	**Knots**	**In. Hg**
Standard Atmosphere	**0**	**15**	**59.0**	**661.7**	**29.92**
	305 (1000)	13.019	55.4	659.5	28.86
	610 (2000)	11.037	51.9	547.2	27.82
	915 (3000)	9.056	48.3	654.9	26.82
	1220 (4000)	7.075	44.7	652.6	25.84
	1525 (5000)	5.094	41.2	650.3	34.90
	1830 (6000)	3.113	37.6	647.9	23.98
	2135 (7000)	1.132	34.0	645.6	23.09
	2440 (8000)	-.850	30.5	643.3	22.22
	2745 (9000)	-2.831	26.9	640.9	21.39
	3050 (10000)	-4.812	23.3	638.6	20.58
	3355 (11000)	-6.794	19.8	636.2	19.79
	3660 (12000)	-8.775	16.2	633.9	19.03
	3965 (13000)	-10.756	12.6	631.5	18.29
	4270 (14000)	-12.737	9.1	629.1	17.58
	4575 (15000)	-14.718	5.5	626.7	16.89

The four factors that affect density altitude are altitude, atmospheric pressure, temperature, and moisture content of the air.

Runway length requirements for specific aircraft are usually computed for sea level and standard atmospheric conditions of 59°F/29.92 Hf (15°C/101.32 kPa), with a runway gradient of one percent or less.

Table B-2-3(b) Density Altitude Table

Pressure Altitude	15°C 59°F	20°C 58°F	25°C 77°F	30°C 86°F	35°C 95°F	40°C 104°F	45°C 113°F	50°C 122°F
S.L.	0	550	1,100	1,650	2,200	2,750	3,300	3,850
1,000	1,200	1,750	2,300	2,850	3,400	3,950	4,500	5,050
1,500	1,850	2,400	2,960	3,500	4,050	4,600	5,150	5,700
2,000	2,450	3,000	3,550	4,100	4,650	5,200	5,750	6,300
2,500	3,050	3,600	4,150	4,700	5,250	5,800	6,350	6,900
3,000	3,650	4,200	4,750	5,300	5,850	6,400	6,400	7,500
3,500	4,250	4,800	5,350	5,900	6,450	7,000	7,550	8,100
4,000	4,900	5,450	6,000	6,550	7,100	7,650	8,200	8,750
4,500	5,500	6,050	6,600	7,700	7,700	8,250	8,800	9,350
5,000	6,100	6,650	7,200	7,750	8,300	8,850	9,400	9,950
5,500	6,700	7,250	7,800	8,350	8,900	9,450	10,000	10,550
6,000	7,300	7,850	8,400	8,950	9,500	10,050	10,600	11,150
6,500	7,950	8,500	9,050	9,600	10,150	10,700	11,250	11,800
7,000	8,550	9,100	9,650	10,200	10,750	11,300	11,850	12,400
7,500	9,150	9,700	10,250	10,800	11,350	11,900	12,450	13,000
8,000	9,750	10,300	10,850	11,400	11,950	12,500	13,050	13,600

1. Set altimeter at 29.92. Face of altimeter will now read Pressure Altitude.
2. Note the temperature on the outside air temperature gauge.
3. Find the Pressure Altitude in the Pressure Altitude column.
4. Read to the right of the Pressure Altitude figure until you come to the Temperature column corresponding to the temperature on the outside air temperature gauge. THIS IS THE DENSITY ALTITUDE FIGURE.

B-3 Ground Facilities.

B-3-1 Ground Support Facilities.

Permanent or auxiliary bases for aircraft engaged in wildfire or related operational activities should be arranged so that aircraft ground traffic, parking, and public movement will not delay or hinder the efficient and safe operation. Taxiways and loading areas must afford adequate width and clearance for safe ground maneuvering of the aircraft. Ramps or heliport pads should be designed to support the gross weights of the aircraft and other necessary equipment.

The National Wildfire Coordinating Group's Fire Equipment Working Team has developed an *Airtanker Base Planning Guide* that identifies planning criteria for developing or upgrading airtanker base facilities.

B-3-1.1 Aircraft Rescue and Fire Fighting.

In most cases, rescue and fire fighting operations in response to accidents at an airport will be performed by regular airport fire fighting personnel. However, it may be necessary at times to furnish this service and necessary equipment where such facilities are not provided by the airport management. The National Fire Protection Association has published a number of useful standards, manuals, and guides on this subject, listed in Appendix C.

NOTE: At no time should air attack operations be conducted without approved fire extinguishing equipment and trained personnel on "fire guard."

B-3-2 Airports, Heliports/Helibases, and Helispots.

B-3-2.1 Airports.

Suitable runway lengths for aircraft employed in air operations could vary from a sod runway of 2,000 ft (610 m), being used by single engine detection, reconnaissance, and scouting aircraft, to the 4,000 to 10,000 ft (1220 to 3048 m) of hard surfaced runway capable of supporting, and of adequate length to assure safe operations of, the largest airtankers. Runway length requirements given for specific aircraft usually apply only at sea level altitude with standard day temperatures 59°F (15°C), and where the runway gradient is one percent or less. For other conditions, the runway length must be increased.

Runways for airtanker use must be of sufficient length to assure safe takeoffs and landings. Repaired runways, taxiways, and ramps should be of such structural design that the gross weight of airtanker operations will not cause damage to the surface.

Runway orientation should be such that the crosswind factor can be held to a minimum. If possible, it is desirable to have unobstructed departure and approach lanes for the runways.

Ideally, air traffic should be minimal. If air traffic becomes heavy, employ an approved air traffic controller to expedite departures and arrivals.

Rural-located bases, such as heliports, helibases, or helispots, are rarely confronted with competing activities that slow down or hinder air operations as opposed to an airport-located base. One exception in some areas is military training routes (MTR’s).

The operations building for a permanent or auxiliary base should be of adequate design and size to accommodate present and foreseeable future operations office activities. It should include the necessary communications facilities essential for efficient and safe operations, office space, pilot lounge, etc., in a permanent base operations building.

(a) Altitude. Increase the basic runway length by 7 percent for each 1,000 ft (3-5 m) above sea level.

(b) Temperature. Increase the runway length that has been fixed by altitude by 1/2 of 1 percent for each degree (F) that the mean temperature of the hottest day exceeds 59°F (15°C).

With normally aspirated engines (nonsupercharged), approximately one-half of the rated horsepower is lost at 10,000 ft (3.050 m).

The FAA Flight Standards Service Operations Division has developed the Denalt Performance Computer, which is intended to supplement the aircraft manufacturer’s published performance data for computing takeoff performance. Two types are available: one for fixed pitch and one for variable pitch propeller aircraft.

B-4 General Operating Procedures.

B-4-1 Air Operations Plan.

Considerable evaluation and study will be necessary for those who plan air operations. Firsthand experiences and sound information from others who are using aircraft will be extremely helpful.

Some of the factors involved for consideration will include the overall objectives and need for the operations, cost evaluation, availability of suitable aircraft to fulfill the objectives and need, operational base locations, and ground support facilities, communications, personnel necessary to operate the aircraft, the bases, and ground support facilities, and for the overall supervision of the air operations.

B-4-2 Control of Aircraft During Incidents.

The chain of command at a incident should be: Air Operations Director, Air Attack Supervisor (in the air or on the ground, job may be assumed by Incident Commander or Division Supervisor in early stages of fire), Airtanker Coordinator (lead airplane), smokejumper or cargo aircraft, and first initial attack pilot on the scene.

B-4-2.1 Control Procedures.

Pilots should know before being dispatched who has aircraft control at the fire. They should check in with Aircraft Control at least 5 miles (8 km) from the fire area and should not takeoff, or enter, or remain in the fire area unless both primary and secondary radio frequencies are operating on transmit and receive.

Pilots, including the one arriving to assume control, who are unable to establish communication on the primary or secondary frequencies should remain clear of the fire area and attempt to relay through other stations to control. If no contact can be made, the pilot should return to the base.

Smokejumper or cargo drops, airtanker retardant drops, and helicopter operations should not be conducted simultaneously if one will interfere with the other. Aircraft control should designate which operation has priority when aircraft must accomplish more than one mission.

If an initial attack airtanker arrives when no control plane is in the area, the tanker pilot should attempt to establish ground contact for drop instructions. If contact cannot be established, and the pilot is positive it is not a radio malfunction, and the arrival of a control plane is not imminent, the pilot should circle the fire area at least once, evaluating it for water-chemical drop. The initial pass should be a dry run to check visibility, turbulence, and obstructions and to spot personnel in the anticipated drop area. If the pilot is satisfied that a safe effective drop can be made, the aircraft should proceed to accomplish the drop.

B-4-3 Retardant and Suppressant Drops.

The proper use of air attack is important to resource protection.

The decision to use airtankers should be based on careful consideration of the following:

(a) Fire potential and its likelihood of doing extensive damage or requiring costly suppression efforts.

(b) Threatened safety of lives.

(c) Opportunity to obtain more economic control.

(d) Availability of an airtanker organization sufficiently trained, equipped, and organized to perform the mission.

(e) Accomplishing the mission during daylight hours, with terrain, visibility, and wind conditions permitting safe and effective dropping.

The airtanker is a highly specialized and costly fire fighting tool. It is the responsibility of the incident commander to suspend the use of an airtanker when it is no longer effective or essential.

Specialists with airtanker experience should be consulted and assisted in the planning of the airtanker program. An airport facility guide and map showing the airports suitable for primary and auxiliary airtanker operations, within or adjacent to protection areas, should be made.

Airports selected for either primary or auxiliary airtanker operations should be rated as to the number of airtankers that can be handled simultaneously. This will depend on the size of the airport and area set aside for loading facilities, the mixing and loading facilities, the amount of fire retardant chemical, and the available ground personnel.

The primary objective should be to have airports within 30 min transit time from the areas to be protected by initial attack aircraft. The distance will depend on the performance of the aircraft (*see Table B-2-1.6*).

Pre-wildfire season planning should include preparing the base for airtanker operations.

This will include:

1. An operational check of mixing equipment.
2. Determination of the dry and wet chemical supply, water supply, and storage facilities, and
3. Training of the ground crews that are to support the operation and the logistics necessary to keep the air attack aircraft operational.

B-4-4 Detection, Reconnaissance, and Scouting.

The essential components for a successful airborne detection, reconnaissance, and scouting operation are as follows:

B-4-4.1 Preliminary Planning.

Maps, charts, seen-area composites, spot maps, weather information, fire statistics, and any other information that may help in accomplishing the operation should be utilized.

B-4-4.2 Aircraft Selection Suitable for the Operation.

The aircraft should satisfy all functions of the mission. Aircraft size, performance characteristics, visibility, and safety are of prime importance.

B-4-4.3 Pilot Qualifications.

The selection of a properly qualified pilot capable of accomplishing the mission safely under any conditions that might be encountered. This includes the skill and knowledge necessary to determine when the mission can no longer be considered safe and should be terminated. A properly qualified pilot is usually an excellent observer.

B-4-4.4 Aerial Observers.

Aerial observers should have the proper training and have gained through actual experience the capabilities of distinguishing and interpreting their observations in relation to the mission's objectives. In wildfire and related missions, the observer should be experienced in fire behavior, fuels, weather measurements, and fire suppression.

B-4-4.5 Preflight Briefing.

Pilot and observer should completely understand their individual responsibilities, along with other combined efforts necessary in conducting a successful and safe mission.

B-4-4.5.1 Pilot responsibilities include:

(a) In-flight check points, established at 15-min intervals.

(b) Safety of airplane, cargo, and passengers during takeoff, in-flight, and landing.

(c) Monitor of Weather—turbulent air, altitude, and flight path direction changes, noting storms and cross wind components with regard to mission termination, flight plan revisions, and unscheduled landings.

(d) Check visibility per FAA requirements.

(e) Adjusting of flight route and termination of mission.

B-4-4.5.2 Selecting the proper class and type of mission is usually done with the assistance of the person responsible for dispatching the flight, but qualified observers are often delegated this duty. Observer responsibilities are as follows:

(a) Assemble current information and prepare information, maps, and notes. If on a wildfire mission, assemble current fire and weather information.

(b) Check to see if pilots have reached or will exceed their allowable number of safe flying hours per day or week.

NOTE: Pilots should not be allowed to exceed flight hour limitations.

(c) Be familiar with air safety rules.

(d) Check equipment and forms needed for the mission.

(e) Inform the pilots of mission route, and know deviations such as fire scouting, freight delivery, etc.

(f) Ground check of radio installation.

(g) Observer in-flight duties should include:

1. Recording flying time.

2. Radio communications, forest net radio, and applicable frequencies.

3. Pilot performance.

4. Other necessary activities.

(h) Schedule aircraft in advance when possible.

B-4-4.6 Reconnaissance.

The aircraft should be flown to provide the observer with the best possible visibility. The objective should be on the observer’s side and as free as possible from visibility restrictions. Approaches should be planned to provide the light and background.

Frequently, the pilot can offer assistance to verify questionable observations and, at times, assist by providing data from aircraft instruments, maps, and aircraft radio use.

Flying should be as smooth as possible to relieve the observer of unnecessary strain. The pilot should anticipate the observer’s needs and maneuver the aircraft so that the observer does not have to shift position constantly.

B-4-4.7 Detection.

Flight routes should be planned and timed to give the observer every possible advantage for the best observations. The selection routes should be prepared on charts for each foreseeable condition that may occur and to preclude overlapping of jurisdictions. Systematic profiling of critical areas along the proposed route is essential as this permits easier determination of alternate flight routes. It may be necessary to fly the flight routes several times before establishing the selected route. The observers then should continue to refine and make adjustments.

It may be necessary to adjust flight altitudes and place areas with backgrounds that limit visibility on proper profile for flight line adjustments in improving the efficiency of the detection flights.

B-4-4.8 Direction of Flight in Relation to Drainage.

Normally, in mountainous areas, the flight routes should be planned to parallel the major drainages. This allows the observer to look up or down the secondary drainages. Flights across major drainages restrict the observation behind secondary and minor ridges.

B-4-4.9 Correct Flight Line Altitude.

Correct flight altitudes are determined by:

1. Intensity of search and frequency of observations;
2. Visibility restriction, smokey haze, etc., and its elevation;
3. Width of observation strip;
4. Topographic type;
5. Amount of cloud and topographical shadows;
6. Sun angle and direction; and
7. Background and minimum altitude required for safe flight.

A method of determining flight altitude is to profile and calculate coverage at 500-ft (152-m) intervals and altitudes.

There is very little advantage to flying at high altitudes, even in clear weather, when the observation strip is limited by topography. The best observation altitudes may vary according to terrain. Varying atmospheric conditions may require adjustment of flight altitude.

B-4-4.10 Observation Distance.

The observer should not waste any effort searching the distant horizon. Observations should be confined principally to the assigned strip. The search area ahead should be limited to 15 miles (24 km) or less. For intensive search, such as lightning coverage or during extreme or emergency fire danger, this distance should be reduced. About half the time may be used in forward observation. The rest of the time is spent searching those areas that later will be hidden from view.

B-4-4.11 Flying Speed.

The slow cruise speed of the aircraft is a good observation speed. Under certain conditions, slower speeds may be necessary to observe specific areas. The experience and training of the pilot and observer have an important bearing on the flying speed. High and low speeds have certain advantages, depending on conditions and observation objectives.

B-4-4.12 Number and Frequency of Flights.

The number and frequency of flights will depend on the desired objectives, available personnel and aircraft, and atmospheric conditions.

B-4-4.13 Estimating.

Rapid and accurate estimating is essential to a successful mission. Some of the common methods of estimating from aircraft are:

(a) Distance.

1. Compare the lineal measurements of objects, either visually or from maps and air photos. Lakes, runways, and similar landmarks are suitable for this purpose.

2. Measure the approximate distance by using flight time and airspeed.

(b) Slope.

1. Aircraft instruments, such as the artificial horizon and altimeter, can be used to estimate slopes. Slopes may also be estimated from topographic maps.

B-4-5 Communications.

Satisfactory communications equipment must be installed in the aircraft either permanently or on a temporary basis.

B-4-5.1 Radio.

Suitable transceivers, either permanent or for temporary installation, must be provided for each aircraft. The use of Federal Aviation Administration (FAA) VOR navigational equipment or LORAN may be used to locate ground positions accurately.

B-4-5.2 Message Dropper.

Message droppers should be carried in all aircraft for use when other means of communications are not possible or available.

B-4-5.3 Air-Ground Signals.

A copy of the air-ground signals should be carried in the aircraft and by all crew members.

B-4-6 Flight Plans.

Planned periodic aircraft position reports should be made (frequency shall depend on the mission). These position reports should be followed up promptly if not received within a specified time limit.

Any deviation or change from a planned route should be reported immediately and a new flight plan filed with notification of check points and destination.

A definite procedure should be established designating personnel responsible for follow-up if aircraft is unreported at its destination. This is especially important for flights terminating during hours the dispatching office is not manned.

Following flight procedures and requirements should be mandatory for each flight. Radio contact and a location report should be made at least at 15-min intervals. A flight search should be initiated if contact cannot be established within 30 min.

B-4-7 Records and Reports.

Adequate records and reports are necessary for proper management of air operations. The reports help determine if the operation is:

1. Being conducted safely and economically, and
2. Accomplishing the objectives of the plan.

Once it is determined that both are being met, reports can be reduced to a minimum.

B-4-8 Lead Planes.

The mission of the lead plane pilot is to serve as airtanker coordinator on the fire, assigned to the air attack supervisor. The primary purpose of the airtanker coordinator is to make certain that the airtankers place the retardant or water on the assigned targets safely and effectively.

NOTE: Lead planes are usually light twin engine aircraft.

At the present time, a number of lead plane techniques are used. The two most frequently used are:

(a) The lead plane orbits the fire at 1,000 ft (305 m) above ground level and directs the airtankers by radio. This high-level technique affords better visibility of both the ground and air operations, but radio conversation is often time consuming and time loss is costly.

(b) The lead plane acts in a low-level “show me” method, simulating the airtanker pass, and identifies the target by radio, by rocking its wings over the target, zooming, or by using other methods of identifying the target.

The lead plane pilot also determines if there are fire fighting personnel or others in the proposed drop area and if so notifies the air attack supervisor or incident commander so people on the ground can be warned of the impending drops.

B-4-9 Helitack.

Helitack is designed to transport fire fighters, equipment, and helitack crew trained in the use of specialized accessories, such as cargo nets and helitank, to the fire without delay. The prime value is speed of attack with short turnaround in rugged terrain.

B-4-9.1 Rappelling.

The development of a helicopter rappel deployment technique extends the present use of helicopters as a wildfire suppression tool. Successful rappelling from a helicopter to the ground in stands of tall timber [200 ft (61 m)] has proven that rappelling is possible, and a practical means of delivering specially trained wildfire suppression crews when other means are not possible.

B-4-9.2 Night Operations.

Night vision goggles permit nighttime use of twin engine helicopters over forested areas where only natural light prevails. Special pilot training is needed to perform water and chemical dropping, personnel transportation, cargo hauling, reconnaissance, and medivac operations. Under carefully controlled conditions, the operations can be performed with one or more helicopters.

High intensity lights mounted in the helicopter have also proven to be an effective and safe means of conducting night operations. It is generally a less expensive program than night vision goggles. High intensity lights require no special pilot training and can be used adjacent to populated areas. Combinations of steerable large aircraft landing lights have proven most effective.

B-4-9.3 Coordinated Use.

Airplanes and helicopters may be used in many ways on a single fire. Their use must be coordinated to provide the right action at the right time and to assure a safe air attack operation. This is done by the air attack supervisor.

B-4-10 Smokejumping.

Airplanes can drop smokejumpers into remote, isolated areas for fast initial attack on wildfires or to build and prepare a helispot or landing area, so that ground crews and fire fighters can be landed by helicopters. Smokejumpers may be fire fighters with special training in parachute jumping. Smoke jumpers are used on any fire where their attack is faster than ground-crew attack. Normally, they are transported by airplane to the fire area, making parachute jumps as close to the fire area as possible and starting suppression work immediately. When the situation demands, smokejumpers are dropped near a fire and construct a helispot. Helicopters then shuttle fire fighters to the helispot and return jumpers to bases to be ready for another jump.

B-4-11 Air Traffic Pattern.

The air traffic pattern in the fire area is determined in part by the terrain and wind conditions. Aircraft control should establish the most suitable patterns and coordinate aircraft separation.

Airtankers should orbit at least 1,000 ft (305 m) above the terrain in a left pattern while waiting to drop. The orbit generally will be made at a designated location away from the drop area. The aircraft speed and turning radius will determine size of the pattern. Airtanker aircraft should operate below the observation aircraft.

The aircraft of the air attack supervisor should maintain at least 2,000 ft (610 m) above the terrain, using the flight pattern most suitable to the mission. When descending below 3,000 ft (914 m), the pilot should fly a lefthand traffic pattern.

The lead plane should orbit to the left or wherever necessary to set up and observe the airtanker drops. The exact flight pattern and elevation above the terrain will depend on whether the high-level or low-level system of airtanker direction is used.

Smokejumper and cargo aircraft should advise aircraft control of the best pattern for their purpose. Aircraft control should then establish the aircraft separation required and notify the jumper or cargo aircraft when to proceed. All other aircraft should remain at a designated location well clear of the jumper or cargo drop area until receiving further instructions from aircraft control.

Aircraft control will instruct helicopters to stay clear of the area when any type of drops are being made. If priority use of a helicopter is desired, aircraft control should discontinue the drops until the helicopter has completed its assignment or is clear of the area.

B-4-12 Training Requirements.

All people involved in aircraft operations on wildfires, such as the air operations director, air attack supervisor, lead plane pilot/airtanker coordinator, airtanker pilot, and helicopter pilot must be fully qualified to do their job. Special training is required for these positions.

B-4-13 General Aviation Hazards.

Pilots should be briefed and familiarized with all possible air hazards approaching and returning to the base of operations and within the fire area. When practical, a hazard map should be prepared and the pilot should be given a familiarization flight over the area in which the flight operations will be conducted. Such flight hazards will include:

(a) Restricted areas (military activities, etc.).

(b) Obstructions less than 1,000 ft (305 m) above ground (observation towers, antennas, TV towers, etc.).

(c) Obstructions more than 1,000 ft (305 m) above the ground (radio and TV towers, microwave, and related communications towers).

(d) Valleys, rivers, and lakes with dangerous power lines, telephone lines, or towers.

(e) Power lines and towers, telephone lines, and poles in the immediate vicinity where air operations and low flying may be required.

(f) A single tree or snag that is taller than the other trees in the area, where low flying is to be conducted.

(g) Narrow canyons, valleys, and steep terrain that could cause extreme turbulence or alleys, and steep terrain that could cause extreme turbulence or down-drafts.

(h) Extreme air turbulence or high winds, generally over 30-40 mph (45-65 kmh), that could restrict or suspend low-level flying.

(i) Military flight training routes where low flying, high speed aircraft could present a hazard.

(j) Aircraft or related activities in the vicinity of the airport (parachute jumping).

(k) Obstructions on or near the air base that may affect takeoff or landing of the aircraft.

(l) Geographic features that could cause wind conditions that might be hazardous to flight operations.

(m) Domestic or wild animals on the air base that could cause a collision or damage the operational surface.

(n) Roads crossing air bases that could cause collisions or damage.

(o) Airborne sightseers, news media, etc.

(p) Where required, on-going wildfire operations with aircraft should be coordinated with FAA route structure controllers and military low-level high speed training route schedulers and coordinators.

B-4-14 Airtanker Base Operations.

By the designation of a safety officer or person in charge, the following steps should be taken to assure the safe performance of all airtanker operations:

(a) Keep unauthorized persons out of the mixing and loading areas.

(b) Designate a parking area for needed vehicles, and keep all other vehicles elsewhere or away from the operations base.

(c) Use airport matting around mixing and loading areas to ensure footing of ground personnel. A water hose should be provided to flush retardant materials that cause hazardous conditions.

(d) Require all airtanker operations personnel to wear hard hats, goggles, and earmuffs, and to wear respirators during mixing operations.

(e) Enforce safety regulations for loading and refueling aircraft.

(f) Provide a fire guard with suitable fire extinguishers. Crash trucks should be arranged for or provided when practical.

(g) Require airtanker pilots to wear crash helmet, safety belt, safety harness, and fire resistant clothing.

(h) Prohibit all unnecessary low flying of airtankers over fire camps or other large concentrations of personnel off the fireline.

(i) Airtankers operating from water bases will exercise all water-related safety precautions.

(j) Designated personnel will make periodic inspections of crash and survival gear, replacing and renewing items as needed.

(k) Require all aircraft to be operated in conformance with the operations manuals prepared by the contracting or owning agencies.

(l) Prior to airtanker use, brief the tanker pilot as to the fire situation, general plan of action, and specific missions. The briefing will include hazards, topography, wind velocity, turbulence, anticipated operations at the target site, and whom to contact when about 3 min from the fire, or some other ground contact.

(m) Provide a taxi director for congested ground operations.

B-4-15 Airtanker Water Operations.

Amphibious or float-equipped aircraft can pick up a load of water in a very few seconds. These amphibious aircraft or seaplanes may be equipped with external or internal tanks and range in capacity up to 1,500 U.S. gal (5678 L). The method of filling is generally the same for all aircraft, with fixed, adjustable, or retractable probes. The water is forced up the filling tubes by ram pressure developed by forward movement of the aircraft while planing or taxiing.

Air attack operating principles and procedures are essentially the same as land-based airtankers with the exception of the loading operation. Airtankers making water pickups from the same source can be confronted with water turbulence caused by the preceding aircraft during its filling operation. This can also hold true during the cascading operation if adequate spacing is not maintained. The amount of turbulence depends on the size of the aircraft and prevailing wind and conditions. This turbulence is dispersed more rapidly in high and cross winds. Under normal operating conditions, the minimum spacing of the aircraft making water pickups from the same source would be 1 min apart. With a fast turnaround time, there is a limit to the number of aircraft that can operate from the same source. If more than one loading source is established, it becomes essential that suitable control of loading at the sources and cascading operations at the fire site be conducted in a safe manner.

Amphibious airtankers are usually equipped with an onboard supply of wildland fire and foam and can inject it into the water on the way from the pickup spot to the fire.

To assure safety in flight between the loading source and the fire, adequate aircraft separation and altitudes must be maintained. This separation is usually maintained by a delay between aircraft during the cascading and altitude separation of aircraft attacking the fire, and the aircraft returning from the fire. Safety is always a prime factor when more than one aircraft is involved in the same operation:

(a) Amphibious and float-equipped attack aircraft have a definite advantage over land-based aircraft, provided a suitable water source for loading is available near the fire.

(b) No ground crew or equipment is required at the loading site.

Since loading time generally requires less than 30 sec, delivery time per load is the flying time from the water source to the fire and return. This normally results in more loads per hour than could be delivered and cascaded by land-based aircraft. In many cases, small aircraft operating from a water source close to the fire can equal or surpass the delivery rate in gallons per hour of much larger land-based aircraft. It must be remembered, however, that amphibious aircraft drop suppressants, not retardants; and while not necessarily less effective, they definitely require a different attack strategy than do retardants.

Amphibious and float-equipped aircraft are mobile and independent; they may be moved rapidly from fire to fire with concerns only for normal fuel, oil, and maintenance requirements.

B-4-16 Amphibious and Float-Equipped Support Aircraft.

Amphibious and float-type aircraft are utilized in many support functions ranging from detection, reconnaissance, and survey flights, to the transporting of cargo and personnel. Aircraft that were designed, or could be configured, for water operations have for the past 50 or more years provided vital support to remote inland rivers, lakes, and coastal areas.

B-4-17 Helicopter Operations.

Helicopter operations will comply with the applicable general rules for aerial operations and practices prescribed for specialized helicopter operations.

The pilot is responsible for the safety of the aircraft at all times.

With the exception of specially trained pilots equipped for nighttime operations, daytime operation of the helicopter will be conducted during the period of time defined as 1/2 hr before sunrise to 1/2 hr after sunset.

Helicopters must not be dispatched for mountain flying when average velocity over a 5-min period at exposed peaks is 30 mph (27 KNTS) or more.

The helicopter pilot must not be permitted to fly more than the maximum number of allowable hours in a day.

A person trained in helicopter use should be stationed at each helicopter landing area during flight operations to supervise loading operations and enforce safety regulations.

Nighttime helicopter operations can be conducted with a qualified pilot, using night vision goggles or high intensity lights when performed within closely controlled and defined limits.

Helicopter arm signals should be practiced by all personnel assigned to helitack operations.

Ground-to-air signals and FAA ground signals should be remembered and use by associated personnel.

B-4-17.1 Precautions on the Ground—Helicopters.

All unauthorized personnel will be kept clear of the area of operation. Hard hats with chin straps will be worn at all times.

(a) Keep clear of helicopter rotors. Unless required to go near, stay 50 ft (15.2 m) from small helicopters, 100 ft (30 m) from large helicopters, at all times. When necessary, approach from front or side, in full view of pilot.

(b) Always approach and depart helicopters from downhill side, at a slight crouch, keeping visual contact with pilot at all times.

(c) Before takeoff, fasten and adjust safety belt and shoulder harness. Keep belt fastened until instructed by pilot, after landing, to leave aircraft.

(d) Do not face helicopters when they are landing, taking off, or hovering unless goggles are worn.

(e) Keep clear of main rotor and tail rotor at all times. Carry long-handled tools low and parallel to the ground, keeping clear of the main rotor or stabilizer bar.

(f) Do not overload helicopter; put cargo in racks and tie down securely.

(g) Obtain pilot's approval for all gear stowed in or on the helicopter.

(h) Always indicate wind direction by wind socks, streamers, flagging, or throwing dirt.

(i) Helibases, particularly refueling areas, should be dustproofed by wetting down, using polybinder, or other means, to prevent dust and other foreign objects from entering engine's fuel containers, damaging engine parts of the ship, or presenting danger to the eyes of personnel.

(j) Equip helibase, helispots, and heliport with a minimum of two fire extinguishers—separated to each side of the landing area.

(k) Keep field helispots clear of debris, equipment, and unauthorized personnel.

(l) When helicopter accessories such as sling loads and helitanks are being used, personnel should never be standing directly beneath any portion of the helicopter or equipment.

(m) Smoking regulations and other safety signs shall be posted at all field heliports.

The following regulations must be observed when refueling helicopters:

1. Helicopter engine must be stopped and master switch shut off unless a certified and functioning closed circuit refueling system is installed.
2. Helicopters and fuel containers will be grounded.
3. There will be no passengers aboard the aircraft.
4. A suitable fire extinguisher will be available for immediate use.
5. No smoking within 50 ft (15.2 m) of fueling area.
6. No unauthorized personnel within 100 ft (30.5 m) of fueling area.

B-4-17.2 Pretakeoff Briefing.

Conducted by the pilot or helitack personnel. The type of operation will dictate the type of briefing necessary, and the following topics should be discussed:

(a) Overwater Flights. The location and use of flotation gear and other survival equipment aboard; how and when to abandon the helicopter should ditching be necessary.

(b) Flights Over Rough or Isolated Terrain. Occupants should be informed of access to maps and survival gear.

(c) Emergency Instructions. Each passenger should be aware of necessary actions and precautions in the event of an emergency, such as assuming correct body position for best spinal protection against a high vertical impact landing (erect, with back firmly against the seat back) and when and how to exit after landing.

B-4-17.3 Precautions for Passengers During Flight:

(a) No smoking.

(b) Keep clear of the controls.

(c) Hold maps, papers, etc., securely while in flight.

(d) Use chin strap when in flight. If chin strap is not available, hold hard hat securely under arm or in hand.

(e) Keep oriented—aware of bearing—at all times.

(f) Keep alert for hazards, particularly power and telephone lines. Inform pilot of their presence, and assist the pilot, when requested, in watching tail rotor clearance during landings at field landing area.

B-4-17.4 Prelanding Briefing.

The nature of the landing area will determine the information given to passengers. A few items to consider:

(a) If on a hill, depart downhill. If this involves walking around the helicopter to avoid area of the lowest rotor clearance, always go around the front, NEVER THE REAR.

(b) Review of safety precautions for ground operations.

B-4-18 Ground Personnel—Hazards From Airtankers.

All ground personnel should listen and watch for low flying aircraft making retardant or water drops. If no prior notification of the drop has been received, the first warning of the arrival of the aircraft may be the sound of the air to ground warning siren or "whooper," or the aircraft engine sounds during the dry run over the target area. The safest procedure in such a situation is:

(a) Do not run unless escape is assured.

(b) Discard hand tools to the side in as safe a manner as time permits. Do not leave tools where cascading retardants can dislodge them, causing injury to personnel in the area. If uncertain as to safety, retain tools in hand.

(c) Lie face down, head toward the oncoming aircraft, with hard hat in place and grab something firm to prevent being carried or rolled by the dropping liquid.

(d) When in timber, get away from large trees and snags if at all possible. Retardant and water drops can break off both dead and live branches. Do not remain in any area where there are loose rocks or other material that may be dislodged and thrown by the liquid drop.

B-4-19 Air Space Control.

With the smoke, turbulence, and topography problems, the air operations and air attack flying on wildfires can, in themselves, be dangerous. With the added problems of the presence of sightseeing, commercial, and military aircraft in the fire area, the hazards increase greatly, and mid-air collisions become a possibility.

There are measures, however, that can be taken to reduce the nonessential air traffic in the fire area. U.S. Federal Aviation Regulation 91.137, Temporary Flight Restrictions, allow the affected agency to request FAA restriction of air traffic around disaster areas. When this flight restriction is requested, and when a Notice to Airmen has been issued under this section, no person may operate an aircraft within the designated area unless the aircraft is operated in compliance with this flight rule.

The airspace restriction should be requested and set up only when necessary to air operations being conducted in the fire area. When this request is made to the nearest FAA air traffic facility, the FAA files a NOTAM (Notice to Airmen) of existence and location of restriction that could include a request that nonparticipating aircraft avoid using the selected bases of operation to relieve airport traffic congestion. This restriction system is not foolproof, and continued vigilance for other aircraft is absolutely essential.

There are hazards created by military aircraft with their low altitude, high-speed training routes. These routes—Department of Defense Flip Low Altitude Training Routes—cover much of the United States with a constantly moving network of low-level, high-speed military aircraft.

This is a difficult problem without a ready solution. To minimize the problem, Flip Low Altitude Training Route Charts should be available, thus enabling the dispatcher to notify all persons involved that a fire is near a given route. Notification of the base designated responsible for the route does not assure that military training aircraft will always be diverted from this route.

Again, as previously stated, the best defense against this problem is coordination, communication, and constant vigilance.

B-5 An Interagency Airtanker Board Charter.

The Interagency Airtanker Board was established to provide coordination between fire agencies in evaluation, testing, and use of airtankers to accomplish the fire suppression job.

A. Purpose of the Board:

1. Accept, review, and evaluate proposed new or modified airtankers. Recommend approval of acceptable airtankers to concerned agencies.
2. Act as advisor to the agencies and industry operators in the overall improvement of airtanker retardant delivery systems.
3. Provide the vehicle for cooperative effort among all participating agencies and industry operators in the development, evaluation, improvement, introduction, screening, selection, and approval of experimental and operational airtanker retardant delivery systems.
4. Promote, through any and all available means, the long-term improvement in the effectiveness and efficiency of airtanker retardant delivery systems.

B. Objectives of the Board:

1. Through an evaluation and testing process, determine acceptable types of airtanker aircraft, tanks, and gate design, and recommend them for interagency use.

2. Integrate advancement of retardant technology into aerial delivery systems.

3. Provide a central source of data and information regarding evaluation, testing, selection, and introduction of airtankers, tanks, gates, and all participating agencies and industry operators.

C. Function of the Board:

1. Accept and review applications for the development and introduction of airtanker aircraft and tank and gate design as part of the total retardant delivery system. Applications may include the proposal of a concept, design for development, or the completed hardware.

2. Evaluate the application and proposal in reference to:

(a) Mandatory requirements.

(b) Other than mandatory criteria.

3. Select the best flight test programs and qualified organization to conduct or perform flight testing and field evaluation on the drop characteristics of the retardant drop systems.

4. Review and recommend approval or rejection of the proposed airtanker, aircraft tank, and gating system based on the results of the flight test and retardant drop test program.

5. When the airtanker is drop tested, designate an individual, agency, or facility to supervise and report on the performance of drop tests, field evaluation, and pattern acceptability and effectiveness.

6. If the drop tests are acceptable and other requirements are satisfactorily completed, recommend approval of the airtanker, tank, and gating system and type of aircraft for interagency use. If not acceptable, recommend redesign, or reject the proposed airtanker, tank, and gating system.

7. Obtain an operational field evaluation from the participating agency or other concerned agencies after the first season of use and provide appropriate agencies with the results.

8. When a given type of aircraft is approved as an airtanker, the Board, as a matter of expediency, may recommend temporary approval of proposed additional airtankers that are to be modified in conformity to the same TC/STC approval, pending submission of the required conformity statement, weight and balance data, and revised flight manual.

D. Membership of the Board:

1. The Board shall be composed of eight voting members. Three members shall be appointed by the Director, Office of Aircraft Services, and Department of the Interior. Three members shall be appointed by the Director of Fire and Aviation Management—Forest Service, Department of Agriculture. One member shall be appointed jointly by the two Directors from a list of candidates submitted by the National Association of State Foresters. The eighth member, who will serve as chairperson, shall be appointed jointly by the two directors for a term not to exceed 4 years.

2. The Board may call upon advisors from industry, research, and equipment development as needed, in addition to state and FAA representatives, contracting or other technical specialists, none of whom may be voting members.

3. Membership on the Board, and participation as advisor to the Board, shall be with the concurrence of the individual's organization. Individual expenses incident to the Board operation will be funded by the unit of assignment of the individual, or the company of employment.

E. Operation of the Board:

1. The Board shall meet annually, and at other times as needed, to act on any applications and proposals.

2. All requirements of the evaluation procedures, including aircraft modification, tank and gate design, flight and drop tests, and certification, will normally be financed by the operator/proponent.

3. A weighting process, such as a point system, will be used by the Board in evaluating all “other than mandatory criteria,” or some other equitable and workable systems for evaluation.

4. Changes in the criteria for requirements of airtankers will be recommended to the appointing authorities for approval before they may be included as a requirement.

5. All tankers approved by the Interagency Airtanker Board, and the Military Airborne Fire Fighter System (MAFFS), are to be considered approved tankers. Any tanker with sufficient deficiencies evidenced by use may be subjected to further review by the Board for determination of continuing approval or withdrawal of such.

6. All Board recommendations will be jointly submitted to the Director, Office of Aircraft Services, Department of Interior; and the Director, Fire and Aviation Management, Forest Service, Department of Agriculture. Acceptance or rejection of the recommendations will be coordinated between the directors and then communicated to the Board Chairperson. In the event of disagreement between the directors, additional information may be required from the Board to assist in the negotiation of a final agreement. Approval of tankers will be communicated to the Board, aircraft owner, and the airtanker contracting officers by the staff of the Director of the agency currently chairing the Board.

7. Nothing in this plan is to preclude any agency from establishing additional requirements or operating limitations in contracting for the use of airtankers.

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 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 Publications.

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

NFPA 18, *Standard on Wetting Agents*, 1990 edition

NFPA 298, *Foam Chemicals for Wildland Fire Control*, 1989 edition

NFPA 402M, *Manual for Aircraft Rescue and Fire Fighting Operations*, 1991 edition

NFPA 403, *Standard for Aircraft Rescue and Fire Fighting Services at Airports*, 1988 edition

NFPA 407, *Standard for Aircraft Fuel Servicing*, 1990 edition

NFPA 408, *Standard for Aircraft Hand Fire Extinguishers*, 1989 edition

NFPA 409, *Standard on Aircraft Hangars*, 1990 edition

NFPA 410, *Standard on Aircraft Maintenance*, 1989 edition

NFPA 412, *Standard for Evaluating Aircraft Rescue and Fire Fighting Foam Equipment*, 1987 edition

NFPA 414, *Standard for Aircraft Rescue and Fire Fighting Vehicles*, 1990 edition

NFPA 901, *Uniform Coding for Fire Protection*, 1990 edition

NFPA 1001, *Standard for Fire Fighter Professional Qualifications*, 1987 edition

NFPA 1201, *Recommendations for Developing Fire Protection Services for the Public*, 1989 edition

NFPA 1221, *Standard for the Installation, Maintenance, and Use of Public Fire Service Communication Systems*, 1991 edition

NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, 1987 edition

NFPA 1901, *Standard for Pumper Fire Apparatus*, 1991 edition

"Wetting Agents and Wet Water Foams—Making Water More Efficient," NFPA *Fire Protection Handbook*, 1962, 12th Edition

C-2 Bibliographical References.

The following documents or portions thereof are recommended within this standard 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-2.1 Boise Interagency Fire Center Publications.

Boise Interagency Fire Center Publications, PMS, 3905 Vista Ave., Boise, ID 83705.

NWCG Handbook 1, *Wildfire Cause and Determination Handbook*, 1983 (PMS 412-1)

NWCG Handbook 3, *Fireline Handbook*, 1990 (PMS 410-1)

NWCG-NFES No. 1363-1988, *Spark Arrester Guide, General Purpose and Locomotive* (6 P/L) Volume 1 (PMS No. 430-2)

NWCG-NFES No. 1363-1988, *Spark Arrester Guide, Multiposition Small Engine* (MSE) Volume 2 (PMS No. 430-2)

NWCG *Airtanker Base Planning Guide*

C-2.2 Other Publications.

Alberta Forest Service *Wildland Fire Foam Manual*, Second Edition, 1989.

Brown, A. A. and K. P. Davis, *Forest Fire Control and Use*, New York, NY, McGraw-Hill Book Co., 1973, Second Edition.

California Department of Forestry, *Fire Fighter Training Course*, Vols. I and II, Sacramento, CA, 1981.

California Division of Forestry and USDA, Forest Service, *Forest Fire Fighting Fundamentals*, 1950.

Canadian Forestry Service, Environment Canada; Canadian Forest Fire Weather Index Tables, *Forestry Technical Report 25*, 1978.

Clar, Raymond C. and Leonard R. Chatten, *Principles of Forest Fire Management*, California

Division of Forestry Sacramento, 1972.

Deeming, J. E., R. E. Burgan and J. D. Cohen, *The National Fire-Danger Rating System*, USDA, For. Serv. Gen. Tech. Rep. INT-39, and INT-40, Intermt. For. and Range Exp. Stn., Ogden, Utah 1978.

Deeming, J. E. and J. W. Lancaster, *Background Philosophy, Implementation—National Fire Danger Rating System*. USDA Fire Control Notes 32(2): 4-8, 1971.

Department of Lands, Forests, and Water Resources, British Columbia Forest Service, *Handbook on Forest Fire Suppression*, Victoria, BC, 1972.

Florida Forest Service, *Fire Fighter's Guide*, Tallahassee, 1964.

Gaylor, Harry P., *Wildfires: Prevention and Control*, Robert J. Brady Co., Bowie, MD, 1974.

Lancaster, J. W., *Fire Management Applications of the National Fire Danger Rating System* 1978. USDA Forest Service, Cooperative Fire Protection, 1978.

Lawson, B. D., *An Interpretive Guide to the Canadian Forest Fire Behavior Rating System*, Can. Forestry Serv., Pacific Forest Res. Center Rep. BCP-3-72, 1972.

Madrzykowski, Daniel. *Study of the Ignition Inhibiting Properties of Compressed Air Foam*. Gaithersburg, MD: U.S. Department of Commerce, National Institute of Standards and Technology, Center for Fire Research, 1988.

Marx, Martin, Mark Harper, and Todd Halter. *Introduction to Quantitative Modelling of Fire Fighting Foam*. Boise: Computer Integration and Literacy, 1988.

McKenzie, Dan. *Engineering Analysis of Threshold Compressed Air Foam Systems (CAFS)*. San Dimas, CA: U.S. Department of Agriculture, Forest Service, Technology and Development Center, 1987.

National Fire Protection Association. *Fire Protection Handbook*. 1986. 16th Edition. Section 19, Chapter 4. Quincy, MA: NFPA.

National Fire Protection Association. *Standard on Fire Chemicals for Wildland Fire Control*. Quincy, MA: NFPA, 1989.

National Wildfire Coordinating Group. *Foam Applications for Wildland and Urban Fire Management*. Vol. 1, No. 1, 1988.

National Wildfire Coordinating Group. *Foam Applications for Wildland and Urban Fire Management*. Vol. 3, No. 1, 1990.

National Wildfire Coordinating Group. Draft: *Foam vs. Fire*. Contact Doc Smith, FEWT's Foam Task Group Chairman, Kaibab National Forest, 1990.

Rochna, Ron. *In Line CAFS Instructions*. Boise: U.S. Department of Interior, Bureau of Land Management, 1990.

Rochna, Ron, Clarence Grady, and Paul Schlobohm. *A Performance Test of Low Expansion Nozzle Aspirated Systems and Wildland Foam*. Salem, OR: U.S. Department of Interior, Bureau of Land Management and Chemeketa Community College, 1988.

Rochna, Ron and Paul Schlobohm. *An Operational and Tactical Guide to Ground-Applied Foam Applications*. Salem, OR: U.S. Department of Interior, Bureau of Land Management, 1987.

Rochna, Ron and Paul Schlobohm. Personal experience.

Schlobohm, Paul and Ron Rochna. *Foam as a Fire Suppressant: An Evaluation*. Wildland Fire 2000 Symposium, April 1987: South Lake Tahoe, California. Berkeley, California: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, 1987.

Schlobohm, Paul and Ron Rochna. *Relationships between Water, Wet Water, Foam, and Wildland/Urban Interface Fire Suppression*. In: Proceedings, Protecting People and Homes from Wildfire in the Interior West, October 1987: Missoula, MT. Missoula, MT: U.S. Department of Agriculture, Forest Service, 1987.

Schroeder, Mark J. and C. C. Buck, *Fire Weather . . . A Guide for Application of Meteorological Information to Forest Fire Control Operations*. USDA For. Serv. Agr. Hdbk., 1970.

Smith, Richard. Combating forest fires with foam requires a reassessment of tactics. Fire: *The Journal of British Fire Services*, Vol. 75. Unisaf House, Kent, England, 1982.

Society of American Foresters. *Glossary of Wildland Fire Management Terms Used in the United States,*Washington, DC, 1990.

Stechisen, Edward. *Effectiveness of Firefighting Foams. Foam Applications for Wildland and Urban Fire Management*. Vol. 3, No. 1, 1990.

Turner, J. A. and B. D. Lawson, *Weather in the Canadian Forest Fire Danger Rating System.* Forestry Service, Environment Canada, Pacific Forest Research Centre Report BC-X-177, 1978.

U.S.D.A. Forest Service *Interim Requirements and Manufacturer Submission Procedures for Wildland Fire Foam*.

Van Wagner, C. E., *Structure of the Canadian Forest Fire Weather Index*. Can. Dep. Environ., Can. Forest. Serv. Pub. 1333, 1974.

Williams D. E., *Forest Fire Danger Manual*. Canada, Department of Forestry Pub. No. 1027, 1963.

C-2.3 U.S. Federal Aviation Regulations.

The following publications are available from the U.S. Government Printing Office, Washington, DC 20402.

Vol. I:

Part 1—Definitions and Abbreviations

Vol II:

Part 11—General Rule-Making Procedures

Part 13—Enforcement Procedures

Part 15—Nondiscrimination of Federally Assisted Programs for the FAA

Part 21—Certification Procedures for Products and Parts

Part 37—Technical Standard Order Authorization

Part 39—Airworthiness Directives

Part 45—Identification and Registration Marking

Part 47—Aircraft Registration

Part 49—Recording of Aircraft Titles and Security Documents

Part 183—Representatives of the Administrator

Part 187—Fees

Part 189—Use of Federal Aviation Administration Communication Systems.

NFPA 297

1995 Edition

Guide on Principles and Practices for Communications Systems

1995 Edition

This edition of NFPA 297, *Guide on Principles and Practices for Communications Systems*, was prepared by the Technical Committee on Public Fire Service Communications 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 297 was approved as an American National Standard on August 11, 1995.

Origin and Development of NFPA 297

The Guide on Telecommunications Systems was originally published by the NFPA in 1975. Its purpose was, and still is, to provide general information relating to communication requirements of agencies involved in wildfire suppression operations. The guide was revised by the Technical Committee on Forest and presented to the Association for adoption at the 1985 Fall Meeting as NFPA 297.

During the 1995 Annual Meeting revision cycle, the title of the document was changed to reflect that communication systems are used in many applications. Communication systems are an integral resource for proper incident management, span of control, accountability, and personnel safety.

Communication systems are changing daily. Today, the ability to track personnel and apparatus is instantaneous. Geographic positioning systems (GPS), automatic vehicle locating systems (AVS), enhanced 911 (E-911), cellular phones, mobile data terminals, and computer-assisted dispatch have enhanced communication capabilities.

The technical committee members will continue to keep current with changing technology and terminology, and incorporate those changes into future editions. These changes will also be reflected in NFPA 1221.

Technical Committee on Public Fire Service Communications

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Committee Scope: This Committee shall have primary responsibility for documents relating to the operation, installation and maintenance of public fire service communication systems.

NFPA 297

Guide on Principles and Practices for Communications Systems

1995 Edition

Information on referenced publications can be found in Chapter 6 and Appendix D.

Chapter 1 Introduction

1-1 Scope.

1-1.1

This guide deals with systems and their components and operations that involve the transfer of information over a distance utilizing electrical or electronic means. It is intended to provide general information only. More specific technical data should be secured from manufacturers or communication specialists in state, provincial, or local governments.

1-2 Purpose.

1-2.1

The need for reliable communications has long been recognized in the fire service. This guide focuses on four basic elements in the communications requirements of a fire department. Included are communications between the public and the fire department; communications within the fire department under emergency and nonemergency conditions; communications among fire departments; and communications between the fire departments and other agencies.

1-3 General.

1-3.1

Radio, telephone, and other electronic equipment, operating procedures, and personnel training should enable messages to be conveyed as quickly and reliably as the situation requires. Messages should be sent and received correctly with no delay. Effective operating practices should be developed and training should be provided to meet the needs of each department. The measure of adequate service is the ability of the system to handle both emergency situations and the normal daily activities of the department.

1-4 History.

In early America, fire companies were brought together by the ringing of bells and gongs, shouting, and word of mouth. In contemporary America, municipal fire department companies are equipped with direct line or radio signaling systems, while suburban or rural companies may alert volunteers with a loud, audible signal produced by siren or horn, or by radios or paging systems at their homes or businesses.

The need for reliable communications has long been recognized in the fire service and is exemplified by the crossed trumpets insignia on the chief officer's badge. The use of the trumpet as a megaphone by chief officers was one of the earliest methods of extending communications beyond the normal range of the human voice. The fire bell in the steeple was an early form of communication used to notify volunteers of the existence of a fire. Hand signals had their beginning in the early days of the fire service and are still used successfully today. With the inventions of telephone, radio, and computers, the field of fire communications took giant leaps forward.

1-5 Definitions.

Unless expressly stated elsewhere, the following terms will, for the purpose of this guide, have the meanings indicated below.

Acknowledgment. The act by which one operator signifies to another that a message has been received.

Added Information Message. A message sent to supplement a previous message and referred thereto.

Air Net. A radio communications network designed to provide air-to-air and air-to-ground communications for agency-owned or contract aircraft. Air nets are often designed on a regional basis.

Amplitude Modulation (AM). Modulation in which the amplitude of the carrier-frequency current is varied above and below its normal value in accordance with the audio, picture, or other intelligence signal to be transmitted. The magnitude of the radio wave is varied in accordance with the information to be transmitted or exchanged.

Antenna. A system of wires or electrical conductors employed for reception or transmission of radio waves. Specifically, a radiator that couples the transmission line or lead-in to space, for transmission or reception of electromagnetic radio waves. (Also known as aerial.) Also, a device used on a vehicle and at a station to radiate the transmitted signal and to receive a signal.

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.

Attenuation. The decrease in amplitude of a signal during its transmission from one point to another. It can be expressed as a ratio or, by extension of the term, in decibels.

Audio. The voice component of the transmitted signal. The normal ear responds to audio frequencies.

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.

Band. A range of frequencies between two definite limits. By international agreement, the radio spectrum is divided into nine bands. Also, a term applied to a group of frequencies.

Bandwidth. The width of a band of frequencies used for a particular purpose. Also, the range of frequencies within which a performance characteristic of a device is above specified limits. For filters, attenuators, and amplifiers, these limits are generally three decibels below the average level. Half power points are also used as limits.

Base. Short for “base station.”

Base Station. A land station in the land mobile service carrying on a service with land mobile stations. Also, the two-way radio transmitting location.

Battery Drain. The amount of electrical power taken from the battery through use of the two-way radio equipment. Usually measured in amps.

Broadcast. Radio or television transmission intended for general reception.

Broadcasts.

(a) *Broadcast.* The transmission of a message to the coded area concerned.

(b) *Direct Message.* A message addressed to a specific point or points on a system.

(c) *All Points Bulletin (APB).* A message direction indicating that the message is to be sent to all points.

Cable. One or more insulated or noninsulated wires used to conduct electrical current or impulses. Grouped insulated wires are called a multi-conductor cable.

Cancellation. A message that cancels another, without delay.

Capture Ratio. The ability of an FM radio receiver to reject unwanted signals and interference on the same frequency as a desired signal, measured in decibels. The lower the figure, the better the receiver performance.

Carrier. Radio wave radiated without modulation by a transmitter. Also, an electromagnetic wave at a specific frequency.

Carrier Frequency. The frequency of an unmodulated electromagnetic wave.

Channel. Sometimes used synonymously with “frequency.” It is the electronic signal path through which radio frequency flows.

Channel Bandwidth. The difference between the upper and lower frequency limits of a channel, expressed in hertz.

Channel, Point-to-Point. A radio channel used for radio communication between two definite, fixed stations.

Channel, Radio. An assigned frequency of sufficient width to permit its use for radio communication. The necessary width of a channel depends on the type of transmission and the tolerance for the frequency of emission.

Chassis. The part of the two-way radio that contains the transmitter and receiver assemblies.

Coaxial Cable. A transmission line in which one conductor completely surrounds the other, the two being coaxial and separated by a continuous solid dielectric or by dielectric spacers. (Also called a coaxial line or concentric line.)

Co-Channel Interference. Interference caused by other parties using the same transmitting frequency already being used.

Communication Center. A building or portion of a building specifically configured for the primary purpose of providing emergency communication services to one or more public safety agencies under the authority(ies) having jurisdiction. This facility should apply to all areas necessary for operation, domicile, and the installation of necessary equipment.

Communications Channel. Similar to a radio frequency, but more general. It is a medium over which communications are established and carried out.

Communications Link. Established communications between two parties.

Communications Network. A combination of links that are complete as to some specific function (e.g., a network to serve command personnel; a network to serve air-to-air control).

Communications System. A combination of links or networks that serve a general function (e.g., a ground attack communications system made up of command, tactical, service, and intracamp networks).

Continuous Duty. A rating applied to receivers and transmitters to indicate their capability for use in a continuous duty cycle (as opposed to the term “intermittent duty”).

Control Console. A panel that contains controls to operate communications equipment.

Couple. To connect two circuits so that signals are transferred from one to the other.

Crystal. A device that controls the exact operating frequency of the transmitter or receiver.

Crystal Controlled. Radios in which each operating frequency is determined and controlled by a vibrating quartz crystal. This limits the number of channels available because of the physical size of the crystals required.

Crystal-Controlled Oscillator. An oscillator in which the frequency of oscillation is controlled by a piezoelectric crystal.

Crystal-Controlled Transmitter or Receiver. A radio transmitter or receiver in which the carrier frequency is controlled directly by a crystal oscillator.

Directional Antenna. An antenna possessing the ability to strongly radiate signals in a specific direction.

Directivity. The value of the directive gain of an antenna in the direction of its maximum value. The higher the directivity value, the narrower the beam in which the radiated energy is concentrated.

Dispatcher. Common name applied to the station operator who relays message traffic in the system. (*See Operator.*)

Distortion. Unfaithful reproduction of audio or video signals due to changes occurring in the waveform of the original signal somewhere in the course it takes through the transmitting and receiving system. Classified as linear, frequency, and phase distortion.

Duplex Channel. A communications channel providing simultaneous transmission in both directions. (*For comparison, see Simplex Channel*.)

Duplex Operation. A method of operation in which communication between stations takes place in two directions simultaneously. A separate channel is necessary for each direction of transmission. (*For comparison, see Simplex Operation*.)

Electromagnetic Energy. The type of energy contained in any electromagnetic wave such as radio waves, visible light, x-rays, gamma rays, or cosmic rays. The frequencies of radio waves go up to about 300,000 MHz.

Electromagnetic Radiation. Radiation associated with a periodically varying electric and magnetic field that is traveling at the speed of light, including radio waves, light waves, x-rays, and gamma radiation.

Energy, Radio Frequency. See Electromagnetic Energy.

Facsimile (Fax). Facsimile is the process whereby images (either print or picture) are translated into an electric signal, transmitted over a communications link, and reconstituted at the receiving end into the original image.

Fade. The variation of radio field strength caused by a gradual change in the transmission medium.

Fade Margin. The number of decibels of attenuation that can be added to a specified radio frequency propagation path before the signal-to-noise ratio of the channel falls below a specified minimum.

Fire Department. An organization providing rescue, fire suppression, and related activities. The term “fire department” shall include any public, governmental, private, industrial, or military organization engaging in this type of activity.

Frequency. The number of cycles per second; the reciprocal of the period. Usually refers to the assigned channel. Literally means the time taken by a signal to complete one cycle.

Frequency Deviation. Frequency deviation of an FM signal is the change in the carrier frequency produced by the modulating signal. The frequency deviation is proportional to the instantaneous amplitude of the modulating signal.

Frequency Modulated (FM). The frequency of the radio wave is varied in accordance with the information to be transmitted or exchanged.

Frequency Modulation (FM). A method of modulating a carrier-frequency signal by causing the frequency to vary above and below the unmodulated value in accordance with the intelligence signal to be transmitted. The amount of deviation in frequency above and below the resting frequency is at each instant proportional to the amplitude of the intelligence signal being transmitted. The number of complete deviations per second above and below the resting frequency corresponds at each instant to the frequency of the intelligence signal being transmitted.

Frequency Stability. The ability of the transmitter to keep the transmitted signal within predetermined limits. (All signals radiate energy outside of their intended paths.)

Generator. A device that develops either direct or alternating electrical voltage at any frequency.

Global Positioning System (GPS). A precise radio positioning system utilizing satellites.

Guard Band. A narrow band of frequencies provided between adjacent channels in certain portions of the radio spectrum to prevent interference between stations.

Half-Duplex Channel. A communications channel providing duplex operation at one end of the channel, but not the other. Typically, the base station is operated in the duplex mode. (*For comparison, see Simplex Channel and Duplex Channel.*)

Handset. A telephone-type combination microphone/speaker that allows privacy of sending and receiving messages.

Hertz (Hz). A unit of frequency expressed in cycles per second. One Hz equals one cycle per second.

High Band VHF. Radio frequencies from 132 MHz to 174 MHz.

Incident Management System. An organized system of roles, responsibilities, and standard operating procedures used to manage emergency operations. Such systems are often referred to as Incident Command Systems (ICS).

Interference. See Radio Interference.

Jurisdiction. Any government unit, such as a federal agency, state, county, city, town, or fire-protection district.

Keying. Activating the transmitter. When the push-to-talk button is pressed, the transmitter is keyed.

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.

Link. A transmitter-receiver system and transmission medium forming a two-way path for the transmission of information.

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.

Local Control. Term applied to a locally (rather than remotely) operated station.

Low Band VHF. Radio frequencies from 30 MHz to 50 MHz.

Megahertz (MHz). A common technical term that refers to the frequency of the radio. One MHz equals 1,000,000 cycles, or hertz, per second.

Microwave. A term applied to radio waves in the frequency range of 890 MHz and above.

Mobile Unit. A two-way radio-equipped vehicle or person. Also, sometimes the two-way radio itself, when associated with a vehicle or person.

Modulation. The process of modifying some characteristic of an electromagnetic wave (called a carrier) so that it varies in step with the instantaneous value of another wave (called a modulating wave or signal). The carrier can be a direct current, an alternating current (provided its frequency is above the highest frequency component in the modulating wave), or a series of regularly repeating, uniform pulses called a pulse chain (provided their repetition rate is at least twice that of the highest frequency to be transmitted). Also, the strength of a voice applied to the microphone.

Monitor. To listen to radio messages without transmitting.

Multi-Channel System. A radio system that uses more than one radio channel. Also known as multi-frequency system.

Multiplexer. A device that simultaneously transmits two or more signals over a common carrier wave.

Noise. Interference characterized by undesirable random voltages caused by an internal circuit defect or by some external source.

Noise Cancelling. This term is applied to microphones that blank out bothersome background noises and permit communication in high-noise areas.

Omni-Directional Antenna. An antenna that radiates signals with equal strength in all directions.

Operator. A person or persons certified to receive or retransmit an alarm in the communication center.

Output. The energy resulting from the work the radio performs. Power output is the strength of the signal as it leaves the transmitter. Audio output is the strength of the voice wave as it leaves the speaker. Both are usually measured in watts.

Pager. A compact radio receiver used for providing one-way communications.

Portable Radio. A completely self-contained radio that can be moved from one position to another.

Power Source. The power obtained from the utility distribution system, an engine-driven generator, or a battery.

Power Supply. A device that receives its input power from a power source and converts the input power to the alternating current or direct current voltage(s) required to operate the system.

Propagation Characteristics. Descriptions of how effectively a radio wave is transmitted from one place to another.

Propagation (Electromagnetic). The travel of electromagnetic waves through a medium.

Public Safety Answering Points (PSAP). An identified location for the receipt and routing of emergency calls.

Radio-Frequency Power. The power associated with any signal consisting of electromagnetic radiation that is used for communications.

Radio Interference. Undesired disturbance of radio reception.

Radio Network. A number of radio stations, fixed and mobile, in a given geographical area that are jointly administered or that communicate with each other by sharing the same radio channel or channels.

Radio Receiver. An instrument that amplifies radio-frequency (RF) signals, separates the intelligence signal from the RF carrier, amplifies the intelligence signal in most cases, then converts the intelligence signal back into its original form.

Radio Station. A fixed or mobile installation that is equipped to transmit and receive radio signals.

Radio Transmitter. A radio-frequency power source that generates radio waves for transmission through space.

Relay Station. See Repeater Station.

Repeater Channel. A two-frequency channel that utilizes an intermediate repeater to extend the range of the channel. The repeater unit simultaneously receives on one frequency and transmits on another.

Repeater Station. An operational station established for the automatic retransmission of communications.

Selective Call. A system for communicating individually with selected vehicles, stations, or personnel.

Sensitivity (of a Radio Receiver). The minimum input signal needed by a radio receiver to produce a specified output.

Shadow Area. A dead spot in a communicating area where radio communication is difficult or impossible.

Should. Indicates a recommendation or that which is advised but not required.

Side Band. A frequency band above and below the carrier frequency, produced as a result of modulation.

Simplex Channel. A communications channel providing transmission in one direction only at any given time. (*For comparison, see Duplex Channel*.)

Simplex Operation. A method of operation in which communication between two stations takes place in only one direction at a time. (*For comparison, see Duplex Operation*.)

Single-Frequency Channel. A channel that is direct from transmitter to receiver. Transmitter and receiver frequencies are identical.

Spectrum. Any series of radiant energies arranged in order of frequency.

Squelch. A system for removing objectionable background noise by desensitizing the receiver.

Station Identifier. The radio call sign assigned by the Federal Communications Commission.

Telephone Patch. An instrument that allows a radio to be used as an entrance and exit point from the commercial telephone system.

Text. The body of a message.

Traffic. A message, or communication, between stations.

Transceiver. Combined transmitter and receiver unit.

Transmission Line. A communication medium used to transfer energy from one location to another.

Trunk Line. A telephone line or channel between telephone central officers or switching devices, including lines to the fire alarm telephone switchboard.

Two-Way Radio. A radio that is able to both transmit and receive.

Ultra High Frequency (UHF). Radio frequencies from 300 MHz to 3000 Mhz.

Unit Identifer. An identifier assigned by the licensee to a mobile unit for exact identification.

Very High Frequency (VHF). Radio frequencies from 30 MHz to 300 MHz.

Chapter 2 Basic Concepts

2-1 System Elements.

There are four basic elements in the communications requirements of a fire-protection agency. Each plays an essential part in enabling the fire department to meet its protection responsibility.

The particular method used should provide for each element in order to be effective. (*See Figure 2-1.*)

Radio, telephone, and other electronic equipment, operating procedures, and personnel training should enable messages to be conveyed as quickly and reliably as the situation requires. Messages should be sent and received correctly with no delay. Time delay and the number of messages to be handled are strongly interrelated with service. Systems and equipment should be provided so that the public can notify the fire department of fires or other emergencies. Attention should be given to message types, the number and length of messages, the equipment capabilities, radio frequencies, and system organization. Effective operating practices should be developed and training should be provided to meet the needs of each agency. The measure of adequate service is the ability of the system to handle emergency situations as well as the normal daily activities of the agency. A major conflagration, or multiple fires, generates a much greater need for communications than do normal daily activities.

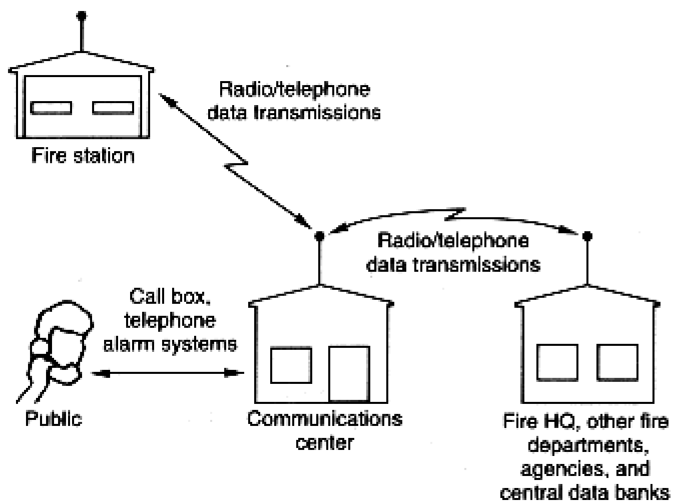

Figure 2-1 Fire communications.

2-1.1 Communications Between the Public and the Fire Agency.

Communications between the public and the fire department revolve around several areas:

(a) Calls from the public for emergency assistance or for reporting fires;

(b) Calls from the public giving information to, or requesting information from, the fire department; and

(c) Calls from the fire department to the public.

Calls from the public, usually received through the telephone system, giving or requesting information, can be of an emergency nature. Whether or not such a call is an emergency is decided by the individual answering the telephone. Many fire departments maintain different administrative and emergency telephone numbers to keep the two types of communications separate. Calls from the fire department to the public usually are of an administrative nature. 9-1-1 (universal emergency number) reporting has become common. (*See Figure 2-1.1.*)

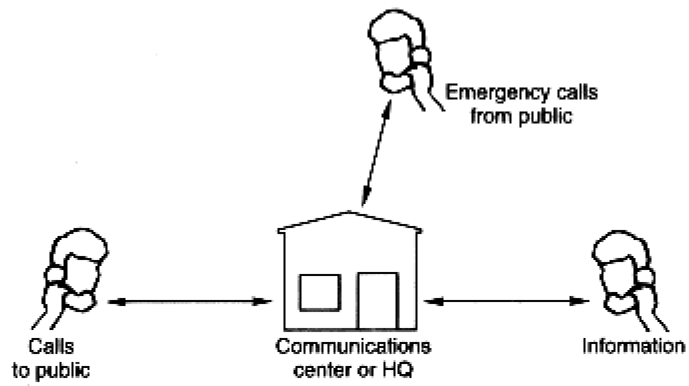

Figure 2-1.1 Typical fire department communications with the public.

2-1.2 Communications within the Fire Department.

Communications between members of the fire department include emergency and nonemergency messages. Communications can be accomplished by radio, telephone, or other transmission methods and might involve the dispatcher, radio-equipped vehicles (land, water, or air), personnel equipped with two-way radios, or personnel at outlying stations in a variety of situations. (*See Figure 2-1.2.*) Examples of such communications are as follows:

(a) The dispatcher gives information to the fire stations and mobile equipment.

(b) Personnel report location and work status to the dispatcher for emergency assignment.

(c) The dispatcher gives coordination information and status to personnel and equipment responding to an emergency.

(d) Incident commanders give instructions to personnel under their command.

(e) Tactical communications at a fire or other emergency scene.

(f) The information on status of personnel and equipment, fire danger rating, weather forecasts, and outdoor burning.

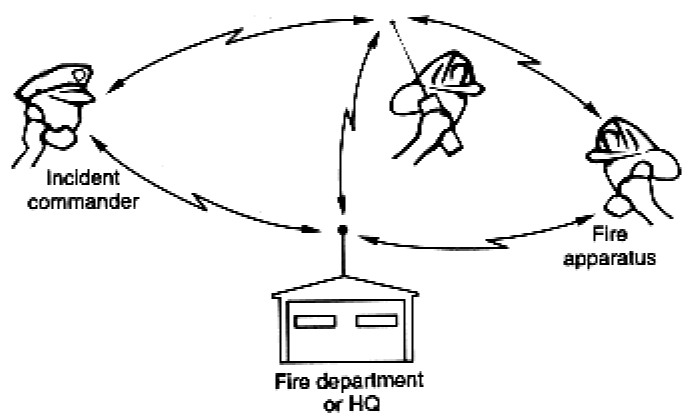

Figure 2-1.2 Fire department radio communications.

2-1.3 Communications Among Fire Departments.

Many fire departments supply neighboring departments with requested information. Such communications are necessary because many small agencies depend on mutual aid agreements. In addition, many fire departments have common information needs.

Incidental or nondirected communication among agencies occurs whenever one agency monitors the transmissions of another, although the information is not specifically intended for interagency distribution. Most of this kind of communication is by radio, especially among agencies that share a radio channel. (When agencies have a choice of channels on which to operate, they must weigh the advantages of mutual monitoring by all system users against the disadvantages of greater message traffic and the resulting problems of channel loading.) This kind of communication is no less important than directed communication, for it allows one agency to be aware of situations in another community or area that may spill over or involve it directly in a short time.

Monitoring of nearby fire departments or fire department transmissions helps the listener to anticipate the need for mutual aid and to be aware of the level of emergency activity in an area larger than the department's or agency's own boundaries. If two fire departments anticipate a need for mutual aid or cooperation, they frequently monitor each other's calls even when not on the same radio channel. Monitor receivers at the dispatcher positions are generally used.

Special mutual aid radio frequencies or channels for mobile use only have been licensed so that fire departments from adjacent jurisdictions can communicate directly with each other. Such a channel can assist normal day-to-day interagency communication needs and emergency communication during widespread disasters. The channels can serve as command channels for interagency communication. Although these are helpful, there are also problems with them. The frequencies can become overloaded very quickly. The multi-channel mobile radio allows all radio traffic to be conducted on the "Agency in Charge" radio system, from initial attack through large fire operations. (*See Figure 2-1.3.*)

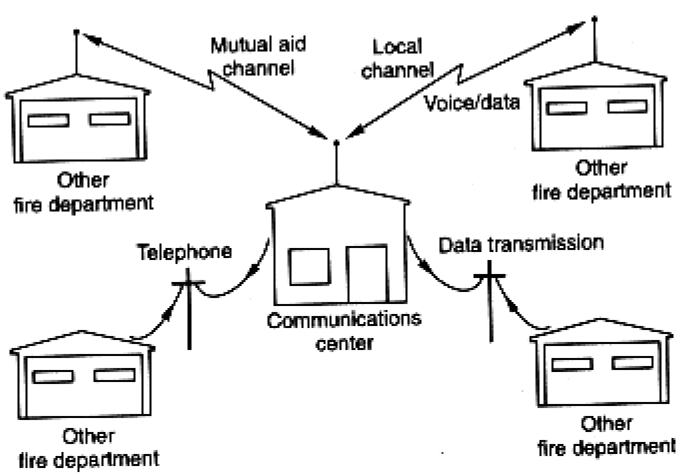

Figure 2-1.3 Interdepartmental communications.

2-1.4 Communications Between the Fire Department and Other Agencies.

Another function of a communications system is to pass messages between the fire department and public safety oriented agencies, such as public works, highway maintenance departments and utilities, hospitals and ambulance services, towing and wrecker services, law enforcement agencies, civil defense units, industries, media, and weather forecasters.

Fire departments exchange a large variety of information with nonfire agencies. Since many of these agencies are radio equipped, they can be of assistance during large fires or other major incidents.

One of the greatest demands for communications with other agencies can occur during major emergencies. The ability to meet this problem necessitates planning for message volumes and for possible language barriers. Communications for a fire department or fire agency should include contingency plans for emergency situations. During an emergency there is little time to set up new communications links. The volume of messages to be handled is likely to exceed most estimates, so plans should include means for handling the volume of message traffic to prevent system breakdown due to overloading. Concerned public and media can rapidly overload a telephone system. Nonfire agencies might not understand the standard language of fire radio. Therefore, liaison personnel familiar with the radio language of the fire service and the assisting organizations are needed to maintain effective communications. Any incident management system should include two important communications concepts, that should improve communications effectiveness during major emergencies. These are:

(a) Common terminology — using clear text or plain language and established standard terms and phrases, and

(b) Integrated incident communications — intending the best possible use of all participating agency radio systems including frequency-sharing agreements. (*See Figure 2-1.4.*)

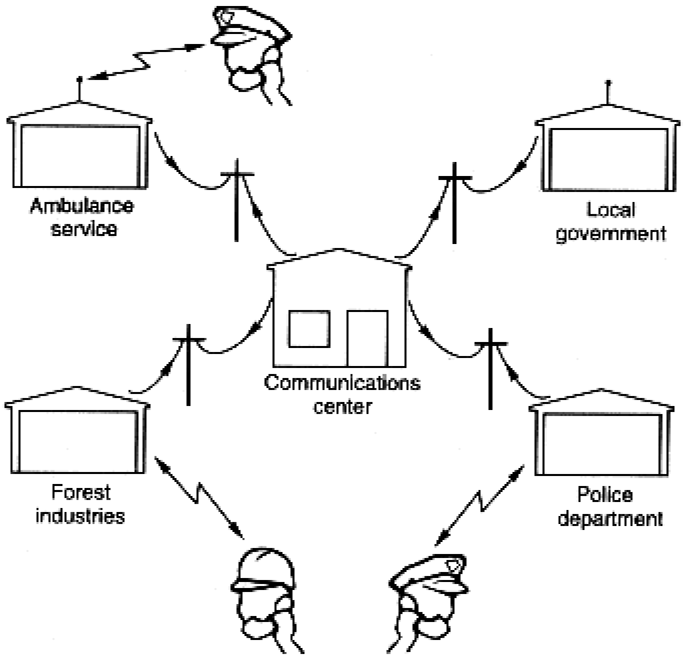

Figure 2-1.4 Communications with other agencies.

2-2 Communications Systems.

Many types of equipment comprise a fire communications system. First, the basic element is the public telephone network. Next is the communications center radio equipment. It consists of transmitters capable of sending messages to every point in the area. Often a control console is used to coordinate communications such as transmitter and receiver control, telephone, computer, and other functions. Antenna systems complete the base station segment of the system. New technology allows use of remote repeaters with self-contained power systems, such as solar power. Portable mobile relays can be used during large fires or remote emergencies. Mobile units complete the system and include two-way radios in administrative vehicles, fire apparatus, aircraft and other transportation, radios carried by individuals, mobile command posts, pocket pagers, and similar units.

2-2.1

There are also data transmission systems, which permit exchange of maps, data, and other information within the department or with other agencies. Low-cost computer systems can provide users with a broad array of intra- and interagency capabilities.

Electronic mail service utilizing computers is often less costly and more efficient for the transmission of messages than conventional mail or voice telephone systems. A wide range of options can be used to tailor electronic mail service to specialized needs.

A computer, modem, communications software, and telephone might be necessary to use electronic mail service.

An originator can send documents or messages directly to a recipient, utilizing a compatible electronic messaging service for immediate reading — or, if more convenient, for storage until it can be read. An electronic mailbox is an option whereby an originator stores a message in a central computer until it is electronically collected by the recipient at a convenient time.

2-2.2 The Telephone System.

The public should be able to contact a fire department quickly when in need of assistance. The telephone system is a natural means of public — fire department contact. It is usually available, and most people know how to use it even under stress conditions. (Use might increase as the national emergency number 9-1-1 is adopted in additional areas of the country.) In addition, the telephone system gives a backup means of communication in case of radio failure, and a means of passing lengthy information not appropriate for radio transmission. In some areas, a system of emergency call boxes is used for reporting fire and is available to the public and the fire department. This provides an alternate means of communication that can augment the radio system.

The telephone system is also relied upon to exchange urgent information between fire departments or other agencies by special hot lines that connect agencies. (*See Figure 2-2.2.*)

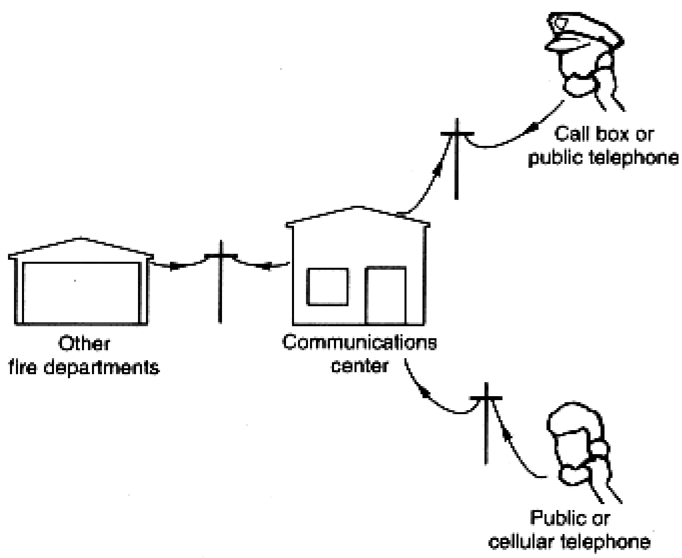

Figure 2-2.2 The telephone system.

2-2.3 The Radio System.

Radio communication is used by most fire departments as their primary means of communications. Its mobility makes it uniquely suited for fire service use. Radio keeps fire-fighting units in touch with the communications center and facilitates reporting on emergency situations by requesting additional assistance and informing other units of emergencies. Radio is also used on special duty work, such as fire prevention, fire hazard inspections, or other projects. Thus, it promotes efficient use of equipment and personnel.

Large, or multiple, incidents necessitate that incident commanders be able to direct their forces continually. Control of sizable forces of personnel and equipment might be needed. Command level personnel cannot make intelligent decisions about deployment unless they obtain constantly updated information on the situation; contact with radio-equipped members of those forces provides the information so it can be acted on at command level. (*See Figure 2-2.3.*)

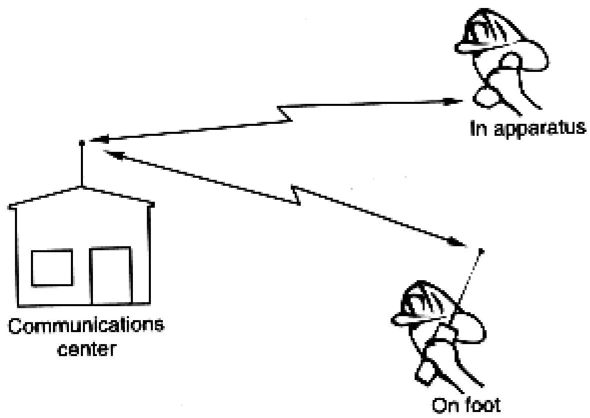

Figure 2-2.3 The radio system.

2-3 Basic System Capabilities.

Communications systems should convey all messages for effective response, protection, and service. The ability to convey messages means that:

(a) There are no excessive delays in sending messages.

(b) Length and content of messages are appropriate.

(c) Information is not degraded by interference on the radio system.

(d) The means of transmitting messages is determined by their emergency nature, privacy needs, and length.

2-3.1

Communications systems should be designed with the goal of minimizing the average waiting time during busy periods. The number of people wishing to use the system will vary in emergency situations, but waiting time increases during periods of heavy message traffic when the urgency of messages might be great.

2-3.2

The second element for an effective system concerns controlling the length and content of messages sent over the system. These should be adequate to convey necessary information, but average length of messages and conversations allowed on a system at a given time determines the average waiting time for any user of the system.

2-3.3

The third element is that messages should not be degraded by interference. Radio interference can consist of:

(a) Signals generated by electrical devices, such as auto ignition, electric motors, and neon signs;

(b) Other radio stations using the same or adjacent frequencies;

(c) Background noise picked up by the user's microphone; or

(d) Faulty radio equipment.

2-3.4

The fourth general element is that the system should provide an alternative means of communication to the primary network. Many messages are not urgent and do not require the speed the primary system provides, or they might be lengthy, using excessive transmission time. The telephone offers one alternative and provides a means of communicating with other fire departments and public service agencies.

2-4 System Demands.

The fluctuation in message traffic over hourly, daily, weekly, monthly, and yearly periods can be a factor in determining system demands. The quantity of messages can change from minute to minute due to factors such as:

(a) Chance occurrence of events needing fire services;

(b) Daily and weekly patterns of human activity;

(c) Changes in patterns due to seasonal and weather conditions;

(d) Special events that necessitate fire services; and

(e) Catastrophes and emergency situations with related events needing fire services.

It is imperative that a fire communications system be reliable and flexible and always available for use. Reliability depends on equipment and method of operation, and can be increased with good quality equipment and competent preventive maintenance with backup capability. Because fire department communications systems perform a variety of functions, they should be flexible to fulfill these functions. They also include the ability to circumvent equipment failures to get messages through and meet the greater demands that future growth might put on the system.

2-4.1

Since communications systems must provide emergency service, reliability requirements for equipment are much higher than for less critical services. Equipment must handle normal peak loads with almost the same rapid response as during times when message loads are minimal. This necessitates that equipment and personnel capacities be geared to handle peak loads rather than average loads.

2-4.2

For maximum reliability, a communications center should not depend upon commercial power as the only source of electrical power supply. A continuing source of electrical power with a standby power plant should be provided. If a power blackout occurs, the standby generator automatically takes over as the power source. Selection of a generator should include consideration of the expected power load. The standby power should be capable of handling the essential load of the building but need not supply the entire electrical load, since it is unlikely that all equipment will be in use at one time. In addition, installation of battery-operated equipment at key locations such as the communications center and relay stations ensures a more fail-safe condition, however the standby generator is still needed.

Chapter 3 Telephone Communications

3-1 Telephone Service Requirements.

Fire agencies require four types of telephone service:

(a) incoming emergency calls,

(b) incoming administrative calls,

(c) outgoing emergency calls, and

(d) administrative calls.

The telephone portion of the system can vary widely depending upon the size of the fire department and the workload. The system might sound a warning alert, summoning volunteers, or might be monitored by an answering service, by a local law enforcement agency, or by a central dispatch service.

3-1.1

A fire department should lease enough lines on the emergency number for all calls, and it should establish a separate group of lines on a second number for callers who do not want emergency service. Different types of lines are available and are used by the fire department. Information on these services is available from local telephone companies. Communications centers need at least one outgoing only line so they can always make an outgoing call when all other lines are busy. All lines should be the type whereby the outside calling party cannot hold the line if the called party hangs up.

3-1.2

It is important that the phone system be capable of operation during a power failure.

3-1.3

A specific telephone number should be assigned for fire alarm emergency service and a separate number assigned for normal fire department business. Telephone directory listings should be as follows:

(a) On the inside front cover of the white pages directory:

FIRE (Symbol optional) (fire number)

In the white pages directory:

FIRE DEPARTMENT

To report a fire (fire number)

Nonfire purposes (business number)

(b) The fire department listing should also appear in the directory under the name of the municipality.

(c) If the directory covers an area that is protected by more than one fire department or fire protection district, each such department or district should be listed as outlined above.

(d) Telephones installed in fire stations should not be listed in the telephone directory.

Where suitable arrangements have been made for the receipt and handling of all emergency calls for fire, police, ambulance, etc., at a single communication center, such as through the use of the national emergency number 9-1-1, the directory listing should be appropriate.

3-1.4

Telephone system backup should be provided. The backup for important leased circuits can be obtained by the use of parallel lines.

Chapter 4 Radio Communications

4-1 The Radio Spectrum.

The fire department radio systems operate on assigned frequencies. When radio frequencies are taken as a group, the term “radio-frequency spectrum” is used. This is a means by which energy can be transmitted at one point and received at another and, in the process, convey information. Every transmission has three basic attributes:

(a) It occupies a certain geographic area,

(b) It occupies a certain period of time, and

(c) It occupies a certain portion of the radio spectrum. (*See Figure 4-1.*)

These are very important to remember. A basic rule is that no two radio users can use the same portion of the spectrum at the same time in the same area without interfering with each other. In order to prevent interference, users should be separated adequately in frequency, area of operation, or time.

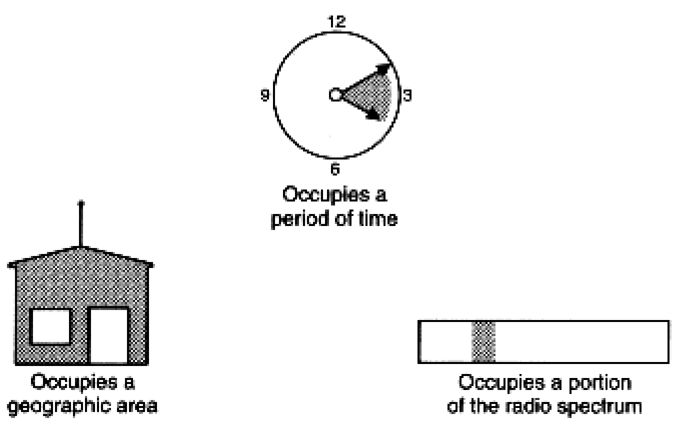

Figure 4-1 Basic attributes of a radio transmission.

4-1.1

The radio spectrum can be compared to the light spectrum; just as a rainbow has colors easily separated from each other, so does the radio spectrum have frequencies with unique characteristics. Groups of frequencies have been assigned for specific uses, such as broadcast radio, television, radio communications for vehicles, and radio voice and data communications. These have been assigned for land mobile service: 30 MHz – 50 MHz (VHF low band) 132 MHz – 174 MHz (VHF high band), and 450 MHz – 512 MHz (UHF ultra high band). In addition, the 220 MHz – 222 MHz and 802 MHz – 869 MHz band is now available.

Each of these bands has unique characteristics. Presuming the transmit power is the same and no repeaters or automatic relays are used, the VHF low band provides the longest signal range of the three bands and is ideal for open country operation but can be seriously affected by sunspots or other long-range interference. The VHF high band provides shorter range than low band, but is less susceptible to radio interference, and ideal for combination city – country coverage. The UHF band provides the shortest range of the three bands. It is least affected by interference and seems to provide the best communications in congested city areas with tall structures.

4-1.2

Certain radio frequencies have been made available for use by fire departments around the country. Each band consists of a group of frequencies, with center frequencies 15 KHz apart in the VHF high band and 25 KHz apart in the UHF band. In order to transmit information, a certain amount of the frequency spectrum is needed. This portion of the spectrum is termed the bandwidth of the transmission. Each user is assigned a certain amount of spectrum space, including a small amount of buffer called the guard band, which serves to prevent interference from adjacent channels. Radio transmission equipment should generate a precise signal on one channel or frequency, and the receiving equipment should select this signal without being disturbed by signals on nearby channels. Just as a highway or a river can be narrow or wide, so can a radio channel. The narrower the channels, the more channels that can be placed into a given section of the radio spectrum.

4-1.3

Channels on the VHF high band and UHF bands have desirable propagation characteristics. If used properly, they provide the most efficient coverage of an area by reaching into all locations, but they are less likely to provide coverage over long distances. Because of their desirability and the relatively small area of spectrum available in each, the VHF high band and UHF bands have become crowded. Interference exists in some areas due to violation (often unavoidable) of the basic rule that radio transmission must be separated by time, geographical area, or frequency.

4-2 FCC Rules and Regulations.

Frequencies, their assignment, and the widths of channels are regulated throughout the world. In the United States, the Federal Communications Commission (FCC) provides this regulation through allocation, licensing, and rule making for all except federal government allocations. [In Canada, the similar regulating agency is the Department of Communications (DOC).] The Office of Communications Policy helps develop national spectrum utilization policy. The Interdepartmental Radio Advisory Committee (IRAC), under the Office of Communications Policy, performs functions similar to the FCC, but only for federal agencies. Wire line and radio communications are subject to FCC rules and regulations, which govern many areas of radio usage (called “service”). Of primary concern to fire communications systems users are the Public Safety Radio Services, which provide for use of radio communication systems by nonfederal governmental entities.

The needs of fire communications fall primarily within this category of regulations. The FCC apportions frequencies between commercial broadcast uses and nonbroadcast services, such as fire service radio. The Commission's prime resource, the radio spectrum, is not available without prior restrictions, since the federal government claims large portions of spectrum space for military and other operational use. Competition for frequencies is intense between users. The fire radio service and the forestry conservation radio service are only two parts of the land mobile group.

4-2.1

The FCC has established requirements and specifications for radio equipment characteristics in order to reduce or eliminate harmful interference and to conserve the use of the radio-frequency spectrum. During discussions with radio equipment manufacturers, the system planner should have knowledge of the regulations that deal with frequency stability, type of emission, power level, and acceptable equipment. The provisions are in Part 90, Subpart B of the FCC Rules and Regulations. In the interest of reducing interference, the FCC has established certain rules basic to any station operation. Supervisors should make sure these rules are being observed constantly. Violations could result in suspension of their radio license.

4-2.2

The basic FCC rules and regulations are as follows:

(a) All communications, regardless of nature, are restricted to minimum practical transmission time (excepting microwave systems).

(b) Continuous radiation of an unmodulated carrier (excepting microwave systems) is prohibited except when necessary for test purposes.

(c) Licensees are to take reasonable precautions to prevent unnecessary interference. If harmful interference does result, the FCC may require any or all stations to monitor the transmitting frequency before transmission.

(d) Tests may be conducted by any licensed station as required for proper station and system maintenance, but such tests are to be kept to the minimum. Precautions are to be taken to avoid interference with other stations.

(e) Maintain the required radio station records.

(f) The frequency and modulation must be measured and recorded when the transmitter is initially installed and when any change is made in the transmitter that might affect the frequency or modulation.

It is advisable to have frequency, power output, and modulation measurements made to ensure that the equipment operates within the parameters stipulated by the FCC.

(g) Posting of the radio license is required.

(h) Identify radio station when transmitting.

(i) Do not reassign or transfer a radio station license without the approval of the FCC.

4-3 Frequency Coordination and FCC License Application.

Frequency assignment in the land mobile radio services is difficult because there are more users than can be readily accommodated in available spectrum space. This is particularly true for fire and police radio in and near metropolitan areas. The FCC, which issues licenses and allocates frequencies, has designated user groups in land mobile radio services to coordinate assignments in each service. The coordination committees include the International Municipal Signal Association (IMSA) for the fire, special emergency, and emergency medical radio services; the Associated Public Safety Communications Officials, Inc. (APCO) for the police and local government radio services, and all public safety users at 800 MHz; the Forestry Conservation Communication Association(FCCA) for the forestry conservation radio service; Forest Industrial Telecommunications (FIT) for the forest products radio service; and the American Association of State Highway and Transportation Officials (AASHTO) for the highway maintenance radio service.

4-3.1

Frequency coordination is the process of selecting and recommending to an applicant and the FCC one or more radio frequencies for use by the applicant that will cause the least amount of interference to other radio users and to the applicant, and yet provide serviceable channels. This includes coordination of applications for new licenses and license modifications (involving power and antenna heights) with existing frequency assignments. Thus, the function of these frequency advisory committees is to minimize the likelihood of interference being caused to other systems by the operation of a proposed system. An application might require a committee to perform extensive research in determining physical separation, propagation paths, and the existence of other systems licensed on adjacent channels but in another service. If the application is favorably commented upon by a frequency advisory committee, the statement of the committee accompanies the application to the FCC, where it is processed.

4-4 System Design Considerations.

A system (network) is defined as a number of radio stations in a certain geographical area, jointly administered or communicating with each other by sharing the same channel or channels. The size and degree of formal organization of fire radio networks varies widely. Many have been formed as a result of unstructured evolutionary growth, and in these cases there is little cooperation among users. Others are highly organized and feature strong cooperation. The following basic factors roughly characterize network structure:

(a) Location of dispatching points or those points receiving reports of fire;

(b) Location of base station radio equipment and repeaters or mobile relays;

(c) Number of frequencies or channels in the network; and

(d) Operation of channels that make up the network.

In general, one can consider each factor to be independent of the others. For each, there exists a pair of tradeoffs that should be considered when building a network, such as the following pairs:

(a) Dispersed or central location of dispatching points;

(b) Dispersed or central location of base station equipment;

(c) Single- or multi-channel networks; and

(d) Simplex or duplex operation of the channels.

Other design considerations can include the following:

(a) Types of interference to which the network is susceptible;

(b) Available methods of channel isolation to prevent interference within the network;

(c) Performance under heavy message loads;

(d) Radio coverage characteristics;

(e) Existence, or nonexistence, of mobile-to-mobile and base-to-base communications in the network; and

(f) The use of special devices (such as facsimile equipment) within the network.

4-4.1

Radio systems differ by the number of frequencies used to provide a base-mobile channel, by the number of two-way channels in a system (or network), by whether system operation is simplex or duplex, and by whether or not repeater stations are used. The most commonly encountered systems are:

(a) Single-frequency simplex (simplex means that signals can be transmitted in only one direction at a time between two users);

(b) Two-frequency simplex; and

(c) Two-frequency half-duplex (duplex means that signals can pass in both directions at the same time between two users).

4-4.2

The single-frequency simplex system, the most widely used two-way radio system, uses the least radio spectrum space and is the most economical two-way system to purchase and operate. With this system, the base station and mobile units share the same channel (frequency). This means that only one user of the system can transmit at any one time. Multiple transmissions usually will interfere with each other. All receivers within range can listen to the same transmission, somewhat like many people listening to the same station on their home radios. Under this method, communication is three-way: base to mobile; mobile to base; and mobile to mobile. Single-frequency operation is advantageous to fire departments because all units covering on a fire location are kept informed of all messages that affect the fire-fighting operation. (*See Figure 4-4.2.*)

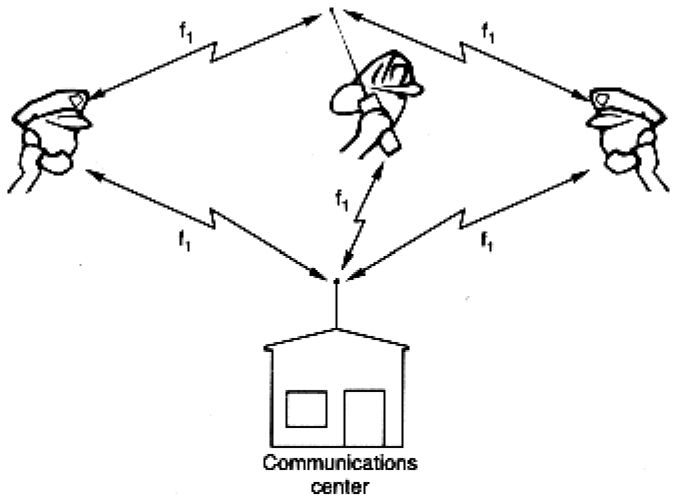

Figure 4-4.2 Single-frequency simplex operation.

4-4.3

The two-frequency simplex system is similar to the single-frequency simplex system except that the base station broadcasts to the mobile units on one frequency, and they broadcast to the base station on a different frequency. This prevents base station broadcasts of one department from interfering with mobile unit broadcasts of another department when they are nearby and share the same frequencies. Thus, it is suited to areas that have densely packed stations on the same frequency. A disadvantage of this mode of operation is that mobile units cannot hear each other's transmissions because their receivers are tuned to the frequency of the base station transmitter.

4-4.4

A third radio system is the two-frequency half-duplex system. It differs from its simplex counterpart in that operation at the base station is duplex; that is, the base station can receive and transmit simultaneously. If a large geographic area is to be covered by radio communications, or if obstructions such as mountains separate the service area, it might be necessary to use one or more repeater stations to amplify signals and rebroadcast them. Repeater stations can also be used to ensure complete coverage by low-powered portable radios.

4-4.5

Because of the relatively small number of frequencies available for the fire service, it is not possible for every fire department to have its radio system operating on a separate frequency that is free from interference and not used by any other fire department. A group of small fire departments adjacent to each other should operate on a single frequency for coordination of response under mutual aid arrangements. (All fire departments operating their own radio service, or departments operating in a group, should have one or more separate frequencies and additional frequencies where the radio traffic load warrants.) The disadvantage of a single-frequency group system is that during normal periods, each department will hear the calls of all other fire departments. This can be annoying and can interfere with fire-fighting emergencies arising simultaneously in two or more jurisdictions. In planning to operate on a single frequency, a group of fire departments should prepare a set of rules or operating procedures that each can follow.

4-4.6

Under FCC rules and regulations, a fire frequency utilization plan can be filed for the state. Under such a plan, the state is divided into fire districts or counties used as fire districts. A common or intradistrict frequency is designated for each district, with one or more frequencies assigned for interdistrict or intrastate communications. The setup in a district will vary with the size of the fire departments, the radio traffic load, and normal mutual aid operations between various individual places. Experience has shown that 15 to 30 radio-equipped vehicles can operate at a fire or emergency on one frequency, but more vehicles result in a message load too great for one frequency. Multi-channel radios should be purchased.

4-4.7

A group of fire departments can choose to operate a regional communications system. Each group should designate a communications coordinator to assist in planning intradistrict and interdistrict communications. A location should be selected as the communications center for the region. Each region should be allocated a common, or intraregion, frequency, and there can be one or more frequencies assigned for interregion or intrastate communications. System planning on a regional basis is necessary if channel overloading and overlap of tone coding is to be prevented in the future. This guide cannot possibly, nor is it intended to, cover the many technical details of system design. A qualified communications engineer or technician should always be consulted for system technical aspects.

4-5 Radio Equipment.

4-5.1 Vehicular Two-Way Radios.

Radio equipment installed in vehicles is used by field personnel to communicate with the communications center and with each other. These units are indispensable links of the communications chain that aid supervisory personnel in command and control of personnel and equipment in the field. Selective calling, an option offered by some manufacturers, allows mobile units to be called individually. Selective calling is usually coupled with a recall feature that informs an individual who is away from the vehicle of a call by activating the dome light, headlights, siren, or horn.

4-5.2 Portable Two-Way Radios.

The portable two-way radio has become common in fire department and other public safety radio systems. These are designed with self-contained power supplies and antennas, making them suitable for independent operation. Size and weight are kept low enough so these units can be carried by field personnel, providing two-way radio communication to the person on foot. They vary in power output. Multi-channel radios should be purchased. Some portable units can be connected easily to draw power from a vehicle's electrical system and contain other features that make them suitable for vehicle usage. Selective calling is available as an option.

Units can be purchased with relay capability and used as mobile extenders where the portable unit activates the mobile unit as a relay point.

4-5.2.1 Fire departments can use portable radio equipment even though they have no base station or vehicle radios. Three frequencies have been designated for intersystem operation only: 154.265 MHz; 154.280 MHz; 154.295 MHz. Use is primarily base to portable and portable to base. Units on these frequencies are useful for local interagency cooperation in order not to interfere with the main radio system or when the heavy message load on the regular radio system would not permit use of portable units. Fire agencies can license portable units on the same frequency as vehicular units so they can be used from widespread locations.

4-5.3 Pagers.

Pagers, commonly called beepers, can be used for contacting fire personnel. Some can also receive a brief message (voice or data) at the end of the attention tone.

4-5.4 Mobile Communication Centers.

Emergency situations resulting from large fires, transportation accidents, floods, severe storms, and other disasters often create a need for a temporary communications center located close to the scene of the disaster. This need is filled by a communications vehicle, sometimes called a mobile command post. The vehicle, a mobile command and control headquarters, serves as the hub from which activities necessary to control an emergency situation can be directed and coordinated without dependence upon the department’s fixed communications center. These activities include the efforts of local and outside departments and of other public safety organizations, such as police departments and emergency management agencies, in addition to public utilities. Being near the site of the disaster gives communications vehicle personnel and those in command immediate access to the latest information in situations where rapid change is occurring. Further, the ready availability of communications provides the means to call for additional help or to inform other jurisdictions of the situation.

4-5.4.1 A communications vehicle should carry a variety of equipment that allows communication with other fire departments, public safety organizations, and utilities. Other equipment that can increase the flexibility of the system are citizen band (CB) transmitters and cellular telephones. Some vehicles might be equipped for mobile relay operation that can allow them to pick up transmissions of mobile units and retransmit them at higher power levels or on different frequencies to the communications center. Public address systems for directing personnel and for crowd control are useful. Commercial radio and television receivers and service telephones (provided by the phone company at the site) also are valuable in some situations.

4-5.4.2 In areas where telephone lines are unavailable, cellular, radio-telephone, or microwave equipment can be employed to obtain telephone service. Since a normal power supply might not be available, an independent power supply system should be incorporated. The vehicle might have provisions for more than one dispatcher with a communication center type of arrangement. If it is to serve as a temporary headquarters, the vehicle should contain chairs and one or more work tables so that maps and other large documents can be studied. Adequate lighting is also necessary. Some emergency situations might warrant use of the vehicle for extended periods of time. Under such conditions, it is advantageous if the vehicle is self-contained, with heating, cooling, kitchen, sanitary, and sleeping facilities for personnel. In some jurisdictions or departments, very complex communications vehicles have been developed, which can accommodate multiple telephone lines, computer terminals, etc.

4-5.5 Scanning Receivers.

A scanning receiver provides the capability of monitoring several channels automatically. With numerous fire departments using different frequencies, these receivers provide economical means of intercommunications and mutual aid cooperation. Some scanning receivers sample each channel sequentially, waiting for a signal to appear. As soon as a signal is detected, the receiver locks to that channel and stops scanning as long as the signal remains. Some scan with priority, with one channel taking precedence over the others when signals appear simultaneously on both the priority channel and on another. If the receiver is monitoring a nonpriority channel and a signal is heard on the priority channel, the nonpriority channel is released and the priority channel held. Scanning receivers have controls to include or delete channels from the scanning process; thus, one, several, or all channels can be monitored, allowing operational flexibility for different situations. Frequency synthesized scanning receivers are available that can be set to include virtually any channel in the low VHF, high VHF, or UHF bands. The active channels are selected by the operator and do not need crystal or other changes by a technician. The scanning receivers can provide communications between cooperating agencies without the need for multi-channel transmitters, up to a point. That is, each agency transmits on its own assigned frequency but the transmissions are received by anyone equipped with a scanner. The addressed party then transmits on its own frequency and is likewise received on the other scanners.

4-5.5.1 Separate scanning receivers programmable by the operator have one major fault, they cannot and should not be depended upon for a primary channel. Although they are generally as sensitive (able to pick up weak signals) as the most expensive radio receivers, they are not as selective (able to reject adjacent channels). Thus, many multi-channel receivers might completely fail to do the job when placed in an environment in close proximity to transmitters transmitting only 15 KHz to 30 KHz apart.

NOTE: The above does not apply to built-in scanning receivers associated with transmitters in a standard mobile or portable radio configuration. These are very selective, but the operator must remember that a scanning receiver can only receive one channel at a time and will lock out all others (except a priority one if so equipped).

4-5.6 Special and New Devices.

There are many areas of advancing technology that have found, and will continue to find, direct application to fire department systems. Among other things, technology has provided fire departments the ability to:

(a) Keep in constant contact with all personnel and equipment, either in mobile units or on foot;

(b) Exchange data messages between vehicles and base stations;

(c) Improve command and control by television transmission of fire activity to communication centers;

(d) Facsimile transmission of maps, preplans, and other written data; and

(e) Provide vehicle tracking and geographical locations, which may include geographic positioning systems (GPS).

4-5.6.1 Computers can provide users with a powerful array of intra- and interagency capabilities. Some examples of fire service programs that can be used on these systems are:

(a) Computer-aided dispatch (CAD);

(b) Resource management;

(c) Incident reports;

(d) Equipment and personnel data; and

(e) Hazardous materials information.

In multiple-agency environments, computers can be interconnected (networked) to provide an electronic coordination and information system. These systems have become popular and easy to obtain.

4-5.6.2 Departments contemplating the purchase of any computer system should make a detailed needs analysis before purchase. Consideration should be given to alternative methods to accomplish the same needs.

4-5.6.3 Digital computer systems are available that reduce the system's "on" time, can automatically send and receive messages, and provide a hard copy printout of the message. They also provide a degree of communication security, since the transmissions are in digital format rather than voice.

4-5.7 Tone Signaling and Tone Code Squelch.

Coded audible and subaudible tones sent prior to or during transmission time are used in fire radio systems to implement a number of functions not obtainable with voice alone. Tone coded squelch, recall, radio relay control, and remote transmitter keying are examples of tone coding applications. An encoder is needed for transmission of the coded tones, and a decoder is necessary in the receiver to interpret the coded tones. Some tone coded squelch and tone signaling schemes employ single tones sent continuously with regular voice transmission; some use two simultaneous tones with different frequencies. In another variation, two sequential tones are sent: first one, then the other.

4-5.7.1 The purpose of tone coded squelch is to eliminate nuisance interference by other users of the radio channel. The receiver is equipped with a decoder that responds only to proper tone coding. When a signal with correct coding is detected, the receiver squelch opens and the desired signal is heard. The squelch cannot be opened by signals without correct coding. Tone coding can be used for selective calling and recall. In a system with selective calling, the base station is equipped with a tone encoder console capable of generating a number of different code combinations. Particular receivers at fixed locations, or at mobile radios, can be provided with unique decoders corresponding to selective codes. The decoder only allows a properly coded signal to be heard at the receiver output. This system gives the base station the ability to call one or a group of receivers and mobile radio units at a time rather than all simultaneously. At fixed locations, selective calling can be used to turn on alarms, sound sirens, turn on lights, open station doors, etc. Most selective call decoders for mobile units provide a recall feature that alerts individuals to a message when they are out of the vehicle. When in the recall mode, the receipt of a properly coded signal causes activation of a call indicator light, horn, headlights, or dome light of the vehicle.

4-5.7.2 Tone signaling decoding techniques are sometimes used for remote control of base station transmitters. The need for special and costly direct-current telephone lines to provide for transmitter keying from a remote dispatch point is eliminated. The ordinary voice-grade telephone line, which carries voice information to the transmitter, is used to carry the tone also. A simple encoder at the communication center generates a tone when the push-to-talk switch on the microphone is actuated. This tone is sensed by a decoder at the remote base station, causing the transmitter to be activated.

4-5.8 Maintenance.

Ordinarily, three methods of maintaining communications system equipment are used:

(a) The department operates its own service facilities.

(b) One or more technical service companies are called upon to maintain the department's equipment. In some instances, a combination of department operated and contracted maintenance service is used.

(c) Several departments, a municipality or county, or other agency operate the service facilities. This might result from a contract among several agencies for a jointly operated maintenance department, or it might be part of a more extensive joint operation of fire communications facilities. A county or other governmental unit might have a communications department that provides services for all of its governmental communications systems.

4-5.8.1 Major components of a communications system can be expected to fail despite the best maintenance program. Component failure should not produce a system failure if proper preparations are made for such events. Standard techniques to prevent system failure are to provide backup equipment and system redundancy.

4-6 Citizen Cooperation and Assistance.

Two important adjuncts to a communications system under emergency conditions are the Citizens Radio Service, generally known as "CB" for citizen band radios, and the Amateur Radio Service, otherwise known as "hams."

4-6.1

Citizens band radio is a short-range service. CB radios are widespread and can be used to relay emergency messages. An emergency channel (Channel 9) is reserved for such messages. Radio Emergency Associated Citizens Teams (REACT) are groups of CB radio owners organized to provide an emergency or public service. A CB radio at the station or dispatch center tuned to the emergency channel or an agreement with a local CB group, REACT group, or other group of enthusiasts to relay any emergency information or participate in emergency operations can be very helpful.

4-6.2

Amateur radio is the personal use of shortwave radio equipment for direct, worldwide communications on a one-to-one basis. Licensed amateurs are allowed up to 1000 watts of input power; have no channel, distance, or time restrictions; and are actually encouraged to modify and experiment with their equipment.

4-6.2.1 The Amateur Radio Emergency Service (ARES) consists of licensed amateurs who have voluntarily registered their qualifications and equipment for communications duty in the public service when disaster strikes. The possession of emergency-powered equipment is desirable. An emergency coordinator represents the ARES in its dealings with civic and relief agencies.

4-6.2.2 The Radio Amateur Civil Emergency Service (RACES), administered by the Federal Emergency Management Agency of the United States government, is a part of the Amateur Radio Service that provides radio communications for civil preparedness purposes only during periods of local, regional, or national civil emergencies. These emergencies are not limited to war-related activities but can include natural disasters such as fires, floods, and earthquakes. RACES is a radio communication service conducted by volunteer licensed amateurs designed to provide emergency communications to local or state emergency management agencies. RACES' operation is authorized by the FCC upon request of a state or a federal official and is strictly limited to official emergency management activity in the event of an emergency communications situation.

The local amateur club or enthusiasts should be consulted in advance to determine their capabilities and willingness to help where needed.

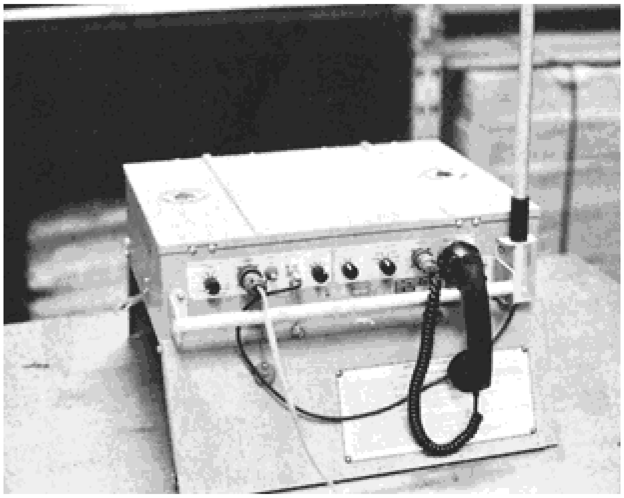

Figure 4-7(a) Portable repeater unit.

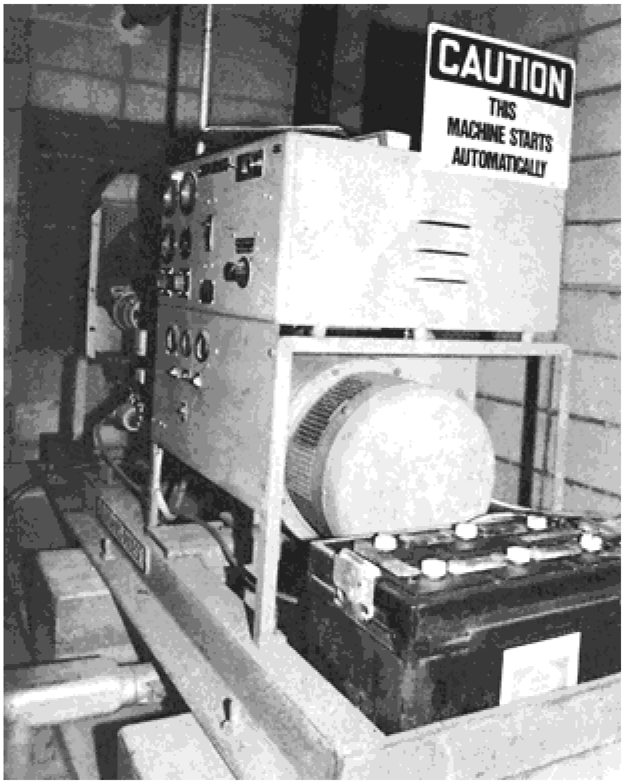

Figure 4-7(b) Emergency standby electric power generator.

Figure 4-7(c) Portable radio in charger base.

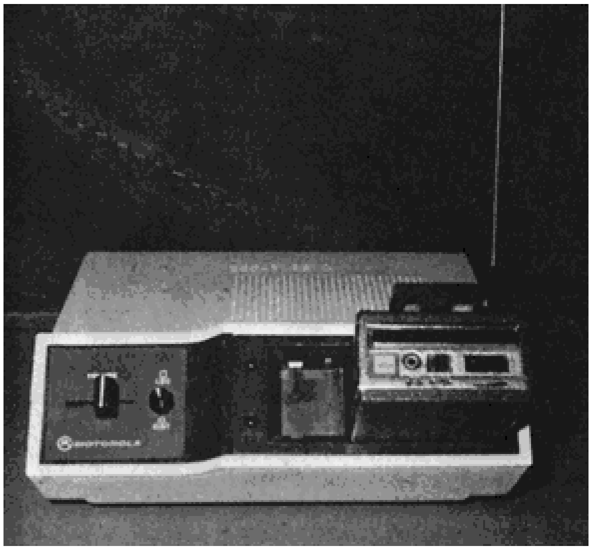

Figure 4-7(d) Tone-encoded fire department pager with amplified charger base.

Figure 4-7(e) Multi-frequency mobile radio control head with electronic siren/public address system; and programmable scanner, portable radio with built in charger, and cellular telephone.

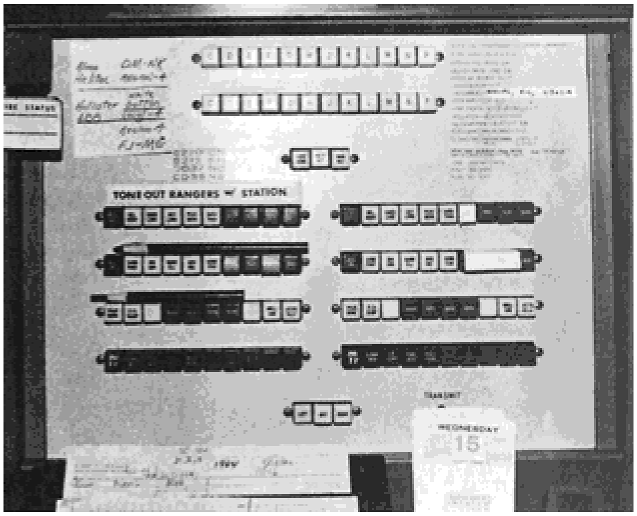

Figure 4-7(f) Tone encoder panel.

Figure 4-7(g) Dispatch and communication console with multi-line telephone system, computer-assisted dispatch, built in tone encoding panel, fax machine, and digital playback recorder.

Chapter 5 Operations and Procedures

5-1 Communication Centers.

There must be a communication center, or a definite location established, where all calls by telephone, radio, or fire alarm system are received and action taken. This location should be constantly attended during the time it is needed. Suitable expansions can be utilized as necessary.

The complexity and size of the communication center will vary with different jurisdictions. While a large communication center might be staffed 24 hours a day by several operators, other jurisdictions might use a continuously attended watch desk in a fire station. The staffing needs for watch desk operators or communication center operators pose problems for departments with limited funds and limited full-time personnel. Some jurisdictions solve this problem by having one center handle the emergency calls of all public safety or emergency organizations. Another solution for fire departments is to have a number of neighboring fire departments operate a joint communications center. To achieve maximum value from limited facilities, fire departments can pool operations with mutual aid arrangements, which are facilitated when a common communication center is used. There are many regions and rural and suburban areas, for example, where no one fire department can afford a communications center. However, they could establish a multi-jurisdictional communications center and share the expense.

5-1.1

Populated areas frequently extend over several contiguous communities with multiple fire jurisdictions. A telephone company does not limit or separate services on the basis of municipal boundaries. The continued expansion of the public telephone network might cause calls to a telephone company operator to be routed to a distant location. A person dialing the telephone company operator to report a fire is not assured that the operator will be able to transmit the alarm to the proper fire department.

Fire departments and other public safety services recognize the need for the public to be able to reach them quickly, no matter where they are when an emergency arises. In January 1968, a proposal was made to implement throughout the country a single national emergency number that the public could use to reach the police, fire department, and other emergency agencies from wherever they might be. The number 9-1-1 was chosen. The 9-1-1 system is an easy-to-remember, three-digit telephone number used to provide the general public with direct access to the emergency service resources.

The call for help terminates at a Public Safety Answering Point (PSAP) where responsive action can be initiated. This point serves all kinds of emergency services — fire, police, medical, etc. The selection of a point to receive emergency calls raises the problem of jurisdiction because telephone exchange boundaries often include several communities or large areas. For this reason, some multi-jurisdictional areas are employing enhanced 9-1-1 telephone features such as Selective Routing, Automatic Number Identification (ANI), and Automatic Location Identification (ALI). Selective Routing automatically routes an emergency call to the proper answering point serving its community, irrespective of municipal and telephone boundary conflicts. ANI and ALI are features that automatically identify and display the telephone number and location of the emergency call. These enhanced 9-1-1 features can result in the overall reduction of emergency response time.

After a call for help has been received at a PSAP, there are several methods by which it can be handled. These are:

(a) *Direct Dispatch Method.* The dispatch personnel at the central answering point perform all call answering and dispatching of an appropriate emergency service unit upon the receipt of a telephone request.

(b) *Relay Method.* A telephone request for emergency services is relayed to appropriate safety agencies for dispatch of an emergency service unit.

(c) *Transfer Method.* A telephone request for emergency service is directly transferred to an appropriate safety agency.

(d) *Referral Method.* The requesting party is provided with the telephone number of the appropriate safety agency in nonemergencies.

5-2 Summoning Volunteers.

Fire departments with volunteers or paid-call fire fighters have the responsibility of summoning their personnel at any hour of the day or night. This problem can be solved by the use of the telephone or radio, supplementing siren or horns that give an outside alarm. Fire calls can be telephoned to the central telephone office where the telephone operator can start a siren or operate an air horn, indicating that there is a fire. In areas where a communications center is not attended 24 hours a day, telephone companies can provide a special telephone line that connects to special telephones located in places of business or residences selected by the jurisdiction. The jurisdiction then arranges to have reports of fire acted upon. In fire departments that have a fire station desk attendant, the telephone central operator can call the station, and the attendant can sound the outside alarm to call volunteers. If there is a code-sounding siren or air horn, coded signals can be sent. Usually a transmitting apparatus is used to send out the code.

If radio equipment is used, a receiver with selective calling equipment can be placed in the home of each volunteer or call fire fighter. Selective signaling is accomplished on a group-call principle, permitting the volunteer or call forces to be divided into several groups that can be summoned as a whole or as individual groups to take care of a particular incident. Pagers are in common use for this purpose since they can be carried anywhere. These units might include either a tone alarm, a voice receiver, or digital display.

5-3 Fire Ground or Other Incident Communications.

The first unit to arrive at a fire or other emergency incident should notify the communications center by radio of its arrival and give a brief description of the conditions visible and the precise location of the incident. The responding officer should report arrival and should establish the initial command post at the fire or other emergency. As soon as conditions allow, the incident commander should report supplementary information to the communications center and should make additional progress reports if operations keep the fire units at the emergency beyond a few minutes. An extended or complex emergency incident might necessitate the use of a communications van for effective coordination, command, and control.

5-3.1

The assignment of a communications officer to incidents that are more complex will ensure that adequate communication is achieved, utilizing both available telephone and radio systems, and that the availability of existing frequencies or networks is maximized and system overloading is minimized. An assigned communications officer can be particularly important and useful on multi-agency fires and other incidents. It might be necessary to establish specific nets and monitoring systems to guarantee communications in some situations. In complex incidents, communications discipline is most important to avoid system overloading.

5-3.2

The common emergency organization, the Incident Management System (IMS), includes two important communications concepts:

(a) *Common Terminology*. All participating departments and agencies use clear text radio and established standard terms and phrases. In multiple-agency emergencies, it is extremely difficult to guarantee that all agency and department codes portray exactly the same meaning. To avoid any potential misunderstandings between cooperators, the ICS requires clear text or plain language for all radio messages. Although this is a significant departure from public safety agency tradition, it has been found to be very efficient in actual practice.

(b) *Integrated Incident Communications.* Participating departments and agencies plan in advance for the use of integrated radio frequencies to tie together all tactical and support units on an incident. To ensure the best possible use of all participating department and agency radios on major incidents, an Incident Radio Communications Plan matrix is developed. This matrix lists all available radio systems on an incident and aids in assigning them to provide command, tactical, and logistical coverage for a complete operation. Preparation of the matrix requires training and a knowledge of cooperating department and agency frequencies and radio components. Use of the matrix is greatly enhanced by the existence of a frequency-sharing agreement. (*See Appendix B.*)

The FCC has no prohibition against public agencies sharing frequencies during emergencies provided that the responsible agency has granted permission to do so to assisting agencies. The agreement specifies the mutual permission of participating agencies to use other agencies' frequencies when assisting them. The agreement lists the terms and conditions of use by others and includes all frequencies that could be made available under critical conditions. Agreements such as this facilitate better multi-agency dispatching and incident communications and can be prepared by groups or agencies who frequently work together.

5-4 Communication Center Operations.

Fire departments should adopt a standard procedure for operations of the communication center. The adoption of standard words in voice communications is important to speed message transmission and avoid errors. With voice communication it is necessary to phrase messages so they will not be misunderstood. Standard messages are used not only to use the communications facilities efficiently, but also to make sure that the standard message can be defined. The department's standard procedures should define how persons originating a message will identify themselves.

5-4.1

Communication center dispatchers must know the capabilities and limitations of the communications systems that they are authorized to operate. They must be familiar with the administrative organization of the agency so as to be able to route traffic properly and be aware of the equipment and resources available to the agency, and they must be familiar with the capabilities of cooperating agencies and with the applicable rules and regulations of the FCC.

5-4.1.1 Many calls from the public are clearly of an emergency nature. Some calls are not of an emergency nature, thus reducing the need for priority handling. Some calls are not clearly in either the emergency or nonemergency category. A dispatcher cannot assume that the call is not urgent. All such doubtful calls must be treated as if they were urgent, representing true emergencies. Many calls to the fire emergency telephone number might be merely requests for information. The dispatcher answering the phone generally must transfer all nonemergency calls as quickly as possible to a nonemergency operator or agency.

5-4.1.2 Dispatchers should possess the following basic qualifications:

(a) Ability to speak clearly and distinctly at all times;

(b) Ability to reduce rambling and disconnected material into concise and accurate messages;

(c) Ability to think and act promptly in emergencies;

(d) Ability to analyze a situation accurately and to take or suggest an effective course of action;

(e) Thorough understanding of the capabilities of the agency's own communications system and a working knowledge of mutual aid systems;

(f) Adequate understanding of the technical operation of the department's own system to facilitate reporting of equipment failures;

(g) Ability to work effectively under all conditions encountered; and

(h) Knowledge of the FCC rules and regulations applying to operator's responsibilities.

5-5 Basic Telephone Techniques.

The telephone is the most available means of access the public has to obtain the services of the fire department. The telephone is also the fundamental method of communication within a department and between departments and agencies.

Fire department personnel using the telephone should adhere to the following rules:

(a) *Answer Promptly.* Treat each call as an emergency. Every ring for the person who might be ill or suffering from fear or panic seems like an eternity.

(b) *Identify Yourself and Your Department.* This assures the caller that the call was placed properly.

(c) *Speak Directly into the Mouthpiece.* This ensures that you will be understood and will not waste time repeating information.

(d) *Observe Telephone Courtesy.* Use a calm, competent, decisive voice in a courteous manner.

(e) *Take Charge of the Conversation.* After the initial exchange, lead the call into meaningful context by asking questions as to who, what, where, and when. Be courteous but firm.

(f) *Record All Information.* Never leave anything to memory.

(g) *Explain Waits.* Explain why it will take time to check for information and that you will call back. A party waiting on a "dead" phone might become irritable and uncooperative.

(h) *Avoid Jargon or Slang.*

(i) *Show Interest in the Person's Call.* The person calling has or needs information and feels it is important.

(j) *Use Caller's Name when Possible.* This makes the caller feel that you have a personal interest in the call.

(k) *Try to Visualize the Caller.* The telephone is an impersonal thing and we tend to be curt or less courteous or to lose our temper more easily than if we were meeting the party in person.

(l) *Make Sure the Information Gets to the Proper Person.* Never give the caller misinformation and never guess, but refer the call to the proper party even if it means transferring the call.

(m) *Advise when You Leave Your Position.* Let your co-workers know of your whereabouts when leaving your position.

(n) *List Frequently Called Numbers.* Place such numbers, as well as all other important numbers, within view of the operating position.

(o) *Transfer Calls Only when Necessary.* When it is necessary to transfer a call, tell the caller what you are going to do.

(p) *Terminate Calls Positively and Courteously.* Verify critical information before terminating a call.

5-6 Basic Radio Techniques.

FCC rules and regulations govern the operation of fire services radio, and a copy of the rules should be maintained at the communication center. In addition, certain rules that are based on common courtesy and achieving maximum efficiency from the system should be observed. Good radio practices include the following:

(a) Always be courteous.

(b) Use proper language. The use of profanity is prohibited by the FCC. This rule is enforced. Violations can and do result in fines, imprisonment, or loss of license.

(c) Answer radio calls promptly.

(d) Think through your message before starting to transmit. Be brief and to the point. Radio channels are crowded. Use brief phrases whenever possible to condense your messages.

(e) If radio dead spots or interference are encountered, move the vehicle and try again. Sometimes only a few feet can make a considerable difference. Many vehicles have directional radio patterns, either toward the front or rear, depending on location of the antenna. Changing vehicle direction can sometimes assist in getting a signal to the base station.

(f) If others are using the air, wait until they are through unless your message is of an emergency nature. If it is, break in on the conversation and request a clear frequency for emergency traffic. Always listen first to be sure the channel is clear before you attempt to transmit.

(g) Pronounce your words distinctly and rather slowly. Talk into the microphone; use a normal tone of voice. Shouting or yelling into the microphone will cause an extremely distorted signal and should be avoided. It is also essential that your voice maintain a constant volume that does not trail off. Do not become excited.

(h) Do not carry on discussions unrelated to department activity. Only pertinent communications are permitted. FCC rules do not permit transmission of messages for unlicensed parties (except in emergency situations) or the transmission of music or commercial messages.

Figure 5-7(a) Incident communications and resource situation/status unit, Southern California FIRESCOPE Project.

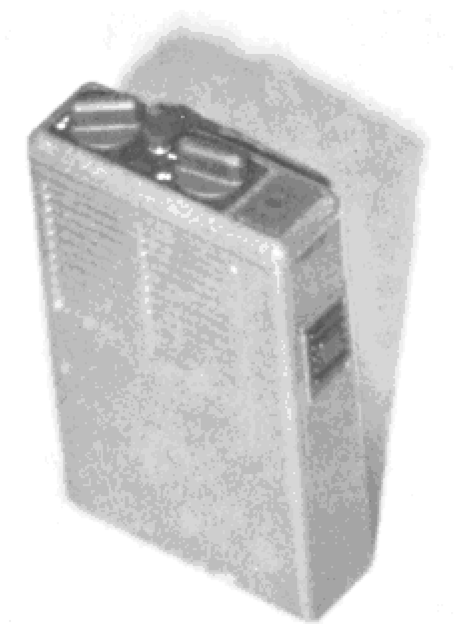

Figure 5-7(b) Tone-encoded pager.

Figure 5-7(c) Digital pager.

Figure 5-7(d) Mobile Incident Command and Communications Unit.

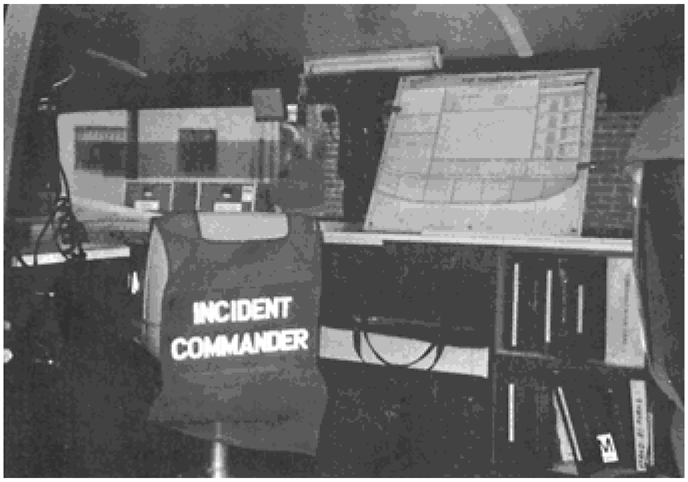

Figure 5-7(e) Radio operator's desk with cooperating agency's radio, tone encoder, and portable base station

as installed in mobile incident command/communications unit.

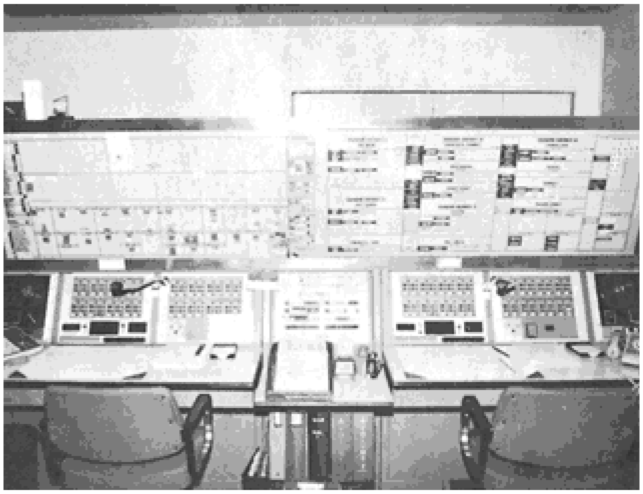

Figure 5-7(f) Two-position dispatch and communications console with resource directories, tone encoder, tape recorder, and resource/situation display.

Chapter 6 Referenced Publications

6-1

The following document 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.

6-1.1 FCC Publication.

U.S. Government Printing Office, Washington, DC.

Code of Federal Regulations, Federal Communications Commission, Title 47, Part 90, "Private Land Mobile Radio Services," 1990.

Appendix A Public Safety Communication Languages

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

There is a need for intercommunication between agencies in the Public Safety Radio Services. The most efficient service rendered to the public in a given area exists when all the resources of public safety can be coordinated. Communication is a vital link in this coordination process, be it by radio, telephone, or other means. It is essential that the operator of one system be able to understand the language of other systems. The only efficient and accurate method of reaching understanding is for these operators to speak the same language.

The best method of providing a common language is through the use of plain language.

The International Phonetic Alphabet

The phonetic alphabet should be used for spelling out unusual names of persons and locations. The names used after each letter have been found to be the most understandable over the air. They should always be given as “A — Alpha, B — Bravo,” never “A as in Alpha” or “B as in Bravo,” etc. The alphabet is easily memorized.

Letter	**Identifying Word**	**Spoken as ***
A	ALPHA	Al *fah*
B	BRAVO	*Brah voh*
C	CHARLIE	*Char* lee (*Shar* lee)
D	DELTA	*Dell* tah
E	ECHO	*Eck* oh
F	FOXTROT	*Foks* trot
G	GOLF	Golf
H	HOTEL	Hoh *tell*
I	INDIA	*In* dee ah
J	JULIETTE	*Jew* lee ett
K	KILO	*Key* loh
L	LIMA	*Lee* mah
M	MIKE	Mike
N	NOVEMBER	No *vem* ber
O	OSCAR	*Oss* cah
P	PAPA	Pah *pah*
Q	QUEBEC	Keh *beck*
R	ROMEO	*Row* me oh
S	SIERRA	See *air* ah
T	TANGO	*Tang* go
U	UNIFORM	*You* (*Oo*) nee form
V	VICTOR	*Vik* tah
W	WHISKEY	*Wiss* key
X	XRAY	*Ecks ray*
Y	YANKEE	*Yang* key
Z	ZULU	*Zoo* loo

*The syllables to be emphasized are italicized.

2400 Hour Time

2400 Hour Time	12 Hour Time
0000	Beginning of day
0001	One minute after midnight (zero zero zero one)
0015	Quarter past midnight (zero zero one five)
0045	45 minutes past midnight (zero zero four five)
0100	One o'clock in the morning (zero one hundred)
0130	One-thirty AM (zero one three zero)
0200	2 am (zero two hundred)
0300	3 am
0400	4 am
0500	5 am
0600	6 am
0700	7 am
0800	8 am
0900	9 am
1000	10 am (ten hundred)
1100	11 am (eleven hundred)
1200	Noon
1201	One minute after noon (twelve zero one)
1215	Quarter past noon (twelve fifteen)
1300 (add 100 to 1200)	1 pm (thirteen hundred)
1345 (add 0045 to 1300)	1:45 pm (thirteen forty-five)
1400 (add 200 to 1200)	2 pm
1500 (add 300 to 1200)	3 pm
1600 (add 400 to 1200)	4 pm
1700 (add 500 to 1200)	5 pm
1800 (add 600 to 1200)	6 pm
1900 (add 700 to 1200)	7 pm
2000 (add 800 to 1200)	8 pm (twenty hundred)
2100 (add 900 to 1200)	9 pm (twenty-one hundred)

2200 (add 1000 to 1200)	10 pm
2300 (add 1100 to 1200)	11 pm
2400 (add 1200 to 1200)	Midnight (twenty-four hundred)

Standard Numerical Pronunciation

1 - “WUN”	emphasizing W and N
2 - “TOO”	emphasizing long OO
3 - “TH-R-EE”	generally rolling R, long EE
4 - “FO-WER”	long O, emphasizing W and R
5 - “FIE-YIV”	long I, emphasizing Y and V
6 - “SIKS”	emphasizing S and KS
7 - “SEV-VEN”	emphasizing S and V with clearly spoken VEN
8 - “ATE”	long A, emphasizing T
9 - “NI-YEN”	emphasizing N, long I, with clearly spoken YEN
0 - “ZERO”	emphasizing Z, with a brief RO

Appendix B Frequency-Sharing Memorandum of Understanding

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

This Memorandum of Understanding is between the several partner agencies, which are: __________ Department of Forestry; ____________ Office of Emergency Services; _________ City Fire Department; ________________ County Fire Department; U.S. Forest Services; (etc.).

The purpose of this Memorandum of Understanding is to establish terms and conditions for use of radio frequencies when partner agencies are engaged in a mutual aid effort on incident(s).

The Reciprocal Fire Protection Act of May 27, 1955 (PL 84-46) authorizes the United States government to enter into this Memorandum of Understanding.

The following terms and conditions are agreed to:

______________________________	______________________________
Department of Forestry	County Fire Department

Date ________________ Date _____________________

___________________________________ ____________________________

Office of Emergency Service U.S. Forest Service

Date ________________ Date _____________________

___________________________________ ____________________________

City Fire Department County Fire Department

Date ________________ Date _____________________

___________________________________ ____________________________

County Fire Department County Fire Department

Date ________________ Date _____________________

The following radio frequencies are licensed by the FCC under Call Sign ________ to the State of __________, Department of Forestry. ____________ is licensed to use them in State of ____________ and vicinity with the exceptions noted. Partner agencies are subject to the same limitations. Partner agencies may use these frequencies on Department of Forestry—Partner Agency fires only after permission to use is given by The Department of Forestry Dispatch and Communication Center responsible for the fire.

RADIO FREQUENCY	EXCEPTIONS
1. __________________	1. ____________________
2. __________________	2. ____________________
(etc.)	(etc.)

Appendix C Radio Organizations

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

AASHTO	American Association of State Highway and Transportation Officials 444 N. Capitol St., NW Suite 249 Washington, DC 20001
ARRL	American Radio Relay League, Inc. 225 Main St. Newington, CT 06111
APCO	Associated Public Safety Communications Officials International 2040 South Ridgewood Avenue

	South Daytona, FL 32119
FCCA	Forestry Conservation Communications Association Virginia Division of Forestry P.O. Box 3758 Charlottesville, VA 22903-0758
FIT	Forest Industrial Telecommunications 871 Country Club Road, Suite A Eugene, OR 97401
IMSA	International Municipal Signal Association P.O. Box 1513 Providence, RI 02901
REACT	Radio Emergency Associated Citizens Teams React International, Inc. 3653 Woodhead Dr. Northbrook, IL 60062

Appendix D Referenced Publications

D-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.

D-1.1 NFPA Publications.

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

NFPA 1221, *Standard for the Installation, Maintenance, and Use of Public Fire Service Communication Systems*, 1994 edition.

NFPA 1561, *Standard on Fire Department Incident Management System,* 1995 edition.

D-1.2 APCO Publications.

Associated Public Safety Communications Officials International, 2040 South Ridgewood Ave., South Daytona, FL 32119.

The Public Safety Communications Standard Operating Procedure Manual, 1990.

"Project 16 Series."

"Project 14 Oral Brevity Code."

"Project 13 Clear Voice vs. 10 Code."

NFPA 298

1994 Edition

Standard on Fire Fighting Foam Chemicals for Class A Fuels in Rural, Suburban, and Vegetated Areas

1994 Edition

This edition of NFPA 298, *Standard on Fire Fighting Foam Chemicals for Class A Fuels in Rural, Suburban, and Vegetated Areas*, was prepared by the Technical Committee on Forest and Rural Fire Protection 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 298

The first edition of NFPA 298 was developed by the Technical Committee on Forest and Rural Fire Protection in 1989 in response to a perceived need for a performance standard dealing with foam chemicals used in control of wildland fires. The 1994 edition is a complete revision, which was necessary to make the document consistent with the changes in Class A foam technology that have been developed since the 1989 edition was adopted.

Technical Committee on Forest and Rural Fire Protection

Richard E. Montague, *Chair*
Incident Management Concepts, CA

Mary D. Chambers, *Secretary*
Bernalillo Cnty Fire District 10, NM

Fred G. Allinson, Nat'l Volunteer Fire Council, WA

Lynn R. Biddison, Chemonics, Fire-Trol, NM

Randall K. Bradley, Lawrence Livermore Laboratories, CA

John E. Bunting, New Boston Fire Dept., NH

Gary L. Buzzini, California Dept. of Forestry & Fire Protection, CA

Hanna J. Cortner, University of Arizona, AZ

Duane Dupor, Wisconsin Dept. of Natural Resources, WI

J. A. Foster, ISO Commercial Risk Services Inc., AZ

Donald C. Freyer, Georgia Forestry Commission, GA

Louis G. Jekel, Rural/Metro Corp., AZ

Robert L. Joens, USDA Forest Service, DC
Rep. United States Forest Service

Ralph R. Lafferty, MacMillan Bloedel Ltd, British Columbia, Canada

Michael W. Lowder, Bladen Cnty Office of Emergency Services, NC

John F. Marker, Firemark Assoc., OR

Paul G. Mason, Arkwright Mutual Insurance Co., CT

Peter Matulonis, Ansul Fire Protection, CA

James F. McMullen, The McMullen Co., Inc., CA

William M. Neville, Neville-Brown, CA

Lane M. O. Pilbin, Schirmer Engineering Corp., CA

Frederick S. Richards, NYS Dept. of State, NY
Rep. Fire Marshals Assn. of North America

James C. Sorenson, USDA Forest Service, GA
Rep. United States Forest Service

Herbert A. Spitzer, Los Angeles Cnty Fire Dept., CA

Edward F. Straw, ISO Commercial Risk Services Inc., GA

Jim Stumpf, U.S. Dept. of the Interior, ID

Howard L. Vandersall, Lawdon Fire Services, Inc., CA

Ronald R. Walker, American Forest & Paper Assn., CA
Rep. American Forest & Paper Assn.

Louis A. Witzeman, Scottsdale Fire Dept., AZ

James T. Wooters, Mizelle, Hodges and Assoc., Inc., GA

Alternates

Dennis N. Gage, ISO Commercial Risk Services Inc., NJ
(Alt. to E. F. Straw)

Robert M. Swinford, USDA Forest Service, UT
(Alt. to R. L. Joens)

William J. Baden, 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 and prevention for rural and suburban areas and forest, grass, brush, and tundra areas.

NFPA 298

Standard on Fire Fighting Foam Chemicals for Class A Fuels in Rural, Suburban, and Vegetated Areas

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 4 and Appendix B.

Chapter 1 Introduction

1-1 Scope.

This standard specifies requirements and test procedures for foam chemicals used on Class A fuels.

1-2 Purpose.

1-2.1

The standard specifies requirements for foam chemicals that are used to help control fires in Class A fuels.

1-2.2

Tests are used to ensure compliance with the requirements of this standard. Tests shall not be deemed as establishing performance levels in actual fire-fighting situations.

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.

Biodegradability. The decomposition of organic matter through the action of microorganisms, which results in the evolution of carbon dioxide.

Class A Foam.* An aggregation of bubbles having a lower density than water. The foam bubbles and the solution draining from them attach to and penetrate Class A fuels due to the reduced surface tension imparted to the water by the foam concentrate. The bubbles hold moisture and release it as the foam breaks down, prolonging the time the moisture can be absorbed by the fuels. The foam acts to exclude air from the fuel, envelopes the volatile combustible vapor and the fuel interfaces where applied in adequate quantities, and resists disruption due to wind, heat, and flame.

Class A Fuel. Combustibles such as vegetation, wood, cloth, paper, rubber, and many plastics.

Drain Time. The time that it takes for a specified portion of the total solution contained in the foam to revert to liquid and to drain out of the bubble structure.

Expansion. The ratio of the volume of the foam in its aerated state to the original volume of the nonaerated foam solution.

Foam. The aerated solution created by forcing or entraining air into a foam solution by means of suitably designed equipment or by cascading it through the air at a high velocity.

Foam Concentrate. The concentrated foaming agent as received by the manufacturer and approved by the authority having jurisdiction for use on Class A fuels.

Foam Solution. A homogeneous mixture of water and foam concentrate in the proportions required to meet the needs of the user.

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.

LC_{50}. The concentration (milligrams of test material per liter of solution) at which 50 percent of the test animals die.

LD_{50}. The dosage (milligrams of test material per kilogram of body weight) at which 50 percent of the test animals die.

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.

Surface Tension. The elastic-like force at the surface of a liquid, which tends to minimize the surface area, causing drops to form.

Use Level. The proportion of foam concentrate in the foam solution, expressed as a percentage. (Use levels for Class A foam solutions generally fall within the range of 0.1 percent to 1.0 percent.)

Water, Fresh. Deionized or distilled water to which 140 ppm of calcium, in the form of calcium chloride, have been added.

Water, Synthetic or Artificial Sea. A solution consisting of 1.10 percent magnesium chloride, 0.16 percent calcium chloride, 0.40 percent anhydrous sodium sulfate, 2.50 percent sodium chloride, and 95.84 percent deionized or distilled water. This composition meets Canadian General Standards Board Standard 28-GP-74M.

Chapter 2 Acceptance Criteria

2-1 Foam Concentrate.

2-1.1* Corrosion.

2-1.1.1 Uniform Corrosion. The foam concentrate shall not exhibit values exceeding those given in Table 2-1.1 when tested in accordance with 3-1.1.

Table 2-1.1 Maximum Allowable Corrosion Rates (in millinches per year)

	2024-T3 Aluminum				4130 Steel				Yellow Brass			
	Total 70°F (21°C)	Immersion 120°F (49°C)	Partial 70°F (21°C)	Immersion 120°F (49°C)	Total 70°F (21°C)	Immersion 120°F (49°C)	Partial 70°F (21°C)	Immersion 120°F (49°C)	Total 70°F (21°C)	Immersion 120°F (49°C)	Partial 70°F (21°C)	Immersion 120°F (49°C)
								mils per year				
Premix Components												
Liquid concentrates	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Mixed Solutions												
Fixed wing	2.0[1]	2.0[3]	2.0[3]	2.0[3]	2.0	2.0	5.0	5.0	2.0	2.0	5.0	5.0
Helicopter with internal or fixed tank	2.0[2]	2.0[2]	2.0[3]	2.0[3]	2.0	2.0	5.0	5.0	2.0	2.0	5.0	5.0
Ground application or helicopter with bucket	2.0	2.0	2.0	2.0	2.0	2.0	5.0	5.0	2.0	2.0	5.0	5.0

[1]If submitted for "helicopter with internal or fixed tank"; for all types, refer to footnote 2.
[2]Test shall be conducted for performance information.
[3]Intergranular corrosion tests shall be performed; no intergranular corrosion shall be permitted.

2-1.1.2* Corrosion of Nonmetallic Materials. The effects of foam concentrate on the hardness and volume of the following nonmetallic materials shall be tested in accordance with 3-1.3. Tested materials shall not exhibit changes in hardness exceeding 10 percent nor changes in volume exceeding 5 percent.

(a) PVC plastic

(b) MIL-S-8802 sealant

(c) MIL-S-81733 sealant

(d) Neoprene rubber AMS (SAE Aerospace Materials Specification) 3208 synthetic rubber CL-Prene 45-55 share

(e) Fiberglass with epoxy resin

(f) Cross-linked polyethylene MIL-C-38359A

(g) High density polyethylene MIL-P-51431A

(h) Teflon AMS 3660

(i) Flexible polyolefin MIL-I-23053/5.

2-1.2* Health and Safety.

2-1.2.1 Toxicity. The foam concentrate shall not exceed the toxicity limits defined in Table 2-1.2.1 when tested in accordance with Section 3-2 by a biological testing laboratory that is certified as adhering to good laboratory practice standards as defined in the *Code of Federal Regulations*, 40 CFR, Part 792 or Part 160.

Table 2-1.2.1 Toxicity Limits for Class A Foam Concentrates and Solutions

	Acute Oral Toxicity[1]	Acute Dermal Toxicity[2]	Primary Dermal Irritation	Prim
				Unwashed
Requirements	$LD_{50} > 500$ mg/kg	$LD_{50} > 2000$ mg/kg	Primary irritation	Mildly irritating
Foam concentrate	If $LD_{50} \geq 50$ but ≤ 500, recommend protective gear/handling procedures. No $LD_{50} < 50$ shall be permitted.	If $LD_{50} \geq 200$ but ≤ 2000, recommend protective gear/handling procedures. No $LD_{50} < 200$ shall be permitted.	Primary irritation score: < 5.0. If more irritating, demonstrate protective gear/handling procedures.	If more irritating, de strate protective gear handling procedures
Requirements	$LD_{50} > 5000$ mg/kg	$LD_{50} > 2000$ mg/kg	Primary irritation score: < 5.0	Mildly irritating

[1]If the acute oral toxicity of the concentrate is ≤ 500 mg/kg, the acute inhalation toxicity test shall be performed. An LC_{50} > 2.0 mg/L shall be permitted.
[2] If the acute dermal toxicity of the concentrate is ≤ 1000 mg/kg, the acute inhalation toxicity test shall be performed. An LC_{50} > 2.0 mg/L shall be permitted.

2-1.2.1.1 Documentation. Upon request, the manufacturer shall provide a summary of the results of toxicity testing described in 2-1.2.1 and a copy of a current material safety data sheet.

2-1.3* Biodegradability.

The foam concentrate shall be tested in accordance with Section 3-3. The concentrate shall be classified as readily biodegradable according to the *Code of Federal Regulations*, 40 CFR, Part 796.3100, as exemplified by a minimum of 60 percent biodegradation within 28 days.

2-1.3.1 Fish Toxicity. The foam concentrate shall be tested in accordance with Section 3-4. The LC_{50} shall be greater than 10 mg/L when measured after 96 hours of exposure.

2-1.4 Characteristics.

2-1.4.1* Temperature Stability. Foam concentrate shall be tested in accordance with Section 3-7. The foam concentrate shall not be stratified, crystallized, or otherwise separated at the end of the test. In addition, expansion and drain time shall be determined in accordance with Section 3-5, using foam solution prepared from the stored concentrate samples. The values for fresh and stored concentrates shall differ by no more than ±15 percent expansion and ±2 minutes drain time.

2-1.4.2 Viscosity. The viscosity of the concentrate shall be measured as described in Section 3-8, at temperatures of 0°, 35°, 70°, and 120°F (–18°, 2°, 21°, and 49°C). The viscosity values obtained shall be reported on the Product Data Sheet.

2-1.4.3 Miscibility. The miscibility of the foam concentrate shall be determined in accordance with Section 3-6 where mixing concentrate and water in the amounts required to prepare 0.3 and 1.0 percent foam solutions. The concentrate at 70°F (21°C) shall be miscible in water at 70°F (21°C). The miscibility of the concentrate in water at the additional temperatures included in Section 3-6 shall be reported on the additional Product Data Sheet.

2-1.4.4 Flash Point. The foam concentrate shall not exhibit a flash point below 140°F (60°C) when tested in accordance with Section 3-10.

2-1.5 Packaging and Labeling.

2.1.5.1 Packaging. Packaging of foam concentrates shall conform with regulations governing ground and air transport of materials. Containers shall meet performance oriented packaging criteria established and recommended by the United Nations as described in 4-1.3.

2-1.5.2 Labeling. In addition to other requirements that might apply, the manufacturer shall provide the following information on a label permanently attached to the concentrate container:

(a) Manufacturer name and address

(b) Product name, lot number, and date of manufacture

(c) 25 percent drain time in deionized water as required in 2-3.1

(d) Expansion in deionized water as required in 2-2.3.2

(e) Manufacturer recommended use levels

(f) Emergency and first aid instructions

(g) Volume (U.S. gallons and liters) of concentrate in the container

(h) Statement certifying that the product has been tested and meets all requirements of this standard.

2-2 Foam Solution.

2-2.1 Corrosion.

2-2.1.1 Uniform Corrosion. The foam solution, over the range of recommended use levels, shall not exhibit values exceeding those given in Table 2-1.1 when tested in accordance with 3-1.1.

2-2.1.2 Intergranular Corrosion. The magnesium and aluminum coupons exposed to the foam solution during uniform corrosion testing shall exhibit no intergranular corrosion when examined in accordance with 3-1.2.

2-2.1.3* Corrosion of Nonmetallic Materials. The effects of foam solution, over the manufacturer's range of recommended use level concentrations, on the hardness and volume of the following nonmetallic materials shall be tested in accordance with 3-1.3. Tested materials shall not exhibit changes in hardness exceeding 10 percent nor changes in volume exceeding 5 percent.

(a) PVC plastic

(b) MIL-S-8802 sealant

(c) MIL-S-81733 sealant

(d) Neoprene rubber AMS (SAE Aerospace Materials Specification) 3208 synthetic rubber CL-Prene 45-55 share

(e) Fiberglass with epoxy resin

(f) Cross-linked polyethylene MIL-C-38359A

(g) High density polyethylene MIL-P-51431A

(h) Teflon AMS 3660

(i) Flexible polyolefin MIL-I-23053/5.

2-2.2 Health and Safety.

2-2.2.1 Toxicity. The foam solution, at the maximum recommended use level, shall not exceed the toxicity limits defined in Table 2-1.2.1 when tested in accordance with Section 3-2 by a biological testing laboratory that is certified as adhering to good laboratory practice standards as defined in the *Code of Federal Regulations*, 40 CFR, Part 792 or Part 160.

2-2.2.1.1 Documentation. Upon request, the manufacturer shall provide a summary of the results of toxicity testing described in 2-2.2.1.

2-2.3 Characterization.

2-2.3.1 Surface Tension. Surface tension values of foam solutions, as measured in accordance with Section 3-9, shall be provided by the manufacturer on the Product Data Sheet at 0.1, 0.3, 0.6, and 1.0 percent concentrations.

2-2.3.2 Expansion. Expansion shall be determined for a foam solution prepared at a 0.3 percent use level in deionized, fresh, and sea water in accordance with Section 3-5. The results shall be reported in accordance with 2-1.5.2 and on the Product Data Sheet.

2-3 Foam.

2-3.1 Drain Rate.

The 25 percent drain time shall be determined for the foam prepared in 2-2.3.2 in accordance with Section 3-5. The results of these tests shall be reported in accordance with 2-1.5.2 and on the Product Data Sheet.

Chapter 3 Test Methods

3-1 Corrosion.

3-1.1 Uniform Corrosion.

Each coupon, 2.5 cm × 10.26 cm × 0.32 cm (1 in. × 4 in. × $^{1}/_{8}$ in.), shall be marked (by vibrating engraver) with a unique identification code, drilled in the upper center to insert the braided dacron string used to suspend it, and then measured to the nearest 0.001 cm (0.000394 in.) for each dimension (length, width, and thickness). Just prior to use, each coupon shall be degreased using an all-purpose liquid cleaner and shall be rinsed in tap water. The coupons then shall be cleaned chemically as described in Table 3-1, rinsed in distilled water, wiped to remove most of the water film, and dried at about 130°F (55°C) for 15 to 30 minutes. After the coupons are cooled to room temperature, they shall be weighed to 0.1 mg (0.00154 grain) and either used immediately or stored in a desiccator. After cleaning, coupons shall be suspended by a length of braided dacron fishing line in a 0.95-L (32-oz) glass jar in such a way that the coupon does not touch the sides or bottom of the jar. Each jar shall contain 0.8 L (24 oz) of liquid for total immersion tests or 0.4 L (12 oz) of liquid for partial immersion tests. The coupon shall be suspended so that one-half its length is immersed in the liquid and one-half its length is exposed to the vapor for partial immersion tests. The coupon shall be completely covered with liquid for total immersion tests. Each jar shall be closed with a screw cap, labeled with coupon identification and starting date, and put in an incubator at 70°F or 120°F (21°C or 49°C), dependent on the desired test condition.

Jars containing the test liquid (three at each exposure and temperature) shall stand undisturbed for 90 days.

At the end of the 90-day test period, the coupons shall be removed from the liquid and rinsed under running water to remove loosely attached corrosion products. If necessary, the coupons shall be lightly scrubbed with a toothbrush or other nonmetallic brush to aid in removal of scale. The coupons then shall be cleaned chemically using the same procedures that were used initially in accordance with Table 3-1. A clean, unused coupon shall be cleaned in the same manner to serve as a control for weight lost during the cleaning process. After rinsing in distilled water, oven-drying, and cooling as before, the final weight of each coupon shall be determined to 0.1 mg (0.00154 grain).

The corrosion weight (Cr) in mils per year (MPY) shall be calculated for each sample as follows:

$$Cr = 534 \frac{Wt_I - Wt_F - Wt_C}{Atp}$$

Where:

Wt_I = initial coupon weight (milligrams).

Wt_F = final coupon weight (milligrams).

Wt_C = weight loss of the control (milligrams).

A = area of the coupon (square inches).
t = exposure (hours).
p = density of the alloy (grams per cubic centimeter) as follows:

2024-T-3 aluminum = 2.77 grams per cubic centimeter.
4130 steel = 7.86 grams per cubic centimeter.
Yellow brass = 8.53 grams per cubic centimeter.
AZ-31-B magnesium = 1.77 grams per cubic centimeter.

Results of replicate tests shall be averaged.

Table 3-1 Procedure for Cleaning Corrosion Coupons

Alloy	Chemical	Time	Temperature	Remarks
Aluminum	70% HNO_3	2–3 min	Room	Follow with light scrub using nonmetallic brush[1]
Aluminum	2% CrO_3 5% H_3PO_4 Soln	10 min	175° – 185°F (79°C – 85°C)	Use when film resists HNO_3 – alternate two treatments as needed
Brass	15–20% HCl	2–3 min	Room	Follow with light scrub using nonmetallic brush[1]
Steel	50g $SnCl$ + 20 g $SbCl_3$ in 1 liter conc. HCl	3–5 min	Cold	Follow with light scrub using nonmetallic brush[1]
Magnesium	15% CrO_3 + 1% $AgCrO_4$ in distilled H_2O	15 min	Boiling	Follow with light scrub using nonmetallic brush[1]

[1]A rubber stopper, Scotch Brite™ or equivalent, nonmetallic scourer or scrubber shall be permitted to be used to scrub coupons with a hard or severe coating.

3-1.2 Intergranular Corrosion Test.

The mixed solution shall be tested for intergranular corrosion as required by 2-2.1.2 as follows:

At least one coupon for each exposure and temperature from 90-day weight loss tests on the specified alloys shall be sliced as shown in Figure 3-1.2, mounted, polished to 0.3 micron alumina finish, etched with Keller's reagent using standard metallurgical techniques, and examined at a magnification of 500X on both the transverse and longitudinal cross sections.

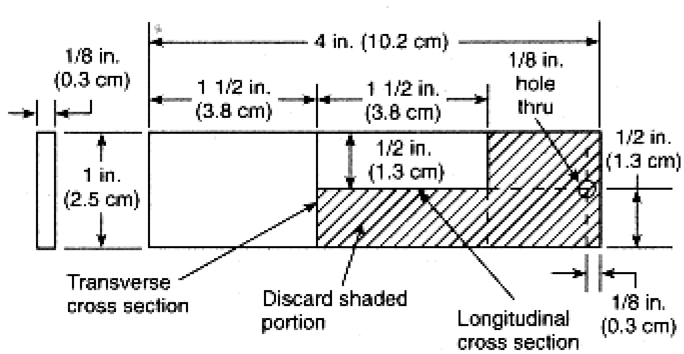

Figure 3-1.2 Intergranular corrosion test.

3-1.3 Nonmetallic Corrosion Tests.

3-1.3.1 Volume Test. A wide-mouth bottle of approximately 0.12 L (4 oz) with a tightly fitted screw cap shall be used as the test container. A piece of the nonmetallic material to be tested shall be prepared with dimensions chosen so that it can be placed in the test container. The volume of the test piece shall be measured using calipers capable of measuring with an accuracy of 0.03 cm (0.01 in.) or volumetrically using a pycnometer to the nearest 0.01 g (0.0003 oz). This value shall be recorded. The test coupon shall be placed in the container and then the container shall be filled with the test concentrate or solution so that the coupon is totally immersed. The test container shall be closed tightly to prevent liquid evaporation for the duration of the test. Triplicate determinations shall be made on each test material and liquid.

The test chamber and sample shall be stored at 70°F (21°C) for 28 days. The sample shall be removed (without wiping, rinsing, or drying) from the concentrate or solution and placed on top of the container lid for 8 hours each day during the normal 5-day work week. At the end of this period and on weekends, the test materials shall be returned to the test chamber. Any lost material shall be replenished so that the coupon continues to be totally immersed.

At the end of the 28-day period, the test material shall be removed from the liquid, rinsed with distilled water, and dried. The dimensions of the test piece shall be measured and its total volume calculated. The change in volume shall be calculated and compared with its initial volume to determine the change that occurred during the test. The average of the triplicate results shall be reported.

3-1.3.2 Hardness Test. The hardness of the nonmetallic coupons described in 3-1.3.1 shall be determined according to Federal Test Standard No. 601, Methods 3021 and 3025, both prior to and following the submerged storage described in 3-1.3.1.

Material	Apparatus
PVC plastic	Shore A2
MIL-S-8802 sealant	Shore A2
MIL-S-81733 sealant	Shore A2
Neoprene rubber	Shore A2
Fiberglass	Shore D
Cross-linked polyethlene	Shore A2
High density polyethylene MIL-P-51431A	Shore D
Teflon AMS 3660	Shore D
Flexible polyolefin, MIL-I-23053/5	Shore A2

The average of the triplicate results shall be reported.

3-2 Toxicity.

The foam concentrate shall be tested in accordance with “Pesticide Assessment Guidelines, Subdivision F, Hazard Evaluation: Human and Domestic Animals,” U.S. Environmental Protection Agency, Washington, D.C., Protocols: FIFRA Guidelines series 81, Acute Toxicity and Irritations Studies.

3-3 Biodegradability Test.

3-3.1 Aerobic Aquatic Biodegradation, CFR 40, Part 796.3100.

This test is designed to develop data on the rate and extent of aerobic biodegradation that might occur when chemical substances are released to aquatic environments. A high biodegradability result for this test provides evidence that the test substance is biodegradable in natural aerobic freshwater environments. On the contrary, a low biodegradation result might have causes other than poor biodegradability of the test substance. Inhibition of the microbial inoculum by the test substance at the test concentration might be observed. In such cases, further work is needed to assess the aerobic aquatic biodegradability and to determine the concentrations at which toxic effects are evident. An estimate of the expected environmental concentration shall help to put toxic effects into perspective.

3-3.2 Definitions.

Adaption. The process by which a substance induces the synthesis of any degradative enzymes necessary to catalyze the transformation of that substance.

Ready Biodegradability. An expression used to describe those substances that, in certain biodegradation test procedures, produce positive results that are unequivocal and that lead to the reasonable assumption that the substance will undergo rapid and ultimate biodegradation in aerobic aquatic environments.

Ultimate Biodegradability. The breakdown of an organic compound to CO_2, water, the oxides or mineral salts of other elements, or to products associated with normal metabolic processes of microorganisms or to a combination of these.

3-3.3

This test method is based on the method described by William Gledhill. The method consists of a 2-week inoculum build-up period during which soil and sewage microorganisms are provided the opportunity to adapt to the test compound. This inoculum is added to a specially equipped Erlenmeyer flask containing a defined medium with test substance. A reservoir holding barium hydroxide solution is suspended in the test flask. After inoculation, the test flasks are purged with CO_2-free air, sealed, and incubated with shaking in the dark. Periodically, samples of the test mixture containing water-soluble test substances are analyzed for dissolved organic carbon (DOC), and the $Ba(OH)_2$ from the reservoirs is titrated to measure the amount of CO_2 evolution. Differences in the extent of DOC disappearance and CO_2 evolution between control flasks containing no test substance and flasks containing test substance are used to estimate the degree of ultimate biodegradation.

3-3.4 Prerequisites.

The total organic carbon (TOC) content of the test substance shall be calculated or, if this is not possible, analyzed to enable the percent of theoretical yield of carbon dioxide and percent of DOC loss to be calculated.

3-3.5 Test Information.

3-3.5.1 Information on the relative proportions of the major components of the test substance will be useful in interpreting the results obtained, particularly in those cases where the result lies close to a “pass level.”

3-3.5.2 Information on the toxicity of the chemical might be useful in the interpretation of low results and in the selection of appropriate test concentrations.

3-3.6 Reference Substances.

Where investigating a chemical substance, reference compounds might be useful and an inventory of suitable reference compounds shall be identified. In order to check the activity of the inoculum, the use of a reference compound shall be required desirable. Aniline, sodium citrate, dextrose, phthalic acid, and trimellitic acid will exhibit ultimate biodegradation under the conditions of this test guideline method. These reference substances shall yield 60 percent of theoretical maximum CO_2 and show a removal of 70 percent DOC within 28 days. Otherwise, the test shall be considered as invalid and shall be repeated using an inoculum from a different source.

3-3.7 Reproducibility.

The reproducibility of the method has not yet been determined; however, it is believed to be appropriate for a screening test that has solely an acceptance (no rejective) function.

3-3.8 Sensitivity.

The sensitivity of the method shall be determined by the ability to measure the endogenous CO_2 production of the inoculum in the blank flask and by the sensitivity limit of the dissolved organic carbon analysis. If the test is adapted to handle C^{14}-labeled test substances, the test substance concentration can be much lower.

3-3.9 Possibility of Standardization.

This possibility exists. The major difficulty is to standardize the inoculum in such a way that interlaboratory reproducibility is ensured.

3-3.10 Possibility of Automation.

There are none at present, although parts of the analyses might be automated.

3-3.11 Test Procedures.

3-3.11.1 Apparatus. The shake flask apparatus in Figure 3-3.11.1 shall consist of an open reservoir containing 10 ml of 0.2 N $Ba(OH)_2$ suspended over 1 L of culture medium in a 2-L Erlenmeyer flask.

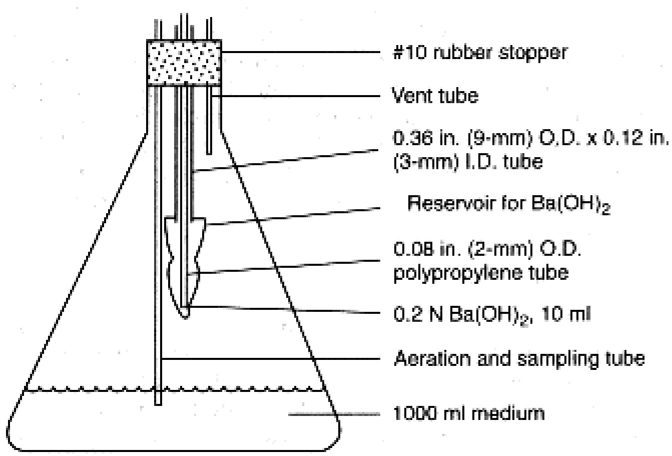

Figure 3-3.11.1 Shake-flask system for carbon dioxide evolution.

The $Ba(OH)_2$ container shall be made by placing a constriction just above the 10-ml mark of a

50-ml heavy-duty centrifuge tube and attaching the centrifuge tube to a 2 mm I.D. × 9 mm O.D. (0.08 in. I.D. × 0.36 in. O.D.) glass tube by means of three glass support rods. The centrifuge tube opening shall be large enough to permit CO_2 to diffuse into the $Ba(OH)_2$, while the constriction permits transferal of the flask to and from the shaker without $Ba(OH)_2$ spillage into the medium. For periodic removal and addition of base from the center well, a polypropylene capillary tube, attached at one end to a 10-ml disposable syringe, shall be inserted through the 9-mm O.D. (0.36-in.) glass tube into the $Ba(OH)_2$ reservoir. The reservoir access port shall be sealed during incubation with a serum bottle stopper. Two glass tubes shall be added for purging, venting, and medium sampling. The tops of these tubes shall be connected with a short section of flexible tubing during incubation.

3-3.11.2 Reagents and Stock Solutions.

(a) Stock solutions, I, II, and III per Table 3-3.11.2

(b) Yeast extract

(c) Vitamin-free casamino acids

(d) 70 percent O_2 in nitrogen or CO_2-free air

(e) 0.2 N $Ba(OH)_2$

(f) 0.1 N HCl

(g) 20 percent H_2SO_4

(h) Phenolphthalein

(i) Dilution water — distilled, deionized water (DIW).

Table 3-3.11.2 Medium Employed for Assay of CO_2 Evolution

Solution1	Compound	Stock Solution Conc. (g/L)
I	NH4Cl	35
	KNO3	15
	K2HPO4-3H2O	75
	NaH2PO4-H2O	25
II2	KCl	10
	MgSO4	20
	FeSO4-7H2O	1
III	CaCl2	5
	ZnCl2	0.05
	MnCl2-4H2O	0.5

$CuCl_2$	0.05
$CoCl_2$	0.001
H_3BO_3	0.001
MoO_3	0.0004

1Each liter of test medium contains 1 ml of each solution.
2Final pH is adjusted to 3.0 with 0.10 N HCl.

3-3.11.3 Soil Inoculum. A fresh sample of an organically rich soil shall be used as the inoculum in the ultimate biodegradation test. Soil shall be collected, prepared, and stored according to the recommendations of Pramer and Bartha. The soil surface shall be cleared of litter and a soil sample shall be obtained to 20 cm (0.8 in.) below the surface. The sample shall be screened through a sieve with 2 mm to 5 mm (0.08 in. to 0.2 in.) openings and stored in a polyethylene bag at 34°F to 39°F (2°C to 4°C) for not more than 30 days prior to use. The soil shall never be allowed to air-dry and shall not be frozen during storage.

3-3.11.4 Acclimation Medium. An acclimation medium shall be prepared by adding for each liter of distilled, deionized water (DIW): 1 ml (0.034 oz) each of solutions I, II, and III in Table 3-3.11.2, 1.0 g of soil inoculum, 2.0 ml (0.068 oz)of aerated mixed liquor (obtained from an activated sludge treatment plant not more than 2 days prior to commencing the acclimation phase, and stored in the interim at 39°F (4°C) and 50 ml (1.7 oz) raw domestic influent sewage. This medium shall be mixed for 15 minutes and filtered through a glass wool plug in a glass funnel. The filtrate shall be permitted to stand for 1 hour, refiltered through glass wool, and supplemented with 25 mg/L each of Difco vitamin-free casamino acids and yeast extract. Appropriate volumes shall be added to 2-L Erlenmeyer flasks. Test compounds shall be added incrementally during the acclimation period at concentrations equivalent to 4 and 8 mg/L carbon on days 7 and 11, respectively. On day 14, the medium shall be refiltered through glass wool prior to use in the test. For evaluating the biodegradability of a series of functionally or structurally related chemicals, media from all inoculum flasks shall be combined before final filtration.

3-3.12 Procedures.

3-3.12.1 Inoculum 100 ml (3.4 oz) of acclimation medium) shall be added to 900 ml (30.6 oz) DIW containing 1 ml (0.034 oz) each of solutions I, II, and III in accordance with Table 3-3.11.2 in a 2-L Erlenmeyer flask. Test compound equivalent to 10 mg/L carbon shall be added to each of the replicate flasks containing the test medium. Ten ml of 0.2 N $Ba(OH)_2$ shall be added to the suspended reservoir in each flask, and duplicate 10-ml samples of $Ba(OH)_2$ also shall be saved as titration blanks for analysis with test samples. Flasks shall be purged with CO_2-free air (for volatile test materials, purging shall be done prior to addition of the chemical), sealed, and placed on a gyrotary shaker (approximately 125 rpm) at 69°F to 77°F (20°C to 25°C) in the dark. For each set of experiments, each test, reference, inhibited, and control system shall be analyzed at time zero and at a minimum of four other times from time zero through day 28. Sampling shall be made with sufficient frequency to allow for a smooth plot of biodegradation with time.

Sampling times shall be varied by the investigator as deemed appropriate to match the rate of degradation of the test substance. Tests shall be terminated when biodegradation reaches a plateau and is consistent (±10 percent) over three consecutive days or on day 28, whichever occurs first. For chemicals that are water soluble at the test concentration, an adequate volume [5 ml to 10 ml (0.17 oz to 0.34 oz)] of medium shall be removed for DOC analysis. Each sample for DOC analysis shall be filtered through a membrane filter of 0.45 micrometer pore diameter before DOC analysis. For all test and reference compounds, $Ba(OH)_2$ from the center well shall be removed for analysis. The center well shall be rinsed with 10 ml (0.34 oz) of CO_2-free DIW and shall be refilled with fresh base. Rinse water shall be combined with the $Ba(OH)_2$ sample to be analyzed. Flasks shall be resealed and placed on the shaker. On the day prior to terminating the test, 3 ml of 20 percent H_2SO_4 shall be added to the medium to release carbonate-bound CO_2.

3-3.12.2 For each set of experiments, each test substance shall be tested in triplicate.

3-3.12.3 For each set of experiments, one or two reference compounds shall be included to assess the microbial activity of the test medium. Duplicate reference flasks shall be prepared by adding reference compound equivalent to 10 mg/L carbon to each of two flasks containing the test medium. Reference compounds that are positive for ultimate biodegradability include sodium citrate, dextrose, phthalic acid, trimellitic acid, and aniline.

3-3.12.4 For each test set, triplicate controls receiving inoculated medium and no test compound, plus all test and reference flasks, shall be analyzed for CO_2 evolution and DOC removal. Results from analysis of the control flasks (DOC, CO_2 evolution, etc.) shall be subtracted from corresponding experimental flasks containing test compound in order to arrive at the net effect due to the test compound.

3-3.12.5 A test system containing a growth inhibitor shall be established as a control for each substance tested for biodegradation by this method. This inhibited system shall contain the same amount of water, mineral nutrients, inoculum, and test substance used in the uninhibited test systems, plus 50 mg/L mercuric chloride ($HgCl_2$) to inhibit microbial activity.

3-3.12.6 Flasks shall be incubated in the dark to minimize both photochemical reactions and algal growth. Appropriate sterile controls or controls containing a metabolic inhibitor, such as 50 mg/L $HgCl_2$, are needed to correct for interferences due to nonbiological degradation. With volatile organic materials, purging with CO_2-free air shall be performed only once just prior to addition of the test chemical. Analyses for CO_2 evolution and DOC removal shall be conducted within 2 to 3 hours of sampling to minimize interferences that could occur in storage. All glassware shall be free of organic carbon contaminants.

3-3.13 Analytical Measurements.

The quantity of CO_2 evolved shall be measured by titration of the entire $Ba(OH)_2$ sample [10 ml (0.34 oz) $Ba(OH)_2$ + 10 ml (0.34 oz) rinse water with 0.1 N HCl] to the phenolphthalein end point. $Ba(OH)_2$ blanks also shall be supplemented with 10 ml (0.34 oz) CO_2-free DIW and titrated in a similar manner. Samples [5 ml (0.17 oz)] for DOC shall be centrifuged or filtered, or both, and supernatant or filtrate shall be analyzed by a suitable total organic carbon method.

3-3.14 Data and Reporting — Treatment of Results.

3-3.14.1 Test compound (10 mg carbon) is theoretically converted to 0.833 mmol CO_2. Absorbed CO_2 precipitates as $BaCO_2$ from $Ba(OH)_2$, causing a reduction in alkalinity by the equivalent of 16.67 ml of 0.1 N HCl for complete conversion of the test compound carbon to CO_2. Therefore, the percent theoretical CO_2 evolved from the test compound shall be calculated at any sampling time from the following equation:

Percent CO_2 evolution = [(TF - CF)/16.67] 100 (for 10 mg/L test compound carbon)

Where:

TF = ml 0.1 N HCl required to titrate $Ba(OH)_2$ samples from the test flask.

CF = ml 0.1 N HCl required to titrate $Ba(OH)_2$ samples from the control flask.

3-3.14.2 The cumulative percent CO_2 evolution at any sample time shall be calculated as the summation of the percent CO_2 evolved at all sample points of the test.

3-3.14.3 The percent DOC disappearance from the test compound shall be calculated from the following equation:

Percent DOC Removal = $[1 - (DTF_x - DCF_x)/DTF_0 - DCF_0)]$ 100

Where:

DTF = Dissolved organic carbon from test flask.
DCF = Dissolved organic carbon from control flask.
0 = Day zero measurements.
x = Day of measurements during test.

3-3.14.4 The difference between the amount of 0.1 N HCl used for the $Ba(OH)_2$ titration blank samples and the $Ba(OH)_2$ samples from the control units (no test compound) shall be an indication of the activity of the microorganisms in the test system. In general, this difference shall be approximately 1 to 3 ml of 0.1 N HCl at each sampling time. A finding of no difference in the titration volumes between these two samples indicates a poor inoculum. In this case, the test set shall be rerun for validity, beginning with the acclimation phase.

3-3.14.5 CO_2 evolution in the reference flasks also shall be indicative of the activity of the microbial test system. The suggested reference compounds shall all yield final CO_2 evolution values in the range 80 to 100 percent of theoretical CO_2. If, for any test set, the percent theoretical CO_2 evolution value for the reference flasks is outside this range, the test results shall be considered invalid and the test shall be rerun.

3-3.14.6 Inhibition by the test compound shall be indicated by lower CO_2 evolution in the test flasks than in the control flasks. If inhibition is noted, the study for this compound shall be rerun, beginning with the acclimation phase. During the test phase for inhibitory compounds, the test chemical shall be added incrementally according to the following schedule:

Day 0 0.5 mg/L as organic carbon
Day 2 1 mg/L C
Day 4 1.5 mg/L C

Day 7   2 mg/L C
Day 10   5 mg/L C. In this case, the $Ba(OH)_2$ shall be sampled on Day 10, and weekly thereafter. The total test duration remains 28 days.

3-3.14.7 The use of C^{14}-labeled chemicals shall not be required. If an appropriately labeled test substance is readily available and if the investigator chooses to use this procedure with a labeled test substance, this alternative shall be permitted. If this option is chosen, the investigator shall use lower test substance concentrations if those concentrations are more representative of environmental levels.

3-3.15 Test Report.

For each test and reference compound, the following data shall be reported:

(a) Information on the inoculum, including source, collection date, handling, storage, and possible adaptation (e.g. the inoculum might have been exposed to the test substance either before or after collection and prior to use in the test).

(b) Results from each test, reference, inhibited (with $HgCl_2$), and control system at each sampling time, including an average test result for the triplicate test substance systems and the standard deviation for that average.

(c) Average cumulative percent theoretical CO_2 evolution for the test duration.

(d) Dissolved organic carbon due to test compound at each sampling time (DTF-DCF).

(e) Average percent DOC removal at each sampling time.

(f) Twenty-eight-day standard deviation for percent CO_2 evolution and DOC removal.

3-4 Fish Toxicity.

Foam concentrate samples shall be tested, using *salmo gairdneri* (rainbow trout), in accordance with “Environmental Protection Series, Biological Test Method: Acute Lethality Test Using Rainbow Trout,” Report EPS1/RM/9, or equivalent test procedure recognized by the authority having jurisdiction where the foam concentrate will be used.

3-5 Foam Expansion and Drain Time.

3-5.1 Test Method.

One hundred fifty ml of a 0.3 percent foam solution, prepared using 70°F ± 5°F (21°C ± 3°C) water, shall be poured into the jar of an Oster 7-speed household blender or equivalent. The jar shall be calibrated and marked in 50-ml increments. The solution shall be blended for 45 seconds at the lowest speed and the volume of foam, as indicated by the container calibrations, recorded. The foam then shall be poured into a 1-L graduated cylinder and the foam volume again measured and recorded. The drain time shall be determined by recording the volume of foam solution drained from the foam at 1-minute intervals for 15 minutes or until 40 ml of solution have been drained, whichever is greater.

The volume of drained solution shall be plotted against time (minutes). The time required for 37.5 ml to drain shall be recorded as the 25 percent drain time.

3-5.1.1 Deionized Water. The test method shall be conducted according to 3-5.1, with the 0.3

percent foam solution prepared with deionized water.

3-5.1.2 Fresh Water. The test method shall be repeated according to 3-5.1, with the 0.3 percent foam solution prepared in accordance with the definition of fresh water in Section 1-3.

3-5.1.3 Artificial Sea Water. The test method shall be repeated once again according to 3-5.1, with the 0.3 percent foam solution prepared in accordance with the definition of artificial sea water in Section 1-3.

3-6 Miscibility.

Five hundred ml of deionized water at the test temperature shall be added to a 1-L beaker. A stirrer, as illustrated in Figure 3-6, shall be inserted into the water to the depth shown on the illustration. The speed of the stirrer motor shall be adjusted to 60 rpm ± 10 rpm. Within approximately a 2-second period, the amount of concentrate needed to produce the required concentration shall be added to the beaker. After 10 revolutions of the stirrer, rotation shall be stopped and the liquid mixture shall be observed. If the solution is not visually homogeneous, it shall be stirred for an additional 10 revolutions. This procedure shall be repeated until the solution is visually homogeneous or the total number of revolutions is equal to 100. The observations made at each 10-revolution interval shall be recorded. The sample shall remain undisturbed for 15 minutes. If the solution is not visually homogeneous after the 15-minute period, the result shall be recorded as “not miscible.”

Three miscibility (ease of mixing) tests shall be made using 70°F (21°C) foam concentrate mixed into 40°, 70°, and 100°F (4°, 21°, and 38°C) deionized water in accordance with the above test method.

A second series of three tests shall be conducted using 40°F (4°C) foam concentrate and the same water temperatures specified in the previous paragraph.

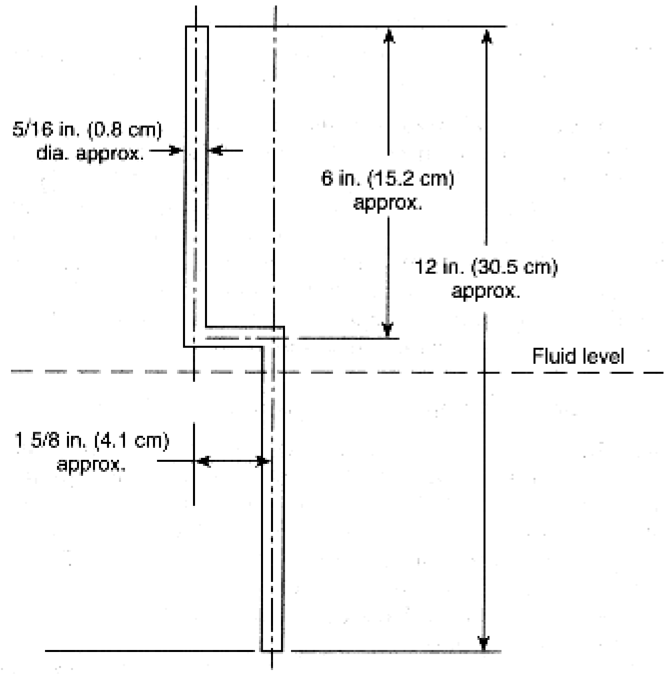

Figure 3-6 Stirrer shaft for miscibility test.

3-7 Stability of Concentrate.

3-7.1

Three 19-L (5-gal) samples of foam concentrate from a single production lot shall be stored in sealed containers, of the type used by the manufacturer for shipping and storage, as described in 3-7.1.2 through 3-7.1.4. The samples shall be designated as Samples 1, 2, and 3.

3-7.1.1 Samples shall not be agitated or disturbed in any way or at any time during or between the entire storage periods.

3-7.1.2 Sample 1 shall be stored at 105°F ± 5°F (41°C ± 3°C) for 30 continuous days. At the end of the 30-day period, the sample shall be removed from the 105°-F (41°-C) environment and stored at 70°F ± 4°F (21°C ± 2°C) for 7 days (168 hours). Sample 1 then shall be handled, opened, and inspected in accordance with 3-7.2.

3-7.1.3 Sample 2 shall be stored at 105°F ± 5°F (41°C ± 3°C) for 30 continuous days in a manner identical to Sample 1. Within 12 hours of removal from the 105°-F (41°-C) environment, Sample 2 shall be placed in an environment at a temperature of 14°F ± 2°F (-10°C ± 1°C). It shall be kept in this cold environment for a second continuous 30-day period and then placed in an environment of 70°F ± 4°F (21°C ± 2°C) for 7 days. At the end of this 7-day period (67 days into the test regimen), Sample 2 then shall be handled, opened, and inspected in accordance with 3-7.2.

3-7.1.4 Sample 3 shall be stored at 14°F ± 2°F (-10°C ± 1°C) for 30 continuous days, removed and held at a temperature of 70°F ± 4°F (21°C ± 2°C) for 7 days. At the end of this period, Sample 3 shall be handled, opened, and inspected in accordance with 3-7.2.

3-7.2

At the end of the storage periods described in 3-7.1, the sealed sample container shall be inverted four times within a 1-minute period. It then shall be opened and the foam concentrate poured into an open pail and allowed to sit undisturbed for 10 minutes to allow bubbles to rise to the surface. The sample then shall be visually examined for separation, stratification, and crystallization. After thoroughly mixing to achieve homogeneity, the expansion and drain time of the concentrate shall be determined in accordance with the procedure in Section 3-5 and in accordance with 2-1.4.1. The empty container shall be examined, as well, for any evidence of residual sediment or crystals.

3-8 Viscosity.

The viscosity of the foam concentrate shall be tested in the following manner as required in 2-1.4.2. A Brookfield viscometer model LVT or LVF, or equivalent, set at 60 revolutions per minute with the appropriate spindle (No. 2 for viscosities from 1 to 500 centipoise and No. 4 for viscosities greater than 500 centipoise) to measure the viscosity shall be used. A Griffith beaker or other straight-sided container containing approximately 800 ml of the test sample shall be positioned under the viscometer. The spindle shall be immersed to the proper depth in the concentrate. The viscometer then shall be turned on and the spindle allowed to rotate for 1 minute prior to reading the dial. Triplicate measurements shall be made, stirring between each measurement, and the viscosity of the sample calculated in centipoise using the appropriate multiplier (5 for spindle No. 2 and 100 for spindle No. 4).

3-9 Surface Tension.

Foam solutions containing 0.1, 0.3, 0.6, and 1.0 g of foam concentrate per 100 g of solution shall be prepared with deionized water preadjusted to 70°F ± 4°F (21°C ± 2°C) and the surface tension of each sample determined according to IS0 304, *Surface Active Agents — Determination of Surface Tension by Drawing Up Liquid Films*, as referenced in 4-1.2.

3-10 Flash Point.

As required in 2-1.4.4 the open cup flash point shall be determined in accordance with ASTM D92, *Method of Test for Flash and Fire Points by Cleveland Open Cup*.

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

“Pesticide Assessment Guidelines, Subdivision F, Hazard Evaluation: Human and Domestic Animals,” U.S. Environmental Protection Agency, Washington, D.C., as found in *Federal Register*, Vol. 43, No. 163.

4-1.2

International Organization for Standardization, ISO 304, *Surface Active Agents —*

Determination of Surface Tension by Drawing Up Liquid Films, second edition, 1985-12-15.

4-1.3

Department of Transportation, *Performance Oriented Packaging Standards: Changes to Classification, Hazard Communication, Packaging and Handling Requirements Based on United Nations Standards and Agency Initiative*: Final Rule, 55FR-52401 - 52729 (December 21, 1990).

4-1.4

Canadian General Standards Board, Standard 28-GP-74M (September 1982).

4-1.5

Code of Federal Regulations, 40 CFR, Parts 160, 792, and 796.3100.

4-1.6

"Environmental Protection Series, Biological Test Method: Acute Lethality Test Using Rainbow Trout," Report EPS1/RM/9, July 1990

4-1.7

Federal Test Standard No. 601, Methods 3021 and 3025 (April 12, 1985).

4-1.8

ASTM D92, *Method of Test for Flash and Fire Points by Cleveland Open Cup*, 1990. American Society of Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

4-1.9

Gledhill, W.E. "Screening Test for Assessment of Ultimate Biodegradability: Linear Alkyl Benzene Sulfonate," *Applied Microbiology*, 30:922-929(1975).

4-1.10

Pramer, D., Bartha, R. "Preparation and Processing of Soil Samples for Biodegradation Testing," *Environmental Letters*, 2:217-224 (1972).

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 Class A Foam.

Types of systems for producing Class A fire suppressant foam are as follows:

(a) *Compressed Air Foam System or Water Expansion Pumping System.* The compressed air foam system (CAFS) is a fire-fighting system that expands water from 1 to at least 60 times its original volume and is designed for foam application on Class A fuels.

(b) *Air-aspirating Foam Nozzle.* Foam concentrate is mixed with water and the solution is pumped to the aspirating nozzle where foam is generated.

(c) *Fixed-wing Aircraft.* Solutions mixed at 0.3 to 1.0 percent by volume are dropped from low altitudes to produce expansion up to 15:1 (depending on drop speed, aircraft height, and mix ratio).

(d) *Helicopters.* Foam solutions are dropped from helicopters equipped with fixed tanks or buckets to produce expansion rates of up to 10:1.

Additional information on each of these foam development and application methods is referenced in Appendix B.

A-2-1.1 Corrosion of Metals.

Generally, foam solutions have a cleansing action that removes loose grease, oil, scale, and paint from metal surfaces, which normally protect metal from the corrosive attack of water.

A-2-1.1.2 If other nonmetallic materials are to be used with foam concentrate, such materials also should be tested in acordance with 3-1.3.

Foam concentrate or foam solutions might cause corrosion of some metal surfaces. Storage of foam solutions or concentrates for long periods of time in metal tanks should be avoided unless the container is fabricated of corrosion-resistant materials.

Solutions containing foam concentrates that interact with or remove galvanizing or similar coatings should not be used where contact with such coatings is likely.

Points of Inspection. All joints, seams, or connections that conceivably could be subject to leakage should be carefully examined because foam solution is capable of passing through openings too small for water. These include valve packing, retainers, bushings, threaded joints, and screw unions.

A-2-1.2 Personnel Protection.

All personnel involved in handling, mixing, and applying foam concentrate and solutions should be trained in the proper procedure with respect to occupational safety and health and environmental impact. All personnel should follow the manufacturer's recommendations on the product label and on the material safety data sheet.

Prolonged contact with concentrate should be avoided. Showering is recommended as soon as possible after prolonged contact with concentrate. Clothing wetted with concentrate should be changed and washed. Soiled clothes should be cleaned on a daily basis.

Individuals who have ingested concentrate should be examined by a doctor as soon as possible. Skin or eyes that come in contact with concentrate should be rinsed and washed immediately. Eyes should be washed for 20 minutes. Fresh water should be available on site for this purpose.

Personnel handling foam solutions should wear protective clothing including eye protection and should avoid ingesting solution.

User Responsibility.

(a) Every container in the workplace that contains foam concentrate should be and should remain labeled in the prescribed manner.

(b) Labels and material safety data sheets should be available in English and such other language or languages as are prescribed by the authority having jurisdiction.

(c) Foam concentrate should not be used at a workplace unless a label and material safety data sheet are present and worker instruction and training have been completed.

(d) A material safety data sheet should be made available in the workplace in such a manner as to allow examination by the workers.

(e) Prescribed safe-handling equipment should be present, in proper repair, and in use at the workplace.

A-2-1.3 Recommended Operational Procedures.

Water Source Protection. The following procedures should be used where mixing and applying Class A fire suppressant foams:

(a) *Filling Mobile Water Supply Apparatus.* All pumps used to fill mobile water supply apparatus using foam should have a check valve on the suction side, an internal check valve, or a check valve next to the pump on the discharge side to avoid water source contamination and siphoning of the tank. Tanks should not leak and operators should avoid overflow spills and discharge hose spills.

(b) *Filling Helicopter Buckets.* A closed portable concentrate container with a long spout, on-board injection system, or similar device should be provided to prevent splashes and concentrate spills caused by rotor downwash.

Portable tanks or sumps used to premix solution or fill buckets should be located at least 100 ft (30 m) from fish-bearing streams or streams flowing into fish-bearing waters, and they should be situated on soil as opposed to gravel floodplains. Spills from portable tanks or sumps should be prevented from entering fish-bearing habitat or water that flows into fish-inhabited water.

(c) *Filling Fixed-wing Aircraft and Helicopters with Attached Tanks.* Mixing operations should be set up and executed to avoid spilling concentrate or solution. Spillage should not drain into drainage systems that empty into fish habitat or waterways that flow into fish-inhabited water.

Air drops should be more than 100 ft (30 m) from fish-bearing streams or streams flowing into fish-bearing streams.

For additional information on applications, see Appendix B.

A-2-1.4.1 Foam Concentrate Compatibility. Product brands and types might not be compatible. Users should flush and rinse concentrate holding containers before adding another brand or type of concentrate. Advice from the manufacturer should be obtained before mixing different concentrates.

A-2-2.1.3 If other nonmetallic materials are to be used with foam solutions, such materials also should be tested in accordance with 3-1.3.

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.

FOAM VS FIRE, June 1992, National Wildfire Coordinating Group, NFES 2246.

Introduction to Class A Foams and Compressed Air Foam Systems for the Structural Fire Service, John Liebson, International Society of Fire Service Instructors, 0-929662-08-3.

NFPA 299

1991 Edition

Standard for Protection of Life and Property from Wildfire

1991 Edition

This edition of NFPA 299, *Standard for Protection of Life and Property from Wildfire*, was prepared by the Technical Committee on Forest and Rural Fire Protection and acted on by the National Fire Protection Association, Inc. at its Annual Meeting held May 19-22, 1991 in Boston, MA. It was issued by the Standards Council on July 19, 1991, with an effective date of August 16, 1991.

The 1991 edition of this document has been approved by the American National Standards Institute.

Origin and Development of NFPA 299

NFPA 299, *Standard for Protection of Life and Property from Wildfire*, is a new standard. It was developed by the Forest and Rural Fire Protection Committee following the tragic wildfires that resulted in the loss of 44 lives and 1,400 homes in the United States in 1985. The purpose of this standard is to provide criteria for fire agencies, land use planners, architects, developers, and local government for firesafe development in areas that may be threatened by wildfire.

Technical Committee on Forest and Rural Fire Protection

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Salvatore M. Grasso, Sedgwick James of New York

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Paul G. Mason, M & M Protection Consultants

Richard E. Montague, Incident Management Concepts

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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.

NFPA 299

Standard for Protection of Life and Property from Wildfire

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 9 and Appendix C.

Chapter 1 Introduction

1-1 Scope.

This standard presents minimum planning criteria for the protection of life and property from wildfire. It includes information on safe procedures and practices at the wildland/urban interface or intermix.

1-2 Purpose.

The purpose of this standard is to provide criteria for fire agencies, land use planners, architects, developers, and local government for firesafe development in areas that may be threatened by wildfire.

1-3 Definitions.

For the purpose of this standard, the following terms have the meanings shown below:

Access Routes. Principal vehicular ingress and egress to a structure or through a development, crossing more than one parcel, including public and private roads, streets, and lanes, that extend to and intersect with a publicly maintained road, street, or lane.

Accessory Building or Structure. Any building or structure used incidentally to another building or structure.

Aerial Fuels. Standing and supported live and dead combustibles not in direct contact with the ground and consisting mainly of foliage, twigs, branches, stems, cones, bark, and vines.

Approved.* Acceptable to the “authority having jurisdiction.”

Aspect. Direction toward which the slope faces.

Authority Having Jurisdiction.* The “authority having jurisdiction” is the organization, office or individual responsible for “approving” equipment, an installation or a procedure.

Average Daily Traffic (ADT). The average daily volume of vehicles traveling on a given road.

Brush. Shrubs and scrub vegetation or other growth heavier than grass but not full tree size.

Building. Any structure used or intended for supporting any use or occupancy.

Classified Roof. A roof constructed with a roof covering that is listed as meeting the requirements for Class A, B, or C roof covering materials (*see NFPA 256, Standard Methods of Fire Tests of Roof Coverings*).

Combustible. Any material that, in the form in which it is used and under the conditions anticipated, will ignite and burn.

Development. Human-made improvement of property.

Driveway. Vehicular ingress and egress routes that serve no more than 2 buildings or structures, not including accessory structures, on one parcel, containing no more than 3 dwelling units.

Dwelling Unit. Any building or structure or portion thereof that contains living facilities with provisions for sleeping, eating, cooking, and sanitation for not more than 1 family.

Fire Hydrant. A valved connection on a piped water supply system having one or more outlets and that is used to supply hose and fire department pumpers with water.

Fuel Break. An area, usually a long strip strategically located, wherein vegetative fuels are reduced in volume and maintained to cause a reduction of fire intensity if ignited by a wildland fire.

Fuel Loading. The volume of fuel in a given area, generally expressed in tons per acre.

Fuel Modification. The removal of fuels, conversion of vegetation to fire-resistant species, increased spacing of individual plants, reduction of fuel loading, or lowering of age class.

Fuels. All Class A fuels within the wildland/urban interface or wildland/urban intermix, including vegetation and structures.

Ground Fuels. Any native or landscape vegetation not considered a tree and generally in contact with the ground.

Hammerhead-T. A roadway that provides a “T” shaped, three-point turnaround for emergency equipment, being no narrower than the road that it serves, with the top of the “T” being a minimum of 40 ft (12.2 m) long.

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 tested in accordance with *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C (1382°F)*, ASTM E136, and conforming to the criteria contained in Section 7 of the referenced standard shall be considered as noncombustible.

Occupancy. The purpose for which a building, or part thereof, is used or intended to be used.

Prescribed Fire. The knowledgeable application of fire to a specific land area, to accomplish predetermined land management objectives.

Roads, Streets, Private Lanes. An open way for passage of vehicles giving access to more than one parcel, any industrial or commercial occupancy, or to a single parcel with 4 or more dwelling units.

Roadway. Any surface improved, designed, or ordinarily used for vehicular travel.

Shoulder. Surface of a road adjacent to the traffic lane.

Slope. Upward or downward incline or slant, usually calculated as a percent of slope [rise or fall per 100 ft (30.5 m) of horizontal distance].

Street or Road Signage. Any sign containing words, numbers, directions, or symbols that provides information to emergency responders.

Structure. That which is built or constructed, an edifice or building of any kind, or any piece of work artificially built up or composed of parts joined together in some definite manner.

Traffic Lane. That portion of a roadway that provides a single lane of vehicle travel in one direction.

Traveled Way. The portion of a roadway that provides for vehicular travel in all permitted directions.

Turnaround. A roadway, unobstructed by parking, that allows for a safe reversal of direction for emergency equipment.

Turnouts. A widening in a roadway of sufficient length and width to allow vehicles to pass one another.

Wildland/Urban Interface. An area where development and wildland fuels meet at a well-defined boundary.

Wildland/Urban Intermix. An area where development and wildland fuels meet with no clearly defined boundary.

Wildfire. An unplanned and unwanted fire requiring suppression action; an uncontrolled fire, usually spreading through vegetative fuels but often threatening structures.

Chapter 2 Wildland/Urban Interface and Wildland/Urban Intermix Analysis

2-1* General.

The analysis of the wildland/urban interface or wildland/urban intermix will help identify and document local problem areas and guide the application of standards and establishment of priorities relative to fire danger.

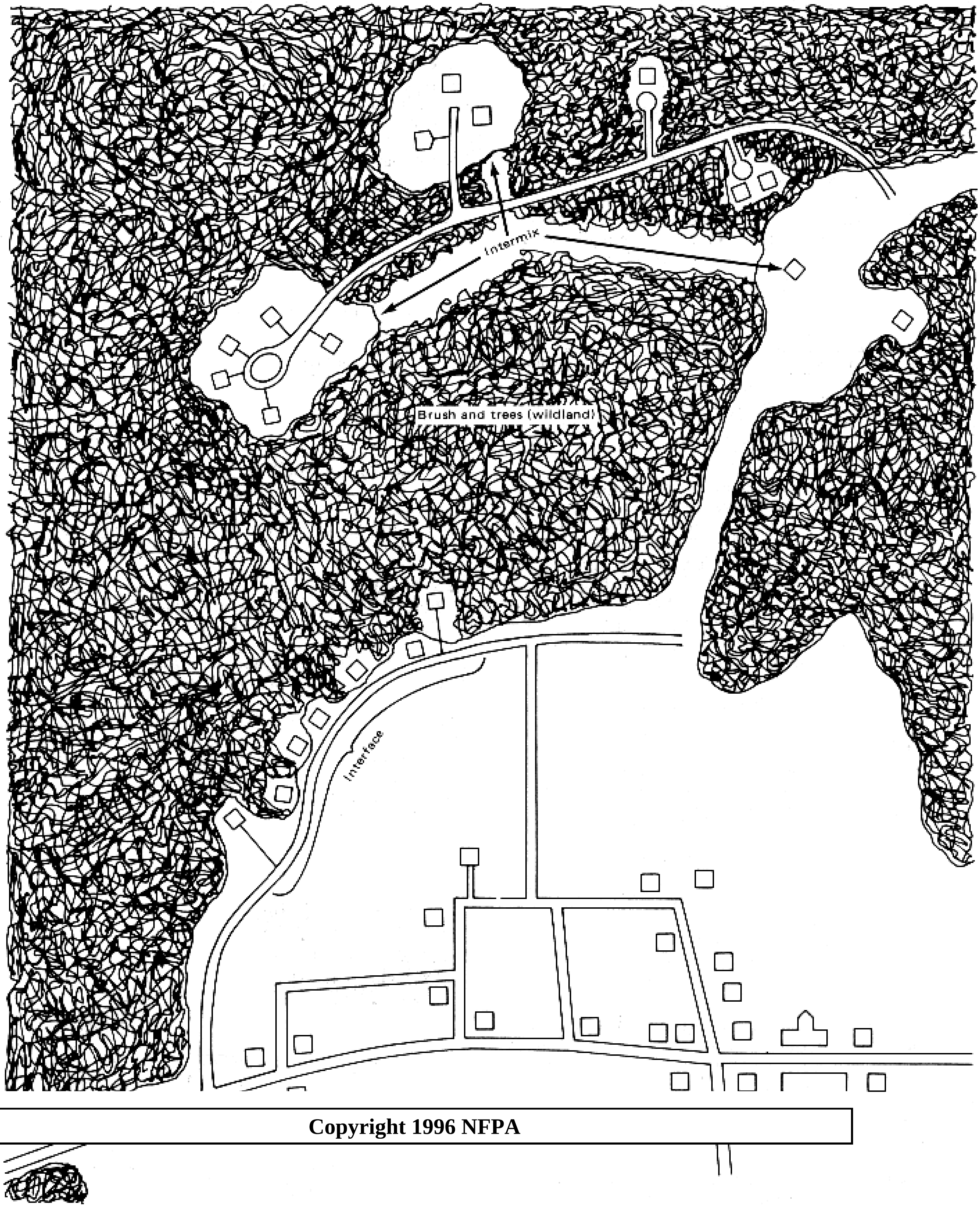
Intermix
Brush and trees (wildland)
Interface

Figure 2-1 Wildland/urban interface and wildland/urban intermix.

2-2 Analysis Ratings.

The authority having jurisdiction shall perform a wildland fire protection analysis of all developments, existing or planned, to determine wildland fire protection ratings. The ratings developed under the authority of this section shall be the basis for the implementation of firesafe design and construction criteria. The higher the relative value, the higher the wildland/urban interface or wildland/urban intermix hazard rating.

2-3 Analysis Components.

The analysis shall contain the following components:

(a) Wildland/urban interface or wildland/urban intermix boundaries

(b) Fuel hazard rating

(c) Slope hazard rating

(d) Structure hazard rating

(e) Additional factors rating

(f) Wildland/urban interface or wildland/urban intermix hazard rating.

2-3.1* Mapping Wildland/Urban Interface or Wildland/Urban Intermix Areas.

Areas shall be delineated as logical units or areas and given a name or number.

2-3.2 Assigning a Fuel Hazard Rating.

For each wildland/urban interface and wildland/urban intermix area, a fuel hazard rating shall be assigned based on Table 2-3.2. Where fuel types vary within an area, the rating assigned for the area shall be that which best represents the predominant fuel type.

Table 2-3.2 Fuel Hazard Rating

Type	Rating
Small, light fuels (grass, weeds, shrubs)	1
Medium size fuels (brush, large shrubs, small trees)	2
Heavy, large fuels (woodland, timber, heavy large brush)	3

2-3.3 Assigning a Slope Hazard Rating.

For each wildland/urban interface and wildland/urban intermix area, a slope hazard rating shall be assigned based on Table 2-3.3. Where slopes vary within an area, the rating for the area shall be that which best represents the predominant slope range.

Table 2-3.3 Slope Hazard Rating

Slope	Rating

Mild slopes (0-5%)	1
Moderate slopes (6-20%)	2
Steep slopes (21-40%)	3
Extreme slopes (41% and greater)	4

2-3.4 Assigning a Structure Hazard Rating.

For each wildland/urban interface and wildland/urban intermix area, a structure rating that best represents the combination of design characteristics in each unit or area shall be assigned based on Table 2-3.4. Ratings occurring between those shown in the table shall be assigned where they represent areas of mixed structures.

Table 2-3.4 Structure Hazard Rating

Design Characteristics	Rating
Classified roof and noncombustible siding materials	1
Classified roof and combustible siding materials	3
Unclassified roof and noncombustible siding materials	7
Unclassified roof and combustible siding materials	10

2-3.5* Assigning an Additional Factor Rating.

Where other factors influence community needs and where determined to be appropriate by the authority having jurisdiction, an additional factor rating shall be assigned based on Table 2-3.5. Other factors that shall be permitted to be considered in addition to those listed in the table include: water supplies, road access, and fire behavior. NFPA 1141, *Standard for Fire Protection in Planned Building Groups*, and NFPA 1231, *Standard on Water Supplies for Suburban and Rural Fire Fighting*, shall be permitted to be utilized.

Table 2-3.5 Additional Factor Rating

Additional Factor	Rating
Rough topography that contains several steep canyons	+2
Areas having a history of higher fire occurrence than surrounding areas due to special situations such as heavy lightning, railroads, escaped debris burning, arson, etc.	+3
Areas that are periodically exposed to unusually severe fire weather such as strong winds.	+4
Existing areas where fuel modification or fuel breaks provide usable fire control points or protection to structures or wildland.	-3

Areas where local facilities such as developed water systems, fire trucks, dozers, or local organizations provide additional protection to structures or wildland. -3

2-3.6 Calculating the Wildland/Urban Interface or Wildland/Urban Intermix Hazard Rating.

The wildland/urban interface or wildland/urban intermix hazard rating shall be calculated for each area by multiplying the fuel hazard rating by the slope hazard rating, adding the structure hazard rating to the subtotal, and then adding or subtracting the additional factor rating from the total.

2-4 Establishing Wildland/Urban Interface or Wildland/Urban Intermix Planning Priorities.

The relative wildland/urban interface or wildland/urban intermix hazard of each area shall be rated from highest to lowest.

Chapter 3 Fuel Modification Planning

3-1 General.

This chapter will provide guidance in the mitigation of measures associated with fuel hazards and special hazard conditions. Fuel modification shall be the primary mitigation measure.

3-2 Evaluation Factors.

As prescribed in Chapter 2 of this standard, a comprehensive assessment of the fuel hazard shall be made. Factors that shall be considered in the assessment and designated on maps include:

(a) Fuel-type identification

(b) Fuel loading (volume)

(c) Size of fuel bed (acres)

(d) Slope and aspect.

3-2.1 Fuel-Type Identification.

All fuel, natural vegetation, as well as other flammable materials existing within the area shall be identified and rated as to its potential to increase the hazard. The ease of ignition and ability to assist in the spread of fire are important factors.

3-2.2 Fuel Loading.

The volume of fuels, both presently existing and likely to be present under expected development, shall be estimated and included on maps.

3-2.3 Slope.

Percent of slope and aspect shall be determined and indicated on maps.

3-2.4* Fuel Modification.

The purpose of the fuel modification effort shall be to develop defensible space to protect structures from approaching wildfire as well as to reduce the potential for a structure fire spreading to the wildland. The defensible space shall be initially provided by the developer and shall be maintained by the property owner.

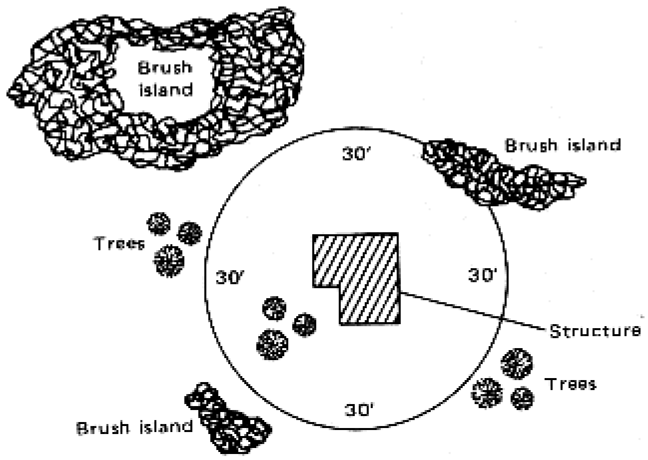

Figure 3-2.4(a) Defensible space (level).

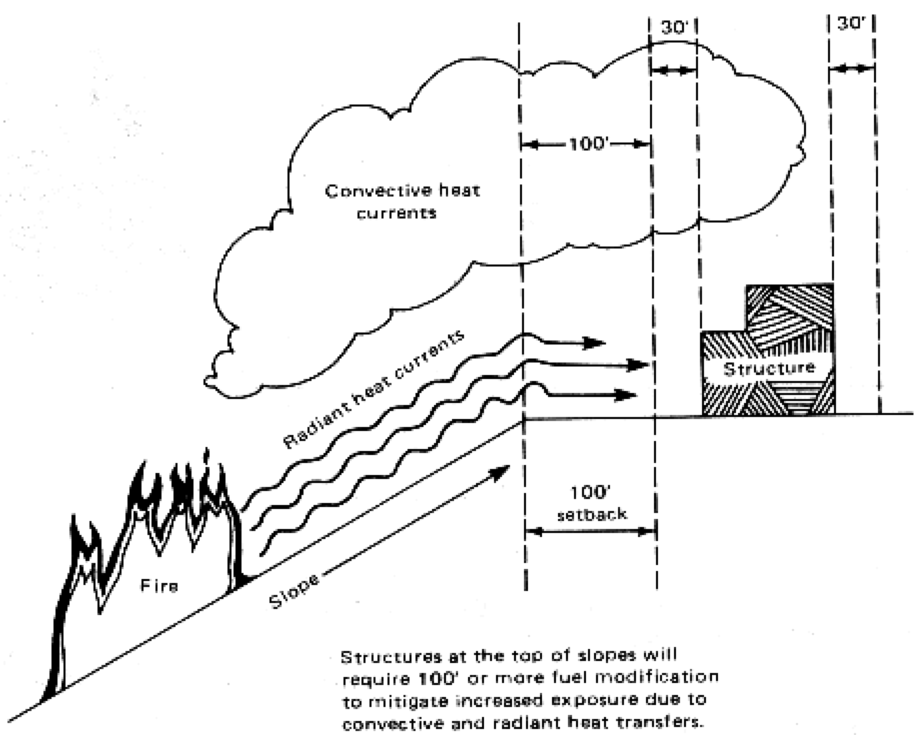

Figure 3-2.4(b) Defensible space (slope).

3-3* Fuel Modification Plan.

[See Appendix A, Figures A-3-3(a)-(d).]

3-3.1* Modification of Fuel Types.

Where consistent with ecological factors, less fire-prone vegetation shall be encouraged.

3-3.2 Reduction of Fuel Loading.

Trees and brush shall be cleared away from structures for a distance that is determined to prevent ignition of either the structure or the vegetation, should the other burn. Vegetation existing away from the immediate area of the structure shall be thinned and pruned to prevent a fire from being carried toward or away from the structure. Annual grasses within 30 ft (9.1 m) of structures shall be mowed to 4 in. (101.6 mm) or less. Ground litter shall be removed annually. Over-mature, dead, and dying trees shall be evaluated as to their potential to ignite and to carry fire. All trees determined to contain such potential shall be removed.

3-3.3 Mitigation of Slope and Aspect Impact.

Slope and aspect greatly affect the potential for carrying fire, and very little opportunity exists to modify them directly. Where degree of slope or aspect are determined to affect the hazards, greenbelts or fuel breaks shall be provided.

Chapter 4 Roads, Streets, and Ways

4-1 General.

Roads, streets, and ways, whether public or private, shall provide for safe simultaneous access for emergency fire equipment and civilian evacuation. The authority having jurisdiction shall be permitted to allow modification of access requirements where the structures being protected are provided with private fire protection systems.

4-2 Roads, Streets, and Ways.

Roads, streets, and ways shall provide for unobstructed traffic circulation during an emergency. Access to fuel breaks and greenbelts, where required by the authority having jurisdiction, shall be provided from roads, streets, and ways. All vehicular access and gates servicing such access shall meet the specifications provided herein. All roads shall be designed and constructed according to standards published by the American Association of State Highway and Transportation Officials but shall also meet the minimum requirements set forth in this document.

4-3 Private Roads, Streets and Ways, Fire Lanes, Parking Lots, and Driveways.

All fire lanes, private streets, parking lots, and driveways shall be designed and constructed according to NFPA 1141, *Fire Protection for Planned Building Groups*.

4-4 Specific Design Requirements.

4-4.1 Access Routes.

All developments shall have more than one access route. The design of access routes shall consider traffic circulation and employ looped road networks.

4-4.2 Public Vehicular Easements and Rights-of-Way.

(a) Public vehicular easements and rights-of-way shall be of sufficient width to accommodate the traveled way, shoulder, parking spaces, vegetation modification, and other local requirements on or along a road, street, or way.

(b) Easements shall be obtained from adjacent property owners where needed to comply with paragraph (a) above.

4-4.3 Road Surface.

All roads and road structures shall be graded and surfaced and of sufficient design to support the weight of 20-ton vehicles.

4-4.4 Width of Traveled Way.

Simultaneous access for emergency vehicles and the evacuation of residents shall be provided for by a traveled way of not less than 24 ft (7.3 m).

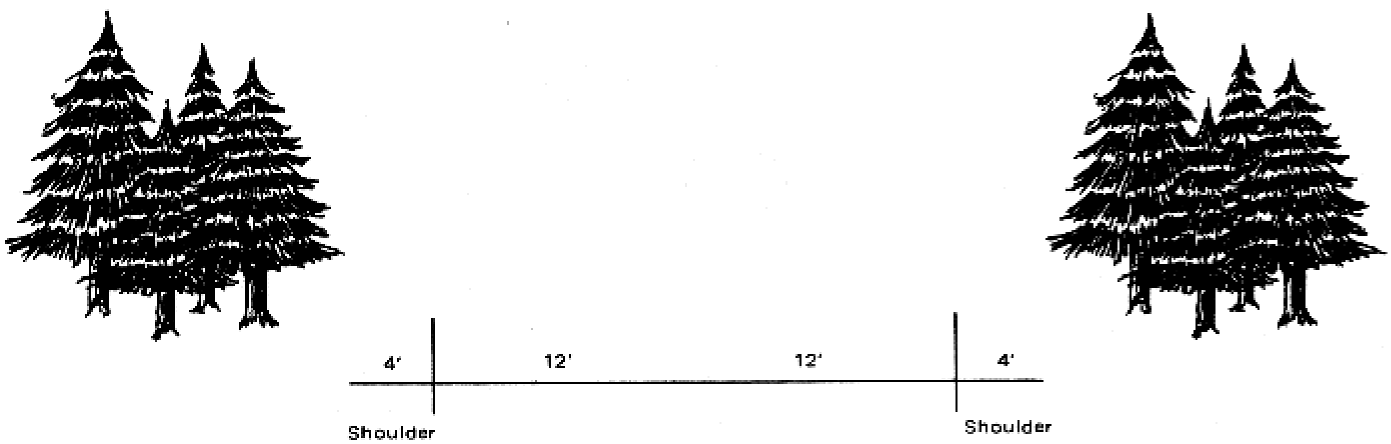

Figure 4-4.4 Traffic lanes all-weather surface.

4-4.5 Maximum Grades.

Grades shall be no greater than 10 percent, except the authority having jurisdiction shall be permitted to allow steeper grades where mitigation measures can be agreed upon by the fire chief and the road engineer.

4-4.6 Minimum Grades.

Roads shall have a minimum grade of not less than 0.5 percent in order to prevent pooling of water in the traveled way. Drainage shall be provided to protect a primary road where it intersects with a secondary road.

4-4.7 Curve Radius.

No roads shall be constructed with a curvature radius of less than 100 ft (30.5 m), measured at the center line.

4-4.8 Shoulders.

(a) Improved gravel shoulder width shall be a minimum of 4 ft (1.2 m) on each side of the traveled surface.

(b) On roads with an average daily traffic in excess of 1000 vehicles per day, shoulders shall be constructed to the same specifications as the traveled way.

4-4.9 Parking.

Where parking is to be allowed along the traveled way, at least 9 ft (2.7 m) of improved width shall be provided (see Figure 4-4.4). If curbs are not provided, the shoulder shall be constructed according to 4-4.8.

4-4.10 Dead-End Roads.

(a) In areas of extreme hazard severity classification, as identified in the wildland/urban interface and wildland/urban intermix assessment in Chapter 2, dead-end roads shall not exceed 600 ft (183 m) in length.

(b) In all other areas, dead-end roads shall not exceed 1000 ft (305 m) in length.

(c) All dead-end roads shall have a turnaround at the closed end of at least 100 ft (30.5 m) in diameter, measured at the outside of the traveled way. However, where wildfire hazard severity is classified as low, the authority having jurisdiction shall be permitted to approve a hammerhead-T designed turnaround to provide emergency vehicles with a 3-point turnaround ability.

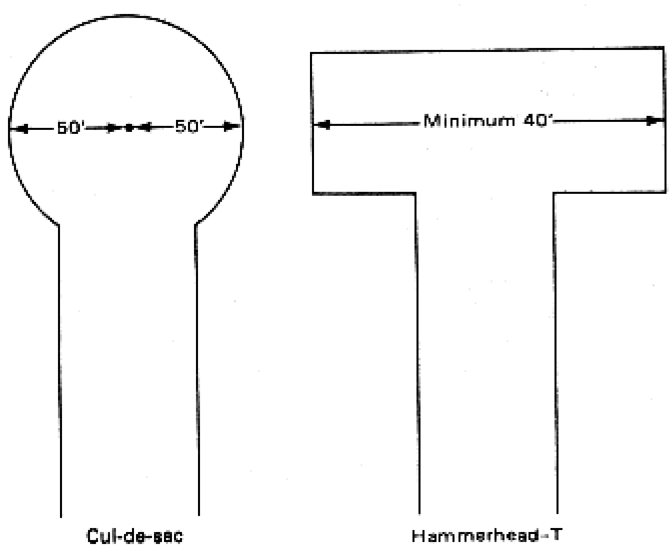

Figure 4-4.10 Cul-de-sac and hammerhead-T turnarounds.

4-4.11 Driveways.

(a) All driveways shall provide a minimum unobstructed width of 12 ft (3.7 m) and minimum unobstructed vertical clearance of 15 ft (4.6 m).

(b) All curb cuts at entrances to driveways or other private ways shall be of sufficient width to permit safe travel by emergency vehicles at all times of year.

(c) Turnouts shall be designed and constructed every 400 ft (122 m) along the driveway's length.

(d) A turnaround shall be provided at all building or structure sites on driveways over 300 ft (91 m) in length and shall be within 50 ft (15.2 m) of the building or structure.

(e) In addition, where applicable, all driveways shall conform with NFPA 1141.

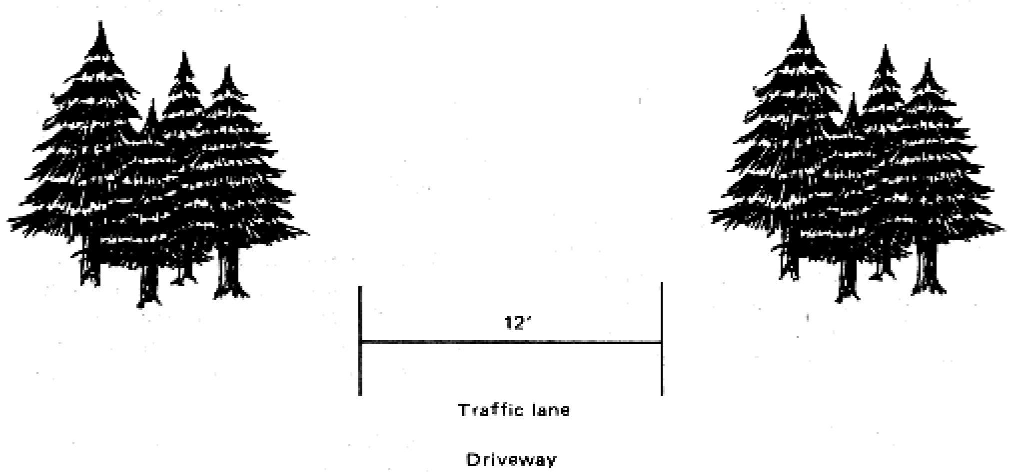

Figure 4-4.11 Driveways.

4-4.12 Gated Entrances.

(a) The clear opening provided through the gate shall be 2 ft (0.6 m) wider than the traveled way.

(b) All gates shall be located at least 30 ft (9.1 m) from the public right-of-way and shall open inward, allowing a vehicle to stop without obstructing traffic on the public road.

Chapter 5 Standards for Signage of Streets, Roads, and Buildings

5-1 General.

To facilitate the locating of a fire and to avoid delays in response, all roads, streets, and buildings shall be designated by names or numbers on signs clearly visible and legible from the roadway on which it is addressed.

5-2 Visibility of Street and Road Signs.

Street and road signs shall be located at intersections and legible from all directions of vehicle travel for a distance of not less than 100 ft (30.5 m).

5-3 Size of Letters, Numbers, and Symbols for Signs.

All letters, numbers, and symbols shall be a minimum of 4 in. (101.6 mm) in height, with a $^1/_2$-in. (12.7-mm) stroke, and shall be reflectorized and contrasting with the background color of the sign.

5-4 Height of Street and Road Signs.

Signs shall be mounted 6 to 8 ft (2 m) above the surface of the road, unless local conditions or existing standards prescribe otherwise.

5-5 Names and Numbers on Street and Road Signs.

Newly constructed or approved public and private roads and streets shall be identified by a name or number in a consistent system that provides for sequenced or patterned numbering and nonduplicated naming within each jurisdiction.

5-6 Signs Indicating Special Conditions.

On other than through-traffic roads, signs identifying pertinent information shall be placed at the entrance to such roads.

5-7 Installation of Road and Street Signs.

Signs shall be installed in a horizontal orientation and prior to final acceptance of road improvements.

5-8 Addresses for Buildings.

All buildings shall be issued an address and street number by the authority having jurisdiction. Accessory structures shall be required to have a separate address.

5-9 Size of Letters, Numbers, and Symbols.

Letters, numbers, and symbols indicating addresses shall be a minimum of 4 in. (101.6 mm) in height with a $^1/_2$-in. (12.7-mm) stroke, shall be contrasting with background colors, and shall be visible from the road.

Chapter 6 Emergency Water Supplies

6-1 General.

This chapter describes the process by which provisions for emergency water supplies shall be evaluated, designed, constructed, and maintained.

6-2 Notification.

The authority having jurisdiction shall be notified in writing before any water system is constructed, altered, or removed and before site development or construction of any structure commences so that fire protection can be evaluated and ample water supply capabilities pertinent to such construction can be established.

6-3 Evaluation of Water Supply Needs.

6-3.1 Authority.

The fire protection agency having jurisdiction shall evaluate all buildings, proposed and existing, to obtain information required for computing minimum water supply. Information obtained from plans or on-site surveys and determinations made and recorded shall reflect the water supply category required. The computation of minimum water supplies for other than municipal, domestic, or fixed fire protection systems shall be in accordance with NFPA 1231.

6-3.2 Design, Construction, and Maintenance.

Based upon the water supply evaluation, the authority having jurisdiction shall approve the design, construction, and maintenance of water supplies and distribution systems to ensure that fire protection concerns have been addressed and adequate water supplies and access thereto have been provided.

6-4 Minimum Water Supply Requirements.

Water shall be available to provide a minimum fire flow of 250 gpm (946 L/min) for 2 hr.

6-5 Static Water Supplies.

The design and construction of and access to static water supplies shall be in accordance with NFPA 1231.

6-6 Signage of Water Supplies.

Each fire hydrant or access to water shall be identified as follows:

(a) A reflectorized marker, with a minimum dimension of 3 in. (76.2 mm), shall be located on the driveway address sign signifying the hydrant location and on a fire-retardant post located near the fire hydrant, and

(b) A fire-retardant reflectorized sign with the words “DRAFT WATER” or “PRESSURE WATER” having letters a minimum of 4 in. (101.6 mm) in height, with $^{1}/_{2}$-in. (12.7-mm) stroke, reflectorized and contrasting to the background color, shall be located near the hydrant or access to water.

(c) The signpost shall be within 3 ft (0.9 m) of said fire hydrant or access to water, with the sign no less than 3 ft (0.9 m) nor greater than 5 ft (1.5 m) above the ground and visible from the driveway.

Chapter 7 Structural Design and Construction

7-1 General.

All buildings in the wildland/urban interface or wildland/urban intermix shall be designed and constructed to comply with one of the model building codes and with this standard.

7-1.1 Minimum Requirements.

Structures and developments in or adjacent to wildland fire hazard areas shall be located, designed, and constructed in a manner to minimize the possibility of ignition from a wildfire and to minimize the spread of a structural fire to the wildland.

7-2 Roofing.

Roof coverings shall be a minimum of Class C. Subdivision covenants, conditions, and restrictions shall not require the use of roof covering materials that do not meet Class C requirements.

7-3 Vents, Overhangs, and Stilt Construction.

7-3.1 Vents.

Vents shall be screened with a corrosion-resistant, noncombustible wire mesh with the mesh not to exceed nominal $^{1}/_{4}$ in. (6.35 mm) in size.

7-3.2 Overhangs.

Eaves, cantilever balconies, and similar undersides of overhangs shall be enclosed with materials that equal or exceed $^{1}/_{2}$-in. (12.7-mm) nominal sheathing.

7-3.3 Stilt Construction.

The underside of decks and structures with stilt foundations shall be enclosed with the material specified in Section 7-4.

7-4 Exterior Vertical Walls.

Exterior vertical walls shall be constructed of at least $^{1}/_{2}$-in. (12.7-mm) nominal sheathing or equivalent material and shall extend from ground level to roof line.

7-5 Glazed Openings.

All glazed openings that face concentrations of vegetative fuels within 30 ft of the openings shall be provided with closable, solid exterior shutters.

7-6 Chimneys and Flues.

7-6.1 Outlet Screen.

Every chimney, flue, or vent shall be provided with an approved spark arrester consisting of 12-gauge welded or woven wire mesh not exceeding $^{1}/_{2}$ in. (12.7 mm).

7-6.2 Construction.

Chimney outlets shall be constructed with 10-ft (3.1-m) clearance from all vegetation and obstructions.

7-7 Manufactured Homes.

Manufactured homes shall meet all applicable construction and safety standards and shall be provided with full skirting constructed of material as specified in Section 7-4. Any porches and sundecks shall be constructed of nonflammable or listed fire-retardant materials.

Chapter 8 Public Fire Prevention and Firesafety Information and Education

8-1 Information and Education Plan.

The authority having jurisdiction shall prepare a year-round fire prevention and firesafety public information/education plan. The plan, at a minimum, shall identify and analyze:

(a) Specific hazards

(b) Risks

(c) Fire causes

(d) Applicable prevention and safety programs

(e) Target audiences

(f) Activities.

The plan shall utilize a variety of communication techniques to achieve desired objectives. (*See Appendix B for a sample public information/education program and delivery techniques*.)

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 256, *Standard Methods of Fire Tests of Roof Coverings*, 1987 edition

NFPA 1141, *Standard for Fire Protection in Planned Building Groups*, 1990 edition

NFPA 1231, *Standard on Water Supplies for Suburban and Rural Fire Fighting*, 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-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.

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.”

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

Weather is the most critical element. Wind, wind direction, and frontal activity are the prime factors in most major wildland fires. The topography element key issue is slope. Slope modifies fire spread and creates more drafting and preheating ahead of the fire. Slopes over 50 percent are especially critical.

Fuel beds should be evaluated in terms of continuity, arrangement, and fire history. Additionally, fuel beds in heavy brush and/or woodland-timber should be evaluated for abundance of down or dead fuels.

Response times are an indirect factor that should be evaluated specially in a developing wildland/urban interface. An important question that must be asked is: Can resources and personnel arrive in time to protect structures and valued resources prior to the fire?

A-2-3.1

The map should show elevations (slope contours). A color coding system should be used to show grasslands (yellow), medium brush (blue), heavy brush (red), and woodland or timber (green).

A-2-3.5

Table A-2-3.5 shows an example of the calculations for several sample units or areas.

Table A-2-3.5 Wildland/Urban Interface or Wildland/Urban Intermix Hazard Rating

Unit	Fuel Hazard Rating ×	Slope Hazard Rating +	Structure Hazard Rating =	Interface Hazard Rating
Dunville	2	4	9	17
Jerry Flat	3	2	6	12
Crossroads	2	3	5	11
Hope Lake (a)	3	1	3	6
Hope Lake (b)	1	3	2	5
T Valley	1	1	2	3

A-3-2.4 Abnormal accumulations of down or dead fuels, caused by age class, snow kill, and disease may be color coded (brown) and plotted on the map. These areas can be addressed with a fuel management program discussed in Chapter 4 of this standard.

A-3-3

See Figures A-3-3(a)-(d).

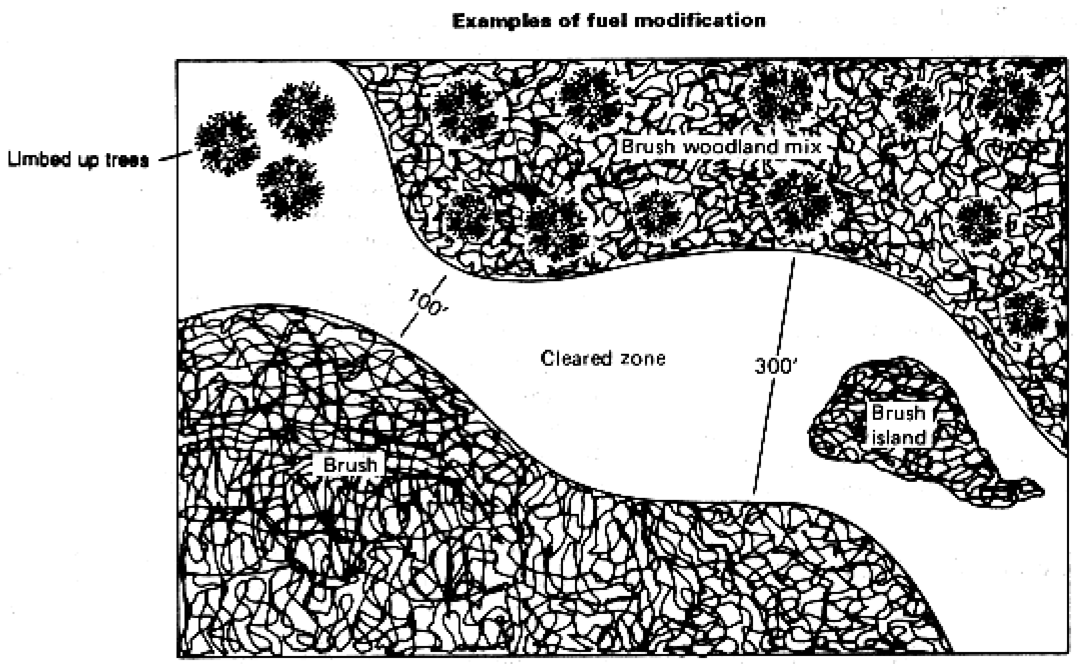

Figure A-3-3(a) Fuel break.

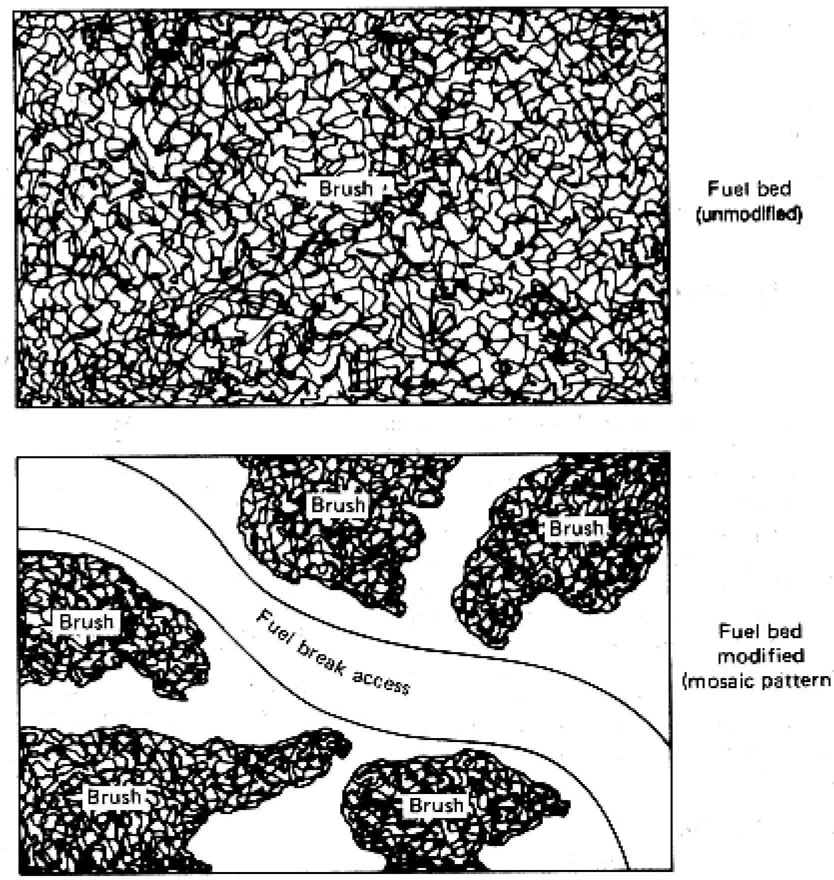

Figure A-3-3(b) Wildland fuel bed unmodified and modified.

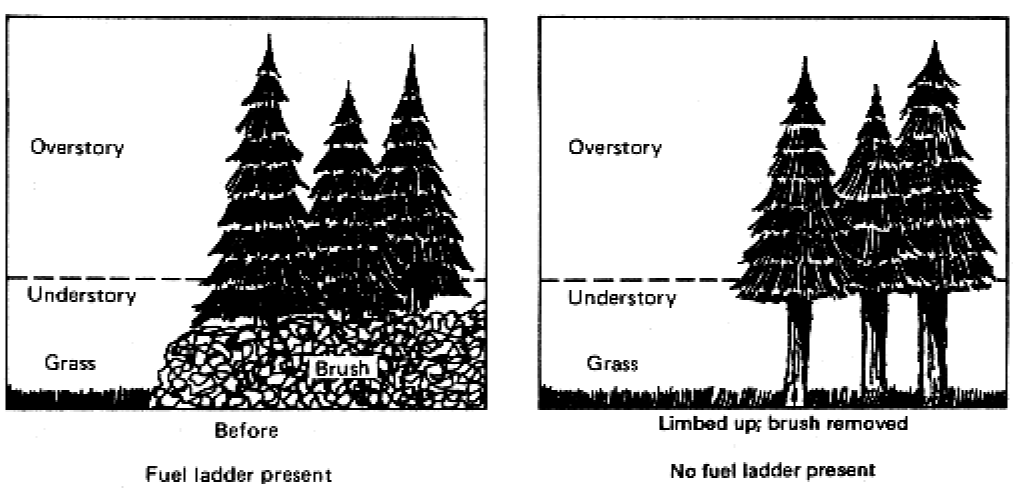

Figure A-3-3(c) Shaded fuel break concept.

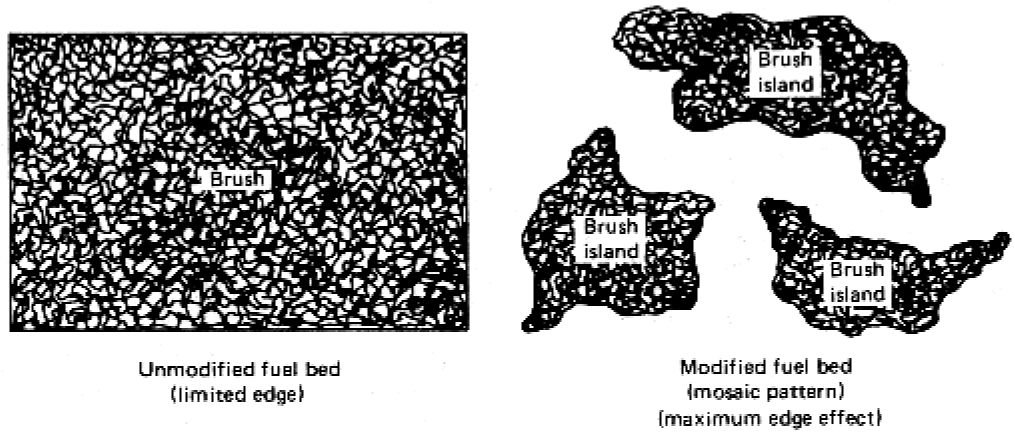

Figure A-3-3(d) Edge effect.

A-3-3.1

An example would be the substitution of perennial grasses to annuals.

Appendix B Public Firesafety and FirePrevention Information/Education

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

The following outlines various types of information and education programs and techniques that can be utilized for fire prevention and firesafety information programs.

The choice of programs and techniques will depend on an analysis of the problem, the target audience, and the desired objectives. Generally, programs that include personal contacts are the most effective and should have the highest priority.

I. Exhibits and Displays

A. Exhibits and displays are excellent means of presenting broad interest messages to the general public. As with school programs, a general message or theme should be selected. The story board development process works well with this format.

B. Remember, you must attract your audience to the display, so make it attractive, interesting, and compelling. Use posters, photos, captions, graphics, slide programs, puppets, and skits that involve the viewer. Keep handouts to a minimum, but ensure that they reinforce your message. Have knowledgeable people on hand to answer questions and present your message personally. Consider sharing a space or setting up adjacent to other groups or agencies that present similar themes or messages.

C. Parades provide another opportunity to present a firesafety message, although the presentation should be kept simple and should be able to withstand the stresses of a moving vehicle.

II. Roadside Signs

A. Roadside signs can present a wide variety of fire prevention messages to the general public but should be kept simple and clear to traffic driving by at high speed. Signs 4 ft × 8 ft (1.22 m × 2.44 m) are considered the standard, but signs as small as 4 ft × 4 ft (1.22 m × 1.44 m) can be used effectively.

B. Messages may include “Hazardous Fire Area,” “Burning Permits Required,” “Spark Arresters Required,” or many other traditional messages. The winning poster from a school contest can be painted on the roadside sign to recognize the winner and present a pertinent theme.

C. Obtain written permission from private landowners or prepare agreements with county or state highway departments. Solicit corporate sponsorship for signs and billboards. Keep the signs in good repair and current with the season and message.

III. Group, Youth, and Club Programs

Opportunities to present prevention and safety messages to groups, youths, and clubs should focus on their group activities, specifically their outdoor programs.

IV. Developing and Delivering Presentations

A. General Guidelines: Define your topic for presentation. Outline the points to be covered, based on attention span, knowledge, skill level, and interest. Be sure the presentation focuses on the message you have chosen. Develop the full presentation as outlined. Ask someone else to review your presentation. Rehearse and time your presentation. Remember to speak clearly and with inflection in your voice. Use good posture, keep eye contact, and use your hands for emphasis.

B. Slide-Video-Graphic Presentations: If developed as an independent program, or in conjunction with an existing speech, the program should be complete and complementary. Develop a story board to prepare a complete flow of thoughts and cover all points with appropriate slides or film. Choose the right graphic-visual display to present your points, based on program objective, size of audience, location of audience, and, of course, the budget you have to work with. Use progressive disclosure of information to keep your audience with you and prevent information overload. Keep the story in line with the visuals. Write the script as you develop your visuals. Label and number your slides and graphics.

Rehearse and review your program for smoothness and time. Make sure the right equipment is on hand for your presentation. Consider “canned” programs for use by less technically knowledgeable staff. Graphics must be visible to the person in the farthest corner of the room.

V. Mass Media

Mass media campaigns provide excellent opportunities to disseminate general and specific firesafety messages to a broad spectrum of the public. Progressive or phased campaigns can capitalize on preceding messages or piggyback on recent events. Mass media contacts inform the public and raise their level of awareness and understanding, as well as marketing an agency’s image.

A. Developing a Campaign

As with any fire prevention presentation, a central message theme must be identified. Obviously, a professional public relations agency can prove costly and may be prohibitive. Search for assistance from local universities, or corporate donations of airtime, professional assistance, materials, or financial support.

The theme may be broad, allowing many specific areas or messages to be included under that umbrella, whether seasonal or regional in nature.

Developing a goal: The defined goal should consider the target audience, area distribution, level of awareness or information to be received, and the result to be accomplished.

B. Target Audiences

The target audience may be very broad or very narrow, but should be identified and included as compatible with the message theme.

C. Setting Time Frames

Time frames will vary with the type of media used, the seasonal nature of the message presented, and the time lines of the message. The value of your message can be increased through good time management.

D. Getting to Know the Media

To disseminate a firesafety message effectively, you must know and understand the needs and constraints of each type of media outlet.

Newspapers: Local daily and weekly newspapers provide good outlets for detailed stories with readable local angles. Hard news, those stories of immediate interest, such as fire, have short lead times, and information should be provided as soon as possible and as completely as possible. Soft news, those feature stories or campaign messages that have longer lead times, allow publishing during an appropriate time period, such as a holiday or the beginning of fire season. Contact the newspaper to determine who you should talk to, depending upon the type of story.

Television: Again, time frames will depend on the type of news and the individual station format. Feature-type stories should allow for good pictures and action or examples to take advantage of television’s visual nature. Talk shows and public affairs programs are excellent vehicles to present a complete story, covering all of the issues. Plan ahead. Lead times to schedule these types of programs should be 6–8 weeks, yet program length can run from 10 min to 1 hr.

Radio: Most radio news stories are limited to 30–60 sec to cover the whole issue. Lead time for program scheduling may exceed 4 weeks. The question-answer format of radio talk shows can allow an in-depth presentation and discussions with the audience. Weekly calendars and public service announcement times can introduce activities, exhibits, and other firesafety programs.

Newsletters: Professional and community newsletters often provide opportunities to present focused messages to target audiences even regionally directed. Lead time and publishing frequency will vary widely.

E. Who to Contact/Visit

Media contacts and telephone numbers change frequently, too. Keep your lists up to date, and stop by to see the reporters periodically.

Print Media: Identify the city desk editor, feature editor, assignment editor, and beat reporters. Find out the lead times and publication dates.

Television: Who are the news director and assignment editor? What types of program formats are available? What are the lead times to schedule?

Radio: Who is the news director? Who is the public affairs director? What is the lead time for program scheduling? What format is best, audio cassette tapes or script, for public service announcements?

F. Preparing News Releases

Probably the most common type of media contact. They provide brief, factual, informative materials to assist an editor in developing a story. The lead paragraph should present a synopsis of the news and include: who, what, when, where, and why. Write in present tense and be concise yet clear. All releases should include the following:

(a) Contact name, title, agency, and phone number

(b) A catchy headline (optional)

(c) Double-spaced text

(d) Two-page maximum text.

Include photographs, preferably 8 in. × 10 in. glossy black and white, with your story, including a caption describing the photograph and identifying all people in the photograph.

G. When to Use a News Advisory

News advisories inform or remind the media about an upcoming event and are most often used to secure broadcast or news coverage of an event. Use the who, what, where, and when scenario when writing the news advisory. Keep it brief and write in the future tense.

Ensure that the news advisory arrives several days before the event. Follow-up your advisory with a phone call reminder just prior to the event.

H. Public Service Announcements (PSAs)

PSAs can be taped on audio cassettes for radio, video cassettes for television, or written in script format for live reads. Like news and feature presentations, PSAs must grab the listener’s/viewer’s attention and provide clear, concise message delivery. Lengths vary: 15–30 sec for radio, 15–30 sec for television. Take the opportunity to include your agency name and logo in the PSA. PSAs should be mailed or delivered with a cover letter and written transcript a minimum of 4 weeks before you want them to air.

Solicit corporate sponsorship to support the cost of the filming and production. Always follow up with a call to the station to determine when the PSA will air, what time slots, and how many times.

I. Feature Articles

The preparation of a feature-length article or a letter to the editor can allow you to control the story content. Contact the newspaper for specific details about length, format, and publication.

J. Using a Recognized Spokesperson

Benefits of a spokesperson: It is always easier to sell an idea when the person presenting the idea is recognized and respected in the community. The spokesperson may be just someone local or may have regional recognition in many of the households throughout the nation.

This person presents credibility that helps to market your product or service. The spokesperson tends to convey a neutral position, thus not having the bias that an “official” might have.

Appendix C Bibliographical References

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.

In addition to the wildland fire protection analysis described in Chapter 2, a number of other analysis methods have been developed across the country. Each method addresses problems common to a particular section of the country. Each differs in the amount of data required and the complexity of the analysis. To assist the authority having jurisdiction in developing the analysis process that best fits local needs and concerns, a number of references are listed below and may be obtained from the issuing agency.

Aids to Determining Fuel Models for Estimating Fire Behavior, Hal E. Anderson, United States Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, General Technical Report INT-122, Ogden, UT 84401, April 1982.

Fire Hazard Rating: For Existing Wildland Residential Developments or Single Structures in Montana, Montana Department of State Lands, Missoula, MT 59801

Fire Safe Guides for Residential Development in California, California Department of Forestry and Fire Protection, P.O. Box 94244, Sacramento, CA 94244-2460, 1980

Glossary of Wildland Fire Management Terms Used in the United States, Society of American Foresters, 5400 Grosvenor Lane, Washington, DC 20014, 1990

Protecting Residences from Wildfires: A Guide for Homeowners, Lawmakers and Planners, Howard E. Moore, General Technical Report PSW-50, United States Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, 1960 Addison St., Berkeley, CA 94704

Sierra Front Classification Procedures, Forest Supervisor, Toiyabe National Forest, 1200 Franklin Way, Sparks, NV 89431

Wildland Fire Protection Analysis, Georgia Forestry Commission, Box 819, Macon, GA 31298

Wildland/Urban Interface Fire Protection: A National Problem with Local Solutions, August 1988, National Fire Academy, Federal Emergency Management Agency, Washington, DC

NFPA 302

1994 Edition

Fire Protection Standard for Pleasure and Commercial Motor Craft

1994 Edition

This edition of NFPA 302, *Fire Protection Standard for Pleasure and Commercial Motor Craft*, was prepared by the Technical Committee on Motor Craft 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 302

This *Fire Protection Standard for Motor Craft* represents the cumulative result of over 69 years of attention to fire safety of power boats by the NFPA. The first edition of this standard was adopted by the Association in 1937. Successive editions adopted are as follows: 1939, 1948, 1950, 1951, 1952, 1953, 1954, 1955, 1957, 1960, 1964, 1966, 1968, 1972, 1980, 1984, and 1989.

Prior to 1937, the information was contained in Appendix D of NFPA 301, *Fire Prevention Regulations for the Construction and Maintenance of Vessels*.

For the 1994 edition, NFPA 302 was completely revised to improve its usability and adoptability, to make it compatible with industry practice and other industry standards, as well as to create a new chapter on lightning protection systems for boats. The Committee on Motor Craft also amended the existing provisions in Chapter 6 on gas-fueled equipment as well as added provisions for new fuels being used for cooking appliances on boats.

Technical Committee on Motor Craft

Bolling F. Douglas, *Chair*
Marine Assoc., Inc., GA

David Beach, Nat'l Marine Mfrs. Assn., IL

Ernest F. Braatz, Boat Owners Assn. of the U.S., VA

Russell Chiasson, Trident Marine Consultants, Inc., Canada

Desmond Connolly, Nat'l Assn. of Marine Surveyors Inc., MA

Bruce F. Dining, Marine Energy Systems, Inc., NH
Rep. Nat'l Propane Gas Assn.

David J. Duea, Fire Etc., CA
Rep. Nat'l Assn. of Fire Equipment Distributors Inc.

Charles B. Ford, Queenstown, MD
Rep. U.S. Coast Guard Auxiliary

E. Charles Game, Hatteras Yachts, NC

Lysle B. Gray, American Boat and Yacht Council, MD
Rep. American Boat & Yacht Council Inc.

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

Ralph E. Lambrecht, Independent Marine Engineer, IL

Robert Loeser, Underwriters Laboratories Inc., FL

Kim I. MacCartney, CIGNA Loss Control Services Inc., VA

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Committee Scope: This Committee shall have primary responsibility for documents on fire prevention and protection of motor craft and the encouragement of their use by designers, builders and owners.

NFPA 302

Fire Protection Standard for Pleasure and Commercial Motor Craft

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 11 and Appendix D.

Chapter 1 General

1-1 Scope.

1-1.1

This standard provides minimum requirements for the prevention of fire and explosion and for life safety in case of fire. This standard also provides minimum requirements for:

(a) The elimination of possible sources of vapor ignition;

(b) Ventilation of accommodation spaces, fuel tanks, and machinery;

(c) The use of combustible materials; and

(d) Fire extinguishing equipment and fire exits.

1-1.2

This standard shall apply to boats of less than 300 gross tons (305 metric tons) used for pleasure and commercial purposes.

1-1.3

No requirement of this standard shall be construed as reducing applicable federal regulations.

1-2 Purpose.

1-2.1

The purpose of this standard is to minimize the loss of life and property due to fires and explosions aboard pleasure and commercial motor craft. The intent of this standard is to make motor craft as free from the hazards of fire as practicable.

1-2.2

The requirements of this standard shall be considered necessary to provide a reasonable level of protection from loss of life and property from fire and explosion. These requirements reflect the conditions and the state of the art at the time the standard was issued.

1-2.3 Applicability.

Unless otherwise noted, it is not intended that the provisions of this standard be applied to facilities, equipment, structures, or installations existing or approved for construction or installation prior to the effective date of the standard, 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 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 in place of those required by the standard, provided technical documentation is submitted to the authority having jurisdiction to demonstrate equivalency.

1-4 Units.*

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 falls outside of but is recognized by SI, is used commonly in international fire protection. These units are listed in Table 1-4 with their conversion factors.

Table 1-4

Name of Unit	Unit Symbol	Conversion Factor
Millimeter	mm	1 in. = 25.4 mm
Meter	m	1 in. = 0.0254 m
Square centimeter	cm^2	1 $in.^2$ = 6.452 cm^2
Square meter	m^2	1 ft^2 = 0.093 m^2
Cubic centimeter	cm^3	1 $in.^3$ = 16.39 cm^3
Cubic meter	m^3	1 ft^3 = 0.0283 m^3
Grams	g	1 oz = 28.35 g
Liter	L	1 gal = 3.785 L
Kilopascal	kPa gauge	1 psi = 6.90 kPa gauge
Bar	Bar	14.50 psi = 1 Bar

Meters^3 per minute	m^3/min	1cfm = 0.0283 m^3/min

1-4.1

If a value for a required measurement in this standard is followed by an equivalent value in metric units, the first stated value shall be regarded as the requirement. The equivalent value that follows is approximate.

Exception: For motor craft under the jurisdiction of Canadian authorities, the metric unit value shall be the requirement.

1-4.2

SI units have been converted by multiplying the quantity by the conversion factor and then rounding the result to the appropriate number of significant digits.

1-5 Definitions.

For the purpose of this standard, the following terms are defined as follows:

AC Grounded Conductor. A current-carrying conductor intentionally maintained at ground potential that is connected to the side of the source.

AC Grounding Conductor (Green). A normally noncurrent-carrying conductor that connects the exposed metallic noncurrent-carrying parts of electrical equipment to the AC system and engine negative terminal or its bus for the purpose of minimizing shock hazard to personnel.

Accessible. Capable of being reached for inspection, maintenance, or removal without disturbing the permanent hull structure.

Accommodation Space. Space designed for living purposes.

Approved.* Acceptable to the authority having jurisdiction.

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

Battery Cold Cranking Rating. The discharge load in amperes that a battery at 0°F (-17.8°C) can deliver for 30 sec while maintaining a voltage of 1.2 volts per cell or higher.

Battery Reserve Capacity. The number of minutes for which a new, fully charged battery at 80°F (26.7°C) can be discharged at 25 amperes while maintaining a voltage of 1.75 volts per cell or higher (10.5 volts for a 12-volt battery or 5.25 volts for a 6-volt battery).

Bonding Conductor. A normally noncurrent-carrying conductor that is not intended to carry leakage current from either the AC or the DC system. Bonding conductors connect underwater metallic objects as part of any cathodic protection system and serve as lightning grounding conductors. If used, they shall be colored green or shall be of bare copper.

Butane. See LPG (Liquefied Petroleum Gas).

CNG (Compressed Natural Gas).* A natural lighter-than-air gas that consists principally of methane in gaseous form plus naturally occurring mixtures of hydrocarbon gases.

DC Grounded Conductor. A current-carrying conductor connected to the side of the source that is intentionally maintained at boat ground potential.

DC Grounding Conductor. A normally noncurrent-carrying conductor used to connect metallic noncurrent-carrying parts of a direct current device to the engine negative terminal or its bus for the purpose of minimizing stray current corrosion.

Double Insulation System. An insulation system comprised of insulation and supplementary insulation, with each insulation physically separated and so arranged to prevent its simultaneous subjection to the same level of deteriorating influences (temperature, contaminants, and the like) as the other.

Engine Exhaust System. The means by which products of combustion are conducted from the engine exhaust manifold to an outboard terminus. This system includes related accessories that can be metallic or nonmetallic, such as pipes, mufflers, silencers, turbochargers, spark arresters, and all necessary connecting and supporting fittings. Wet exhaust systems are provided with water injection into the exhaust gas stream; dry exhaust systems do not have this provision.

Engine Negative Terminal. The point on the engine at which the negative battery cable is connected.

Galvanic Isolator. A device installed in series with the AC grounding (green) conductor of the shore power cable to block, in effect, the low voltage DC galvanic current flow, yet permit the passage of AC current normally associated with the AC grounding (green) conductor.

Galvanically Compatible.* Metals that are related closely to each other in the galvanic series.

Gross Ton. Identical to document tonnage; generally related to the total internal volume of the vessel. Gross tonnage is a measurement of volume, not displacement.

Ground. The electrical potential of the earth's surface. The boat's ground is established by a conducting connection (intentional or accidental) with the earth, including any conductive part of the wetted surface of a hull.

Grounded Conductor. A current-carrying conductor intentionally maintained at ground potential that is connected to the side of the source.

Ground-Fault Circuit-Interrupter (GFCI). A device intended for protection of personnel that functions to deenergize a circuit or portion thereof within an established period of time when a current-to-ground exceeds some predetermined value that is less than that required to operate the overcurrent protective device of that supply circuit.

Ground-Fault Protector (GFP). A device intended to protect equipment by interrupting the electric current to the load when a fault current-to-ground exceeds some predetermined value that is less than that required to operate the overcurrent protection device of that supply circuit.

Grounding Conductor. A normally noncurrent-carrying conductor provided to connect the exposed metallic enclosures of electrical equipment to ground for the purpose of minimizing shock hazard to personnel.

Ignition Protection.* The design and construction of a device such that under the designed operating conditions:

(a) The device does not initiate ignition when surrounded by a flammable hydrocarbon mixture if an ignition source causes an internal explosion; or

(b) The device is incapable of releasing sufficient electrical or thermal energy to ignite a hydrocarbon mixture; or

(c) The source of ignition is hermetically sealed.

A flammable hydrocarbon mixture is a mixture of gasoline and air or propane plus air between the lower explosive limit (LEL) and upper explosive limit (UEL).

LPG (Liquefied Petroleum Gas).* The terms “liquefied petroleum gas,” “LP-Gas,” and “LPG” are synonymous and include any product composed predominantly of any of the following gaseous hydrocarbons: propane, propylene, butane, isobutane, butylenes, or a mixture thereof.

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.

Machinery Space. Any space containing an internal combustion engine.

Open to the Atmosphere. A space or compartment that has at least 15 in.^{2}/ft^3 (97.5 cm^2/m^3) of net open area directly exposed to the atmosphere of net compartment volume.

Overcurrent Protection Device. A device, such as a fuse or circuit breaker, designed to interrupt the circuit when the current flow exceeds a predetermined value.

Panelboard. An assembly of devices for the purpose of controlling or distributing, or both, power on a boat. It can include devices such as circuit breakers, fuses, switches, instruments, and indicators. Panelboards are intended to be installed in enclosures and are accessible from the front or rear.

Permanently Installed. Fastened in place and not intended for ready removal except for service, repair, or replacement.

Pigtail. An external conductor that originates within an electrical component or appliance installed by the manufacturer.

Polarized System (DC). A system in which the grounded (negative) and ungrounded (positive) conductors are connected identically in relation to all terminals or leads on all devices in the circuit.

Polarized System (AC). A system in which the grounded (white) and ungrounded conductors are connected identically in relation to all terminals or fixture leads on all devices in the circuit, including the shore power connections.

NOTE: This standard assumes the shore power source is wired in accordance with NFPA 70, *National Electrical Code®, Article 555.*

Propane. See LPG (Liquefied Petroleum Gas).

Readily Accessible. Capable of being reached quickly and safely for effective use under emergency conditions without the aid of tools.

Self-Limiting. A machine with a maximum output restricted to a specified value by its magnetic characteristics.

Shall. Indicates a mandatory requirement.

Sheath. A material, such as overlapping electrical tape, molded rubber, molded plastic, or flexible tubing, used as a continuous protective covering around one or more insulated conductors.

Shore Power Inlet. A reverse service-type fitting designed for mounting on a boat that requires a female connector on the shore power cable in order to make the electrical connection.

Should. Indicates a recommendation or that which is advised but not required.

Transformer, Isolation. A transformer installed in the shore power supply circuit of a boat to isolate electrically all AC system conductors, including the AC grounding conductor (green) on the boat, from the AC system conductors of the shore power supply.

Transformer, Polarization. A transformer ("dry-type" lightning transformer) installed in the shore power supply circuit on the boat to isolate electrically the normally current-carrying AC system conductors, but not the AC grounding conductor (green), from the normally current-carrying conductors of the shore power supply.

Trip-Free Circuit Breaker. A thermal or magnetically operated, or both, overcurrent protection device designed so that the resetting means cannot be pressed in manually to override the current-interrupting mechanism.

Watertight. So constructed that water does not enter the enclosure under test conditions specified in NEMA 250, *Enclosures for Electrical Equipment (1000 V Maximum).*

Weatherproof. Constructed or protected so that exposure to the weather does not interfere with successful operation.

NOTE: For the purpose of this standard, where applied to marine use, weatherproof implies resistance to rain, spray, and splash.

Ventilation. The changing of air within a compartment by natural or mechanical means. Ventilation can be achieved by introduction of fresh air to dilute contaminated air or by local exhaust of contaminated air.

Chapter 2 Hull

2-1 General Arrangement.

2-1.1

The hull shall be arranged so that all compartments are accessible and all escape hatches are unobstructed and readily accessible. Means of egress from accommodation spaces shall be provided without necessitating passage through the engine room.

2-1.1.1 Every boat having enclosed accommodation spaces shall have a readily accessible and unobstructed means of egress.

2-1.1.2 Every boat having enclosed accommodation spaces shall have a second accessible means of egress if it is possible for one exit to be blocked by a fire in a galley or machinery area.

2-1.1.3 The means of egress in 2-1.1.1 and 2-1.1.2 shall provide for minimum clear opening dimensions of $14^1/_2$ in. × $18^1/_2$ in. (36.8 cm × 47 cm) (rectangular); or 18 in. diameter (45.7 cm) (circular); or 270 in.^{2} (1741 cm^2) with a minimum dimension of $14^1/_2$ in. (36.8 cm) (oval).

2-1.1.4 Any hatch that is required for egress shall have a means of being operated from the inside and a means of being operated from the outside when not secured from the inside. All hinged hatches shall have a means or method to support the hatch in an open position.

2-1.2*

Bulkheads or enclosures shall be installed between machinery spaces and accommodation spaces. These bulkheads or enclosures shall be continuous, except for necessary penetrations, to minimize the escape of fire extinguishing agents discharged into the machinery space.

2-1.3

Bilges of spaces containing fuel line fittings shall be separated from bilges of accommodation spaces and other enclosed spaces containing sources of ignition by bulkheads that shall not permit more than 0.25 fl oz (7.4 m) of leakage per hour when the liquid in the bilge is at a height of 12 in. (30 cm) or $^1/_3$ the maximum height of the bulkhead, whichever is less. Above heights of 12 in. (30 cm) or $^1/_3$ the maximum height, the bulkhead shall be permitted to have openings for the passage of conductors, piping, ventilation ducts, mechanical equipment, doors, hatches, and access panels, provided the maximum annular space around each item is not greater than $^1/_4$ in. (6.4 mm).

Exception: Boats using diesel fuel only.

2-1.4

Machinery spaces shall be readily accessible.

2-1.5

Materials used for thermal and acoustical insulation in any compartment or enclosure containing an internal combustion engine or heater shall have a flame spread index of 75 or less. Material shall be labeled or listed as having been tested to meet the requirements of NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*.

2-1.6

Materials used for thermal and acoustical insulation shall not disintegrate in the presence of hydrocarbon vapor.

2-1.7

Materials used for thermal and acoustical insulation shall be designed and installed such that hydrocarbon vapors cannot accumulate within the material and thereby reduce its flame spread rate.

2-2 Spaces Open to the Atmosphere.

2-2.1

Compartments or spaces connecting with engine or portable fuel tank spaces that are open to the atmosphere shall require ventilation if the connecting space has an open area of less than 15 in.^{2}/ft^3 (2.8 cm^2/m^3) of its net volume. The open area shall be open either to the atmosphere or to another open space, provided that, for the combined net volumes of the connecting spaces, there is a total area open to the atmosphere of at least 15 in.^{2}/ft^3 (2.8 cm^2/m^3).

2-2.2

Long, narrow spaces formed by side panels or accommodation floors shall have openings at both ends or along the sides if they are to be considered open to the atmosphere.

2-3 Connecting Compartments or Spaces by a Natural Ventilation System.

2-3.1

A natural ventilation system shall be provided for each compartment in a boat that:

(a) Contains a permanently installed gasoline engine;

(b) Has openings between the compartment and a compartment that requires ventilation, where the aggregate of those openings exceeds 2 percent of the area between the compartments, except as provided in 2-3.1(e)(2);

(c) Contains a permanently installed fuel tank and an electrical component that is not provided with ignition protection;

(d) Contains a fuel tank that vents into that compartment; or

(e) Contains a nonmetallic fuel tank that:

1. Has an aggregate permeability rate exceeding 1.2 g (0.04 oz) of fuel loss in 24 hours per cubic foot of net compartment volume; or

2. Is located where the net compartment volume is less than 1 ft^3. The nonmetallic fuel tank shall have a permeability rate not exceeding 1.2 g (0.04 oz) of fuel loss in 24 hours. Reference fuel “C” at 104°F ± 36°F (40°C ± 2°C) from ASTM D471, *Standard Test Method for Rubber Property, Effect of Liquids*, shall be used in determining the permeability rate.

Exception: Compartments open to the atmosphere.

2-3.2

Each required supply opening shall be located on the exterior surface of the boat.

Exception: An accommodation compartment located above a compartment requiring ventilation that is separated from the compartment requiring ventilation by a deck or other structure shall not be required to meet the provisions of 2-3.1(e)(2).

2-3.3

An accommodation compartment located above a compartment requiring ventilation that is separated from the compartment requiring ventilation by a deck or other enclosure shall not be considered a connecting compartment.

2-4* Natural Ventilation.

2-4.1

Each compartment not open to the atmosphere shall be provided with a natural ventilation system where such a compartment:

(a) Contains a permanently installed gasoline engine.

(b)* Contains a portable fuel tank that vents into the compartment. Space under a motor well in outboard boats that is large enough to accommodate a 6-gal (23-L) portable fuel tank but is not intended for such usage shall be labeled to prohibit its use for fuel storage.

(c) Contains fuel tanks and contains components without ignition protection.

2-4.2

Each natural ventilation system shall be constructed with at least one intake and one exhaust opening that shall be located on the boats exterior surface.

2-4.3*

Each compartment requiring natural ventilation shall be equipped with an exhaust duct(s) originating in the lower one-third of the compartment, with the duct opening permanently fixed above the normal accumulation of bilge water. If the compartment is an engine compartment, the exhaust duct(s) shall be located as near below the engine(s) as practicable.

2-4.4

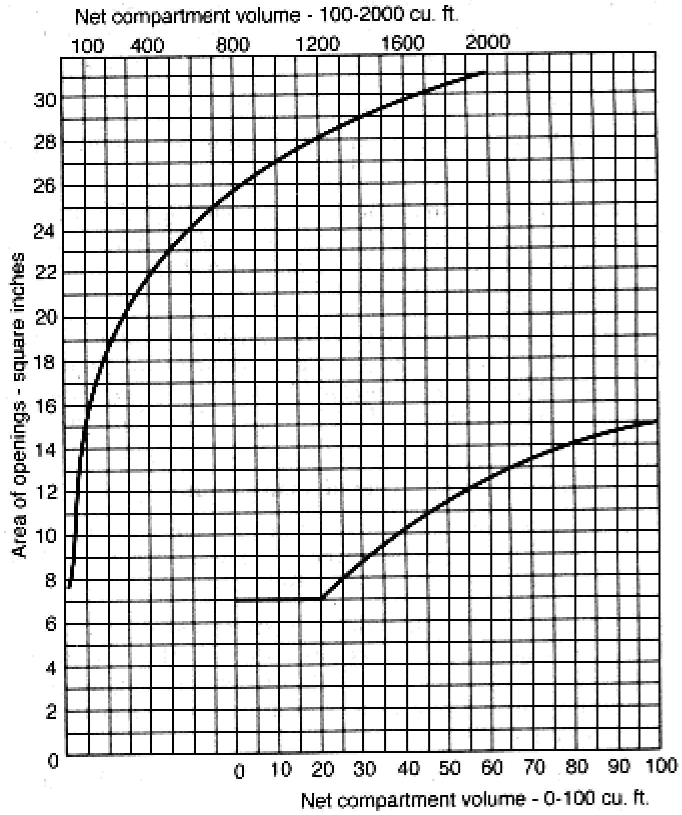
Each exhaust duct shall be fitted with a cowl or its equivalent at the discharge opening, that shall face aft.

2-4.5

Air intake openings inside a compartment shall be separated from exhaust duct openings inside the compartment by at least 24 in. (0.60 cm) or the longest compartment dimension.

2-4.6

The minimum aggregate internal cross-sectional area of intake ducts or openings shall be as shown in Figure 2-4.6.



Note: The values in Figure 2-4.6 are based on the following equation:

$$A = 5 \log_e \left(\frac{V}{5}\right)$$

where: A = the minimum aggregate internal cross-sectional area of the openings or ducts in square inches.

V = the net compartment volume in cubic feet, including the net volume of other compartments sharing the same ventilation system.

$\log_e \left(\frac{V}{5}\right)$ = the natural logarithm of the quantity $\left(\frac{V}{5}\right)$ See Figure 2-4.6.

Figure 2-4.6 Area of openings.

2-4.7

The minimum aggregate internal cross-sectional area of exhaust ducts or openings shall be calculated in the same manner as for intakes. (*See 2-4.6.*)

2-4.8

Duct size shall be based on nominal diameters and shall be at least 3 in. (7.5 cm) in diameter. Openings shall be of at least equivalent cross-sectional area. See Table 2-4.8 for standard duct sizes.

Table 2-4.8

Standard Duct Sizes

7.07 in.^{2} (46.0 cm^2)	(3 in. dia) (7.5 cm)
9.62 in.^{2} (62.5 cm^2)	(3$^1/_2$ in. dia) (8.8 cm)
12.57 in.^{2} (81.7 cm^2)	(4 in. dia) (10 cm)
19.63 in.^{2} (12.6 cm^2)	(5 in. dia) (12.5 cm)

2-4.9

The minimum cross-sectional area of terminal fittings for flexible ventilation ducts shall not be less than 80 percent of the required internal cross-sectional area of the flexible ventilation duct.

2-5 Powered Ventilation System.

2-5.1

Each compartment, not open to the atmosphere, that has a permanently installed gasoline engine with a cranking motor shall be ventilated by an exhaust blower.

2-5.2 Blowers.

2-5.2.1 Blowers shall be rated for continuous operation at 120 percent of nominal voltage.

2-5.2.2* Blowers shall meet the external ignition protection requirements of UL 1128, *Standard for Safety Marine Blowers*, or UL 1500, *Standard for Safety Ignition-Protection Test for Marine Products*.

2-5.2.3 Blowers shall be rated for airflow in cubic feet per minute, at nominal voltage, in accordance with Figure 12 of AMCA/ANSI 210, *Laboratory Methods of Testing Fans for Rating*, or UL 1128, *Standard for Safety Marine Blowers*. (*See Figure 2-5.2.3*.)

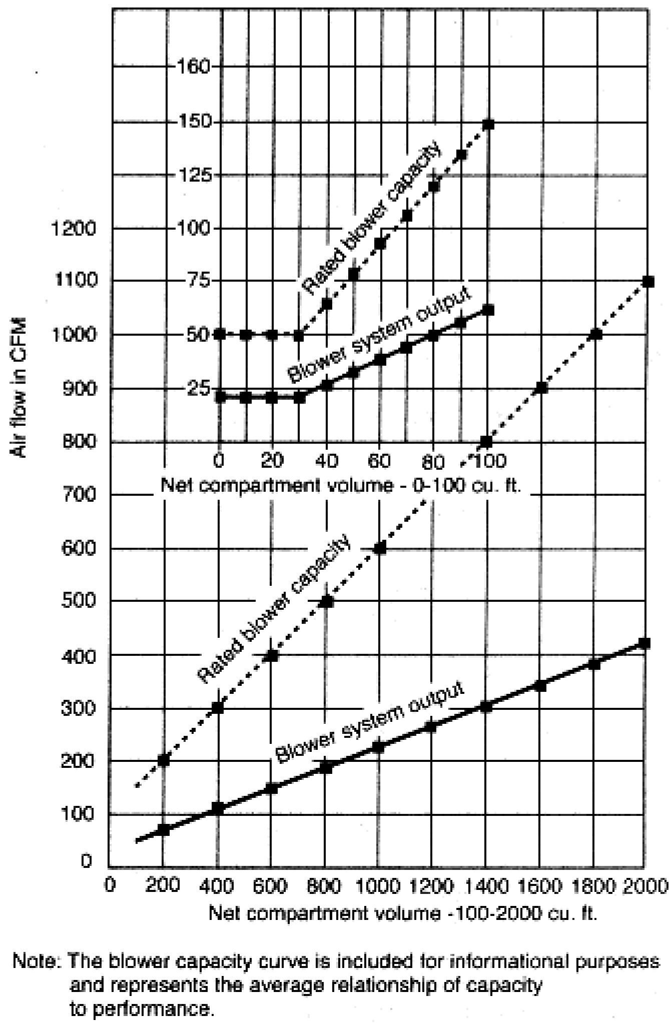


Figure 2-5.2.3 Minimum blower capacity and system performance.

2-5.3 Installation of Powered Ventilation.

2-5.3.1 Blower(s) capacity shall be selected in accordance with the blower capacity curve in Figure 2-5.2.3. More than one blower shall be permitted.

2-5.3.2 As installed, the blower system(s) shall exhaust air from the boat at a rate in accordance with the system performance curve in Figure 2-5.2.3 when the engine is not operating and the blower is operating at the electrical systems nominal voltage.

2-5.3.3 Blowers shall be mounted above the normal level of accumulated bilge water.

Exception: Submersible blower motors.

2-5.3.4 Blowers shall be installed with ducts having intake openings that are:

(a) Permanently secured;

(b) Located in the lower one-third of the compartment;

(c) Located above the normal level of accumulated bilge water; and

(d) Located as near below the engine(s) that they serve as practicable.

2-5.3.5 Electrical wiring shall be installed in accordance with Chapter 7 or Chapter 8.

2-5.3.6 Each boat that requires a powered ventilation system shall display a warning label that provides the information that follows, located in plain view of the operator, and located as close as practicable to each ignition switch (including auxiliary equipment).

The powered ventilation label shall read as follows:

W A R N I N G

Gasoline Vapors Can Explode

Before Starting Engine:
1. Check Engine Compartment for Gasoline or Vapors
2. Operate Blower for 4 Minutes

2-6 Arrangements of Openings.

2-6.1

Ventilation openings shall be located to prevent the entrance of water in amounts that could impair the stability or handling of the vessel or that could cause machinery malfunction under conditions of maximum heel or trim, reverse operation, eccentric loading or wave action, and all operating conditions.

2-6.2

External openings of intakes and exhausts shall be located to minimize re-entry of exhausted fumes.

2-6.3

External openings of intakes and exhausts shall be located and oriented to prevent entry of fuel vapors. In no instance shall the intakes and exhausts be closer than 15 in. (38 cm) horizontally from the gasoline fill and vent fittings.

2-6.4

Ventilation openings shall be unobstructed by side curtains, cockpit enclosures, dodgers, and other weather enclosures.

Chapter 3 Engines

3-1 Exposed Engine Surface Temperatures.

Exposed engine surfaces shall not exceed 225°C (437°F) under normal operating conditions. An audible or visual device shall be installed to warn of excessive engine temperature.

Exception: Short branch connections between liquid-cooled exhaust manifolds and cylinder head exhaust ports, or hot spots on intake manifolds.

3-1.1

Gasoline engine fuel pumps of the diaphragm type shall be designed so that fuel shall not be released to the engine space if primary diaphragm failure occurs. Means shall be provided to determine that diaphragm failure has occurred without dismantling the fuel pump.

3-1.2* Marine Carburetors.

3-1.2.1 Marine carburetors shall not leak more than 5 cm^3 (0.17 fl oz) of fuel in 30 seconds when the float valve is open, the carburetor is at half throttle, and the engine is cranked without having been started or when the fuel pump is delivering the maximum pressure specified by its manufacturer.

3-1.2.2 Each updraft and horizontal draft carburetor shall have a device that collects and holds fuel that flows out of the carburetor venturi section toward the air intake, prevents collected fuel from being carried out of the carburetor assembly by the shock wave of a backfire or by reverse airflow, and returns collected fuel to the engine induction system after the engine starts.

3-1.2.3* Spark ignition engine air intakes shall be fitted with a means of backfire flame control approved by the U.S. Coast Guard or meeting the requirements of UL 1111, *Standard for Safety Marine Carburetor Flame Arresters*.

3-1.3

Electrical components for engines shall comply with Chapters 7 and 8, as applicable.

3-1.4 Air-Cooled Engines.

3-1.4.1 Permanently installed air-cooled engines with self-contained fuel systems shall be located only on open decks or on cabin tops. Any housing over such units shall be open whenever the engine is operating.

3-1.4.2 If air-cooled engines are enclosed, the following shall apply:

(a) Factory installed engine air-cooling shrouding shall be constructed and mounted to trap all engine-cooling air and lead it to a point from which it can be discharged outside the hull or engine box by means of ducting.

(b) Ducts for engine-cooling air shall have a flame spread index of 75 or less. Material shall labeled or listed as having been tested to meet the requirements of NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*.

(c) Engine-cooling air shall not be used as a direct source of cabin heating.

3-1.5

Portable gasoline engines with integral fuel tanks or portable gasoline fuel tanks shall be stowed securely in an open or ventilated space in accordance with Sections 2-2 and 7-8 so that fuel or vapors cannot reach interior spaces.

3-1.6

Nonpropulsion engines intended for automatic operation shall be equipped with an automatic shutdown device actuated by low oil pressure, excessive engine overheat, and excess heat from exhaust pipe or exhaust gas ducting.

3-1.7*

High tension cable assemblies shall conform to SAE J2031, *Standard for High Tension Ignition Cable*.

3-1.8

Ignition distributors shall conform to UL 1500, *Standard for Safety Ignition-Protection Test for Marine Products*.

NOTE: For information on ignition distributors, see SAE J1294, *Recommended Practice for Ignition Distributors—Marine*.

Chapter 4 Engine Exhaust Systems

4-1 General Requirements.

4-1.1

Exhaust systems shall:

(a) Be gastight to hull interiors;

(b) Have all connections accessible;

(c) Be supported to minimize failure from vibration, shock, expansion, and contraction;

(d) Have no threaded fittings into nonmetallic exhaust system components; and

(e) Have no discharge from other devices into the exhaust.

Exception: Engine-cooling water.

4-1.2

Wherever personnel or combustibles can come in contact with hot surfaces, effective protection shall be provided by water-jacketing, lagging, shielding, guards, or engine enclosures.

4-1.3

Hangers, brackets, or other means used to support metallic exhaust systems shall be noncombustible:

(a) Within 6 ft (1.8 m) of the engine connection(s) for wet exhaust systems.

(b) For the full length of dry exhaust systems.

4-1.4

A means to indicate loss of exhaust-cooling water shall be provided so that it is effective at all helm positions.

Exception: Outboard engines.

4-1.4.1 Auxiliary engines shall be permitted to use an automatic shutdown device in place of an audible or visual device for response to high exhaust temperature.

4-1.5

A separate exhaust system shall be provided for each engine.

4-2 Materials.

4-2.1

Materials used in engine exhaust systems shall be resistant to fuels, water, corrosion, and the products of combustion.

4-2.2

Copper shall not be used in contact with dry diesel exhaust gases or within six pipe diameters downstream from the point of water entry in water-cooled exhaust systems.

4-2.3

As installed, nonmetallic exhaust system components shall retain watertight integrity for two minutes after a total loss of cooling water, with the engine operating at full power.

4-3 Hose Connections.

Hose connections shall be double-clamped.

Exception: Single-clamped hoses designed for specific use as part of an engine assembly.

4-4 Temperature Protection.

The turbine side of nonwater-jacketed turbochargers and unjacketed, single-wall, dry exhaust components shall be installed so that the temperature of adjacent combustible surfaces shall not exceed 250°F (121°C).

4-5 Labeling.

All nonmetallic exhaust components shall be labeled or marked “marine exhaust.”

NOTE: For information on nonmetallic exhaust components, see UL 1129, *Standard for Safety Wet Exhaust Components for Marine Engines*.

Exception: Components designed for use as a part of a specific engine assembly.

Chapter 5 Fuel Systems

5-1 Scope.

5-1.1

The requirements of this chapter shall apply to the design, construction, choice of materials, and installation of permanently installed fuel systems (except compressed gas) that run from the fuel fill opening to the connections at each engine or at auxiliary equipment.

5-1.2

The requirements of this chapter shall apply to all tanks that are permanently installed. Any tanks with a capacity of more than 7 gal (27 L) shall be permanently installed.

5-2 General Requirements.

5-2.1

Fuel systems shall be liquid- and vapor-tight with respect to hull interiors. Individual system components and the system as a whole shall be designed and installed to withstand the stresses of and exposure to marine service such as pressure, vibration, shock, movement, grease, lubricating oil, bilge solvents, high aromatic fuels, and corrosive environments.

5-2.2

All individual components of the fuel system, as installed in the boat, shall be capable of withstanding a $2^1/_2$-minute exposure to free-burning fuel without a failure that results in leakage of liquid or vapor.

Exception No. 1: Fuel distribution lines on boats shall not be required to comply with 5-2.4 if a break at any point in the line will cause a discharge of not more than 5.0 fl oz (150 ml) of fuel within $2^1/_2$ minutes. (See 5-6.2.2.)

Exception No. 2: Self-draining fuel tank vent hose located outside the engine compartment shall not be required to comply with 5-2.4.

5-2.3

To ground static electricity, the resistance between ground and each metallic or metallic-plated component of the fuel fill system and fuel tank that is in contact with fuel shall be less than 1 ohm.

5-2.4

Pressurized fuel tanks shall not be used.

5-3 Fuel Tank Materials.

5-3.1

Fuel tanks shall not be integral with the hull structure.

Exception: Tanks for diesel fuel in boats with metal hulls.

5-3.2

Materials for fuel tanks shall be corrosion-resistant. Materials meeting the specifications of 5-3.2.1 through 5-3.2.5 and of Table 5-3.2 shall be considered as satisfying this corrosion resistance requirement. Any departure from these specifications shall be identified and marked specifically.

Table 5-3.2 Minimum Plate Thickness for Fuel Tank Corrosion Resistance

Material	Specification	Minimum Nominal Sheet Thickness	Gauge
Nickel-copper	ASTM B127 Class A	0.031 in.	22
Copper-nickel steel	ASTM B122 M	0.045 in.	17
Aluminized steel	ASTM A90 M	0.0747 in.	14
Aluminum	ASTM A463	0.0478 in.	18
	Alloy 5052	0.090 in.	
	Alloy 5083		

	Alloy 5086		
Stainless steel	316L	0.031	22

For SI units: 1 in. = 2.5 cm
NOTE: Gauges provided in Table 5-3.2 are U.S. Standard for nickel-copper, AWG for copper-nickel, and Manufacturer's Standard for steel.

5-3.2.1 Steel tanks used for fuel shall:

(a) Be galvanized inside and outside by the hot-dip process;

Exception: Diesel fuel tanks shall not be galvanized on the inside.

(b) Be constructed of aluminized steel;

(c) Not be constructed of terneplate steel.

5-3.2.2 Aluminized steel tanks with a wall thickness of less than 0.0785 in. (2 mm) shall be installed only above the cockpit floor or above deck if not clearly defined cockpit exists.

5-3.2.3 Stainless steel tanks shall be cylindrical with domed heads and shall have a capacity of less than 20 gal (76 L).

5-3.2.4 Seams of tanks constructed of nickel-copper shall be made by using oxyacetylene, shielded arc, atomic hydrogen, electric resistance seam welding, brazed joints, and riveted and brazed joints.

5-3.2.5 Seams of 22-gauge nickel-copper shall be formed by electric resistance seam welds. Fuel tanks formed of 22-gauge nickel-copper shall not be used for tanks exceeding 30 gal (114 L) capacity.

5-3.3

Nonmetallic materials meeting the applicable requirements of Chapter 5 shall be permitted to be used for tanks, provided the aggregate permeability rate of such tank does not exceed 1.2 g/ft^3 (0.04 oz/m^3) in 24 hours (1.2 g/m^3) in 24 hours of fuel loss of net compartment volume, or, if the compartment volume is less than 1 ft^3 (0.03 m^3), the permeability rate does not exceed 1.2 g (0.04 oz) of fuel loss in 24 hours. (*See 5-5.4*.)

5-4 Fuel Tank Design and Construction.

5-4.1

Fuel tanks shall conform to the following:

(a) They shall not have openings in bottom, sides, or ends.

(b) Openings for fill, vent, and feed pipes and level gauges (if installed) shall be at or above the topmost surface of tanks.

(c) Clean-out plates shall not be installed.

(d) Plates used for fittings shall be secured in such a manner that they cannot be used for clean-out purposes.

Exception: Diesel fuel tanks shall not be required to comply with 5-4.1.

5-4.2

Tanks shall be constructed so that, when installed, exterior surfaces shall not trap water.

5-4.3

Threaded fittings shall conform to Table 5-4.3.

Table 5-4.3 Minimum Thread Engagement

Thread Engagement	Minimum Length of I. P. S.
$^1/_4$ in.	$^3/_8$ in.
$^3/_8$ in.	$^3/_8$ in.
$^1/_2$ in.	$^1/_2$ in.
$^3/_4$ in.	$^9/_{16}$ in.
1 in.	$^5/_8$ in.
$1^1/_4$ in.	$^5/_8$ in.
$1^1/_2$ in.	$^5/_8$ in.
2 in.	$^{11}/_{16}$ in.

For SI units: 1 in. = 2.5 cm

5-4.4

Fuel tanks with a capacity of 25 gal (95 L) or greater shall not leak when subjected to the pressure impulse test requirement of Title 33, *Code of Federal Regulations*, Subpart 183.586.

5-4.5

Fuel tanks with a capacity of less than 25 gal (95 L) shall not leak when subjected to the shock test requirement of Title 33, *Code of Federal Regulations*, Subpart 183.584.

5-4.6

Fuel tanks with a capacity of 200 gal (760 L) or more shall not leak when subjected to the slosh test requirement of Title 33, *Code of Federal Regulations*, Subpart 183.588.

5-4.7

All metal tanks and the metal fitting plates of nonmetallic fuel tanks shall be provided with a bonding terminal suitable for the attachment of a No. 8 AWG bonding conductor.

5-4.8

Indentations for labeling or other identification shall not weaken the fuel tank.

5-4.9

All fuel tanks shall bear a legible, permanent label located so that it is visible for inspection after installation. The label shall provide the following information:

(a) Manufacturer's name or logo and address

(b) Month (or lot or serial number) and year of manufacture

(c) Capacity in U.S. gallons (capacity also shall be permitted to be expressed in liters)

(d) Construction material and thickness

(e) Fuel for which tank is intended

(f) Maximum test pressure

(g) Model number, if applicable

(h) A statement that reads "This tank has been tested under Title 33, *Code of Federal Regulations*, Subpart 183.510(a)"

Exception: Diesel fuel tanks.

(i) A statement that reads "Must be installed aft of the half-length of the boat," if the tank has been tested under Title 33, *Code of Federal Regulations*, Subpart 183.584, at less than 25 G vertical accelerations.

5-4.10

All fuel tanks shall be tested by the manufacturer for fuel tightness at 3.0 psig (21 kPa gauge) or 1.5 times the maximum head to which they can be subjected during service, whichever is greater.

5-4.11

Because the tank can flex in service, the design of the pick-up tube shall preclude damage to the tank bottom.

5-4.12

The use of gauge glasses shall be restricted to day or service tanks of diesel fuel systems.

5-5 Fuel Tank Installation.

5-5.1

Fuel tanks and their fittings shall be accessible.

5-5.2

Metallic fuel tanks shall be positioned above normal accumulations of bilge water and supported in a manner that shall ensure complete drainage of water from all exterior tank surfaces, as installed.

Exception: Diesel fuel tanks that are integral with the hull.

5-5.3

Fuel tanks shall be installed and secured to prevent permanent deformation and to provide immobilization to the extent practicable.

5-5.4

Nonmetallic fuel tanks that expand dimensionally after exposure to fuel shall:

(a) Be installed in accordance with the fuel tank manufacturer's instructions, which shall indicate clearly in diagram form the clearances required; and

(b) Be provided with a warning label that includes the following information:

WARNING: To prevent hull and tank damage due to expansion of the tank while in service, installation shall be in accordance with the manufacturer's instructions.

5-5.5

In order to permit free circulation of air, contact between metallic fuel tanks and other structures shall be limited to necessary structural supports.

5-5.6

All abrasive or absorbent surfaces of tank supports and braces shall be insulated effectively from contact with tank surfaces by a nonabrasive and nonabsorbent material.

5-5.7

Aluminized steel tanks of thicknesses less than 0.0785 in. (2 mm) shall be installed above the cockpit deck, or above deck if there is no clearly defined cockpit.

5-5.8

Nonferrous and nonmetallic fuel tanks shall be permitted to be foamed in place if they comply with the requirements of Title 33, *Code of Federal Regulations*, Subpart 183.516. (*See 5-5.4*.)

5-5.9

Fuel tanks shall not be installed above the engine or other sources of ignition.

5-6 Fuel Lines and Related Accessories.

5-6.1

For the purposes of this section, fuel lines shall mean all pipes, tubing, or hoses that conduct fuel from the deck fill plate to the engine connection. Related accessories shall include any attachments to fuel lines such as valves, filters, strainers, pumps, and connecting fittings.

5-6.2 General Requirements.

5-6.2.1 Rigid metallic fuel lines shall be made of seamless, annealed copper, nickel-copper, or copper-nickel having a minimum nominal wall thickness of 0.032 in. (0.8 mm).

5-6.2.2 Flexible nonmetallic fuel hose shall be U.S.C.G. Type A-1 hose where $2^1/_2$ minutes minimum fire resistance is required or shall be U.S.C.G. Type B-1 hose where $2^1/_2$ minutes minimum fire resistance is not required. (*See 5-2.2*.)

5-6.2.3 Fuel lines, connections, and accessories shall be accessible.

5-6.2.4 Plastic pipe and fittings shall not be used in fuel distribution lines, vent lines, and fill lines. (*See 5-2.2*.)

Exception No. 1: Components of deck fill fittings, vent fillings, carburetor fittings, fuel pump *fittings, and fuel filter fittings.*

Exception No. 2: Engineering grade plastics such as glass-reinforced nylons.

5-6.2.5 Fuel lines shall be secured against movement or vibration by the use of noncombustible clips or straps without rough surfaces or sharp edges. Clips and straps shall have fire resistance equivalent to the requirement of the line they support.

5-6.2.6 Where making up threaded pipe connections, a gasoline-resistant sealing compound or tape shall be used.

5-6.2.7 Where making flared tubing connections, tubing shall be cut squarely and flared by tools designed for the purpose. Tubing shall be deburred, and copper tubing shall be annealed prior to being flared.

5-6.2.8 Outlets for drawing fuel from the system are prohibited.

Exception: Filter bowl plugs provided for the purpose of servicing only.

5-6.2.9 Manually operated multiposition valves shall be required to indicate only their open and closed positions. Manually operated stop valves shall be designed with positive stops in the open and closed positions.

5-6.3 Installation of Fill and Vent Pipes.

5-6.3.1 Fuel tank fill and vent pipes shall be located to prevent the escape of liquid and vapor overflow to the inside of the hull and to provide protection from the flow of vapors escaping into the hull.

5-6.3.2 No liquid fuel shall enter the boat from the fill due to an overflow rate of 5 gpm (19 Lpm) for 5 seconds when the boat is in its static floating position.

5-6.3.3 The vent pipe shall terminate as remotely as practicable from any hull opening and shall be installed to minimize the intake of water without resisting the release of vapor. Overflow from the vent at a rate of 2 gpm (7.7 Lpm) shall not enter the boat.

5-6.3.4 The minimum inside diameter of the fill pipe system shall be $1^1/_4$ in. (3.2 cm) [a minimum hose diameter of $1^1/_2$ in. (3.8 cm)].

5-6.3.5 The fill pipe shall run as directly as possible, preferably in a straight line, from the deck plate or other closable plate to the tank top spud.

5-6.3.6 The fuel fill shall be identified by a permanent marking indicating the type of fuel.

5-6.3.7 If a nonmetallic hose is used in the fill pipe system, it shall be secured tightly with a minimum of two corrosion-resistant metal clamps of $^1/_2$ in. (12.7 mm) minimum width at each end of the hose. Clamps depending solely on spring tension shall not be used.

5-6.3.8* Bonding wire ends shall not be clamped between the fill pipes and the flexible tubing.

5-6.3.9 There shall be no blow-back of fuel through the fill fitting while filling at a rate of 9 gpm (35 Lpm) and to a level of $^1/_4$ to $^3/_4$ of the capacity indicated by the tank label.

5-6.3.10 The vent pipe connection shall be at the highest point of the tank, when installed in the boat, under conditions of normal trim.

5-6.3.11 The minimum inside diameter of any component of the vent line system shall be not less than $^{7}/_{16}$ in. (11 mm).

5-6.3.12 The fittings at the hull vent line opening shall be corrosion-resistant. Each fuel tank vent system shall have a flame arrester that can be cleaned, unless the vent system itself is a flame arrester.

Exception: If metallic vent lines are used and serve as effective flame arresters, the hull vent fitting shall not be required to be a flame arrester.

5-6.4* Installation of Fuel Feed Lines and Accessories.

5-6.4.1* Electric fuel supply pumps shall operate only when the engine is operating, when the cranking motor is energized, or when they are operated by a momentary switch for priming and shall be located either on or within 12 in. (30 cm) of the engine. Hose installed on the pressure side of the fuel pump shall be U.S.C.G. Type A-1.

Exception: Priming pumps in outboard motor fuel systems.

5-6.4.2 Fuel lines shall be run with as few connections as practicable.

5-6.4.3 Anti-siphon protection shall be provided in fuel systems that are exempted from the requirements of 5-2.2 or where the fuel level in the tank is higher than the carburetor inlet fitting. Anti-siphon protection shall be provided by one of the following methods:

(a) All parts of the fuel distribution lines shall be kept above the tank top when the boat is in its static floating position.

(b) An anti-siphon valve shall be installed at or above the tank withdrawal fitting.

(c) An electrically operated valve shall be installed, at or above the tank withdrawal fitting, that opens only when the engine is energized and that provides for manual override.

5-6.4.4 A readily accessible manual shutoff valve shall be installed on all fuel tanks directly at the tank connection, except on those fuel systems provided with anti-siphon protection. If the fuel tank(s) is located in machinery space(s), a remotely operated means of closing the valve(s) without opening machinery spaces shall be provided.

5-6.4.5 That part of the fuel feed line secured to the hull members shall be separated from that part secured to the engine by a flexible section meeting the requirements of 5-6.2.2.

5-6.4.6 The fixed fuel line shall be fastened to structures within 4 in. (10 cm) of the connection to the flexible section to secure against vibration and movement.

Chapter 6 * Cooking, Heating, and Auxiliary Appliances

6-1 General.

6-1.1

Printed instructions for proper installation, operation (including refueling, where applicable), and maintenance shall be provided with each appliance. The instructions shall include information on the hazards associated with appliance air consumption and installer information regarding the proper display of a warning label.

6-1.2

Appliances using gasoline in liquid or solid form for priming or fuel shall be prohibited.

6-1.3*

The design and installation of appliances shall consider the air consumption of the appliances and the venting of exhaust products.

6-1.4

An appliance shall be mounted in accordance with the manufacturer's instructions and shall be fastened securely when in use or stored.

6-1.5

A burner system shall be capable of operation without creating a fire hazard during periods of boat pitch and roll at angles up to 30 degrees from horizontal in any direction sustained for 15 seconds and shall be capable of continuous operation at angles of heel up to 30 degrees.

6-1.6

A durable and permanently legible sign mounted to be readily visible and detailing the proper operation and any unique hazards of the appliance shall be provided.

6-1.7

Operating controls shall be located to be easily accessible and to reduce the likelihood of injury from burners or elements while in use.

6-1.8

Appliances with automatic igniter glow plugs or continuously lighted pilot lights for burner ignition shall be prohibited.

Exception No. 1: Automatic igniter glow plugs in appliances using sealed combustion chambers.

Exception No. 2: An oven control flame that operates only when the stove is in use.

6-1.9

Appliances shall be marked or identified permanently with the following information in a location visible after installation:

Manufacturer's name or trademark
Model number
Serial number, if applicable
Fuel/energy used
Maximum power consumption in kW when operating at capacity.

6-2 Cooking Appliances Installation.

6-2.1

Exposed materials and finishes above, below, and surrounding heat-generating surfaces of appliances shall have a flame spread index of not more than 75 as determined in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*.

6-2.2

Fabrics located above and within 39 in. (1 m) of a galley stove top, used for decorative or other purposes, shall be flame resistant in accordance with NFPA 701, *Standard Methods of Fire Tests* *for Flame-Resistant Textiles and Films*.

6-2.3

With the appliance installed, the temperature of vertical combustible surfaces below and surrounding heat-generating surfaces shall not rise more than 150°F (65°C) above the compartment's ambient temperature when tested using the temperature test of UL 858, *Standard for Safety Household Electric Ranges*, Section 53.

6-3 Coal, Charcoal, and Wood Burning Appliances.

6-3.1

Solid-fuel burning appliances shall not be installed in gasoline powered boats.

6-3.2

Coal, charcoal, and wood burning stoves shall be either mounted on a noncombustible base (preferably hollow tile) or mounted on legs providing a clearance of at least 5 in. (13 cm) between the stove bottom and the deck, and the deck shall be insulated with a noncombustible material or sheathing. The sides and backs of uninsulated stoves shall have a minimum clearance of 9 in. (23 cm) from the exposed materials and finishes, which shall meet the requirements of 6-2.1 or shall be separated by fire-resistant thermal insulation. The sides and backs of insulated stoves shall have a minimum clearance as specified by the manufacturer.

6-3.3

Single-wall smoke pipes and stacks shall have a minimum clearance of 9 in. (23 cm) from combustible materials, including painted surfaces, or shall be separated by fire-resistant thermal insulation. Listed and labeled double- or triple-wall smoke stacks shall be installed with a minimum clearance specified by the manufacturer.

Exception: At decks equipped with water irons.

6-3.4

Permanently installed solid-fuel burning appliances shall be equipped with a double- or triple-wall smoke pipe or stack that shall terminate above deck, with smoke heads designed to minimize water entry, spark emission, and backdraft.

Exception No. 1: Solidified alcohol galley stoves.

Exception No. 2: Exterior mounted grills.

6-3.4.1 Double- or triple-wall smoke stacks meeting the requirements of UL 103, *Standard for Safety Chimneys, Factory-Built, Residential Type, and Building Heating Appliances*, shall be installed in accordance with the specifications of the manufacturer.

6-3.5

To prevent spontaneous combustion, charcoal shall be kept dry and stored in a closed, dry, metal container.

6-4 Liquid Fuel Appliances [Does not include LPG (Liquefied Petroleum Gas)].

6-4.1

Both pressure and gravity-fed burners shall be permitted.

6-4.2

Fuel supply tanks shall be constructed of corrosion-resistant metal or of metal having a corrosion-resistant finish or coating.

6-4.2.1 Pressurized liquid fuel tanks that are integral with an appliance shall withstand an internal pressure of four times the relief valve setting or 200 psig (1400 kPa gauge), whichever is greater. The tanks shall be shielded or insulated so that, under continuous operation at maximum heat, the pressure in the tank shall not exceed 50 percent of the relief valve setting. The complete system shall be tested up to the pressure of the relief valve setting.

6-4.2.2 Pressure tanks for remote installation shall be able to withstand a test pressure of at least 100 psig (700 kPa gauge) or twice the appliance relief valve setting, whichever is greater. The tanks shall be secured rigidly in an accessible location, allowing convenient filling and pump operation.

6-4.2.3 Gravity tanks installed in the compartment with the appliance shall be located or shielded so that, when installed and under continuous operation at maximum heat output, the fuel temperature shall not rise more than 25°F (–4°C) above the compartment temperature.

6-4.2.4 No gravity tank shall have a capacity exceeding 2.1 gal (8 L). Tanks of larger capacity shall meet the requirements of Section 5-3 and shall be capable of withstanding a pressure of 3 psig (21 kPa gauge).

6-4.2.5 Nonintegral gravity tanks shall have provisions for filling and venting at a distance of at least 39 in. (1 m) from open flame unless separated by a vapor-tight partition or bulkhead.

6-4.2.6 A readily accessible shutoff valve, not integral with the appliance, shall be located near liquid fuel gravity tanks and at or on all remote pressure fuel supply tanks. The valve shall close against fuel flow and shall indicate clearly the closed and open positions.

6-4.2.7 Liquid fuel supply lines from remote tanks shall be installed as a continuous run from the shutoff valve at the tank to the appliance or to the flexible section located immediately before a gimbaled stove.

6-4.2.7.1 Flexible liquid fuel supply hose sections shall be compatible with the fuel used.

6-4.2.8* The fill openings for remote fuel tanks shall be identified to indicate the type of fuel to be used with the system. The word “fuel” shall not be used alone.

6-4.2.9 In diesel fuel or other liquid-fuel burning appliances having remote gravity tanks, provisions shall be made to relieve any excess pressure in the fuel line between the tank shutoff valve and the burner valve.

6-4.2.10 Liquid-fuel priming pans or troughs shall be secured to the burner or generator so that their mutual function is maintained.

6-4.2.11 A liquidtight, nonflammable drip pan at least $^{3}/_{4}$ in. (19 mm) deep shall be provided below all burners and shall be readily accessible for cleaning.

6-4.2.12 Appliances with integral tanks supplying fuel by gravity or pressure shall display a permanently affixed, legible warning sign that provides the following minimum information and instruction:

DANGER
Fire and explosion hazard; severe burns.
Before filling, turn off burners.

6-4.2.13 Pressurized fuel tanks shall be equipped with relief valves.

6-4.2.14 Unpressurized stoves with fuel held in absorbent matter that are designed with a fuel container that is removed for filling shall display a permanently affixed, legible sign that provides the following minimum information and instructions:

DANGER
Fire and explosion hazard; severe burns.
Before filling, turn off all stove burners.
Remove fuel container from stove.
Fill fuel container away from stove.
Follow filling instructions provided.

6-4.3

If solidified alcohol is used as stove fuel, the container shall be secured on a fixed base to prevent sliding or overturning due to a sudden roll of the vessel.

6-4.4

Stacks and stoves shall comply with the applicable requirements of Section 6-3.

6-4.5

Sealed combustion chamber heaters that burn fuel oil shall be permitted to be used, provided they are designed to provide complete separation of the combustion system from the atmosphere in the boat. A combustion air inlet and flue gas outlet shall be provided as integral parts of the appliance.

6-4.6

Stove operating controls shall be located to be easily accessible and to minimize possible injury from burners or elements while in use. The operation of controls shall not require reaching over or across burners or heated elements.

6-4.7

Means shall be provided on stove top cooking surfaces to prevent both deep and shallow cooking utensils from sliding across or off the stove.

6-4.8

Oven doors shall be provided with a means to prevent their unintentional opening due to the force of sliding food and utensils.

6-4.9

A permanent, legible warning sign shall be affixed in a conspicuous manner on or adjacent to fuel-burning stoves or ranges and shall provide the following information and instructions:

WARNING
Open-flame cooking appliances consume oxygen, which can cause asphyxiation or death in enclosed areas.
Maintain open ventilation.
Do not use appliances for comfort heating.

6-5* Liquefied Petroleum Gas (LPG) and Compressed Natural Gas (CNG) Systems for Permanently Installed Appliances.

6-5.1

The installation for use and storage of stoves with attached (integral) LPG containers of more than 8 oz (230 g) capacity weight of gas shall be prohibited in accommodation spaces in the boat interior.

6-5.2

LPG and CNG appliances shall be permanently installed.

Exception: Those appliances employing integral butane cylinders containing no more than 8 oz (230 g) of fuel complying with 6-5.11.7.

6-5.3

All components of LPG systems subject to cylinder pressure shall have a rated working pressure of at least 250 psig (1725 kPa gauge); components of CNG systems subject to cylinder pressure shall have a working pressure of at least 133 percent of the maximum fill pressure of the cylinder.

6-5.4 Ignition Protection of Electrical Devices.

On boats equipped with LPG or CNG systems, potential sources of ignition of an electrical nature that can function or cycle on and off automatically without the presence of a person, located below the main deck, shall be provided with ignition protection in accordance with UL 1500, *Standard for Safety Ignition-Protection Test for Marine Products*, if located in compartments containing LPG or CNG appliances, cylinders, fittings, valves, or regulators.

NOTE: For information on external ignition protection of marine electrical devices, see SAE J1171, *Recommended Practice for External Ignition Protection of Marine Electrical Devices.*

Exception No. 1: Accommodation spaces.

Exception No. 2: Open compartments having at least 15 in.^{2} (97 cm^2) of open area per cubic foot of net compartment volume exposed to the open atmosphere outside the craft.

6-5.5

Only systems using cylinders of the vapor withdrawal type shall be permitted. Cylinders designed or installed to admit LPG into any other part of the system shall be prohibited.

6-5.6

With each LPG or CNG system installed on a boat, at least two signs required by 6-1.1 and 6-1.6 shall be provided.

These signs shall include:

(a) The signal word “WARNING.”

(b) The introductory statement “To Avoid Fire and Explosion.”

6-5.6.1 These signs also shall provide information in accordance with the following sample wording and shall include:

(a) An applicable statement: “This system is designed for use with (insert “LPG” or “CNG”) only. Do not connect (insert “CNG” or “LPG”) to this system.”

Exception: This statement shall not be required on the sign at the container.

(b) The following instructions:

1. Close container valves when boat is unattended and in case of leak or fire.

2. Close all appliance valves before opening container valves.

3. Always apply the source of ignition to burner before opening burner valve.

4. Test system for leakage whenever system is used, when system is serviced, or when container is changed as follows:

With the appliance valves closed and all other valves open, note pressure on the gauge. Close container valve. The pressure shall remain constant for at least 5 minutes. If pressure drops, locate leakage by application of soapy water solution at all connections. Repeat test for each container in multicontainer systems. NEVER USE FLAME TO CHECK FOR LEAKS. NEVER USE SOAP CONTAINING AMMONIA.

NOTE: If a leak detection device is installed, these instructions shall be permitted to be modified as appropriate.

5. Mark container locker for storage of (insert “LPG” or “CNG”) containers only.

6. Keep valves closed and plugged on empty or unconnected containers.

Exception: This statement shall not be required on the sign at the appliance.

6-5.6.2 On boats that have gasoline engines, the sign also shall include at least the following information and instruction:

WARNING
Avoid fire or explosion.
Open-flame appliances can ignite gasoline vapor, causing fire or explosion.
Turn off all open flame appliances while fueling.

6-5.6.3 The required warning signs shall be installed in plainly visible locations on the outside of each container enclosure and adjacent to each consuming appliance.

6-5.7 Containers.

6-5.7.1 Containers shall be constructed, tested, marked, maintained, requalified for continued service, and refilled in accordance with:

(a) The regulations of the U.S. Department of Transportation for containers in LPG or CNG service; or

(b) Equivalent specifications or regulations determined by the authority having jurisdiction.

6-5.7.2 Containers shall be withdrawn from service when they leak, when corrosion, denting, bulging, or other evidence of rough usage exists to the extent that the container has been weakened, or when exposed to fire.

6-5.8 Container Valves and Safety Relief Devices.

6-5.8.1 Each container shall have a manually operated shutoff valve installed directly into the container outlet opening that can be operated without the use of tools.

Exception: Nonrefillable containers.

6-5.8.2 In addition to the valve required by 6-5.8.1, a readily accessible manual or electrically operated (solenoid) shutoff valve shall be located in the low- or high-pressure line at the fuel supply. The valve or its control shall be operable from within the vicinity of the appliance(s). If the cylinder valve is readily accessible from within the vicinity of the appliance, the shutoff valve on the supply line shall not be required. The location of the shutoff valve or control shall not require reaching across flame or heat-generating surfaces for operation.

6-5.8.3 All containers shall be provided with safety relief devices as required by U.S. Department of Transportation regulations or equivalent regulations.

6-5.8.4 LPG container valves and safety relief devices shall have direct connection with the vapor space of the cylinder.

6-5.8.5 In addition to the valve required at the cylinder, a multiple cylinder system shall be provided with a manual positive shutoff valve or automatic check valve at the cylinder manifold such that each cylinder shall be isolated from the pressure feedback from other cylinders.

6-5.8.6 All relief valves shall discharge to the open atmosphere at a point at least 2 ft (0.6 m) from any opening to a cabin or hull interior or from an engine exhaust terminus.

6-5.8.7 Valve outlets on containers shall be equipped with a plug or cap for thread protection and to keep out foreign material. This plug or cap shall be in place whenever the container is not connected for use, and the valve shall be kept tightly closed.

6-5.9 Reducing Regulators.

6-5.9.1 Each system shall be provided with a pressure-regulating device, specifically designed for the type of gas being used and so adjusted as to deliver gas to the distribution piping at a pressure not to exceed 14 in. (36 cm) water column, approximately 0.735 psig (5.0 kPa gauge) for LPG systems, or 6 in. (15 cm) water column, approximately 0.22 psig (1.5 kPa gauge) for CNG systems.

6-5.9.2 A low-pressure relief valve shall be integral with each regulator. It shall discharge at between 1.7 and 3 times the delivery pressure of the regulator.

6-5.9.3 The relief valve vent outlet shall be located and designed to prevent water from entering the discharge system.

6-5.9.4* Each reducing regulator shall be fitted with a pressure gauge on the high-pressure side. A leak detector shall be permitted to be used in addition to the gauge.

6-5.9.5 Each CNG system shall be supplied with a high-flow check valve located on the container pressure side of the regulating device. The high-flow check valve shall actuate and control gas flow through the vent or vent systems to the atmosphere in the event of regulator malfunction and shall maintain this gas flow within designed pressure limits of the vent system. Relief high-flow restrictor vent outlets shall conform to the requirements of 6-5.8.6.

6-5.9.6 CNG pressure regulators shall be connected directly to the cylinder shutoff valve, using one CGA series 350 connection.

6-5.10 Piping, Hose, and Fittings — LPG and CNG Distribution Systems.

6-5.10.1 Piping. Low-pressure distribution piping between the regulator and appliances shall be galvanically compatible for a marine environment and shall be as specified below:

(a) In LPG systems, piping shall be either copper tubing of standard Type K or Type L, or equivalent, with a minimum wall thickness of at least 0.032 in. (0.8 mm) nominal.

(b) In CNG systems, piping shall be of internally tinned copper tubing of standard Type K or Type L, or equivalent, with a minimum wall thickness of at least 0.032 in. (0.8 mm) nominal.

6-5.10.2 Flexible Hose.

6-5.10.2.1 Hose Specifications.

(a) LPG flexible distribution hose shall meet the requirements of UL 21, *Standard for Safety LP-Gas Hose*.

(b) CNG flexible hose shall meet the requirements of NFPA 52, *Standard for Compressed Natural Gas (CNG) Vehicular Fuel Systems*.

6-5.10.2.2 In both LPG and CNG systems, flexible hose shall be labeled for the fuel being used.

6-5.10.3 Connecting fittings shall be accessible. Metallic connections, if soldered, shall be soldered or brazed with a material having a melting point exceeding 840°F (450°C).

6-5.10.4 Distribution lines shall be protected from physical damage and shall be accessible for inspection.

6-5.10.4.1 Lines shall be secured against vibration.

6-5.10.4.2 Lines shall be protected from abrasion wherever they pass through decks or bulkheads.

6-5.10.4.3 Each appliance shall be served by a separate low-pressure regulated supply line, which shall originate inside the locker or protective enclosure.

6-5.10.4.4 Flexible supply hose shall have permanently attached end fittings, such as a swaged sleeve or a sleeve and threaded insert.

6-5.10.5 Metal tube or piping shall be connected by means of flare fittings or other fittings designed for resistance to loosening due to vibration or movement. Metal-to-metal compression sleeve-type fittings shall not be used.

6-5.10.6 Flexible hose sections connecting appliances to their supply shall be nonmetallic. Flexible metallic connectors shall not be used.

6-5.10.7 A flexible hose section shall be installed to allow the free swing of gimbaled stoves without stress to end fittings at expected extremes of travel.

6-5.10.8 Fuel supply lines shall be continuous lengths of tubing, piping, or hose from the regulating device, solenoid valve or leak detector (if installed), or manifold to the appliance.

Exception: Flexible hose installed to connect tube or piping to a device.

6-5.10.9 Metallic fuel supply lines shall not be used for electrical grounding or bonding.

6-5.11 Appliances.

6-5.11.1 Appliances with automatic igniters for burner ignition are prohibited.

Exception: Appliances with sealed combustion chambers.

6-5.11.2 All gas-fueled appliances shall incorporate a flame failure device on each burner or oven control flame to prevent gas flow if flame is not present.

Exception: Stoves with integral gas cylinders not exceeding 8 oz (230 g) capacity.

6-5.11.3 Cabin space heaters, water heaters, gas-fueled refrigerators, and air conditioners shall be of the sealed combustion chamber type, designed to provide complete separation of the combustion system from the atmosphere in the boat. A combustion air inlet and flue gas outlet shall be provided as integral parts of the appliance.

6-5.11.4 Burner controls shall be equipped or designed to provide a push-turn or other two-phase operation when moved from the "off" position to the "on" position.

6-5.11.5 Cooking appliances shall meet the combustion requirements of ANSI Z21.57, *Recreational Vehicle Cooking Gas Appliances*.

6-5.11.6 A permanent, legible sign shall be affixed in a conspicuous location on or adjacent to appliances not having sealed combustion chambers that shall include the following information and instruction:

WARNING
Open-flame appliances consume oxygen.
Lack of oxygen can cause asphyxiation or death.
Maintain open ventilation when appliance is in use.

6-5.11.7 Means shall be provided on stove top cooking surfaces to prevent both deep and shallow cooking utensils from sliding across or off the stove at boat pitch or roll up to 30 degrees horizontal in any direction.

6-5.11.8 Cooking Equipment with Integral Fuel Cylinders.

6-5.11.8.1 Printed instructions for proper installation, operation, fuel storage, refueling, and maintenance shall be provided with each stove.

6-5.11.8.2 Fuel cylinders with 8 oz (230 g) maximum capacity shall be DOT approved 2P/2Q cylinders with rim vent release.

6-5.11.8.3 Where used in the boat interior, stoves shall be secured in a designated location with a positive means of mechanical retention. The installation shall meet the requirements of Section 6-2.

6-5.11.8.4 A means shall be provided for storing all unattached fuel cylinders in a protected, self-draining location on the exterior of the boat where vapors can flow overboard only.

6-5.11.8.5 The appliance shall have a label to indicate the location of the device relative to all combustible surfaces, meeting the requirements of Section 6-2. The label shall identify the type of fuel to be used with the appliance.

6-5.12 Location and Installation.

6-5.12.1 Containers, regulating devices, and safety equipment shall be:

(a) Rigidly secured;

(b) Readily accessible for operation of valves and testing for leakage; and

(c) Protected by a dedicated locker.

Exception: Containers located on open decks such that escaping vapor cannot accumulate in a cockpit or enclosed spaces, provided regulators, tank valves, and fittings are protected against mechanical damage by a vented housing, shield, or guard.

6-5.12.1.1 A protective dedicated locker shall be:

(a) Located above the waterline;

(b) Vapor-tight to the hull interior;

(c) Provided with a means to latch its cover;

(d) Vented to the atmosphere; and

(e) Located so that, with its cover open or closed, escaping vapor cannot reach the bilges, machinery spaces, accommodations, or other enclosed spaces.

6-5.12.1.2 Venting of LPG container lockers shall be from the bottom by means of a vent pipe of at least $^1/_2$ in. (13 mm) internal diameter that shall lead outboard, without pockets that can trap water, passing through the hull above the waterline at a point lower than the locker bottom, that is at least 2 ft (0.6 m) distant from, and not directly above, any hull opening, including the engine exhaust.

6-5.12.1.3 Compartments and lockers in which CNG cylinders are stored shall have a ventilation opening located above the level of the cylinder of at least $^1/_2$ in. (13 mm) internal diameter.

6-5.12.2 Installation of gas equipment in lockers or housing shall be such that, when the means of access to the lockers or housing is open, the container valves can be conveniently and quickly operated and the system pressure gauge dials are fully visible.

6-5.12.3 Lockers or housings shall not be used for storage of any other equipment, nor shall quick access to the gas system be obstructed in any way.

6-5.12.4 Provisions for storage of unconnected reserve containers, filled or empty, shall be the same as those for containers in use.

6-5.12.5 After installation, distribution tubing shall be tested prior to its connection to the regulator and appliance using an air pressure of not less than 5 psig (34.5 kPa gauge) above ambient. The container valve shall be checked for leakage at its outlet and at its connection to the container by application of liquid detergent or soapy water solution prior to connection of the system. After these tests and when appliances and high-pressure equipment have been connected, the entire system shall be subjected to the following test:

(a) With appliance valves closed, solenoid valve or master shutoff valve at the appliance open, and one container valve open, note the pressure on the gauge.

(b) Close the container valve.

(c) The pressure shall remain constant for at least 5 minutes.

(d) If the pressure drops, locate the leakage by application of soapy water solution at all connections.

(e) Never use flame to check for leaks.

NOTE: Avoid soaps containing ammonia, which cause season cracking at some metal fittings.

6-5.12.6 CNG cylinders and regulating equipment shall be readily accessible and secured against movement.

Exception No. 1: CNG systems where a single container of a capacity not greater than 100 ft^3 (2.8 m^3) at 14.5 psi (1 bar) and 70°F (21°C) is connected to the system. CNG containers of a capacity greater than 100 ft^3 (2.8 m^3) shall be installed in accordance with the same requirements as LPG containers.

Exception No. 2: Lockers required to be vented as in 6-5.12.1.3.

6-5.12.7 CNG cylinders shall not be installed in compartments containing an internal combustion engine.

6-5.12.8 CNG cylinder storage compartments shall not have openings that communicate with the engine space above the level of the pressure regulator.

6-6 Heating Equipment.

6-6.1 Service Water Heating Units and Cabin Heaters.

6-6.1.1 Vent stacks shall lead to the atmosphere and shall be equipped with an effective device for preventing flame extinguishment or flareback from backdraft and entrance of rain or spray.

6-6.1.2 Dampers shall not be installed in vent stacks.

6-7 Auxiliary Appliances.

6-7.1 Lamps.

6-7.1.1 Gasoline shall not be used for fuel.

6-7.1.2 Oil lamps shall have metal bodies and shall be hung in gimbals.

6-7.1.3 Oil lamps shall not be located directly over galley stoves or heating units.

6-7.1.4 Metal shields shall be secured above chimneys.

6-8 Electric Stoves.

6-8.1

Electric stoves shall meet the requirements of UL 858, *Standard for Safety Household Electric Ranges*.

6-8.2

Electric stoves equipped with a lid or cover shall incorporate an automatic power disconnect switch that turns off all surface burners when the lid or cover is lowered over the heating elements.

6-8.3

Electric stoves shall have a light indicating when one or more heating elements are energized.

6-9 Installation of Electric Stoves.

Electric stoves shall be installed in accordance with the manufacturer's instructions.

Chapter 7 Electrical Systems Under 50 Volts

7-1 General.

The standards and practices of this chapter establish requirements for the design and installation of direct current (DC) electrical systems on boats that operate at potentials of 50 volts or less.

Exception: Any wire permanently attached to an outboard engine and extending not more than 72 in. (183 cm) from the outboard engine.

7-2 Requirements — General.

7-2.1 Two-Wire System.

All DC electrical distribution systems shall be of the two-wire type and shall use insulated conductors. The feed and return wires shall run together where the wiring is routed near compasses or other magnetically sensitive equipment. See Diagrams 7-2.1(a) and 7-2.1(b).

Exception: See Section 7-11.

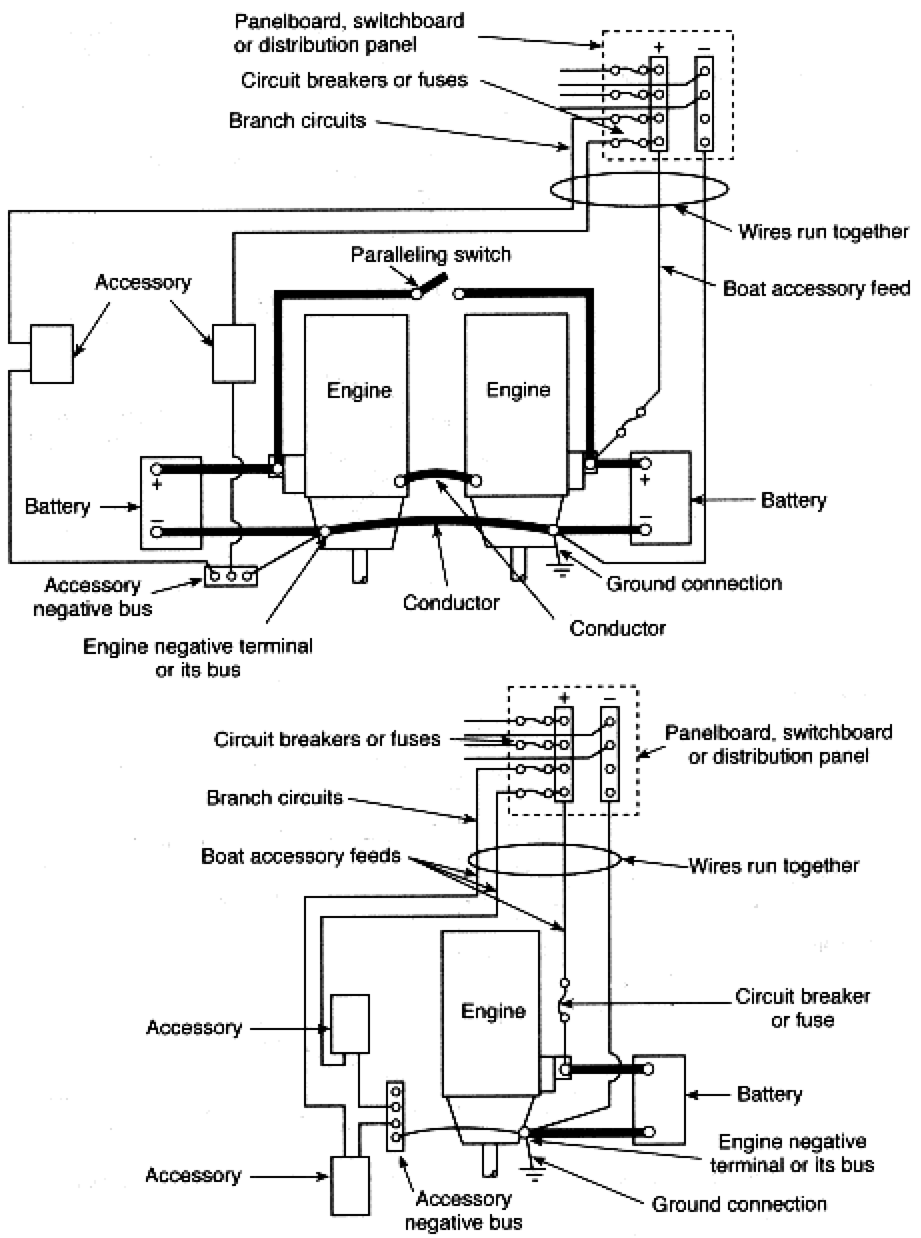


Diagram 7-2.1(a) Typical inboard DC grounding systems.

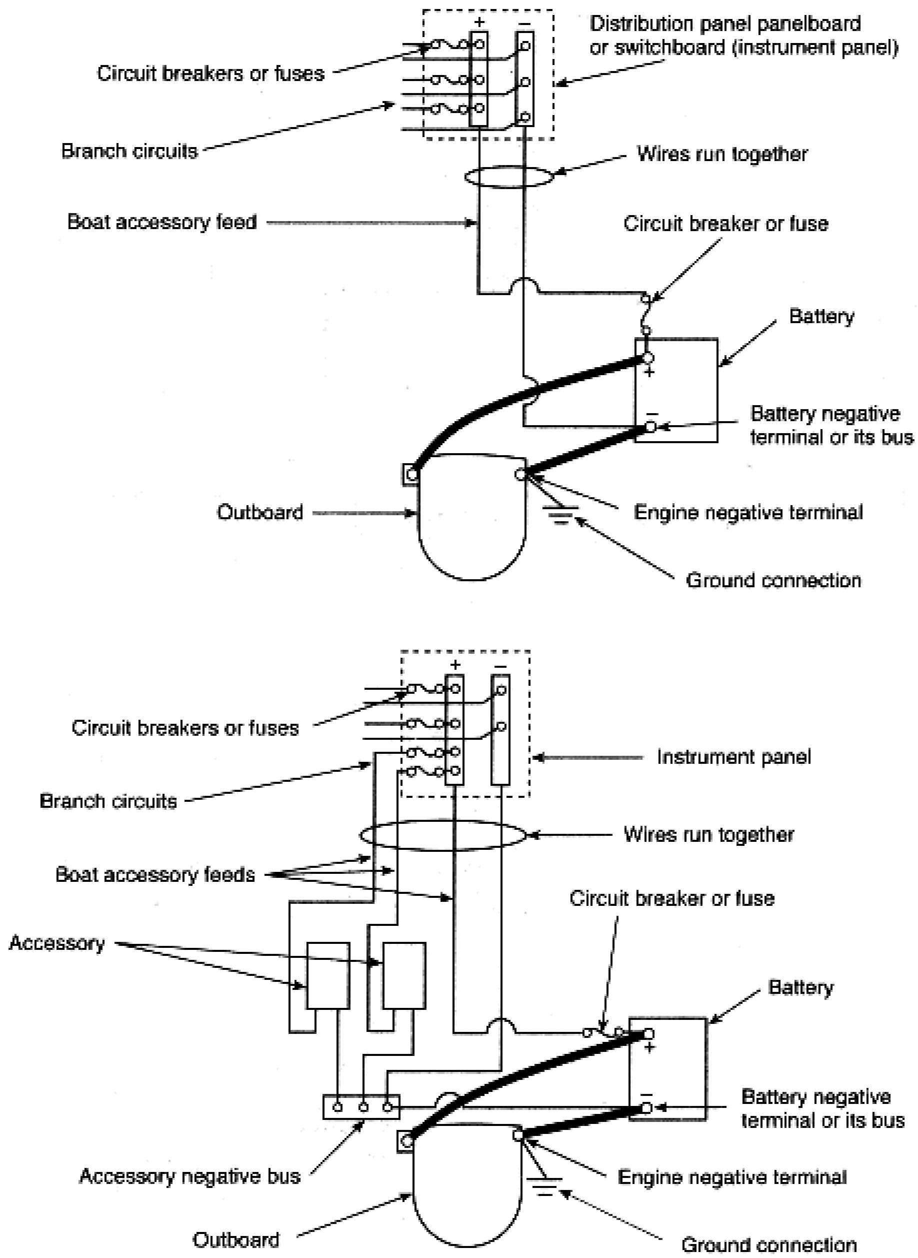


Diagram 7-2.1(b) Typical outboard DC grounding systems.

7-2.2 Return Circuit.

A metal hull, bonding conductor, or grounding conductor shall not be used as a return circuit.
Exception: See Section 7-11.

7-2.3 Grounded Systems.

If one side of a two-wire DC system is connected to ground, it shall be the negative side, and the system shall be polarized.

7-2.4 Multiple Engine Installation.

If a boat has more than one inboard propulsion or auxiliary engine, grounded cranking motor circuits shall be connected to each other by a common conductor that can carry the starting current of each of the grounded cranking motor circuits. Outboard engines shall be connected at the battery negatives.

7-2.5 Crossover (Parallel) Cranking Motor Circuits.

In multiple inboard engine installations (including auxiliary generators) with crossover (parallel) cranking motors systems, the engines shall be connected together with a cable large enough to carry the cranking motor current of the largest cranking motor. This cable and its terminations shall be in addition to and independent of any other electrical connections to the engines, including those required by 7-2.4.

Exception No. 1: Installations using ungrounded DC electrical systems.

Exception No. 2: Outboard engines.

7-3 Batteries.

7-3.1

Batteries shall be accessible for inspection and maintenance.

7-3.2

Batteries shall not be tapped for voltages other than the total voltage of all the cells comprising the battery.

7-3.3

A vent system or other means shall be provided to allow the discharge from the boat of hydrogen gas released by the battery. Battery boxes with a cover that forms a pocket over the battery shall be vented.

NOTE: These provisions also apply to installations of sealed batteries.

7-3.4

Batteries shall be secured to provide immobilization to the extent practicable.

NOTE: For information on securing batteries, see Title 33, *Code of Federal Regulations*, Part 183.

7-3.5

Batteries shall be located in a liquid-tight tray or battery box of adequate capacity to retain normal spillage or boilover of electrolytes. The tray shall be constructed of or lined with materials resistant to deterioration by the electrolytes.

7-3.6

A nonconductive, perforated cover or other means shall be provided to prevent accidental shorting of the ungrounded battery terminals and cell connectors.

7-3.7

Batteries with metal cell containers shall be assembled in nonconductive trays having insulated cell supports. Provision shall be made to prevent other conductive materials that could cause a short circuit from contacting cell containers.

7-3.8

Each metallic fuel line and fuel system component located within 12 in. (30 cm) and above the horizontal plane of the battery top surface, as installed, shall be shielded with dielectric material.

NOTE: For information on shielding with dielectric material, see Title 33, *Code of Federal Regulations*, Part 183.

7-3.9

The positive terminal of each battery shall be identified by the letters "POS" or "P" or by the symbol "+," marked on the terminal or on the battery case near the terminal.

7-3.10

Battery terminal connections shall not depend on spring tension.

7-4 Power Distribution System Negative Connections.

7-4.1

The negative terminal of the battery and the negative side of the electrical power distribution system shall be connected to the engine negative terminal or its bus.

Exception: Outboard boats shall be permitted to use the battery negative terminal.

7-4.2 Separate Negative Bus.

A separate negative bus shall be permitted to be created off the engine, or, in the case of outboard boats, off the battery, provided:

(a) All accessories connected to the bus are branch circuits from the same panelboard.

(b) The negative bus, the negative bus return conductors, and their terminals and connections shall have an ampacity equal to the panelboard feeder.

(c) The negative return conductor from the panelboard feeding the branch circuits that use the separate negative bus shall be equal in size to the positive feeder to the panelboard.

7-5 Continuously Energized Parts.

Continuously energized parts, such as the positive battery terminal and both ends of all wires connected thereto, shall be protected by boots, sleeving, or other insulation to prevent an accidental short circuit.

Exception: Circuits provided with overcurrent protection in accordance with 7-9.6.

7-6 Marking.

7-6.1 Marking.

Switches and electrical controls shall be marked to indicate their use.

Exception: A switch or electrical control whose purpose is obvious and whose erroneous operation cannot cause a hazardous condition shall not be required to be marked.

7-6.2 Marking of Equipment.

Electrical equipment such as an engine shall be marked or identified to indicate:

(a) The manufacturer.

(b) The identifying number.

(c) The DC electrical rating in volts. The rated current of electrical equipment shall be available and shall be permitted to be marked on the device.

(d) The terminal polarity or identification, if necessary to operation.

(e) The ignition protection, if applicable.

Exception: If part of an identified assembly.

7-7 Ambient Temperature.

The ambient temperature of machinery spaces shall be considered to be 122°F (50°C), and the ambient temperature of all other spaces shall be considered to be 86°F (30°C).

7-8 Ignition Sources.

7-8.1

Potential sources of ignition located in gasoline-powered machinery and fuel tank spaces, and in spaces containing joints, fittings, or other connections between components of the gasoline fuel system, shall be ignition-protected, unless the electrical component is isolated from a gasoline fuel source as shown in Figures 7-8.1(a) through (g).

Exception: Boats using diesel fuel as the only fuel.

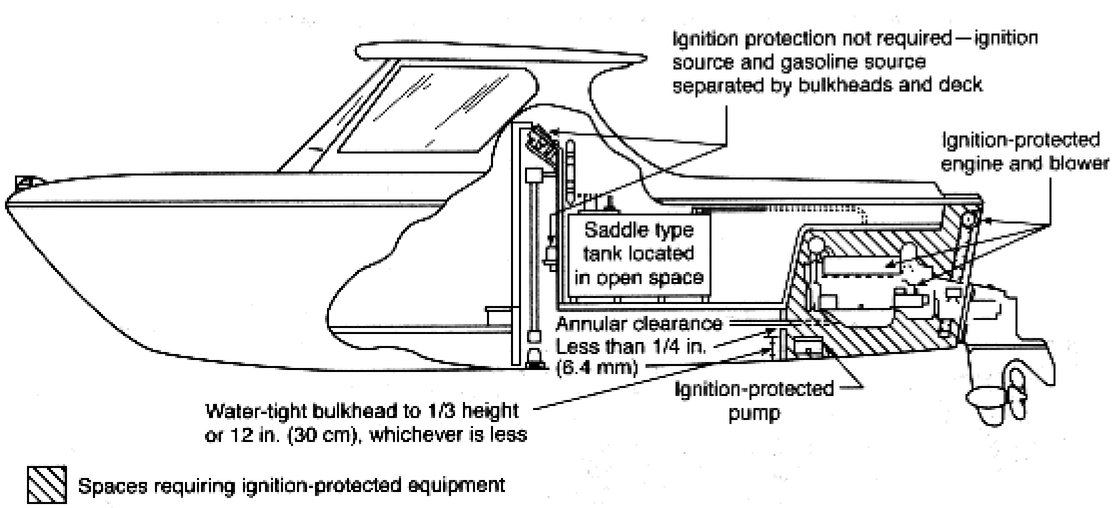


Figure 7-8.1(a) Location of ignition-protected equipment on gasoline-powered inboard engine boats with bulkhead and deck separations.

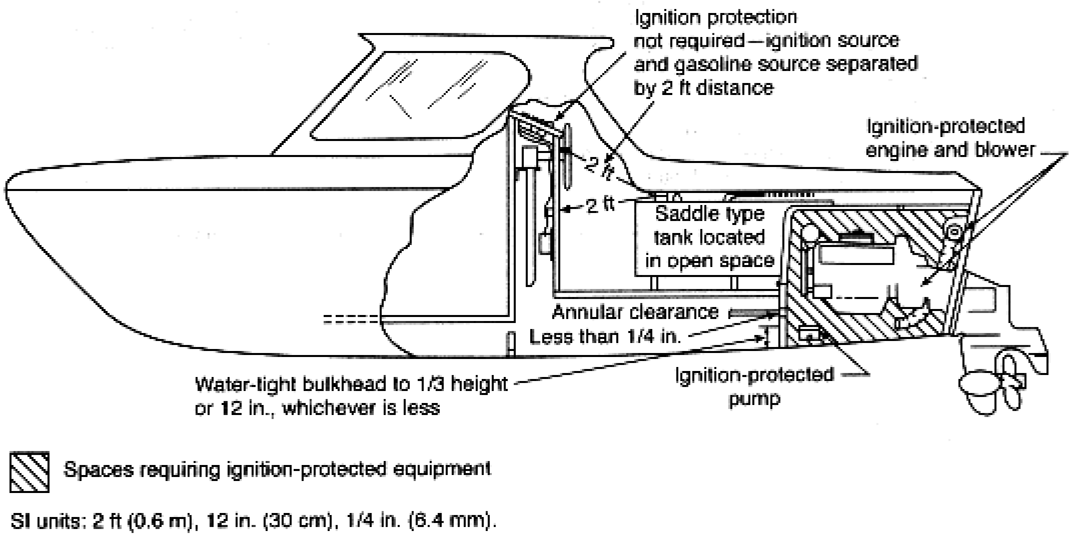


Figure 7-8.1(b) Location of ignition-protected equipment on gasoline-powered inboard engine boats with ignition source and gasoline source separated by 2 ft (0.6 m) distance.

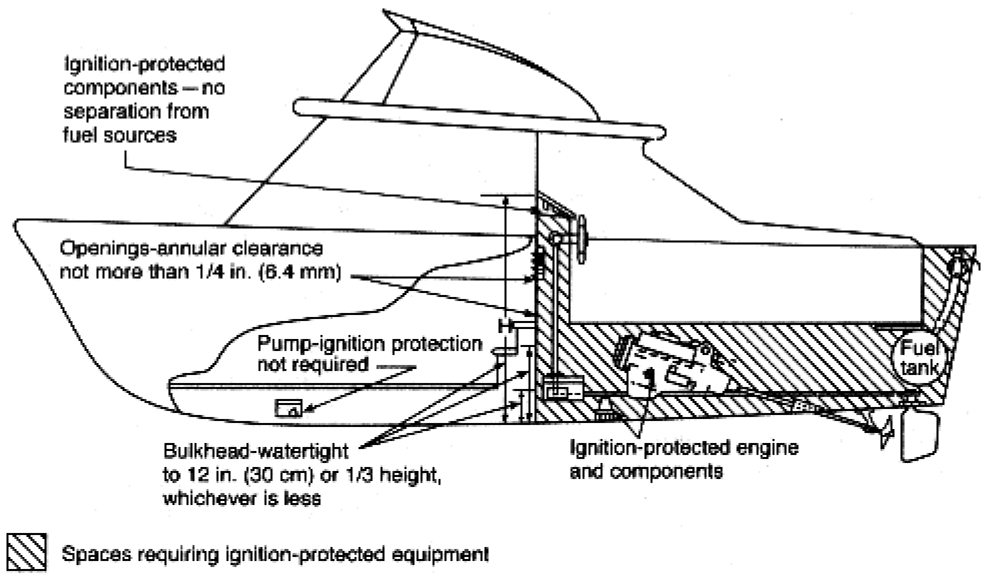


Figure 7-8.1(c) Ignition protection in space containing gasoline engine and fuel line fittings.

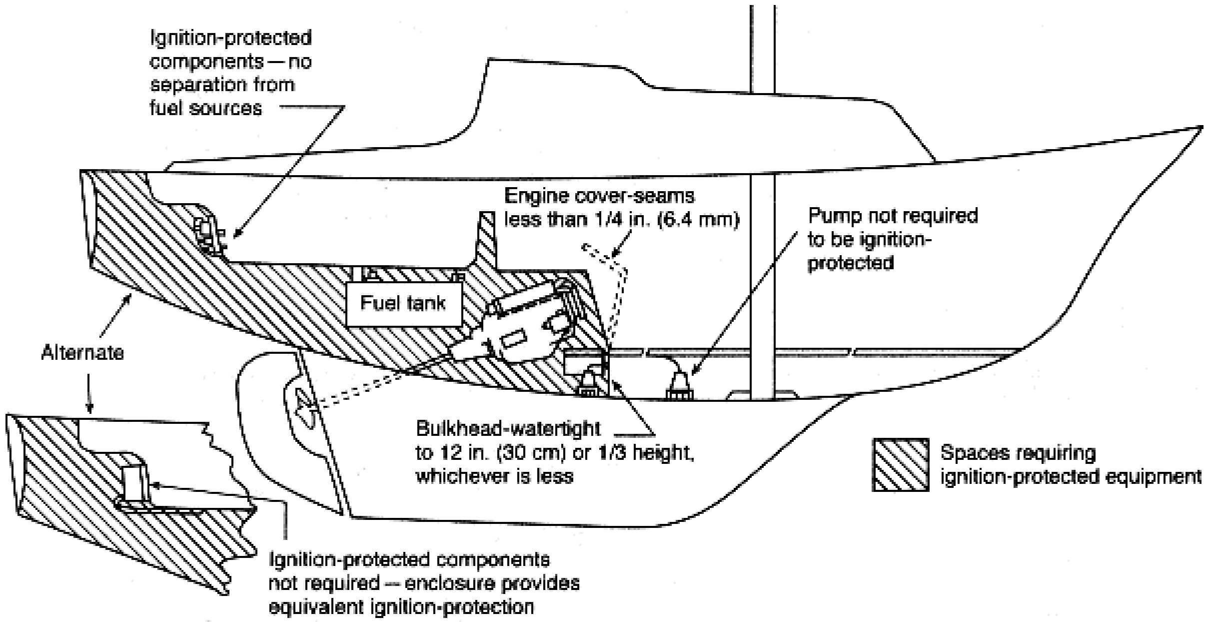


Figure 7-8.1(d) Ignition protection in space containing gasoline engine and fuel line fittings on sailboats.

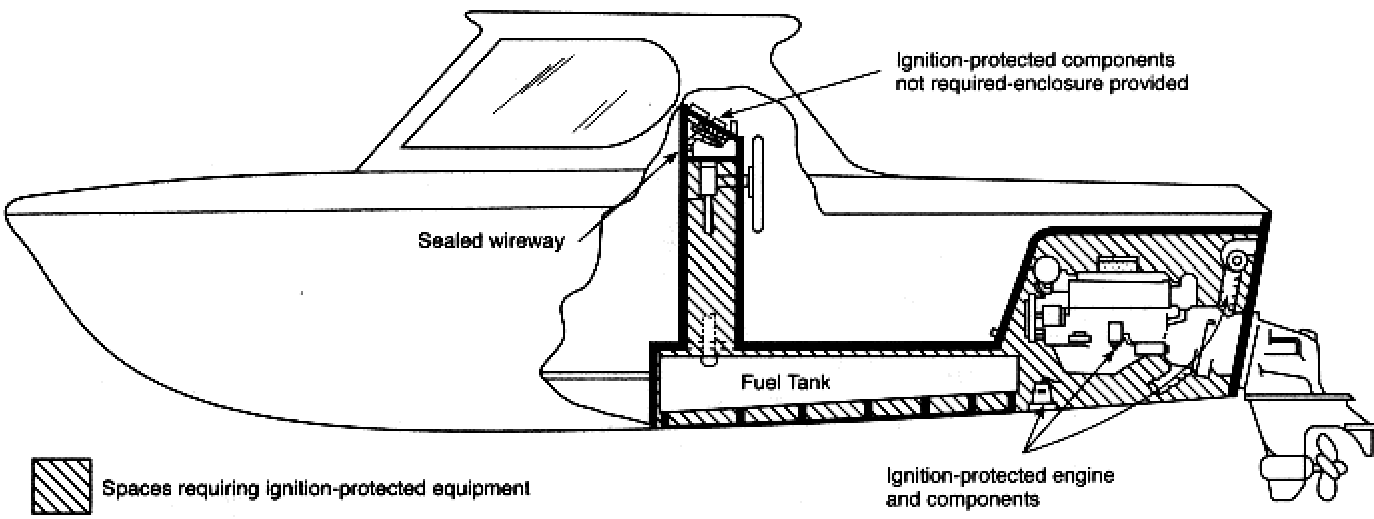


Figure 7-8.1(e) Ignition protection in space containing gasoline engines and fuel line fittings.

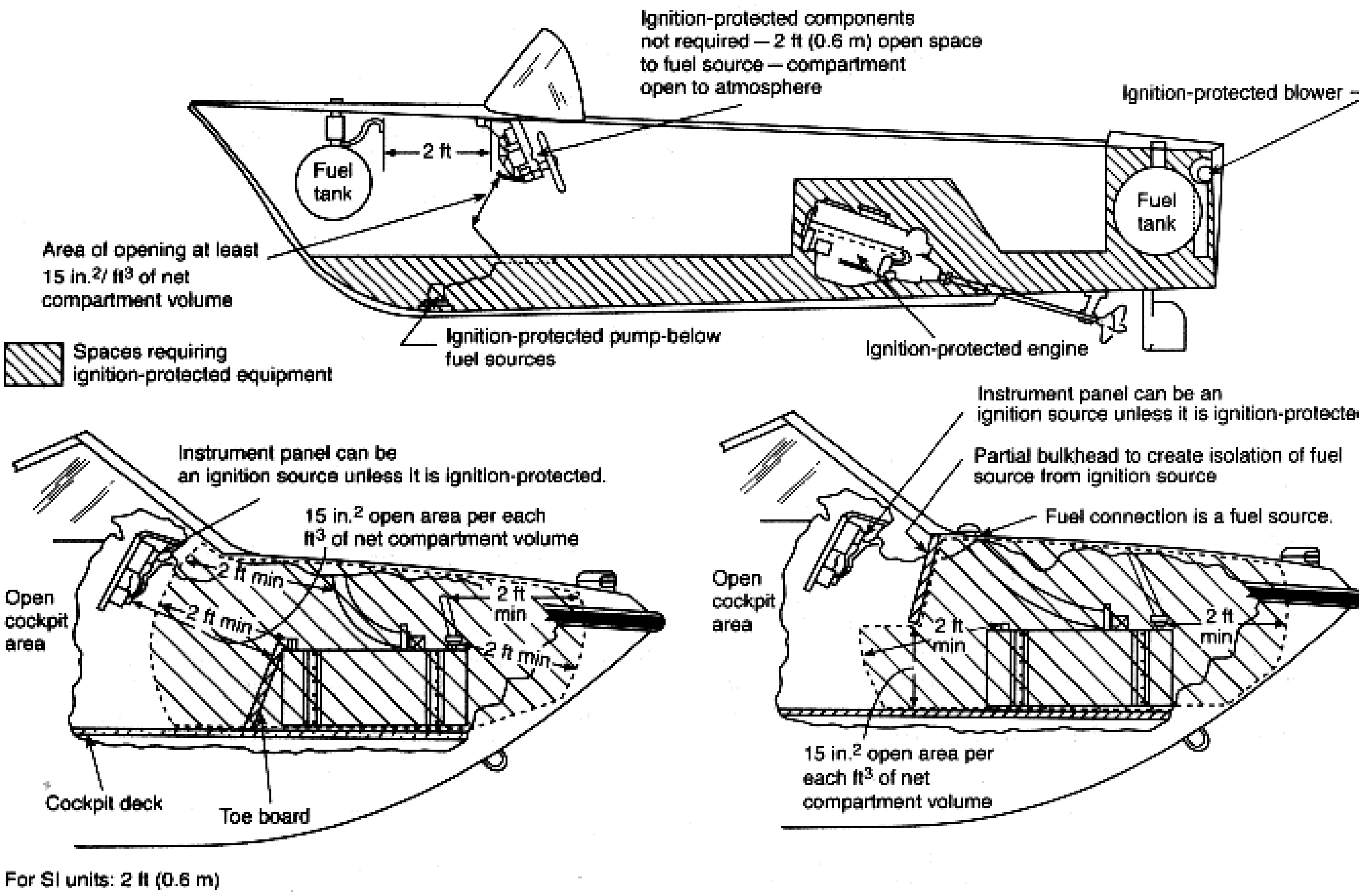


Figure 7-8.1(f) Ignition protection with no bulkhead.

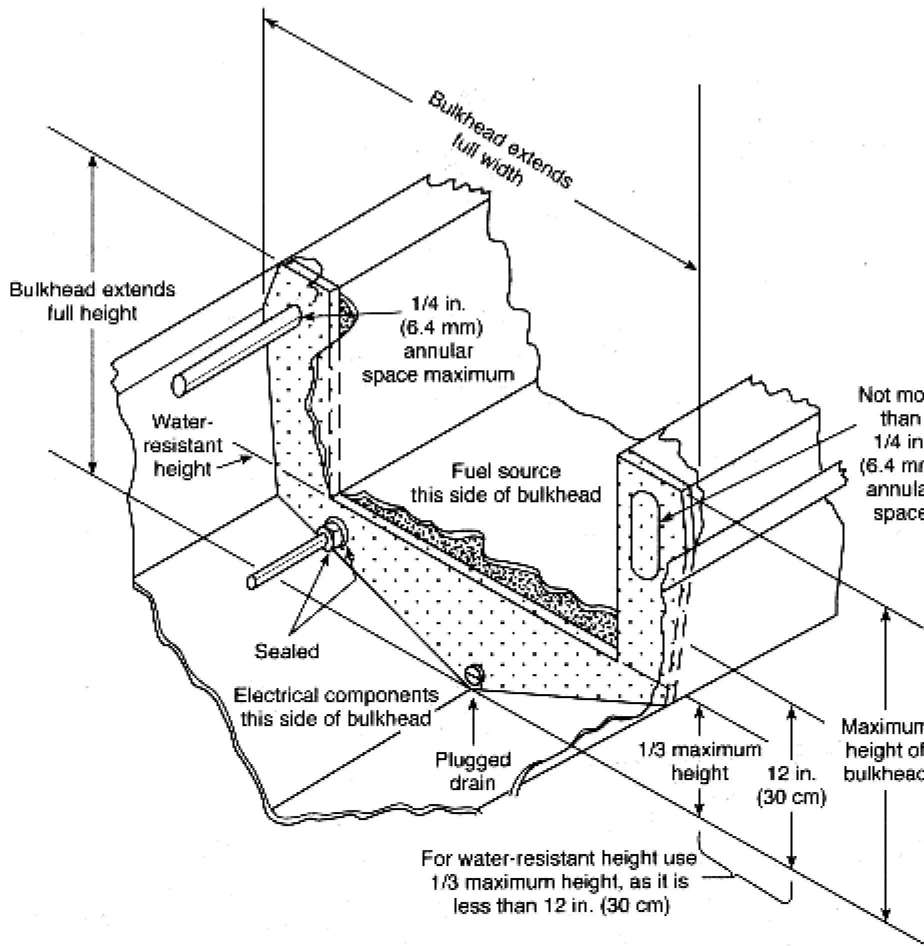


Figure 7-8.1(g) Cutaway illustration showing separation of electrical components from gasoline fuel source.

7-8.2

An electrical component shall be considered to be isolated from a gasoline fuel source, provided:

(a) The distance between the electrical component and the fuel source is at least 2 ft (0.6 m) and the space is open to the atmosphere.

(b) The electrical component is located:

1. Below the gasoline fuel source and a means is provided to prevent gasoline fuel and gasoline fuel vapors that can leak from the gasoline fuel sources from exposure to the electrical component; or

2. Above the gasoline fuel source and a deck or other enclosure is located between the ignition source and the gasoline fuel source; or

(c) A bulkhead is provided between the fuel source and ignition source that:

1. Separates the electrical component from the fuel source and extends the length of both the vertical and horizontal distances of the open space between the gasoline fuel source and the ignition source; and

2. Resists a water level of 12 in. (30 cm) or of greater than $^{1}/_{3}$ of the maximum height of the bulkhead, whichever is lower, without seepage of more than $^{1}/_{4}$ fl oz (7.4 ml) of fresh water per hour; and

3. Has no opening higher than 12 in. (30 cm) or greater than $^{1}/_{3}$ the maximum height of the bulkhead, whichever is lower, unless the opening is used for the passage of conductors, piping, ventilation ducts, mechanical equipment, and similar items or for doors, hatches, and access panels; and unless the maximum annular space around each item, door, hatch, or access panel is not more than $^{1}/_{4}$ in. (6.4 mm).

7-9 Overcurrent Protection.

7-9.1 Overcurrent Protection Location.

Conductors other than cranking motor conductors shall be provided with overcurrent protection within a distance of 7 in. (18 cm) of the point at which the protection is connected to the source of power measured along the conductor. (*See Diagram 7-9.1*.)

Exception No. 1: Up to 40 in. (102 cm) shall be permitted if the conductor, throughout the required distance, is contained in a sheath or enclosure, such as a junction box, control box, or enclosed panel.

Exception No, 2: If the conductor is connected directly to the battery terminal, the 7-in. (18-cm) distance shall be permitted to be increased to 72 in. (183 cm).

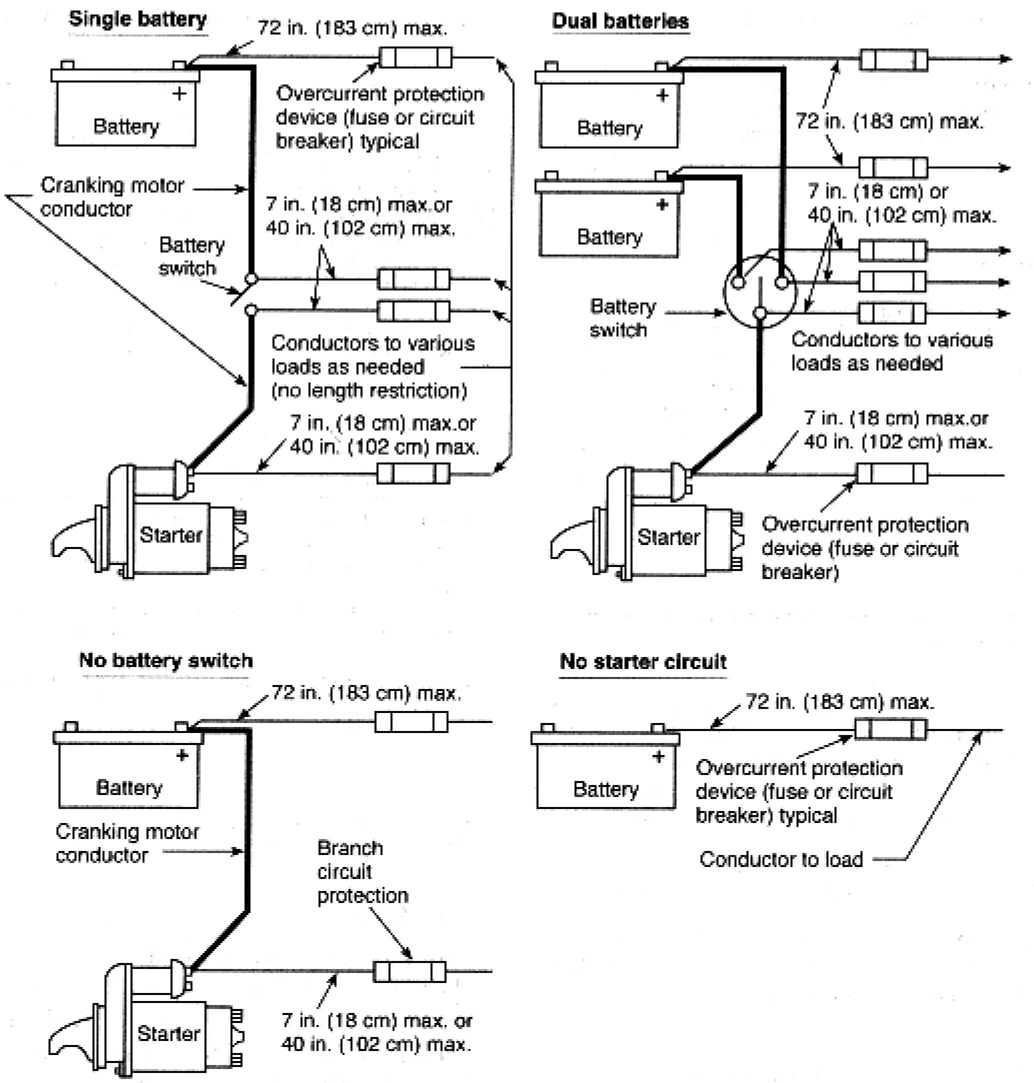


Diagram 7-9.1 Location of overcurrent protection for conductors served by single or dual batteries or without battery switch or starter circuit.

7-9.2 Battery Charging Sources.

Battery charging sources shall comply with the following:

7-9.2.1 Each ungrounded DC conductor that runs from the battery charger or other charging source to a battery or other point of connection to the DC system shall be provided with overcurrent protection within a distance of 7 in. (18 cm) of the point of connection to the DC electrical system or battery.

Exception No. 1: Overcurrent protection shall not be required if the charging source is within 72 in. (183 cm) of the battery measured along the conductor.

Exception No. 2: Overcurrent protection shall not be required if the charging source is within 40 *in. (102 cm) of a point of connection, other than to the battery, and its entire length is contained within a sheath or enclosure, such as a conduit, junction box, control box, or enclosed panel.*

7-9.2.2 Each ungrounded DC output conductor shall be provided with overcurrent protection within the charging source, based on the maximum output.

Exception: Self-limiting devices that are not capable of producing current in excess of the current rating of the connecting conductors shall not require overcurrent protection for the DC output conductors.

7-9.3 *

Motors or Motor-Operated Equipment. Motors and motor-operated equipment, except for engine cranking motors, shall be protected internally at the equipment or by branch-circuit overcurrent devices suitable for motor current. The protection provided shall preclude a fire hazard if the circuit, as installed, is energized for 7 hours under any conditions of overload, including locked rotor.

7-9.4 Resistive Loads.

The rating of overcurrent protection devices used to protect both the conductor and a load other than a DC motor shall not exceed 150 percent of the current-carrying capacity of the conductor being protected.

7-9.5 Branch Circuits.

Each ungrounded conductor of a branch circuit shall be provided with overcurrent protection at the point of connection to the panelboard, unless the main circuit breaker or fuse provides such protection.

7-9.6 Distribution Panels, Panelboards, and Switchboards.

A trip-free circuit breaker or a fuse shall be installed at the source of power for the panelboard. The overcurrent protection shall not be greater than 100 percent of the load capacity of the total load of the panelboard and shall not exceed 100 percent of the current-carrying capacity of the feeders to the panelboard. The protection at the power source shall not be greater than 150 percent of either the supply or return conductor ampacity, unless it also is the distribution panel or switchboard overcurrent protection, in which case it shall not exceed 100 percent of the load capacity. (*See Diagram 7-9.6.*)

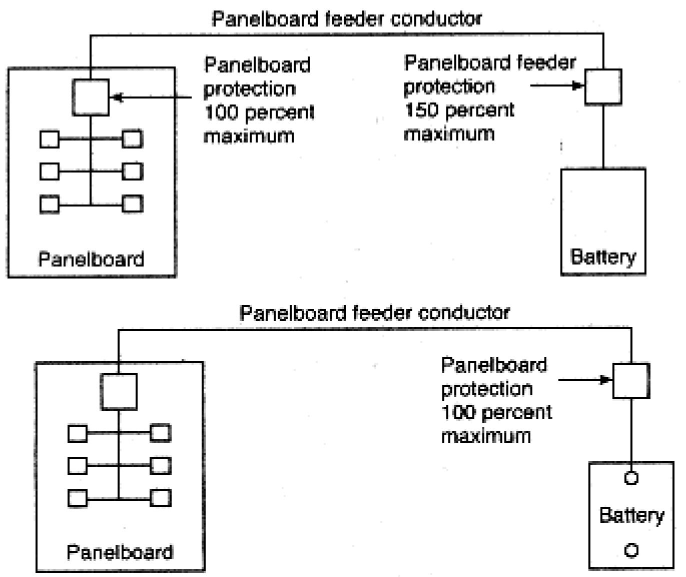


Diagram 7-9.6 Illustration of overcurrent protection for panelboards and panelboard feeder conductors.

7-9.7 Circuit Breakers.

Circuit breakers shall:

(a) Have a DC voltage rating of not less than the nominal system voltage.

(b) Be of the trip-free type.

(c) Be capable of an interrupting capacity in accordance with Table 7-9.7 and shall meet the marine requirements of UL 489, *Standard for Safety Molded-Case Circuit Breakers and Circuit-Breaker Enclosures*, UL 1077, *Standard for Safety Supplementary Protectors for Use in Electrical Equipment*, or UL 1133, *Standard for Safety Boat Circuit Breakers*. Circuit breakers that meet the requirements of UL 1077 shall be permitted to be used as branch circuit breakers if they can interrupt the current specified for branch circuit breakers in Table 7-9.7 alone or in combination with the main circuit breaker.

NOTE: For information on marine circuit breakers, see SAE J1428, *Recommended Practice for Marine Circuit Breakers*.

(d) Meet the requirements of UL 1500, *Standard for Safety Ignition-Protection Test for Marine Products*, at four times their rated current if located in a space that requires ignition protection.

NOTE: For information on external ignition protection of marine electrical devices, see SAE J1171, *Recommended Practice for External Ignition Protection of Marine Electrical Devices*.

Table 7-9.7 Circuit Breaker Minimum Amperage Interrupting Capacity

Cold Cranking Current Rating at °F of Total Connected Battery Capacity	Ampere Interrupting Capacity (A.I.C.) (Amperage Available at Circuit Breaker Terminals) Main Circuit Breaker (Amperes) *(See Note 1)*	Branch Circuit Breaker (Amperes) *(See Note 1)*
12 Volts and 24 Volts		
650 or less	1500	750
651 - 1100	3000	1500
Over 1100	5000	2500
32 Volts		
1250 or less	3000	1500
Over 1250	5000	2500

NOTE 1: The main circuit breaker is considered to be the first breaker(s) in a circuit connected in series with the battery. All subsequent breakers connected in series with a main circuit breaker are considered to be branch circuit breakers.

NOTE 2: Under Battery Council International conversion factors, the following approximate correlations are used for °F:

Cold Cranking Amperes	Ampere Hours (20-hour rating)
630	120
1076	205
1260	240

For the purpose of converting the 20-hour amp/hour rating to approximate cold cranking amps, use a value of 5.25 × the amp/hour rating.

7-9.8 Fuses.

Fuses shall:

(a) Have a DC voltage rating of not less than the nominal system voltage.

(b) Be capable of an interrupting capacity in accordance with Table 7-9.7.

(c) Meet the requirements of UL 1500, *Standard for Safety Ignition-Protection Test for Marine Products,* at four times their rated current if located in a space that requires ignition protection.

NOTE: For information on external ignition protection of marine electrical devices, see SAE J1171, *Recommended Practice for External Ignition Protection of Marine Electrical Devices.*

7-9.9 Integral Overcurrent Protection Devices.

Integral overcurrent protection devices without a manual reset shall be permitted to be used as an integral part of an electrical device, provided the remainder of the circuit is protected by a trip-free circuit protection device(s) or a fuse(s). Integral overcurrent protection shall be sized to protect the accessory in which it is installed.

7-9.10 Pigtails.

Pigtails less than 7 in. (18 cm) in length shall be exempt from overcurrent protection requirements.

7-10 Switches.

7-10.1 Battery Switch Location.

If used, a battery switch shall be mounted as close as practicable to the battery and shall be readily accessible without opening the engine space.

7-10.2

Vessels 26 ft (8 m) and over in overall length shall have an approved master battery switch.

Exception: Automatic bilge pumps shall be permitted to be wired to bypass this switch.

7-10.3 Battery Switch Ratings.

The intermittent rating of a battery switch shall not be less than the maximum cranking current of the largest engine cranking motor that it serves. The continuous rating of a battery switch shall not be less than the total of the ampacities of the main overcurrent protection devices connected to the battery switch.

7-10.4

If single-pole switches are used in branch circuits, they shall be installed in the positive conductor of the circuit.

Exception No. 1: Engine-mounted pressure, vacuum, and temperature-operated switches.

Exception No. 2: Switches such as those used for control of alarm systems.

7-10.5*

Switches shall have voltage ratings of not less than the system voltage and current ratings of the connected load.

7-11 Appliances and Equipment.

7-11.1

Appliances and fixed DC electrical equipment shall be designed so that the current-carrying parts of the device are insulated from all exposed electrically conductive parts.

Exception No. 1: Engine-mounted equipment.

Exception No. 2: The following devices shall be permitted to have their negative conductors connected to exposed electrically conductive parts. The polarity of both the positive and negative connections shall be identified, and these devices shall be mounted only on electrically nonconductive material and shall not be bonded.

1. Communications and audio equipment

2. Electronic navigation equipment

3. Instruments and instrument clusters

4. Cigar lighters

5. Liquid level gauge transmitters (for installation on conductive surfaces)

6. Navigation lights operating at 12 volts or less.

7-11.2 Grounded Liquid Level Gauge Transmitters (Senders).

Grounded liquid level gauge transmitters mounted on metallic tanks or tank plates shall have the transmitter negative return conductor connected directly to the engine negative terminal, its bus, or, for outboard boats, the battery negative terminal. This conductor also shall serve as the static ground or the bonding conductor, or both. If this conductor is used as the tank system bonding conductor, it shall be minimum No. 8 AWG. No other device shall be connected to this conductor.

Exception: Tank fills and vents shall be permitted to be statically grounded to the tank or the tank plate.

7-11.3

Pigtail connections on submersible devices such as submersible bilge pumps shall not be shorter in length than 16 in. (41 cm).

7-12 System Wiring.

7-12.1

Conductors and flexible cords shall have a minimum rating of 50 volts.

7-12.2

The construction of insulated cables and conductors shall conform with the requirements of SAE J1127, *Standard for Battery Cable*, SAE J1128, *Standard for Low Tension Primary Cable*, or UL 1426, *Standard for Safety Electric Cables for Boats*.

NOTE: For information on marine engine wiring, see SAE J378, *Recommended Practice for Marine Engine Wiring*.

7-12.3

Conductors shall be permitted to be selected from the types provided in Table 7-12.3 and Table 8-13.2. The temperature ratings shown assume the routing of wires above bilge water in locations protected from dripping, exposure to weather, spray, and oil.

Table 7-12.3 SAE Conductors

Type	Description	Available Insulation Temp. Rating per SAE J378B
GPT	Thermoplastic insulation, braidless	60°C (140°F) 90°C (194°F) 105°C (221°F)
HDT	Thermoplastic insulation, braidless	60°C (140°F) 90°C (194°F) 105°C (22l°F)
SGT	Thermoplastic insulation, braidless	60°C (140°F) 90°C (194°F) 105°C (221°F)
STS	Thermosetting synthetic rubber insulation, braidless	85°C (185°F) 90°C (194°F)

HTS	Thermosetting synthetic rubber insulation, braidless	85°C (185°F) 90°C (194°F)
SXL	Thermosetting cross-linked polyethylene insulation, braidless	125°C (257°F)

7-12.4

Flexible cords shall conform with NFPA 70, *National Electrical Code*, and shall be selected from the types specified in Table 8-13.3.

7-12.5

Conductors and flexible cords shall be stranded copper according to Table 7-12.5(a) and shall be sized in accordance with Table 7-12.5(b).

Table 7-12.5(a) Conductor Circular Mil (CM) Area and Stranding

Conductor Size	Minimum Acceptable	Minimum Number of Strands	
(AWG)	CM Area*	Type 2**	Type 3***
18	1,537	16	
16	2,336	19	26
14	3,702	19	41
12	5,833	19	65
10	9,343	19	105
8	14,810	19	168
6	25,910	37	266
4	37,360	49	420
2	62,450	127	665
1	77,790	127	836
1/0	98,980	127	1064
2/0	125,100	127	1323
3/0	158,600	259	1666
4/0	205,500	418	2107

*Applies only to systems under 50 volts.

**Conductors with Type 2 stranding, used for central wiring, which is subject to some movement from vibration or minor flexing.

***Conductors with Type 3 stranding, used for any wiring where flexing is involved in normal use.

NOTE: Metric wire sizes are to be used if of equivalent circular mil area. If the circular mil area of the metric conductor is less than that specified, the wire ampacity can be corrected based on the ratio of the circular mil areas.

Table 7-12.5(b) Allowable Amperage of Conductors for Under 50 Volts

	Temperature Rating of Conductor Insulation								
	60°C (140°F)		**75°C (167°F)**		**80°C (176°F)**		**90°C (194°F)**		**105°C (221**
Conductor Size English (metric)	**Outside Engine Spaces**	**Inside Engine Spaces**	**Outside Engine Spaces**	**Inside Engine Spaces**	**Outside Engine Spaces**	**Inside Engine Spaces**	**Outside Engine Spaces**	**Inside Engine Spaces**	**Outside Engine Spaces**
18 (0.8)	10	5.8	10	7.5	15	11.7	20	16.4	20
16 (1)	15	8.7	15	11.3	20	15.6	25	20.5	25
14 (2)	20	11.6	20	15.0	25	19.5	30	24.6	35
12 (3)	25	14.5	25	18.8	35	27.3	40	32.8	45
10 (5)	40	23.2	40	30.0	50	39.0	55	45.1	60
8 (8)	55	31.9	65	48.8	70	54.6	70	57.4	80
6 (13)	80	46.4	95	71.3	100	78.0	100	82.0	120
4 (19)	105	60.9	125	93.8	130	101.4	135	110.7	160
2 (32)	140	81.2	170	127.5	175	136.5	180	147.6	210
1 (40)	165	95.7	195	146.3	210	163.8	210	172.2	245
0 (50)	195	113.1	230	172.5	245	191.1	245	200.9	285
00 (62)	225	130.5	265	198.8	285	222.3	285	233.7	330
000 (81)	260	150.8	310	232.5	330	257.4	330	270.6	385
0000(130)	300	174.0	360	270.0	385	330.3	385	315.7	445

7-12.6

Conductors and flexible cords shall be sized for voltage drop as follows:

(a) Panelboard main feeders — 3 percent

(b) Navigation light circuits — 3 percent

(c) Electronic equipment circuits — 3 percent

(d) Bilge pump, blower, and refrigeration motor circuits — 3 percent

(e) All other noncritical circuits — 10 percent

7-12.7

Conductor sizes shall be permitted to be calculated by means of the following formula based on the voltage drops 3 percent and 10 percent. If the circular mil area is less than the value specified in Table 8-13.4, the next larger size conductor shall be used.

$$CM = \frac{K \times I \times L}{E}$$

Where:

CM = circular mil area of conductor

K = 10.75 (constant representing the mil-foot resistance of copper)

I = load current in amperes

L = length of conductor from the positive power source connection to the electrical device and back to the negative power source connection, measured in feet

E = voltage drop at load in volts (e.g., 12 volt @ 3 percent = 0.36).

7-13 Wiring Installation.

7-13.1

Current-carrying conductors shall be routed as high as practicable above the bilge water level and other areas where water can accumulate.

Exception: Where wiring and connectors are watertight, conductors shall be permitted to be routed through the bilge or other areas where water can accumulate.

7-13.2

Conductors shall be routed as far away as practicable from exhaust pipes and other heat sources. A clearance of at least 2 in. (5 cm) between conductors and water-cooled exhaust components and a clearance of at least 9 in. (23 cm) between conductors and dry exhaust components shall be maintained. This clearance shall be increased to 18 in. (46 cm) where conductors are located directly above a dry exhaust.

Exception No. 1: Wiring on engines.

Exception No. 2: Exhaust temperature sensor wiring.

7-13.3

Battery cables shall not be routed such that they are in contact with metallic fuel system components.

7-13.4

Conductors subject to exposure to physical damage shall be protected by loom, conduit, tape, raceways, or other equivalent protection. The protection shall be self-draining. Conductors passing through bulkheads or structural members shall be protected to minimize insulation damage such as chafing. Conductors also shall be routed clear of sources of chafing such as steering cable and linkages, engine shafts and belts, and throttle connections.

7-13.5

Conductors shall be at least No. 16 gauge.

Exception No. 1: No. 18 gauge conductors shall be permitted to be used if they are included with *other conductors in a sheath and do not extend more than 30 in. (75 cm) outside the sheath.*

Exception No. 2: Conductors contained completely within equipment or enclosures.

7-13.6

Conductors shall be supported for their entire length or, alternatively, shall be secured at least every 18 in. (46 cm) by one of the following methods:

(a) Nonmetallic clamps of a size to hold the conductors firmly in place. Nonmetallic straps or clamps shall not be used over engine(s), moving shafts, other machinery, or passageways if failure can result in a hazardous condition. Conductor material shall be resistant to oil, gasoline, and water and shall not break or crack under flexing within a temperature range of –30°F to 250°F (–34°C to 121°C).

(b) Metal straps or clamps with smooth, rounded edges. That section of the conductor or cable located directly under the strap or clamp shall be protected by means of loom, tape, or other suitable wrapping to prevent injury to the conductor.

Exception No. 1: Battery cables within 36 in. (91 cm) of a battery terminal.

Exception No. 2: Cables attached to outboard motors.

(c) Metal clamps lined with an insulating material resistant to the effects of oil, gasoline, and water.

7-14 Wiring Connections.

7-14.1

Metals used for the terminal studs, nuts, and washers shall be corrosion-resistant and galvanically compatible with the conductor and terminal lug. Aluminum and unplated steel shall not be used for studs, nuts, and washers.

7-14.2

Wiring connections and terminals shall be designed specifically for use with stranded wire.

7-14.3

Each conductor splice joining conductor to conductor, conductor to connectors, and conductor to terminals shall be able to withstand a tensile force equal to at least the value shown in Table 8-14.9 for the smallest conductor size used in the splice for a 1-minute duration without breaking.

7-14.4

Terminal connectors shall be of the ring or captive spade type.

Exception: Friction-type connectors shall be permitted to be used, provided:

1. The voltage drop from terminal to terminal does not exceed 50 millivolts for a 20-ampere current flow; and

2. The connection does not separate if subjected to a 6-lb (26.7-N) tensile force along the axial direction of the connector for 1 minute.

7-14.5

Connections shall be permitted to be made using a set-screw, pressure-type conductor connector, provided a means is used to prevent the set screw from bearing directly on the conductor strands.

7-14.6

Twist-on connectors (wire nuts) shall not be used.

7-14.7*

Solder shall not be the sole means of mechanical connection in any circuit.

Exception No. 1: Battery lugs with a solder contact length of not less than 1.5 times the diameter of the conductor.

Exception No. 2: Conductors contained completely within equipment or enclosures.

7-14.8

Solderless crimp-on connectors shall be attached with the type of crimping tools designed for the connector used.

7-14.9

Each battery terminal post shall not be used for more than one conductor.

Exception No. 1: Connections made for paralleling batteries.

Exception No. 2: One additional conductor shall be permitted where installed in accordance with 7-9.1.

7-14.10

No more than four conductors shall be secured to any terminal stud.

7-14.11

Terminal connectors of the ring and captive spade type shall be the same nominal size as the stud.

7-14.12

Conductors terminating at switchboards, in junction boxes, or at fixtures shall be arranged to provide a length of conductor to relieve tension, to allow for repairs, and to permit multiple conductors to be fanned at terminal studs.

7-14.13

The shanks of terminals shall be protected against accidental shorting by the use of insulation barriers or sleeves.

Exception: Shanks used in grounding systems.

7-15 Receptacles.

7-15.1

Receptacles shall be installed in locations normally not subject to rain, spray, or flooding. If receptacles are used in areas that are subject to such weather exposure, the following requirements shall apply:

(a) They shall be weatherproof if subject to rain or spray.

(b) They shall be watertight if subject to flooding.

7-15.2

Receptacles and matching plugs used on DC systems shall not be interchangeable with receptacles and matching plugs used elsewhere on the boat for AC systems.

7-16 Plug Connectors.

Connectors used in conjunction with harness-type wiring systems shall comply with the following:

(a) Connectors shall incorporate means such as cable clamps, molded connectors, insulation grips, or extended terminal barrels to limit flexing at the connection.

(b) Connectors exposed to weather shall be weatherproof or, if subject to immersion, shall be watertight.

(c) Each terminal in a multiwire connector shall be protected from accidental short-circuiting to adjacent terminals.

(d) Connectors shall have provision for a minimum disengagement force of 6 lb (26.7 N) along the axial direction of the connector for 1 minute.

Chapter 8 * Alternating Current (AC) Electrical Systems on Boats

8-1 General.

The standards and practices of this chapter establish requirements for the design and installation of alternating current (AC) electrical systems on boats operating at frequencies of 50 or 60 hertz and less than 300 volts, including shore-powered systems up to the point of connection to the shore outlet.

8-2 Requirements — General.

8-2.1

The system shall be polarized.

8-2.2

A grounded neutral system shall be required, but the neutral shall be grounded only at the power source, e.g., at the onboard generator, at an inverter, at the secondary of an isolation or polarization transformer, or through the shore power connection. The shore power neutral grounded through the shore power cable shall not be grounded on the boat.

Exception: On systems using an isolation or polarization transformer, the generator or inverter neutral shall be permitted to be the transformer. Secondary neutrals shall be permitted to be grounded at a main grounding bus instead of at the generator inverter or transformer secondaries.

8-2.3

Individual circuits shall not be capable of being energized by more than one source of electrical power at a time. Each shore power inlet or generator shall be a separate source of electrical power.

8-2.4

Energized parts of electrical equipment shall be protected against accidental contact by the use of enclosures or other protective means; these shall not be used for nonelectrical equipment. Access to enclosures containing energized parts of the electrical system shall require the use of hand tools.

8-2.5

The transfer from one power source circuit to another shall be made by a means that opens all current-carrying conductors, including neutrals, before closing the alternate source circuit and that prevents arcover between sources.

8-3 Marking.

8-3.1 Shore Power Inlet Warning.

A permanently mounted, waterproof warning sign shall be located alongside each shore power inlet location on the boat. The warning sign shall include the information shown in the following example.

Marking Example: Shore power inlet warning.

WARNING

To minimize shock and fire hazards:

1. Turn off the boat’s shore connection switch before connecting or disconnecting shore cable.
2. Connect shore power cable at the boat first.
3. If polarity warning indicator is activated, immediately disconnect cable.

Exception: This provision shall not be required if a polarity indicator is not required.

4. Disconnect shore power cable at shore outlet first.
5. Close shore power inlet cover tightly.

DO NOT ALTER SHORE POWER CABLE CONNECTORS.

8-3.2 Marking of Controls.

All switches and controls shall be marked to indicate their use, unless the purpose of the switch is obvious and if operation of the switch cannot under normal operating conditions cause a hazardous condition.

8-3.3 Marking of Equipment.

All electrical equipment shall be marked to indicate:

(a) The manufacturer’s identification.

(b) The model number.

(c) The rating in volts and amperes or volts and watts.

(d) The phase identification, if applicable.

(e) Ignition protection, if applicable.

8-4 System Voltage.

Nominal system voltages for AC electrical systems shall be selected from the following:

(a) 120 volts AC, single-phase

(b) 240 volts AC, single-phase

(c) 120/240 volts AC, single-phase

(d) 120/240 volts AC, delta three-phase

(e) 120/208 volts AC, wye three-phase.

8-5 Ambient Temperature.

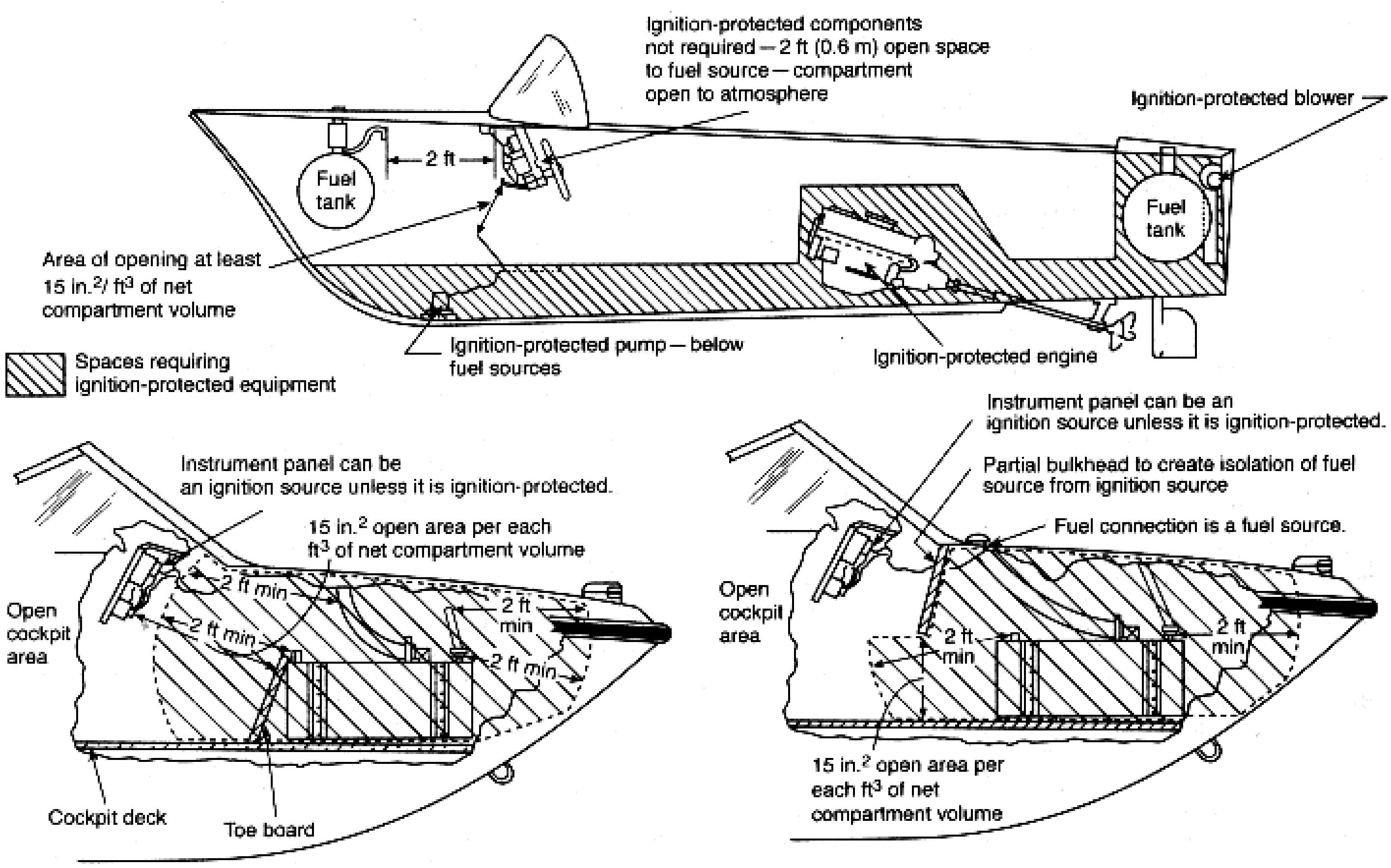
The ambient temperature of machinery spaces shall be considered to be 122°F (50°C), and the ambient temperature of all other spaces shall be considered to be 86°F (30°C).

8-6 Ignition Source.

8-6.1

Potential sources of ignition located in machinery and fuel tank spaces, and in spaces containing joints, fittings or other connections between components of the gasoline fuel system, shall be ignition-protected, unless the ignition source is isolated from a gasoline fuel source as described in 8-6.2.

Exception: Boats using diesel fuel as the only fuel.



For SI units: 2 ft (0.6 m)

Figure 8-6.1 Ignition protection with no bulkhead.

8-6.2

An electrical component shall be considered to be isolated from a fuel source provided:

(a) A bulkhead that meets the requirements of 8-6.3 is located between the electrical component and the fuel source;

(b) The electrical component is located:

(1) Below the fuel source and a means is provided to prevent fuel and fuel vapors that can leak from the fuel sources from exposure to the electrical component; or

(2) Above the fuel source and a deck or other enclosure is located between the ignition source and the fuel source; or

(c) There is a space between the electrical component and the fuel source of at least 2 ft (0.6 m) and the space is open to the atmosphere.

8-6.3

Each bulkhead shall:

(a) Separate the electrical component from the fuel source and extend the length of both the vertical and horizontal distances of the open space between the fuel source and the ignition source; and

(b) Resist a water level of 12 in. (30 cm) or of greater than $^1/_3$ the maximum height of the bulkhead, whichever is lower, without seepage of more than $^1/_4$ fl oz (7.4 ml) of fresh water per hour; and

(c) Have no opening higher than 12 in. (30 cm) or greater than $^1/_3$ the maximum height of the bulkhead, whichever is lower, unless the opening is used for the passage of conductors, piping, ventilation ducts, mechanical equipment, and similar items or for doors, hatches, and access panels; and unless the maximum annular space around each item, door, hatch, or access panel is not more than $^1/_4$ in. (6.4 mm).

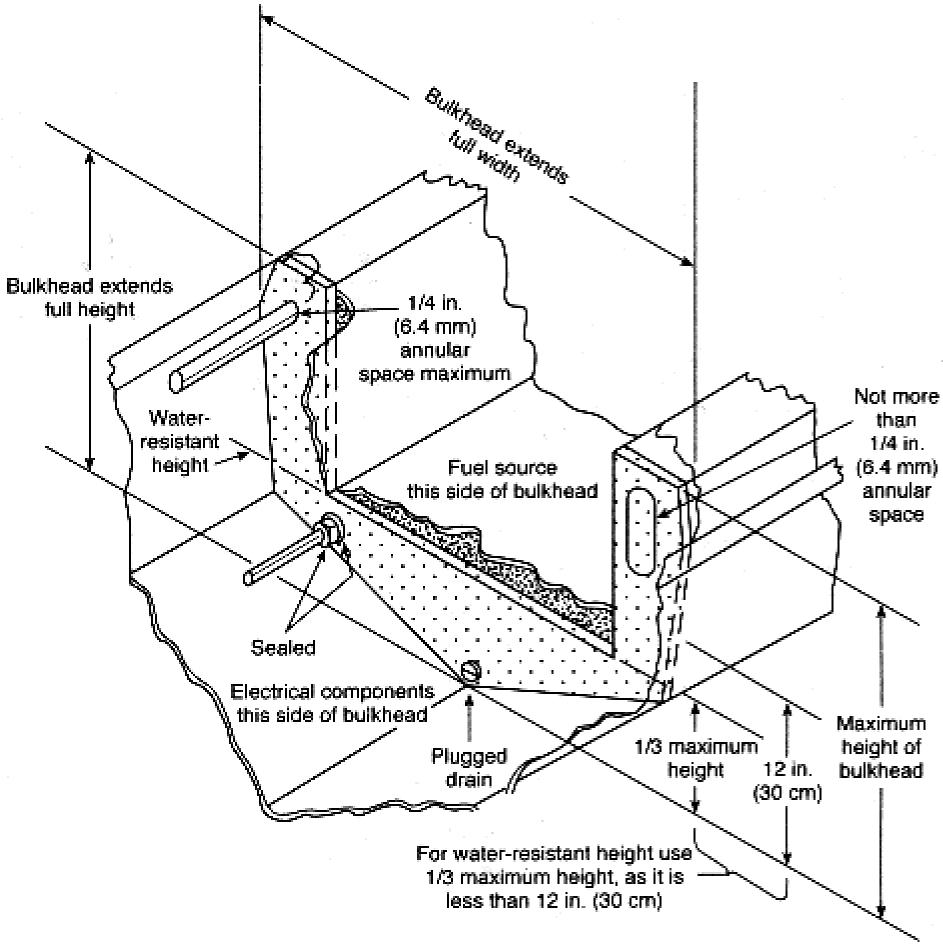


Figure 8-6.3 Cutaway illustration showing separation of electrical components from gasoline fuel source.

NOTE 1: Seepage of not more than $^1/_4$ fl oz (7.4 ml) per hour is permitted below the water-resistant height. This includes bulkhead fastenings and space around hatches, doors, access panels, and items passing through the bulkhead.

NOTE 2: Openings above the water-resistant height cannot have more than $^1/_4$ in. (6.4 mm) annular space around items passing through the openings.

8-7 Shore Power Polarity Devices.

8-7.1

Reverse-polarity indicating devices having a continuous visible or audible signal shall be installed in 120 VAC shore power systems, provided:

(a) The polarity of the system is maintained for the proper operation of electrical devices in the system; or

(b) A branch circuit is provided with overcurrent protection in the ungrounded current-carrying conductors only.

Exception: Systems with polarization or isolation transformers that establish the polarity of the onboard system.

NOTE 1: Reverse-polarity indicating devices should respond only to reversal of the ungrounded conductors and the grounded (white) conductor where there is continuity of the grounding (green) conductor to shore.

NOTE 2: Reverse-polarity indicating devices should not be required to respond to reversals of the ungrounded conductors and the grounding (green) conductor, the grounded (white) conductor and the grounding (green) conductor, or to reversal of three-phase conductors.

8-7.2

The total impedance of polarity-indicating and protection devices connected between normal current-carrying conductors and the grounding conductor shall not be less than 25,000 ohms at 120 volts, 60 hertz at all times.

8-7.3

Conductors shall be identified to indicate polarity according to Diagrams 8-7.3(a) through (i).

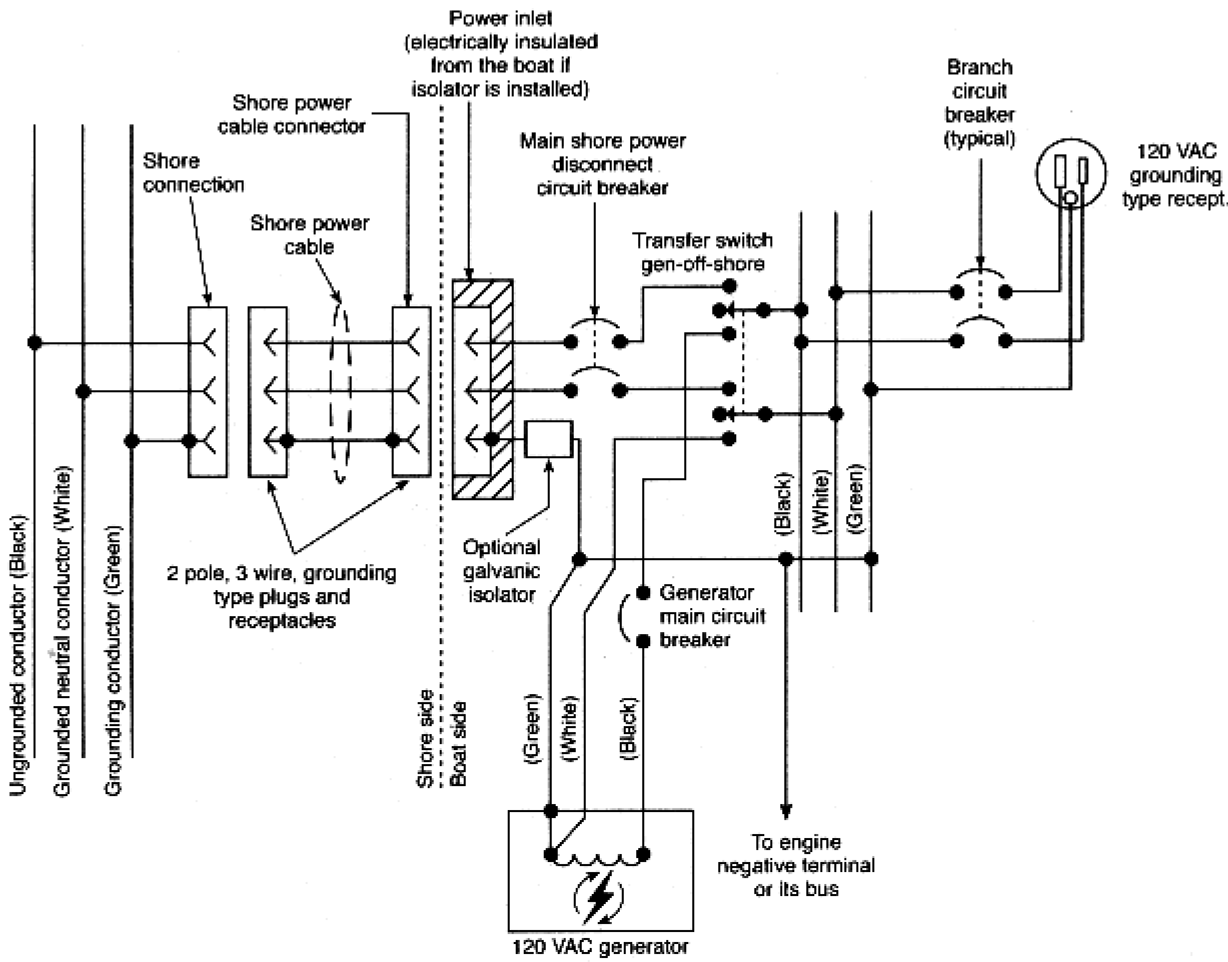


Diagram 8-7.3(a) Single-phase 120-volt auxiliary generator shore power selector switch circuit.

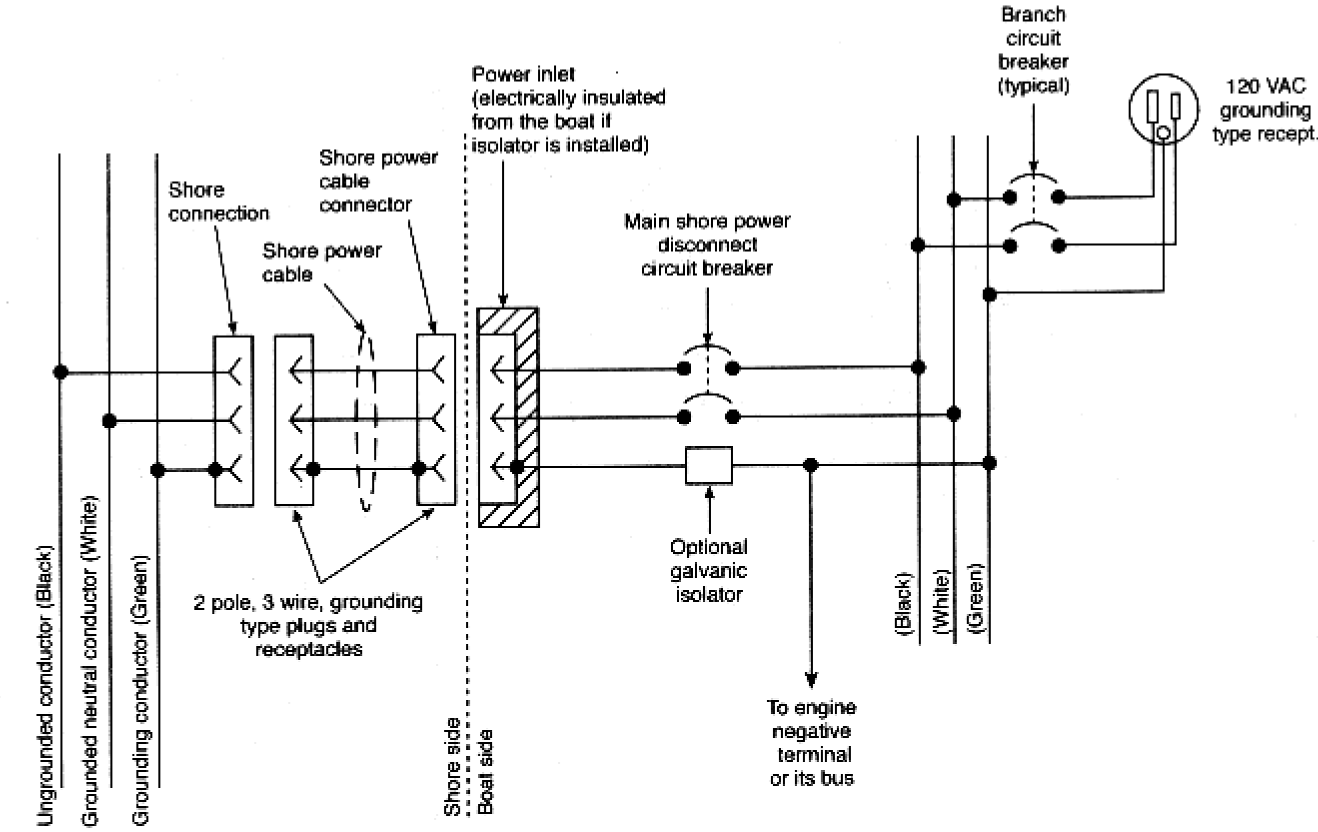


Diagram 8-7.3(b) Single-phase 120-volt system with shore-grounded neutral conductor and shore grounding conductor.

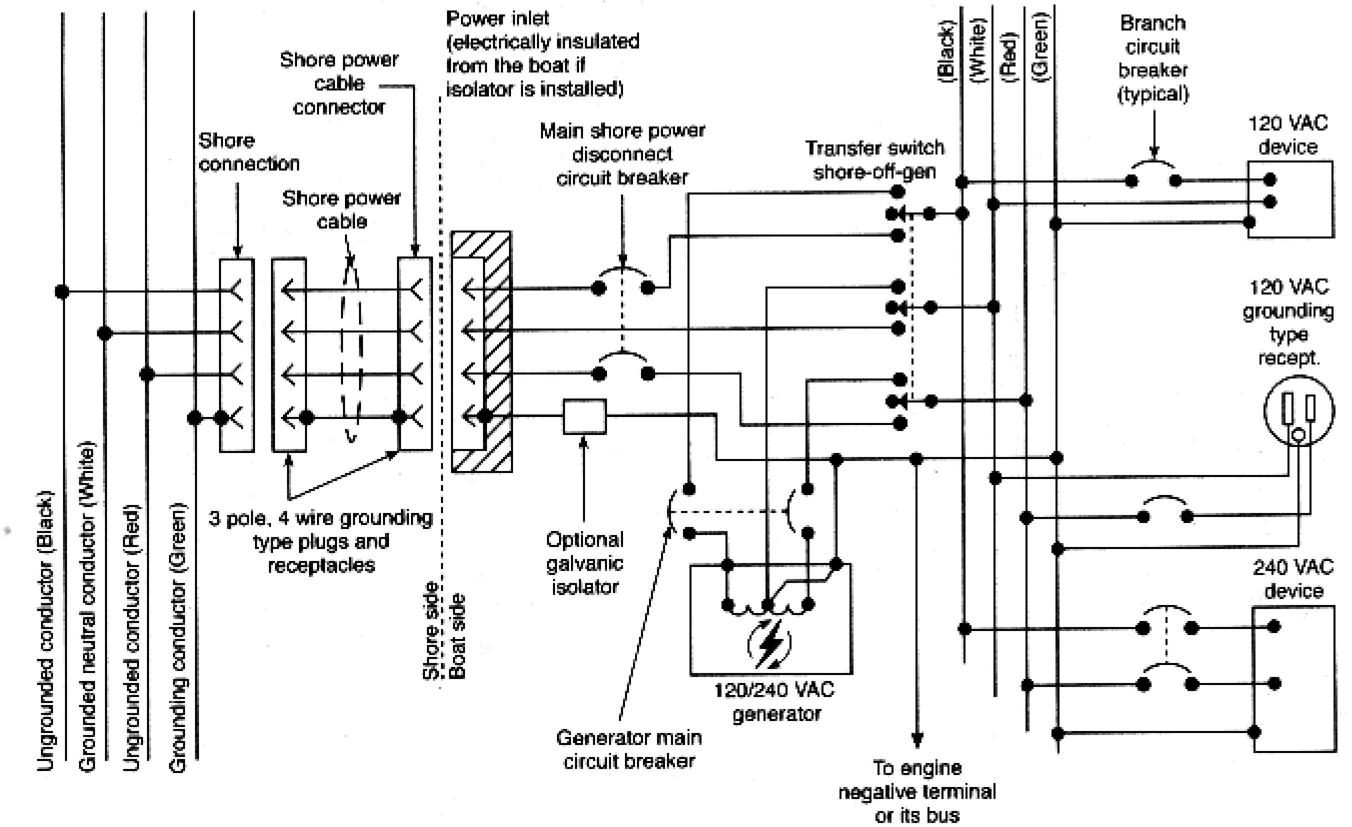


Diagram 8-7.3(c) Single-phase 120/240-volt system with shore-grounded neutral conductor and grounding conductor.

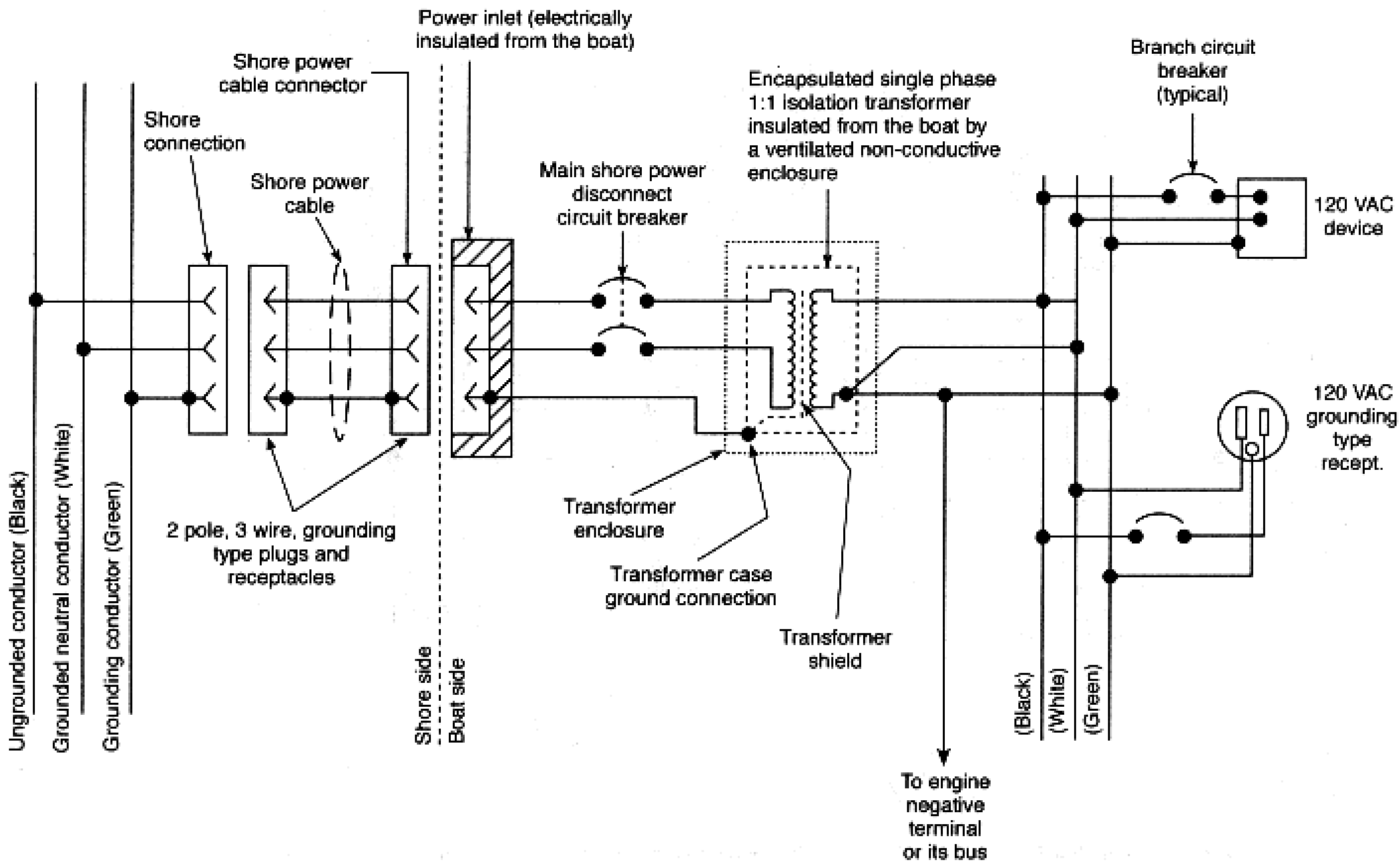


Diagram 8-7.3(d) Single-phase 120-volt isolation transformer system with grounded secondary.

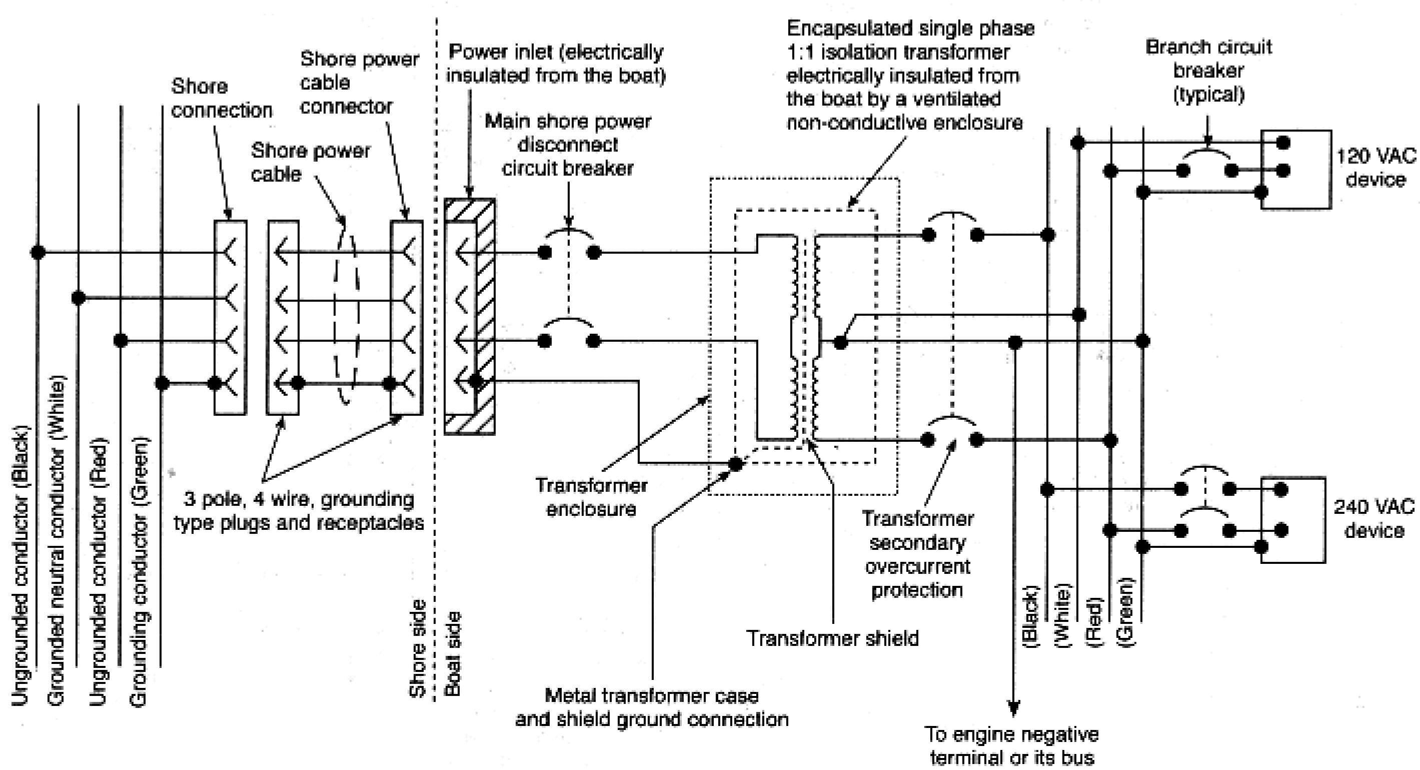


Diagram 8-7.3(e) Isolation transformer system with single-phase 240-volt input and 120/240-volt single-phase output.

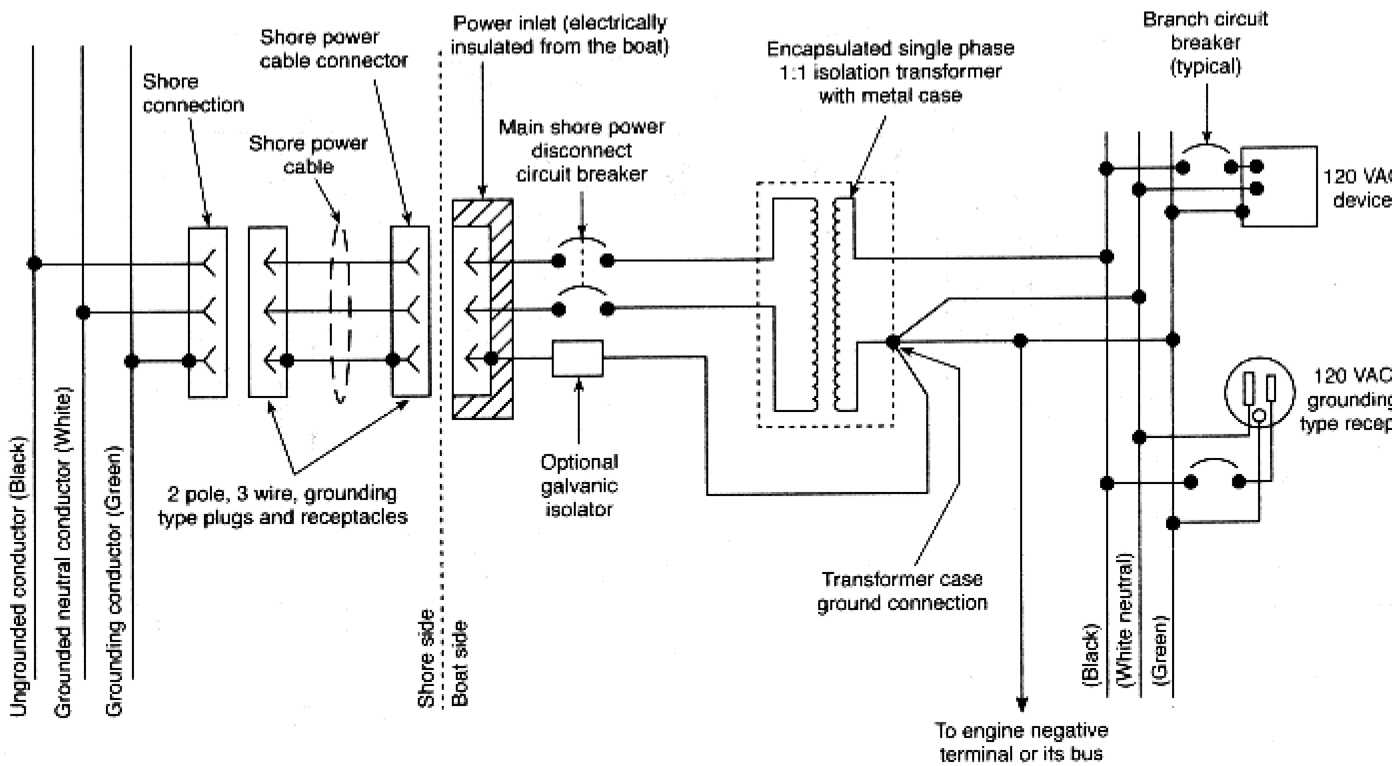


Diagram 8-7.3(f) Single-phase 120-volt polarization transformer system with shore grounding wire protection of transformer primary.

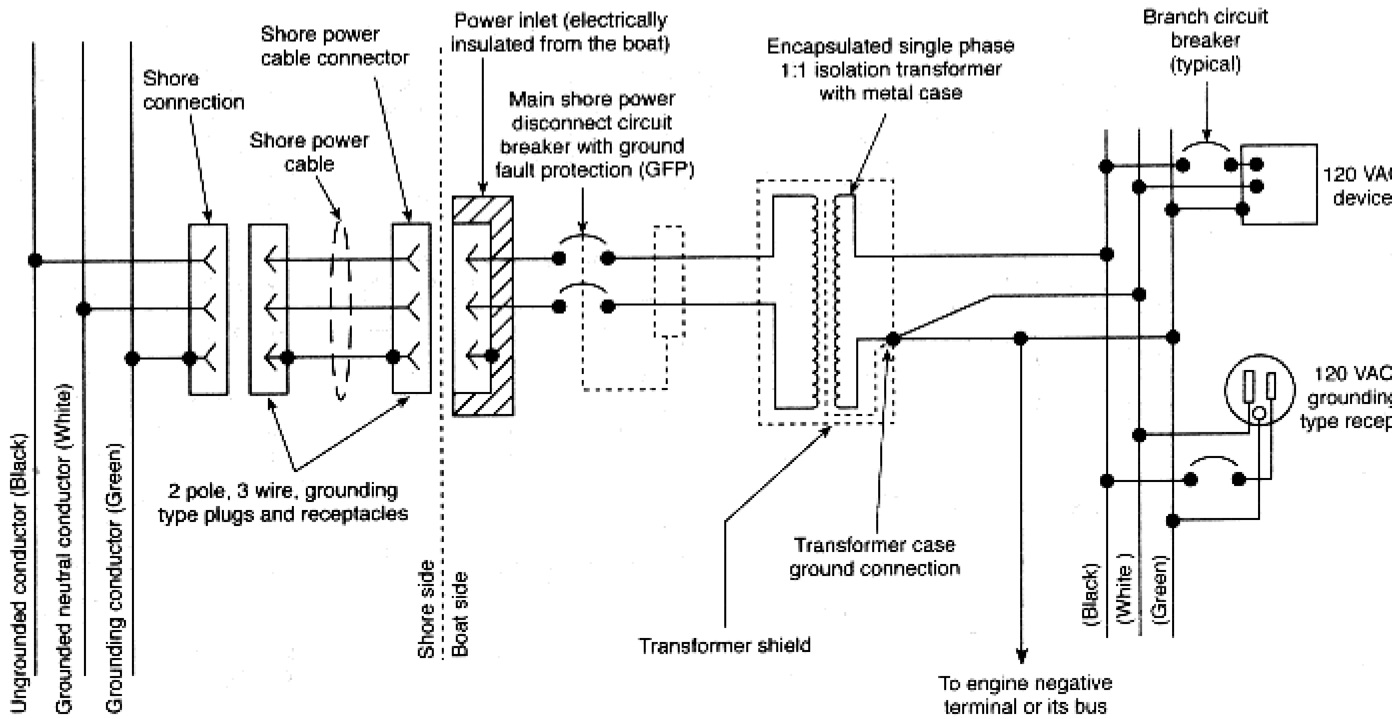


Diagram 8-7.3(g) Single-phase 120-volt isolation transformer system with ground-fault circuit-interrupter (GFCI) protection of transformer primary.

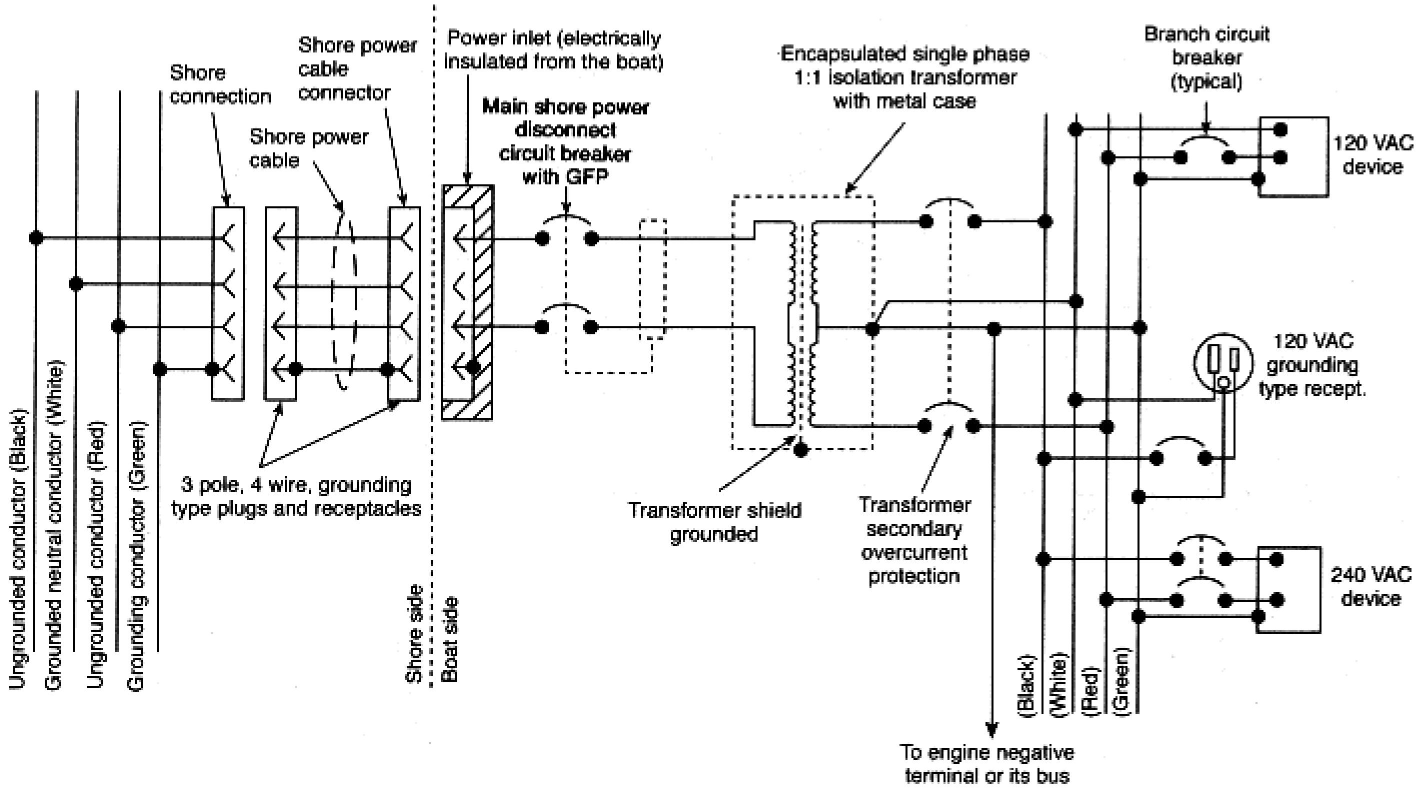


Diagram 8-7.3(h) Isolation transformer system — single-phase 240-volt input and 120/240-volt single-phase output with ground-fault circuit-interrupter (GFCI) protection of transformer primary.

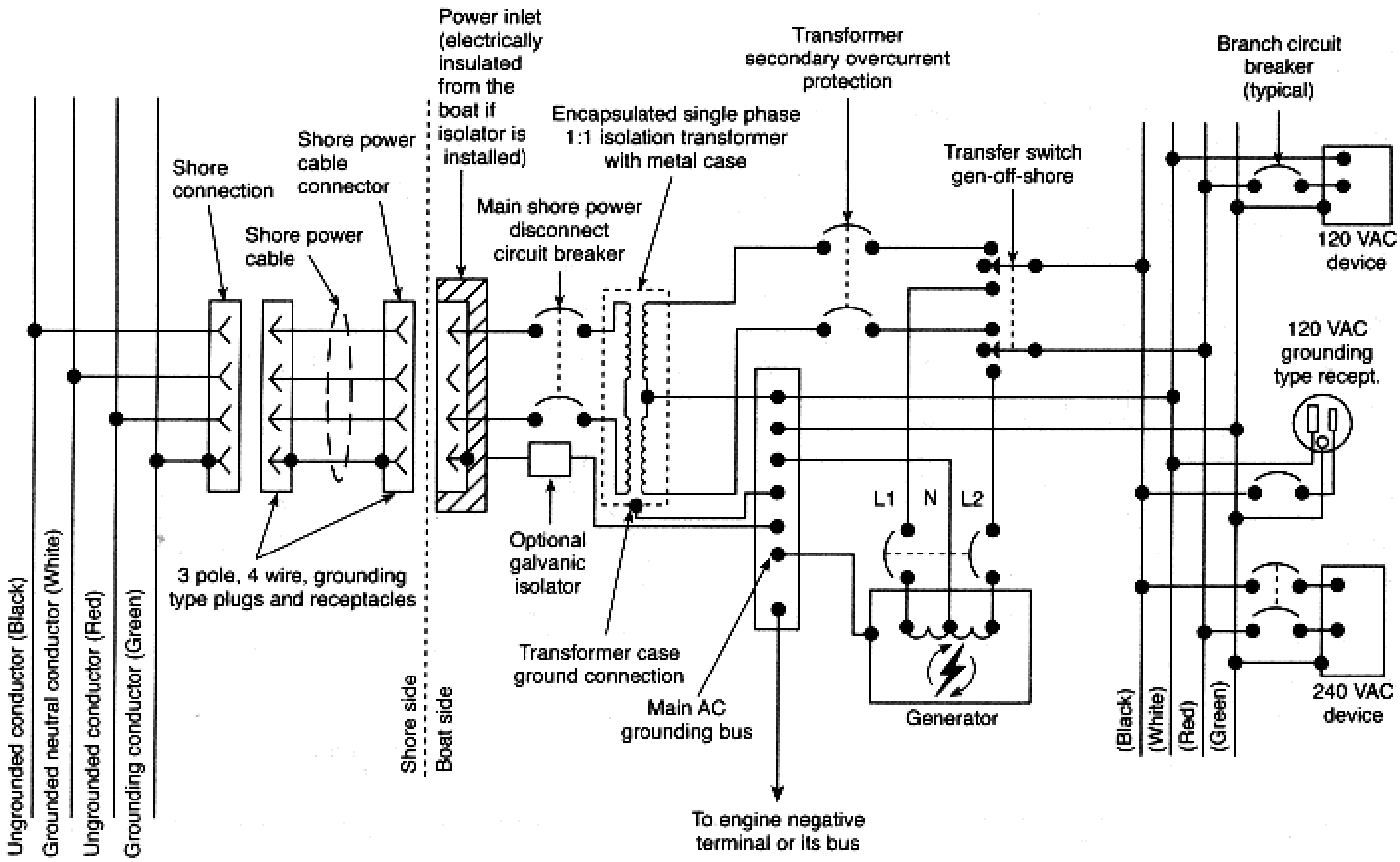


Diagram 8-7.3(i) Single-phase polarization transformer system with single-phase 240-volt input and 120/240-volt single-phase output — shore grounding protection of transformer.

8-8 Overcurrent Protection.

8-8.1 Rating of Overcurrent Protection Devices.

Over- current protection devices shall have a temperature rating and demand load characteristics consistent with the protected circuit and their location in the boat (e.g., in machinery space or other space). The rating of the overcurrent protection device shall not exceed the maximum current-carrying capacity of the conductor being protected.

8-8.2 Circuit Breakers.

Circuit breakers shall:

(a) Meet the marine requirements of UL 489, *Standard for Safety Molded-Case Circuit Breakers and Circuit-Breaker Enclosures*, UL 1077, *Standard for Safety Supplementary Protectors for Use in Electrical Equipment*, or UL 1133, *Standard for Safety Boat Circuit Breakers*.

(b) Be of the trip-free type.

(c) Be capable of an interrupting capacity in accordance with Table 8-8.2.

(d) Be of the manual reset type.

(e) Meet the requirements of UL 1500, *Standard for Safety Ignition-Protection for Marine Products*, at four times their rated current if located in a space that requires ignition protection.

NOTE: For information on external ignition protection of marine electrical devices, see SAE J1171, *Recommended Practice for External Ignition Protection of Marine Electrical Devices.*

Table 8-8.2 Circuit Breaker Interrupting Capacity (Amperes)

Shore Power Source	Main Shore Power Disconnect Circuit Breaker	Branch Breaker
120V - 30A	3000	3000
120V - 50 A	3000	3000
120/240V - 50 A	5000	3000
240V - 50 A	5000	3000
120/208V-3-phase/wye 30A	5000	3000
120/240V - 100 A	5000	3000
120/208V-3-phase/wye 100A	5000	3000

NOTE 1: The main circuit breaker shall be considered the first circuit breaker connected to a source of AC power. All subsequent breakers, including submain breakers connected in series with a main circuit breaker, are considered to be branch breakers.

NOTE 2: A fuse in series with, and ahead of, a circuit breaker shall be permitted to be required by the circuit breaker manufacturer to achieve the interrupting capacity specified in Table 8-8.2.

8-8.3 Fuses.

Fuses shall:

(a) Have a voltage rating of not less than the nominal system voltage.

(b) Be capable of an interrupting capacity at a rated system voltage of at least 5,000 amperes for the feeders between the shore power inlet and the main circuit breaker and 3,000 amperes for branch circuits.

(c) Meet the requirements of UL 198C, *Standard for Safety High-Interrupting Capacity Fuses, Current-Limiting Types*, UL 198E, *Standard for Safety Class R Fuses*, UL 198F, *Standard for Safety Plug Fuses*, or UL 198H, *Standard for Safety Class T Fuses* for Class J, L, R, S, or T fuses.

(d) Meet the requirements of UL 1500, *Standard for Safety Ignition-Protection for Marine Products*, at four times their rated current if located in a space that requires ignition protection.

NOTE: For information on external ignition protection of marine electrical devices, see SAE J1171, *Recommended Practice for External Ignition Protection of Marine Electrical Devices*.

8-8.4 Fuse Holders.

Fuse holders shall meet the requirements of UL 512, *Standard for Safety Fuseholders*, for the class of fuse being used.

8-9 Main Supply.

8-9.1

Common-trip circuit breakers shall be provided in main supply conductors as follows:

(a) 120-volt AC, single-phase — ungrounded and grounded conductors (white)

(b) 240-volt AC, single-phase — both ungrounded conductors

(c) 120/240-volt AC, single-phase — both ungrounded conductors

(d) 120/240-volt AC, delta three-phase — all ungrounded conductors

(e) 120/208-volt AC, wye three-phase — all ungrounded conductors.

8-9.2

If the main supply feeder from the shore power inlet to the main circuit breaker exceeds 10 ft (3 m) in length, additional fuses or circuit breakers shall be provided within 10 ft (3 m) of the shore power inlet. If additional fuses are used, their rating shall be such that circuit breakers trip before the fuses open the circuit in the event of overload.

8-9.3

Overcurrent protection for AC-generator power feeders, if required, shall be within 7 in. (18 cm) of the output connection or shall be permitted to be within 40 in. (102 cm) of the output connections if the unprotected insulated conductors are contained for their entire length within a sheath or enclosure such as a conduit, junction box, control box, or enclosed panel.

8-10 Branch Circuits.

8-10.1

Each ungrounded conductor of a branch circuit shall be provided with overcurrent protection at the point of connection to the panelboard bus. Each circuit breaker or fuse used for this purpose shall not be rated in excess of the current rating of the smallest conductor between the fuse or circuit breaker and the load.

8-10.2

In branch circuits, circuit breakers and switches shall open all grounded and ungrounded conductors simultaneously.

Exception No. 1: A polarized circuit with a polarity indicator.

Exception No. 2: The neutral leg of a grounded secondary of a polarization or isolation transformer.

8-10.3

Fuses shall not be used in the grounded conductor.

8-10.4

If circuits contain two or more ungrounded current-carrying conductors that are protected by fuses, means shall be provided to disconnect all energized legs of the circuit simultaneously or to remove all fuses from the circuit simultaneously.

8-10.5 AC Motors.

Each motor or motor-operated device shall be protected by an overcurrent protection device that is responsive to the motor current. The overcurrent protection device shall not be rated at more than 125 percent of the motor full-load current rating and shall be permitted to be integral and of an automatic resetting type.

Exception: Motors that do not overheat under locked rotor conditions.

8-10.6 Battery Chargers.

Each ungrounded conductor to a battery charger shall be provided with overcurrent protection at the point of connection to the main switchboard, the distribution panel, or the battery. In addition, the ungrounded conductor shall be provided with overcurrent protection within the battery charger, based on the maximum output of the charger, unless the battery charger output is current-limited.

8-11 Ground-Fault Circuit-Interrupters.

8-11.1

A ground-fault circuit-interrupter (GFCI) shall be permitted to be used on any single-phase AC circuit and shall be used for all receptacles in the head, the galley, and machinery spaces and on weather decks.

8-11.2 Ground-Fault Circuit-Interrupter (GFCI) Breakers.

(a) GFCI breakers shall meet the requirements of UL 943, *Standard for Safety Ground-Fault Circuit-Interrupters*, and UL 489, *Standard for Safety Molded-Case Circuit Breakers and Circuit-Breaker Enclosures*.

(b) If installed in a head, galley, or machinery space or on a weather deck, the receptacle shall be protected by a Type A (nominal 5 milliampere) ground-fault circuit-interrupter.

(c) GFCI breakers shall be permitted to be installed as panelboard feeder breakers to protect all associated circuits or in individual branch circuits.

8-11.3 Ground-Fault Circuit-Interrupter (GFCI) Receptacle Devices.

(a) GFCI receptacle devices shall meet the requirements of UL 943, *Standard for Safety Ground-Fault Circuit-Interrupters*, and UL 498, *Standard for Safety Attachment Plugs and Receptacles*.

(b) GFCI receptacle devices shall be permitted to be installed as part of a convenience outlet installation, either in single outlet applications or in multiple “feed-through” installations.

8-11.4 Isolation Transformer Primary.

GFCI circuit breakers shall be permitted to be installed as the main breaker on the primary side of isolation transformers.

NOTE: This GFCI breaker provides ground-fault protection for the primary winding of the transformer only.

8-12 Appliances and Equipment.

8-12.1

Appliances and fixed AC electrical equipment used on boats shall be designed so that the current-carrying parts of the device are insulated effectively from all exposed electrically conductive parts.

8-12.2

All exposed electrically conductive noncurrent-carrying parts of fixed AC electrical equipment and appliances intended to be grounded shall be connected to the grounding system.

8-12.3

If an appliance has a neutral-to-ground bonding strap, the bonding strap shall be removed.

8-13 Conductors and Flexible Cords.

8-13.1

Conductors shall have a minimum rating of 600 volts. Flexible cords shall have a minimum rating of 300 volts.

8-13.2

Conductors shall be selected from the types specified in Table 8-13.2.

Table 8-13.2 Acceptable Insulation Types

Types	Description	Available Insulation Temperature Rating
THW	Moisture- and heat-resistant, thermoplastic	75°C (167°F)
TW	Moisture-resistant, thermoplastic	60°C (140°F)
THWN	Moisture- and heat-resistant, thermoplastic	75°C (167°F)
XHHW	Moisture- and heat-resistant, cross-linked synthetic polymer	90°C (194°F)
MTW	Moisture-, heat-, and oil-resistant, thermoplastic	90°C (194°F)
AWM	Moisture-, heat-, and oil-resistant, thermoplastic	105°C (221°F)
Style Nos.*:	Thermosetting	
1230		

1231		
1275		
1276		
1329		
1335		
1336		
1337		
1339		
1340		
1345		
1388		
3403		
UL 1426	Boat cable	*(See UL 1426, Standard for Safety Electric Cables for Boats)*

*Numbers listed are style numbers.

8-13.3

Flexible cords shall be selected from the types specified in Table 8-13.3.

Table 8-13.3 Flexible Cords

Type	Description	Insulation Temperature Rating	Application
SO	Hard service cord—oil-resistant compound	60°C (140°F) 75°C (167°F) & higher	General use except for machinery space General use
ST	Hard service cord thermoplastic	60°C (140°F) 75°C (167°F) & higher	General use except for machinery space General use
STO	Hard service cord—oil-resistant thermoplastic	60°C (140°F) 75°C (167°F) & higher	General use except for machinery space General use
SJO	Junior hard service cord oil-resistant compound	60°C (140°F) 75°C (167°F) & higher	General use except for machinery space General use
SJT	Junior hard service cord thermoplastic	60°C (140°F) 75°C (167°F) & higher	General use except for machinery space General use
SJTO	Junior hard service	60°C (140°F)	General use except for machinery

cord thermoplastic	75°C (167°F) & higher	space General use

8-13.4

Conductors and flexible cords shall be of stranded copper with circular mil area and stranding in accordance with Table 8-13.4.

Table 8-13.4 Conductor Circular Mil (CM) Area and Stranding

Conductor Size (AWG)	Nominal CM Area*	Minimum Type 2**	Number of Strands Type 3***
18	1,620	16	
16	2,580	19	26
14	4,110	19	41
12	6,530	19	65
10	10,380	19	105
8	16,510	19	168
6	26,240	37	266
4	41,740	61	420
2	66,360	127	665
1	83,690	127	836
1/0	105,600	127	1064
2/0	133,100	127	1323
3/0	167,800	259	1666
4/0	211,600	418	2107

* To recognize stranded conductors made of AWG elements, note that the actual nominal CM area can differ from the specified nominal CM area but by no more than 7 percent. The circular mil area is equal to the mathematical square of the specified diameter of the AWG standard solid copper conductor measured in one thousandths of an inch.

$$\text{Area (sq in.)} = \frac{\text{pi} \times \text{(circular mils)}}{4\ (1{,}000{,}000)}$$

** Conductors with Type 2 stranding shall be permitted to be used for wiring that is subject to movement from vibration or minor flexing. If four or more conductors are run in a cable, Type 2 stranding shall be permitted to be used for frequent flexing applications.

***Conductors with Type 3 stranding shall be used for any wiring where frequent flexing is involved in normal use.

NOTE: Metric wire sizes can be used if of equivalent circular mil area. If the circular mil area of the metric conductor is less than that listed, the wire ampacity needs to be corrected based on the ratio of the circular mil areas.

8-13.5

Conductor sizes, as determined by Table 8-13.4, shall not carry current greater than that indicated in Table 8-13.5, based on the temperature rating of the wire and the following derating factors:

(a) Conductors used in or routed through an engine space shall be corrected in accordance with Note 1 of Table 8-13.5.

(b) Current-carrying conductors that are bundled shall be derated in accordance with Note 2 of Table 8-13.5.

Table 8-13.5 Ampacities of Insulated Conductors

Conductor	**Temperature Rating of Conductor Insulation**						
Size AWG	**60°C (140°F)**	**75°C (167°F)**	**80°C (176°F)**	**90°C (194°F)**	**105°C (221°F)**	**125°C (257°F)**	**200°C (392°F)**
18	10	10	15	20	20	25	25
16	15	15	20	25	25	30	35
14	20	20	25	30	35	40	45
12	25	25	35	40	45	50	55
10	40	40	50	55	60	70	70
8	55	65	70	70	80	90	100
6	80	95	100	100	120	125	135
4	105	125	130	135	160	170	180
3	120	145	150	155	180	195	210
2	140	170	175	180	210	225	240
1	165	195	210	210	245	265	280
0	195	230	245	245	285	305	325
00	225	265	285	285	330	355	370
000	260	310	330	330	385	410	430
0000	300	360	385	385	445	475	510

NOTE 1: Engine room temperature derating factor:

	60°C (140°F)	75°C (167°F)	80°C (176°F)	90°C (194°C)	105°C (221°F)	125°C (257°F)	220
Temperature rating of conductor	0.58	0.75	0.78	0.82	0.85	0.89	

NOTE 2: Current-carrying conductor bundling derating factor:

Number of Energized Wires in a Bundle	Correction factor
3	0.70
4 to 6	0.60
7 to 24	0.50
25 and above	0.40

8-13.6

Conductors shall be at least No. 16 AWG.

Exception: Conductors contained completely within equipment or enclosures.

8-13.7

All conductors shall meet the applicable standards of Underwriters Laboratories Inc. and shall be so labeled.

8-14 Installation.

8-14.1

All connections normally carrying current shall be made in enclosures with interior surfaces having a flame spread rating of not more than 25.

8-14.2

All conductors shall be supported to relieve strain on connections. Where AC and DC conductors are run together, the AC conductors shall be sheathed, bundled, or otherwise kept separate from the DC conductors.

Exception: Conductors contained completely within equipment or enclosures.

8-14.3*

Conductors shall be supported for their entire length or, alternatively, shall be secured at least every 18 in. (46 cm) by one of the following methods:

(a) Nonmetallic clamps of a size to hold the conductors firmly in place. Nonmetallic straps or clamps shall not be used over engine(s), moving shafts, other machinery, or passageways if failure can result in a hazardous condition. Conductor material shall be resistant to oil, gasoline, and water and shall not break or crack under flexing within a temperature range of –30°F to 250°F (–34°C to 121°C).

(b) Metal straps or clamps with smooth, rounded edges to hold the conductors firmly in place without damage to the conductors or insulation. That section of the conductor or cable located directly under the strap or clamp shall be protected by means of loom, tape, or other suitable wrapping to prevent injury to the conductor.

(c) Metal clamps lined with an insulating material resistant to the effects of oil, gasoline, and water.

8-14.4

Junction boxes, cabinets, and other enclosures in which electrical connections are made shall be weatherproof or installed in a protected location to minimize the entrance or accumulation of moisture or water within the boxes, cabinets, or enclosures. In wet locations, metallic boxes, cabinets, or enclosures shall be mounted to minimize the entrapment of moisture between the box, cabinet, or enclosure and the adjacent structure. If air space is used to achieve this, the minimum space shall be $^1/_4$ in. (6.4 mm).

8-14.5

Unused openings in boxes, cabinets, and weatherproof enclosures shall be closed.

8-14.6

Current-carrying conductors shall be routed as high as practicable above the bilge water level and other areas where water can accumulate. If conductors are forced to be routed through the bilge or other areas where water can accumulate, the wiring shall be of a submersible type and connections shall be watertight.

8-14.7

Conductors shall be routed as far away as practicable from exhaust pipes and other heat sources. Unless an equivalent thermal barrier is provided, a clearance of at least 2 in. (5 cm) between conductors and water-cooled exhaust components and a clearance of at least 9 in. (23 cm) between conductors and dry exhaust components shall be maintained. Where conductors are located directly above a dry exhaust, the clearance shall be increased to 18 in. (46 cm). Conductors that are exposed to physical damage shall be protected by loom, conduit, tape, raceways, or other equivalent protection. The protection shall be self-draining. Conductors passing through bulkheads or structural members shall be protected to minimize insulation damage such as chafing. Conductors also shall be routed clear of sources of chafing such as steering cable and linkages, engine shafts, and throttle connections.

8-14.8

All permanently installed appliances and utilization equipment shall be mounted securely to the boats structure.

8-14.9 Wiring Connections.

(a) Wiring connections shall be designed and installed to make mechanical and electrical joints without damage to the conductors.

(b) Metals used for the terminal studs, nuts, and washers shall be corrosion-resistant and galvanically compatible with the conductor and terminal lug. Aluminum and unplated steel shall not be used for studs, nuts, and washers.

(c) Each conductor splice joining conductor to conductor, conductor to connectors, and conductor to terminals shall be able to withstand a tensile force equal to at least the value shown in Table 8-14.9 for the smallest conductor size used in the splice for a 1-min duration without breaking.

(d) Terminal connectors shall be of the ring or captive spade type.

Exception: Friction-type connectors shall be permitted to be used on components, provided:

1. The circuit is rated at not more than 10 amperes;

2. The voltage drop from terminal to terminal does not exceed 50 millivolts for a 20-ampere current flow; and

3. The connection does not separate if subjected to a 6-lb (26.7-N) tensile force along the axial direction of the connector for 1 min.

Table 8-14.9 Tensile Test Values for Connections

Conductor Size	Tensile Force (lb/N)		Conductor Size (gauge)	Tensile Force (lb/N)	
18	10	44	4	70	311
16	15	66	3	80	355
14	30	133	2	90	400
12	35	155	1	100	444
10	40	177	0	125	556
8	45	200	00	150	667
6	50	222	000	175	778
5	60	266	0000	225	1000

8-14.10

Connections shall be permitted to be made using a set-screw, pressure-type conductor connector, provided a means is used to prevent the set screw from bearing directly on the conductor strands. Set-screw-type conductor connectors without such means shall be used only on seven-strand conductors.

8-14.11

Twist-on connectors (wire nuts) shall not be used.

8-14.12

Solder shall not be the sole means of mechanical connection in any circuit.

Exception: Conductors contained completely within equipment or enclosures.

8-14.13

Solderless crimp-on connectors shall be attached with the type of crimping tools designed for the connector used.

8-14.14

No more than four conductors shall be secured to any terminal stud. If additional connections are necessary, two or more terminal studs shall be connected together by means of jumpers or copper straps.

8-14.15

Terminal connectors of the ring and captive spade type shall be the same nominal size as the stud.

8-14.16

Conductors terminating at panelboards, in junction boxes, or fixtures shall be arranged to provide a length of conductor to relieve tension, to allow for repairs, and to permit multiple conductors to be fanned at terminal studs.

8-14.17

The shanks of terminals shall be protected against accidental shorting by the use of insulation barriers or sleeves.

Exception: Shanks used in grounding systems.

8-15 Receptacles.

8-15.1

Receptacles shall be installed in locations normally not subject to rain, spray, or flooding, but if receptacles are used in areas that are subject to such weather exposure, the following requirements shall apply:

(a) Receptacles installed in locations subject to rain, spray, or splash shall be weatherproof to the degree provided by a spring-loaded, self-closing cover.

(b) Receptacles installed in areas subject to flooding or momentary submersion shall be of as watertight a design as can be provided by a threaded, gasketed cover.

8-15.2

Receptacles shall be of the grounding type with a terminal provided for the grounding (green) conductor in accordance with ANSI/NEMA WD-6, *Wiring Devices — Dimensional Requirements*.

8-15.3

Receptacles and matching plugs used on AC systems shall not be interchangeable with receptacles and matching plugs used on DC systems.

8-15.4

Power wiring for receptacles shall be connected so that the grounded (white) conductor attaches to the terminal identified by a letter(s) or a light color (normally silver). The ungrounded conductor(s) shall be attached to the terminal identified by a letter(s) or a dark color (normally brass or copper).

8-15.5

A branch circuit supplying a combination of receptacle loads and permanently connected loads shall not supply fixed loads in excess of the following:

(a) 600 watts for a 15-ampere circuit

(b) 1000 watts for a 20-ampere circuit.

8-15.6

Receptacles provided for the galley shall be located so appliance cords can be plugged in without crossing a traffic area, galley stove, or sink.

8-15.7

If installed in a head, galley, or machinery space or on a weather deck, the receptacle shall be protected by a Type A (nominal 5 milliamperes) ground-fault circuit-interrupter (GFCI).

8-15.8

Electrical systems not equipped with polarity indicators using two-pole circuit breakers shall use two-pole GFCI in place of single-pole GFCI receptacles in those circuits that supply receptacles.

8-16 Main Panelboard.

8-16.1

A main panelboard shall be installed in a readily accessible location, shall be weatherproof or protected from weather and splash, and shall be permitted to serve as a distribution center.

8-16.2

Boats equipped with both DC and AC electrical systems shall have their distribution on separate panelboards, or there shall be a partition to separate the AC sections and the DC sections of the panelboard when the panel is open for service.

8-16.3

Panelboards shall be permanently marked with the system voltage and either “VAC” or the system frequency (e.g., “120 VAC” or “120V-60 hertz”).

8-16.4

If the frequency is other than 60 hertz, the frequency shall be indicated. For three-phase systems, the system voltage, phase, and number of conductors shall be indicated.

8-16.5

A system voltmeter shall be installed, provided:

(a) The system is designed to supply motor circuits; or

(b) An onboard generator is installed.

8-17 AC Generators.

8-17.1

AC generators shall be connected to the electrical distribution system through a selector switch in accordance with 8-2.3 and Diagram 8-7.3(a).

8-17.2

The power feeders from the AC generator shall be sized to accommodate at least the generator's maximum rated output and shall be protected at the generator with overcurrent protection devices in accordance with Section 8-8. The rating of these overcurrent protection devices shall not exceed 120 percent of the generator's rated output.

Exception: Self-limiting generators having a maximum overload current not exceeding 120 percent of their rated current output shall not require additional external overcurrent protection.

8-18 Isolation of Galvanic Currents.

8-18.1

Boats with aluminum or steel hulls or aluminum outdrives subject to accelerated galvanic corrosion (via the grounding conductor) shall use an isolation transformer system in accordance with 8-22.4 or 8-22.7 or a galvanic isolator in the grounding conductor in accordance with 8-18.2.

8-18.2

The isolator shall [*see Diagram 8-7.3(a)*]:

(a) Effectively block galvanic current flow through the grounding (green) wire.

(b) Withstand the application of power from a test circuit capable of delivering 5000 amperes RMS symmetrical at the test terminals when tested in series with a 25-ft (7.6-m) length of shore power cable and a circuit breaker of the same rating as the isolator.

(c) Not introduce a voltage drop in excess of 2.5 volts at 100 percent of the shore-power cable ampacity rating in addition to the voltage drop of the shore power cable and connections.

8-19 Shore Power.

8-19.1 Power Inlet.

The receptacle installed to receive a connecting cable to carry AC shore power aboard shall be a male-type connector.

(a) Power inlets installed in locations subject to rain, spray, or splash shall be weatherproof to the degree provided by a spring-loaded, self-closing cover, the integrity of which shall not be affected when the receptacle is in use (female-type connector inserted).

(b) Power inlets installed in areas subject to flooding or momentary submersion shall be of as watertight a design as can be provided by a threaded, gasketed cover.

(c) See Marking Example 8-3.1 for shore-power inlet warning sign.

(d) If a boat uses an isolation transformer or an isolator to prevent galvanic current flow through the grounding conductor, the metallic shell of the shore power inlet shall be insulated from metallic surfaces or any contact with a boat ground. [*See Diagrams 8-7.3(d), (e), (f), (g), (h), and (i).*]

8-19.2 Shore Power Cable.

Boats with an AC electrical system(s) intended to use shore power provided in accordance with NFPA 70, *National Electrical Code*, Article 555, and NFPA 303, *Fire Protection Standard for Marinas and Boatyards*, shall be provided with a shore power cable that:

(a) Is provided with a male locking and grounding-type connection that conforms to NFPA 70, *National Electrical Code*, Article 555, and to ANSI/NEMA WD-6, *Wiring Devices — Dimensional Requirements*, if a configuration for that service exists in ANSI/NEMA WD-6.

(b) If provided, shall have a female boat connection of the locking and grounding type and in conformance with ANSI/NEMA WD-6, *Wiring Devices — Dimensional Requirements*, if a configuration for that service exists in ANSI/NEMA WD-6.

(c) Has a minimum length of 25 ft (7.6 m) and meets the marine requirements of UL 817, *Standard for Safety Cord Sets and Power-Supply Cords*.

8-20 Devices Employing Isolation Transformers.

Devices employing isolation transformers, such as battery chargers, shall be permitted to be connected directly to the shore conductors or to the secondary of the system isolation transformer.

8-21 Application of Types of Shore Power Circuits.

8-21.1 Single-Phase 120-Volt System with Shore-Grounded Neutral and Shore Grounding Conductor.

This system, wired in accordance with the basic circuit shown in Diagram 8-7.3(b), shall be permitted to be used on any nonmetallic hull boat with underwater hardware of metal alloys that are at least as galvanically noble as manganese bronze. This system also shall be permitted to be used with metal hull boats if protection against galvanic corrosion is provided by means of a cathodic protection system or a galvanic isolator.

8-21.2 Single-Phase 120/240-Volt System with Shore-Grounded Neutral and Shore Grounding Conductor.

This system, wired in accordance with the basic circuit shown in Diagram 8-7.3(c), shall be permitted to be used on any nonmetallic hull boat with underwater hardware of metal alloys that are at least as galvanically noble as manganese bronze. This system also shall be permitted to be used with metal hull boats if protection against galvanic corrosion is provided by means of a cathodic protection system or a galvanic isolator.

8-21.3 Single-Phase 120-Volt Primary and Secondary Isolation Transformer System.

With shore grounding protection of the transformer core, this system, wired in accordance with the basic circuit shown in Diagram 8-7.3(d), shall be permitted to be used with any metallic or nonmetallic hull boat. In this system, the grounded transformer core and the metallic shell of the shore power inlet shall be insulated from contact with any boat ground. The transformer secondary shall be grounded on the boat.

8-21.4 Isolation Transformer with Single-Phase 240-Volt Input and 120/240-Volt Output with Shore Grounding Protection of Transformer Core.

This system, wired in accordance with the basic circuit shown in Diagram 8-7.3(e), shall be permitted to be used with any boat and shall be used on all metal hull boats if other means of protection against galvanic corrosion, such as a galvanic isolator, is not provided. The metallic shell of the shore power inlet shall be insulated from contact with any boat ground. The center leg of the transformer secondary shall be grounded on the boat, establishing a new neutral for the boat system.

8-21.5 Single-Phase 120-Volt Primary and Secondary Polarization Transformer System with Shore-Grounded Neutral and Shore Grounding Protection of Transformer.

This system, wired in accordance with the basic circuit shown in Diagram 8-7.3(f), shall be permitted to be used on any nonmetallic hull boat with underwater hardware of metal alloys that are at least as galvanically noble as manganese bronze. This system also shall be permitted to be used with metal hull boats if protection against galvanic corrosion is provided by means of a cathodic protection system or a galvanic isolator. The transformer secondary shall be grounded on the boat.

8-21.6 Single-Phase 120-Volt Primary and Secondary Polarization Transformer System with Shore-Grounded Neutral and GFCI Protection of Transformer Primary.

This system, wired in accordance with the basic circuit shown in Diagram 8-7.3(g), shall be used with any metallic or nonmetallic hull boat. The metallic shell of the shore power inlet shall be insulated from contact with any boat ground. The transformer secondary shall be grounded on the boat.

8-21.7 Single-Phase Isolation Transformer with 240-Volt Input and 120/240-Volt Secondary with GFCI Protection of Transformer Primary.

This system, wired in accordance with the basic circuit shown in Diagram 8-7.3(h), shall be permitted to be used with any metallic or nonmetallic hull boat. The metallic shell of the shore power inlet shall be insulated from contact with any boat ground. The central leg of the transformer secondary shall be grounded on the boat, establishing a new neutral for the boat system.

8-21.8 Single-Phase Polarization Transformer with 240-Volt Input and 120/240-Volt Secondary and Shore Grounding Conductor Protection of Transformer Core.

This system, wired in accordance with the basic circuit shown in Diagram 8-7.3(i), shall be permitted to be used on any nonmetallic hull boat with underwater hardware of metal alloys that are at least as galvanically noble as manganese bronze. This system also shall be permitted to be used with metal hull boats if protection against galvanic corrosion is provided by means of a cathodic protection system or a galvanic isolator. The center leg of the transformer secondary shall be grounded on the boat, establishing a new neutral for the boat system.

Chapter 9 Lightning Protection

9-1* General Principles.

A lightning protection system, if installed, shall be installed in accordance with the provisions of this chapter.

9-1.1

The probability of a lightning strike varies with geographic location and the time of the year, but when the conditions that create an electrical charge between clouds and the earth exist, there is nothing that can be done to prevent a lightning discharge. A boat can be struck in open water or while tied to a dock. A lightning protection system for a boat is a system of electrical conductors designed to provide a low resistance path that extends directly from a point above the boat to the water so as to dissipate a charge as quickly and efficiently as possible. Successful protection of persons and watercraft from lightning is dependent upon a combination of proper design, maintenance of the system, and training of personnel. Maintenance and personnel behavior are covered in Appendix C. Unless special protective metallic enclosures are provided and circuit wiring can be disconnected, electronic equipment connected to the vessel's wiring system can be damaged by a lightning strike, even with the use of a lightning protection system. Because of the wide variation in structural designs and materials of watercraft construction, specific guidelines cannot be provided for individual watercraft. However, the basic guidelines contained in this chapter shall be considered and used in installing a lightning protection system for any given watercraft.

Exception No. 1: A lightning protection system offers no protection for a watercraft that is out of water.

Exception No. 2: A lightning protection system affords no protection, and is not intended to afford protection if any part of the boat contacts a power line or other high-voltage source while afloat or ashore.

9-1.2

A grounded vertical lightning protection mast projecting above the boat with a conductivity equivalent to No. 4 AWG copper conductor (41,740 circular mil area) generally can divert to itself direct lightning strikes that otherwise fall within a cone-shaped space, the apex of which is the top of the conductor or lightning protective mast and the base of which is a circle at the surface of the water that has a radius related to the height. [*See Figures 9-1.2(a) and 9-1.2(b)*.]

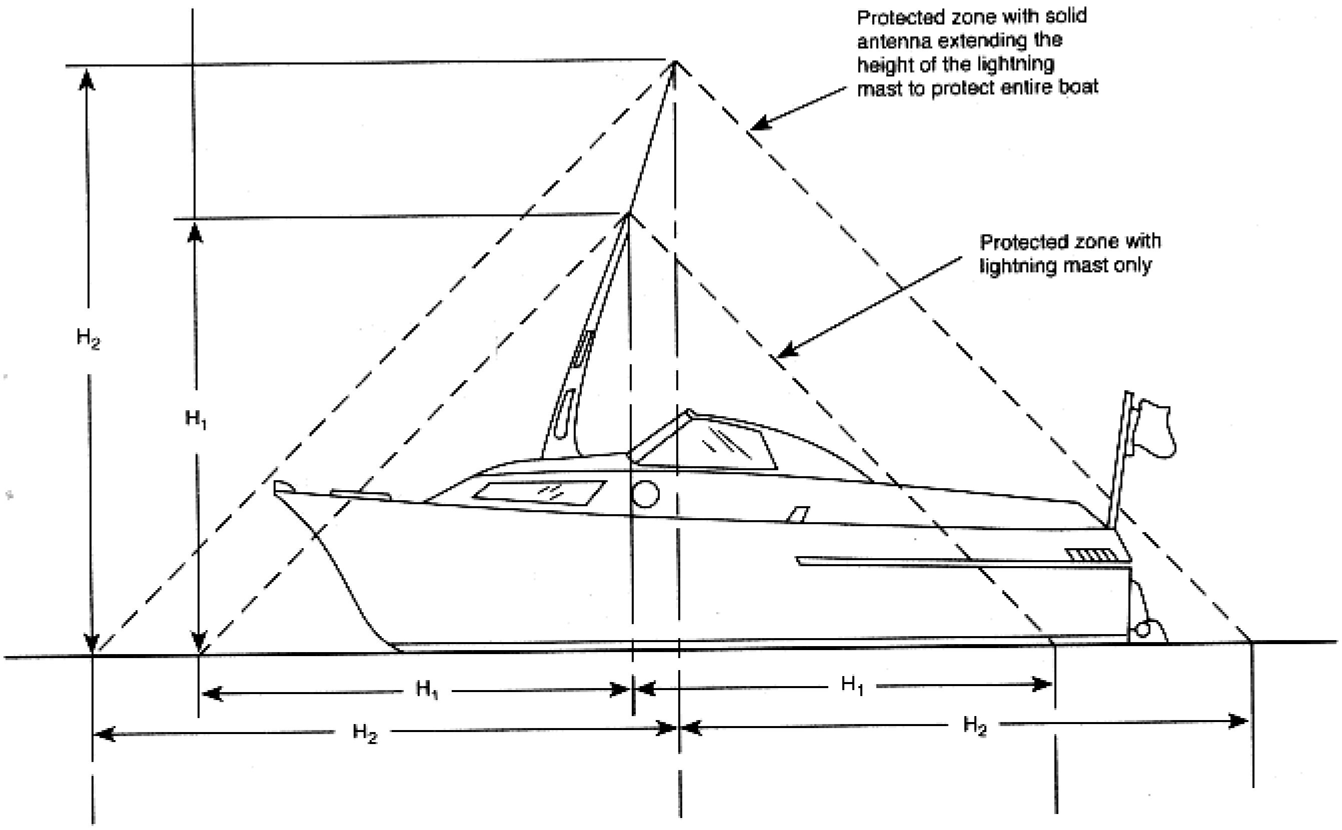


Figure 9-1.2(a) Diagram of boat with mast not exceeding 50 ft (15 m) above the water.

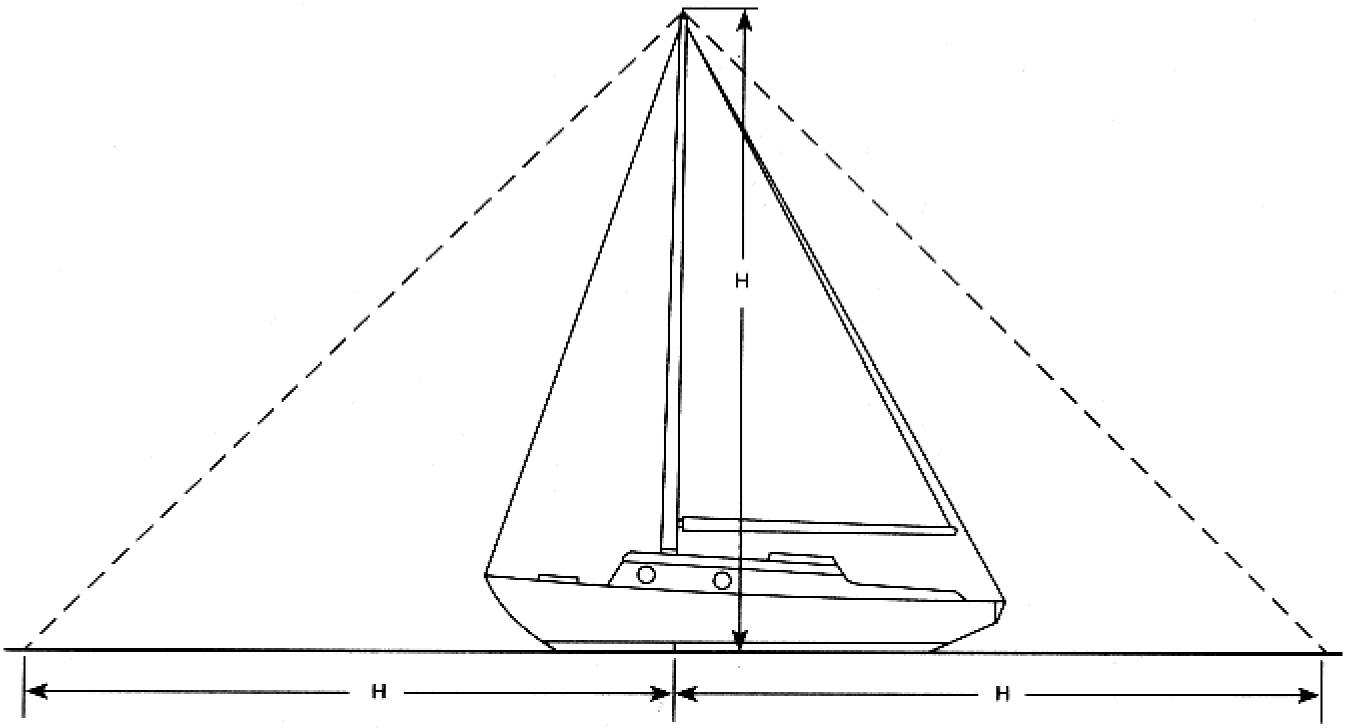
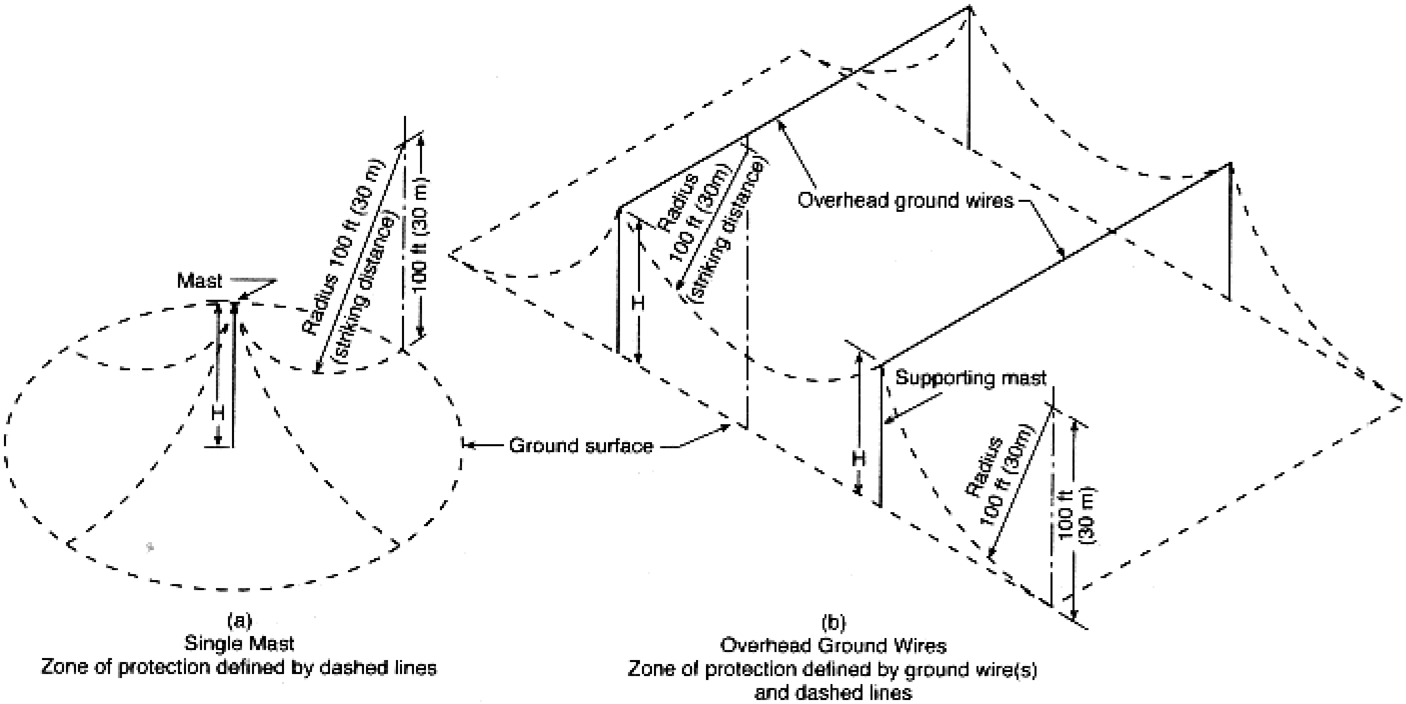


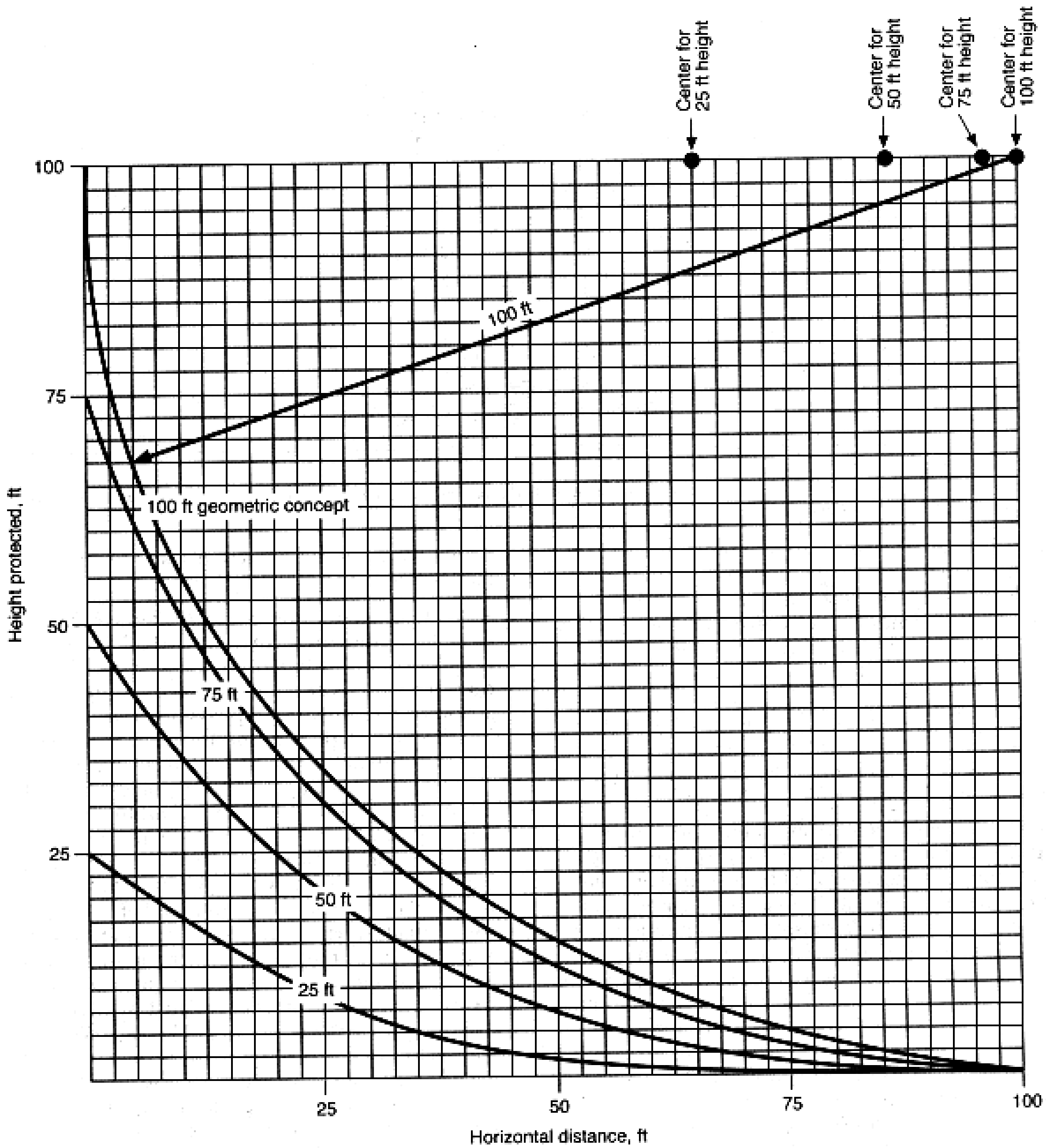
Figure 9-1.2(b) Diagram of small sailboat with mast not in excess of 50 ft (15 m).

9-1.3 Rods, Masts, and Overhead Ground Wires.

9-1.3.1 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 can strike any grounded object within the striking distance of the point from which final breakdown occurs, the zone of protection is defined by an upward circular concave arc [*see Figure 9-1.3.1(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 9-1.3.1(b) and* 9-1.3.1(c).]



Figures 9-1.3.1(a) and (b).



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 9-1.3.1(c) Zone of protection — 100 ft (30 m) striking distance.

9-1.3.2 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, a zone that is protected based on a striking distance of 100 ft (30 m) shall be considered to be adequately protected. Where more than one mast is used, the arc passes through the tips of adjacent masts.

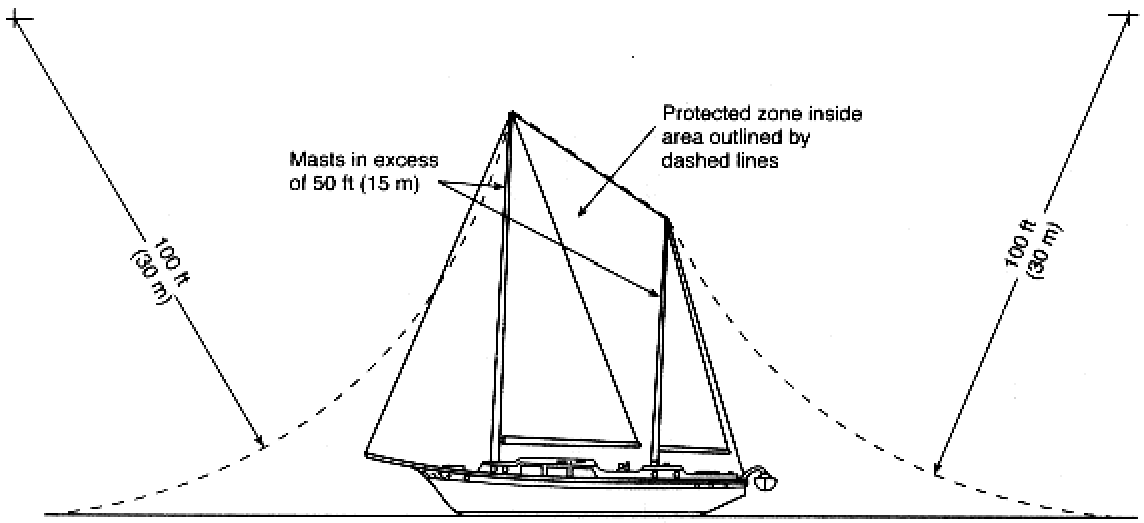


Figure 9-1.3.2 Diagram of boat with masts in excess of 50 ft (15 m) above the water — protection based on lightning striking distance of 100 ft (30 m).

9-1.3.3 The zone of protection afforded by any configuration of masts or other elevated, conductive objects can be readily determined graphically. Increasing the height of a mast above the striking distance will not increase the zone of protection.

9-1.4

For metallic masts, the bonding conductor from the mast to the lightning grounding plate or lightning grounding strip shall have a conductivity equivalent to No. 4 AWG (41740 CMA) copper conductor.

9-1.5

Where a nonmetallic mast with an air termination point (generally a pointed stainless steel rod) or a cap is used, the down conductor from the air termination point to the lightning ground plate or strip shall have conductivity equivalent to No. 4 AWG (41740 CMA) copper conductor. The path-to-ground from the air termination point shall be essentially vertical and as straight as possible. Where multiple shrouds and stays are used as part of the lightning conductive path-to-ground, the aggregate conductivity shall not be less than that of No. 4 AWG (41740 CMA) copper conductor, including the mast. Where stainless steel shrouds and stays are used in the lightning protection system, every shroud and stay shall be connected at its lower end, or at the chainplates, directly to the lightning grounding plate or lightning grounding strip, with conductors of at least No. 8 AWG (16510 CMA). (*See Section 9-4.*)

9-1.6

To minimize damage from sideflashes, an interconnecting conductor equivalent to at least No. 8 AWG (16510 CMA) 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, to the lightning grounding strip, or to the equalization bus, if provided, in accordance with Section 9-5. Sideflashes are most likely to occur if the routing of the main lightning grounding conductor is horizontal for any distance and if the metal object provides a more direct vertical path-to-ground. Metallic tanks shall be connected directly to the lightning ground plate, lightning grounding strip, or equalization bus, and routing of the grounding wire with other boat wiring shall be avoided.

9-1.7

The lightning grounding conductors shall be routed as remotely as possible from the boat's wiring to minimize both sideflashes and to avoid introducing high voltages into the boat's wiring. The lightning grounding conductors and the boat's wiring shall be routed so that the two wiring systems are separated from one another as far as possible and so that the boat wiring is not parallel to lightning grounding conductors.

9-1.8

Lightning protection provisions are likely to receive scant attention after installation, and, therefore, their composition and assembly shall be strong, and the materials used shall be highly resistant to corrosion.

9-2 Installation.

9-2.1 Lightning Protection Mast.

The lightning protection mast shall be so located and of sufficient height to provide a zone of protection that covers the entire boat. (*See Section 9-1*.)

9-2.2 Permanent Lightning Protective Mast.

A permanent lightning protective mast shall be located near the center of the deck plan area. The mast shall be mechanically strong to withstand exposure to the roll and pitching action of the hull and to heavy weather. The mast shall be fitted with a lightning air terminal that extends at least 6 in. (15 cm) above the mast. The air terminal shall be connected either to the mast, if metallic, or, in the case of a nonmetallic mast, to a copper conductor or copper strip securely fastened to the mast. The metallic mast or the lightning conductor fastened to a nonmetallic mast shall be equivalent to No. 4 AWG (41740 CMA) conductor. The mast shall be permitted to be raked at an angle but shall be substantially vertical. If the mast penetrates the cabin top and extends to the cabin sole, the mast shall be permitted to be fastened directly to the lightning ground plate or strip with a No. 4 AWG (41740 CMA) conductor. If the mast is stepped on deck, a No. 4 AWG (41740 CMA) conductor secured to the mast at the base shall be routed as vertically and directly as possible to the lightning grounding plate, the lightning grounding strip, or the equalization bus. If the conductor is routed around a passageway located directly below the mast, two No. 6 AWG (26240 CMA) conductors connected in parallel and routed on both sides of the opening shall be used. The mast and the conductors connecting the mast to the lightning ground plate shall be positioned, routed, or covered to minimize physical contact by persons on the boat.

9-2.3 Temporary Lightning Mast.

On small boats that cannot be equipped with a permanent lightning mast due to trailer transportation or for other reasons, a plug-in mast shall be permitted to be provided. The base of the plug-in mast shall be located as close to the geometric center of the boat as possible, but, if necessary, shall be permitted to be offset, provided the zone of protection covers the entire boat when the mast is plugged in. The location of the mast base shall be such that persons on the boat can avoid physical contact with the mast or the base. The base shall extend as high as possible, and provision shall be made to plug in the upper section of the lightning mast so that it cannot be displaced by rolling and pitching of the boat in rough water. The plug-in length shall not be permitted to be less than 3 in. (7.5 cm), unless a threaded coupling that can be tightened is provided. The plug-in mast shall be entirely of metal, aluminum, or steel tubing and equivalent to at least No. 4 AWG (41740 CMA) conductor.

Exception: A solid stainless steel whip antenna or equivalent shall be permitted to be used because of its higher melting temperature, but it does not provide as low a resistance path for the lightning.

9-2.4 Radio Antennas and Outriggers.

A solid metal-type vertical radio antenna shall be permitted to serve as a lightning mast, provided provision is made to ground the metal antenna base with a conductor equivalent to No. 4 AWG (41740 CMA) copper conductor that is routed vertically to the lightning grounding plate, to the lightning grounding strip under the boat, or to an equalization bus. The height of the antenna shall be sufficient to provide the required zone of protection for the boat and occupants. Because a loading coil presents a high impedance to the flow of lightning currents, the coil shall be provided with a suitable surge suppression device (lightning arrester) for bypassing the lightning current. The path to the lightning ground shall be permitted to be completed by means of a changeover switch that selects either radio operation or lightning protection or by means of the lightning gap across the loading coil to the lightning grounding system. The gap limits the voltage rise to the radio equipment to some extent, but damage is possible, depending on the severity of the strike.

9-2.4.1 Nonmetallic radio antennas with spiral-wrapped conductors shall not be permitted to serve as lightning protection.

9-2.4.2 Stainless steel shrouds of small diameter and stays on small sailboats that are trailered do not have the conductivity (less than that of No. 8 AWG (16510 CMA) conductor) necessary to conduct lightning currents to ground. Therefore, such shrouds and stays shall be grounded at their lower ends and used in addition to the grounding of the mast, which shall serve as the primary lightning grounding conductor.

9-3 Materials.

9-3.1

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.

9-3.2

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: For those components made of conductive materials that are part of the structure of the boat, such as aluminum masts, only copper shall be used in a lightning conductor system. Where copper is used, it shall be of the grade ordinarily required for commercial electrical work, which generally is designated as providing 98 percent conductivity where annealed.

9-3.3 Copper Conductor.

Copper cable conductors shall be of a diameter not less than No. 4 AWG (41740 CMA) for the main down conductor, not less than No. 6 AWG (26240 CMA) for two parallel paths, or No. 8 AWG (16510 CMA) for more than two paths, such as those to shrouds and stay connections on sailboats. The size of any single strand in a copper conductor shall not be less than No. 17 AWG (2048 CMA). The thickness of any copper ribbon or strip shall not be less than No. 20 AWG (1022 CMA). Where other materials are used, the gauge shall be such that it provides conductivity equal to or greater than the required conductor size.

9-3.4 Joints.

Joints shall be mechanically strong and shall be made so that they shall not have an electrical resistance in excess of that of 2 ft (0.6 m) of conductor.

9-4 Exterior Grounding Plate or Grounding Strip.

9-4.1 Vessels with Metal Hulls.

If an electrical connection exists between metallic hulls and a lightning protection mast or other metallic superstructure of adequate height to provide the zone of protection required in Section 9-2, no further protection against lightning shall be required; however, surge suppression in accordance with 9-5.5 shall be provided. Nonconducting objects projecting above metal masts or superstructures shall have such objects grounded with a grounding conductor connected to the grounded hull or superstructure.

9-4.2 External Ground Plate.

An exterior grounding plate of copper, copper alloys, stainless steel, or aluminum shall be permitted to be provided by a strip having an area of at least 1 ft^2 (0.09 m^2) that shall be located, as closely as possible, directly below the lightning protection mast. The connection to the ground plate shall be a fastener having a conductivity equivalent to No. 4 AWG (41740 CMA) copper conductor. The boat's propellers, shaft, metallic rudders, and other metallic surfaces that meet the required 1-ft^2 (0.09-m^2) area shall be permitted to be used effectively only on small boats where the lightning protection mast is located at the stern above the in-water metallic objects used as the lightning system ground. The stern mast shall be tall enough to provide a zone of protection that extends to the bow of the boat.

9-4.2.1 Boats that use a lightning grounding plate instead of a lightning grounding strip shall ground backstays or other objects aft to the engine negative terminal using a metallic rudder or other external ground at the aft end of the boat. The lightning ground shall not be routed through the boat to the lightning grounding plate forward under the lightning mast.

9-4.3 Grounding Strip.

An external grounding strip of copper, copper alloys, stainless steel, or aluminum installed under the boat in a fore and aft direction shall be permitted to be used as the earth ground connection for the lightning system. The strip shall have a minimum thickness of $^{3}/_{16}$ in. (4.8 mm) and a minimum width of $^{3}/_{4}$ in. (19 mm). The length of the strip shall be permitted to extend from a point located directly below the lightning protection mast to the aft end of the boat, where a direct connection can be made to the vessel's engine, but the total length of the strip shall not be less than 4 ft (1.2 m). In a sailing vessel, the backstay and engine shall be connected to the aft end of the strip. The strip shall be secured to the hull with one, or preferably two, galvanically compatible through-bolts at each end. The bolts shall have a minimum conductivity equivalent to No. 4 AWG (41740 CMA) copper conductor. The use of these bolts at each end, spaced 1 in. to 2 in. (2.5 cm to 5 cm) apart, helps to prevent any tendency of the strip to rotate when the electrical connections are made inside the hull. The strip shall be located so that it is submerged under all operating conditions. If the strip is not located so as to be submerged when a sailboat is heeled to port or starboard, then a strip shall be required on both the port and starboard sides. All connections to the strip shall be as short and direct as possible. Additional through-hull bolts shall be permitted to be located along the length of the strip for additional connections, such as those on a two-mast 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 through-hull bolt connections, an equalization bus shall be permitted to be installed in accordance with Section 9-5.

Exception: Stainless steel grounding strips shall have a minimum thickness of $^{1}/_{8}$ in. (3.2 mm).

9-4.3.1 The aft end of the lightning grounding strip shall be connected directly to the engine negative ground terminal to provide a path inside the hull for any DC stray currents that are imposed on the through-hull bolts from the lightning grounding strip where those bolts contact bilge water.

9-5 Interconnection of Metallic Masses.

9-5.1 Equalization Bus.

On larger vessels 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 boat parallel to the underwater lightning grounding strip. Permanently installed large metallic masses inside the boat shall be connected directly to the equalization bus. The equalization bus shall be connected to the underwater lightning grounding strip at both ends.

9-5.2 Seacocks and Through-Hull Fittings.

Seacocks and through-hull fittings, if connected to the lightning grounding system, shall not be connected to the main down conductor but shall be permitted to be connected to the underwater grounding strip, the lightning ground plate, or the equalization bus.

9-5.3

Metal masses, such as engines, generators, metallic tanks, steering systems inside the boat, and other items such as metal life rails, that come within 6 ft (1.8 m) of the lightning conductor at any point shall be connected to the lightning grounding underwater strip or ground plate or to the equalization bus as directly as possible.

9-5.4

To minimize the flow of lightning discharge currents through 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 lightning protection system.

9-5.5 Protection of Equipment.

Wherever possible, electronic equipment shall be enclosed in metal cabinets that are connected to the lightning grounding system with minimum No. 8 AWG (16510 CMA) conductor. Surge suppression devices shall be installed on all wiring entering or leaving electronic equipment.

9-6 Protection of Nonmetallic Sailboats.

9-6.1 Sailboats.

Sailboats without inboard engines that are equipped with metallic masts and metallic rigging shall be considered to be protected adequately if the mast and the rigging are connected to a lightning grounding plate or lightning grounding strip located directly below the mast.

9-6.2 Open Day-Sailers.

Because the stainless steel rigging and preventors usually are not equivalent to No. 8 AWG (16510 CMA) 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 with which the operator will come into contact shall be of nonconductive materials. Metallic keels or centerboards shall be connected directly to the lightning grounding plate or strip or shall be permitted to serve as the lightning grounding means if they provide the 1-ft^2 (0.09-m^2) area required for 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.

9-6.3 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.

Chapter 10 Fire Protection Equipment

10-1 General Requirements.

Portable fire extinguishers shall meet the requirements of and be inspected and maintained in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*, and shall be U.S. Coast Guard-approved or UL Marine-listed.

10-2 Equipment.

10-2.1*

All boats shall be equipped with portable fire extinguishers at least to the extent of the minimum requirements ofs Tables 10-2.1(a) and (b) and the requirements of this section.

Exception No. 1: CO_2 and Halon 1211 extinguishers having USCG Type B-I classification shall be permitted to be used.

Exception No. 2: CO_2 and Halon 1211 extinguishers having USCG Type B-I or Type B-II classification shall be permitted to be used.

Table 10-2.1(a) Number and Distribution of Fire Extinguishers [Boats up to but not including 65 ft in (19.7 m) length]

Type of Boat	No. of Existing	Minimum ANSI/UL Rating (See Notes 2 and 3)	Minimum USCG Rating (See Note 1)	Location
Open boats under 16 ft (4.8 m) with fiberglass or metal hulls and a light load of flammable Class A materials	1	5 B:C	B-1	Steering position
Open boats under 16 ft (4.8 m)	1	1A: 10B:C	B-1	Steering position
Boats 16 ft (4.8 m) to, but not including, 26 ft (8 m)	2	1A: 10B:C	B-1	Steering position and galley, when onboard, or cockpit
Open boats 16 ft (4.8 m) to, but not including, 26 ft (8 m)	2	1A: 10B:C	B-1	Steering position and galley or cockpit
Boats 26 ft (8 m) to, but not including, 40 ft (12 m)	3	1A: 10B:C	B-1	Outside engine compartment, steering position, and near galley or passenger cockpit
Boats 40 ft (12 m) to, but not including, 65 ft (20 m)	4	1A: 10B:C	B-1	Outside engine compartment, steering position, crew quarters, and galley, when onboard, or cockpit

NOTE 1: If a discharge port is installed, a USCG Type B-1 portable fire extinguisher might not be adequate. [See Table 10-2.1(a).]
NOTE 2: Extinguishers intended for machinery space protection are not required to have a Class A rating.
NOTE 3: Boats under 26 ft (8 m) in length without enclosed accommodation spaces or enclosed galleys shall be permitted to be equipped with a bucket with attached lanyard in lieu of Class A rated portable fire extinguishers.

Table 10-2.1(b) Number and Distribution of Fire Extinguishers [Boats equal to and greater than 65 ft (19.7 m) in length]

Gross Tonnage	No. of Extinguishers	Minimum ANSI/UL Rating	Minimum USCG Class.	Location
Under 50	1 (*See Note 1*)	4A: 60B:C	B-II	Outside engine compartment
	1 (*See Note 2*)	4A: 60B:C	B-II	Helmsman's position
	3 (*See Note 2*)	1A: 10B:C	B-I	Galley, crew quarters, and cabin
50 to less than 100	1 (*See Note 1*)	4A: 60B:C	B-II	Outside engine compartment
	2 (*See Note 2*)	4A: 60B:C	B-II	Helmsman's position and galley
	2 (*See Note 2*)	1A: 10B:C	B-I	Crew quarters and cabin
100 to less than 300	1 (*See Note 1*)	4A: 60B:C	B-II	Outside engine compartment
	3 (*See Note 2*)	4A: 60B:C	B-II	Helmsman's position galley and crew quarters
	1 (*See Note 2*)	1A: 10B:C	B-I	Cabin

NOTE 1: If the total horsepower exceeds 1000 bhp, an additional Type B-II portable fire extinguisher is required for each additional 1000 bhp or fraction thereof.
NOTE 2: The required Type B-I or Type B-II portable fire extinguisher shall be permitted to be distributed among the recommended locations as desired.

10-2.1.1 All required fire extinguishers located in accommodation spaces shall have Class A capability. All extinguishers shall be located adjacent to exit paths. It shall not be necessary to travel more than half the length of the boat or 33 ft (10 m), whichever is less, to reach an extinguisher.

10-2.1.2 At least one extinguisher shall be located at each occupied level.

10-2.2*

All inboard-powered boats with an enclosed engine compartment shall have provisions for discharging extinguishing agent directly into the space immediately surrounding the engine without opening the primary access. Where portable equipment is provided for use, a small, suitably labeled, readily accessible port to the enclosure shall be provided that shall permit the extinguisher to remain upright during discharge.

Exception: If the access port cannot be positioned so as to allow the portable extinguisher to remain upright, the portable extinguisher shall be equipped with a discharge hose.

10-2.2.1 Where portable equipment is provided for use, size shall be as specified in Table 10-2.2.1.

Table 10-2.2.1 Minimum Gaseous Portable Extinguisher Sizes for Flooding an Engine Compartment

Agent	Minimum Extinguisher Size	Maximum Compartment Volume
CO_2	5 lb (2.3 kg)	66 ft^3 (1.9 m^3)
CO_2	10 lb (4.5 kg)	133 ft^3 (3.8 m^3)
CO_2	15 lb (6.8 kg)	200 ft^3 (5.7 m^3)

CO_2	20 lb (9.1 kg)	266 ft^3 (7.5 m^3)
Halon	$2^1/_2$ lb (1.1 kg)	108 ft^3 (3.1 m^3)
Halon	3 lb (1.4 kg)	130 ft^3 (3.7 m^3)
Halon	4 lb (1.8 kg)	174 ft^3 (5.0 m^3)
Halon	5 lb (2.3 kg)	217 ft^3 (6.2 m^3)
Halon	9 lb (4.1 kg)	391 ft^3 (11.1 m^3)
Halon	13 lb (5.9 kg)	565 ft^3 (16.0 m^3)

For SI units: 1 lb = 454 gm; 1 ft^3 = 0.028 m^3

NOTE 1: Table 10-2.2.1 represents extinguishers containing concentrations of 45 percent CO_2 at 70°F (21°C) based on 0.075 lb agent /ft^3 (1.2 kg/m^3) or 5 percent halon at 70°F (21°C) based on 0.023 lb agent/ft^3 (0.37 kg/m^3).

NOTE 2: Halon means Halon 1211, Halon 1301, or a mixture thereof.

10-2.2.2 If an extinguisher is portable and readily removable from its fixed mounting, it shall be permitted to be credited as one of the extinguishers required in Tables 10-2.1(a) and (b).

10-2.3* Fixed Systems.

10-2.3.1 Systems shall be permitted to be manually or automatically operated, or both. Carbon dioxide systems that are installed to protect accommodation compartments or to protect engine compartments that normally can be occupied shall be equipped with a predischarge alarm.

10-2.3.2 If spaces are connected, such spaces shall be considered as a single space when determining the capacity of the system. In determining the extent of connecting spaces, the requirements of Section 9-5 shall be used. The actuation of the system shall be such that all the connecting spaces are flooded. If multiple units are used to provide the required capacity, they shall discharge simultaneously.

10-2.3.3* If a manual or manual/automatic fixed system is installed, the system shall be installed and maintained in accordance with the manufacturer's instructions and 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*, or NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*, as appropriate, and shall be U.S. Coast Guard-approved or UL Marine-listed. The system shall incorporate a visible or audible means outside of the protected space to indicate that the system has discharged.

10-3 Installation.

10-3.1

Portable fire extinguishers shall be located to be readily accessible from outside the compartment that they are intended to serve. Extinguishers shall be secured with a marine bracket to permit immediate release.

10-3.2*

Fixed extinguishing systems shall be installed in accordance with the manufacturer's installation procedures and with 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*, or NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*, as appropriate.

10-3.2.1 Extinguishing agent cylinders shall be mounted a minimum of 2 in. (5 cm) above moist or wet surfaces to reduce the danger of corrosion.

10-3.2.2* Manual controls shall be located to be readily accessible from outside the spaces served by the systems.

10-3.2.3 Systems shall be designed for one of the following modes of application (*see 10-2.3.2*):

(a) An independent system installed to cover one of various unconnected protected spaces;

(b) A single system of sufficient capacity to flood all protected spaces simultaneously; or

(c) A single system of sufficient capacity for the largest protected space, distributed to the selected space by valves at the controls.

Chapter 11 Referenced Publications

11-1

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.

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 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 52, *Standard for Compressed Natural Gas (CNG) Vehicular Fuel Systems*, 1992 edition.

NFPA 70, *National Electrical Code*, 1993 edition.

NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, 1990 edition.

NFPA 303, *Fire Protection Standard for Marinas and Boatyards*, 1990 edition.

NFPA 701, *Standard Methods of Fire Tests for Flame-Resistant Textiles and Films*, 1989 edition.

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*, 1994 edition.

11-1.2 Other Publications.

11-1.2.1 AMCA Publication. Air Movement and Control Association, 30 W. University Drive, Arlington Heights, IL 60004-1893.

AMCA/ANSI 210-85, *Laboratory Methods of Testing Fans for Rating.*

11-1.2.2 ANSI Publications. American National Standards Institute, 11 West 42nd Street, New York, NY 10036.

ANSI Z21.57-90, *Recreational Vehicle Cooking Gas Appliances.*

ANSI/NEMA WD-6-88, *Wiring Devices — Dimensional Requirements.*

11-1.2.3 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187.

ASTM A90M-93, *Standard Test Method for Weight (Mass) of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings.*

ASTM A463-88, *Standard Specification for Steel Sheet, Cold-, Rolled, Aluminum-Coated, Type 1 and Type 2.*

ASTM B122M-A-92,*Standard Specification for Copper-Nickel-Tin Alloy, Copper-Nickel-Zinc Alloy (Nickel Silver), and Copper-Nickel Alloy Plate Sheet, Strip, and Rolled Bar.*

ASTM B127-93, *Standard Specification for Nickel-Copper Allow Plate, Sheet, and Strip.*

ASTM D471-79, *Standard Test Method for Rubber Property, Effect of Liquids.*

11-1.2.4 NEMA Publication. National Electrical Manufacturers Association, 2101 L Street, NW, Suite 300, Washington, DC 20037.

NEMA 250, *Enclosures for Electrical Equipment (1000 V Maximum), 1991 edition.*

11-1.2.5 SAE Publications. Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.

SAE J1127-88, *Standard for Battery Cable.*

SAE J1128-88, *Standard for Low Tension Primary Cable.*

SAE J2031-90, *Standard for High Tension Ignition Cable.*

11-1.2.6 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 21-91, *Standard for Safety LP Gas-Hose.*

UL 103-89, *Standard for Safety Chimneys, Factory-Built, Residential Type, and Building Heating Appliances.*

UL 198C-86, *Standard for Safety High-Interrupting Capacity Fuses, Current-Limiting Types.*

UL 198E-88, *Standard for Safety Class R Fuses.*

UL 198F-88, *Standard for Safety Plug Fuses.*

UL 198H-88, *Standard for Safety Class T Fuses.*

UL 489-91, *Standard for Safety Molded-Case Circuit Breakers and Circuit-Breaker Enclosures.*

UL 498-91, *Standard for Safety Attachment Plugs and Receptacles.*

UL 512-93, *Standard for Safety Fuseholders.*

UL 817-94, *Standard for Safety Cord Sets and Power-Supply Cords.*

UL 858-93, *Standard for Safety Household Electric Ranges.*

UL 943-93, *Standard for Safety Ground-Fault Circuit-Interrupters.*

UL 1077-87, *Standard for Safety Supplementary Protectors for Use in Electrical Equipment.*

UL 1111-88, *Standard for Safety Marine Carburetor Flame Arresters.*

UL 1128-88, *Standard for Safety Marine Blowers.*

UL 1133-88, *Standard for Safety Boat Circuit Breakers.*

UL 1500-82, *Standard for Safety Ignition-Protection Test for Marine Products.*

11-1.2.7 U.S. Government Publications. U.S. Government Printing Office, Superintendent of Documents, Washington, DC 20402.

Title 33, *Code of Federal Regulations,* Part 183.

Title 49, *Code of Federal Regulations,* Parts 100 to end, U.S. Department of Transportation 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-1-4

For additional conversion information, see ASTM E380, *Standard for Metric Practice*.

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 Compressed Natural Gas (CNG).

Mixtures of hydrocarbon gases and vapors, consisting principally of methane in gaseous form that has been compressed for use as a fuel.

A-1-5 Galvanically Compatible.

Corroded End (anodic, or least noble)

Magnesium
Zinc
Aluminum
Cadmium
Steel or iron
Cast iron
Chromium-iron (active)
Lead-tin solders
Lead
Tin
Nickel (active)
Brasses[1]
Copper[1]
Bronzes[1]
Copper-nickel alloys[1]
Nickel-copper alloys
Silver solder
Nickel (passive)
Chromium-iron (passive)
Silver
Graphite
Gold
Platinum

Protected End (cathodic, or most noble)

[1]These metals and alloys are considered the best to use in combination for marine application.

A-1-5 Ignition Protection.

It is not intended that such devices be "explosionproof" as the term is defined in NFPA 70, *National Electrical Code®, where it pertains to shore systems or Title 46, Code of Federal Regulations*, Subpart 110.15-65(e) of Coast Guard 259, Subchapter J, "Electrical Engineering." It is intended that the protection provided generally be equivalent to that of wiring permitted by this standard wherein a definite short or break is necessary to produce an open spark.

Devices that are "explosionproof" are considered to be provided with ignition protection where installed with the appropriate fittings to maintain their "explosionproof" integrity.

It is not intended that such devices be “intrinsically safe” in accordance with NFPA 70, *National Electrical Code*, Article 500, or Title 46, *Code of Federal Regulations,* Subpart 111.80-5(a)(3) of Coast Guard 259, Subchapter J, “Electrical Engineering.”

Devices that are “intrinsically” safe are considered to be provided with ignition protection.

A-1-5 Liquefied Petroleum Gas (LPG).

Any material having a vapor pressure not exceeding that allowed for commercial propane composed predominantly of the following hydrocarbons, either by themselves or as mixtures: propane, propylene, butane (normal butane or isobutane), and butylenes. See NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*.

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-2-1.2

The use of marine fire retardant paints and varnishes is recommended for engine, fuel tank, and galley compartments.

A-2-4

Ventilation cannot be relied upon to remove all flammable vapors that can result from fuel system failures (leakage). Therefore, compliance with the ventilation requirements of this standard should be considered valid only where it has been determined that the entire fuel system complies with the requirements of Chapter 5.

A-2-4.1(b) Label.

WARNING LABEL FOR NONVENTILATED SPACE

WARNING

Do not store fuel or flammable liquids here.

Ventilation has not been provided for explosive vapors.

A-2-4.3

Exhaust(s) and intake(s) might not function as intended when wind direction varies.

A-2-5.2.2 See SAE J1171, *Recommended Practice for External Ignition Protection of Marine Electrical Devices*.

A-3-1.2

See SAE J1223, *Recommended Practice for Marine Carburetors*.

A-3-1.2.3 See SAE J1223, *Recommended Practice for Marine Carburetors*.

A-3-1.7

See SAE J1191, *Recommended Practice for High Tension Cable Assemblies—Marine*.

A-5-6.3.8 The purpose of this requirement is to preserve the fuel tightness at either end of the flexible section.

A-5-6.4

If fuel tanks are located in a compartment other than the engine compartment, or if the engine and fuel tanks are separated by a distance of more than 12 ft (3.7 m), an approved manual stop valve should be installed at the engine end of the fuel line to stop fuel flow when the engine is being serviced.

A-5-6.4.1 The purpose of the 12-in. (30-cm) requirement is to minimize the amount of pressurized piping when the pump is operating.

A-6

Open-flame devices are subject to careless, unskilled, or ignorant operation more than any other boat equipment involving fire risk. It is, therefore, imperative that such items be selected and installed with the aim of minimizing personal and physical hazards.

A-6-1.3

The calculation method for the minimum effective area of fixed ventilation for accommodation spaces is as follows:

$$V > 2200\ U + 440\ F + 650\ P$$

Where:

V = effective area in sq mm (minimum 4000 sq mm)

U = nominal heat input of non-flued appliances (cooker, stove, lamps) in kW

F = nominal input of open, flued appliances (refrigerator, water heater, cabin heater) in kW

P = number of persons for which the cabin is designed.

A-6-4.2.8 Examples of fuel system marking are as follows:

Stove Fuel — Diesel

Stove Fuel — Alcohol

A-6-5

In the interest of safety, it is important that the properties of liquefied petroleum gases be understood and that safe practices for their use be followed. LP-Gases liquefy under moderate pressure; they readily vaporize to the gaseous state upon relief of the pressure. Such characteristics prove to be an advantage when these gases are used. For convenience, they are shipped and stored under pressure as liquids. In the gaseous state, propane poses a hazard comparable to any flammable natural or manufactured gas, except that propane vapors are heavier than air. Although vapors tend to sink to the bottom of an enclosed compartment into which such gases are released, they diffuse throughout the compartment and cannot be dispelled readily by overhead ventilation. Safety demands that the escape of any propane should be prevented because, when mixed with air in certain proportions, propane will explode if ignited.

It also is important that the properties of natural gas be known and understood. Natural gas is a colorless, tasteless, and nontoxic flammable gas. It is a light gas, weighing about one-half as much as air, and it tends to rise and diffuse rapidly in air when it escapes from those systems covered by this standard. Natural gas is nontoxic but can cause asphyxiation when it displaces the normal 21 percent oxygen in air in a confined area without adequate ventilation. Its composition consists primarily of methane and varying amounts of ethane, propane, butane, and higher hydrocarbons. Some constituents of natural gas can be corrosive to carbon steel.

A-6-5.9.4 The purpose of the pressure gauge is to provide a convenient and quick means of testing the system for leakage from the container valve to, and including, the appliance valves. It is recommended that testing be done at least every two weeks and after any emergency. No leakage, however minor, should be permitted.

A-7-9.3

This might necessitate the use of thermally responsive protection devices on the equipment or system if the motor is not capable of operating continuously at maximum possible loading. If it is necessary to test as installed in order to ensure compliance with the locked rotor requirement, then voltage drop due to wire size and delay characteristics of the overcurrent protection device should be adjusted to protect the motor.

A-7-10.5

Consideration should be given to the selection of special switches for use with high-current inductive loads.

A-7-14.7

If a connection is soldered, the flexibility of the wire is affected and can be subject to failure from movement. If a crimped connection is soldered, it can reduce the mechanical strength of the joint.

A-8

This standard recognizes that shore power voltage varies in different geographic areas. The selection of motor-operated equipment should consider this variation.

A-8-14.3

If a connection is soldered, the flexibility of the wire is affected and can be subject to failure from movement. If a crimped connection is soldered, it can reduce the mechanical strength of the joint.

A-9-1

For detailed information on protection of shore structures, see NFPA 780, *Lightning Protection Code*.

A-10-2.1

On boats without Class A combustibles or accommodation spaces, a U.S. Coast Guard Type B-I extinguisher having only B:C capabilities may be permitted to be used. For equivalent ratings, use the following table:

Table A-10-2.1 U.S. Coast Guard Classification of Portable and Semiportable Fire Extinguishers

USCG	Size	Halon - (lb) (*See Note 2*)	CO_2 (lb)	Dry Chem. (lb)
B	I	$2^1/_2$	5	2

B	II	10	15	10
B	III		35	20

NOTE 1: The specified weights are the minimum for the stated classification.

NOTE 2: The halon column should be used for extinguishers containing Halon 1211, Halon 1301, or mixtures of these agents only.

A-10-2.2

Similar installations are recommended for all other under deck-enclosed spaces subject to potential fire hazards. As a minimum, a portable Halon 1301 or Halon 1211 unit intended to flood an engine compartment and a connecting compartment or space should provide at least 1 lb (0.45 kg) of capacity for each 40 ft^3 (1.1 m^3) of enclosed volume, including the connecting compartment of the space described above. If incomplete extinguishment occurs, excessive toxic breakdown products are produced. A portable CO_2 unit intended to flood an engine compartment should have at least the capacity outlined in Table A-10-2.3.3.

A-10-2.3 Fixed Systems.

(a) **Halon.** There are two basic types of halon systems. The first consists of a complete system of many components, including the storage tank, separate nozzle or nozzles, separately located detector or detectors with associated control devices, pressure switches for engine shutdown, override switches for convenience of engine restart, and monitor devices to signal that a system is in operational condition.

The second type of halon system consists of a self-contained device that holds the halon agent and is intended to be hung somewhere in the engine compartment or immediately adjacent thereto. These units are equipped with a storage tank, a nozzle, a heat sensor, and, in some cases, a pressure switch or a manual control combined into a single assembly, or both. Both types of systems have been approved by the U.S. Coast Guard.

Complete systems are referred to as engineered or pre-engineered systems and, when installed in accordance with the U.S. Coast Guard-approved installation manual, provide adequate protection for the volume specified in the approval documentation and the manual. A self-inspection form is available that should be completed by the installer or the owner and returned to the manufacturer. The manufacturer then provides a certificate, which is submitted to the authority having jurisdiction as evidence of an approved system.

The self-contained device systems include an installation manual that also warns of their limitations. It is extremely important that these limitations, as outlined below, be observed:

(1) Independently activated multiple units should not be used to provide protection for a volume larger than the smallest unit installed. If multiple self-contained units are installed in a single compartment, it is extremely unlikely that they would function simultaneously.

(2) Units should be located with their sensor near the top of the protected space.

(3) In calculating the volumes of the space to be protected, all connecting compartments or spaces into which extinguishing vapor can migrate easily, such as bilges, tank compartments, and storage areas should be included. For information on connecting compartments or spaces,

see Section 2-3.

If halons are used on a fire without complete extinguishment, excessive toxic breakdown products are produced.

All devices that consume air from the protected spaces should be shut down prior to or at the time of system actuation.

(b) **Carbon Dioxide.** A CO_2 fixed system consists of the storage container, actuation controls, pressure switch, and nozzles. All devices that consume air from the protected spaces should be shut down prior to or at the time of system actuation. Since this normally includes the main propulsion engine, it frequently is preferred that the system be actuated manually without automatic detection.

A-10-2.3.3 In the absence of a manufacturer's instruction manual, Table A-10.2.3.3 provides information that may be permitted to be used to determine weight per maximum volume of space protected for carbon dioxide, Halon 1211, or Halon 1301. A new, clean agent fire extinguishant should be installed and maintained in accordance with manufacturer's instructions and should be U.S. Coast Guard-approved or UL Marine-listed.

Table A-10-2.3.3 Recommended Weight of Carbon Dioxide or Halon (1211 and 1301)

Max Volume of Space (net ft)^3	Carbon Dioxide (lb[1])	Halon 1211 (lb[2])	Halon 1301 (lb[2])
90 (or less)	5	2.4	2.1
140	10	3.7	3.3
220	15	5.8	5.1
300	20	7.8	6.9
375	25	9.8	8.7
525	35	15.0	12.1
800	50	21.0	18.4
1200	75	31.2	27.6
1600	100	41.6	36.8

For SI units: 1 cu ft = $2.83 \times 10^{-2} m^3$

1. From 1,600 to 4,500 ft^3 (45 to 127 m^3), there should be 1 lb per 18 ft^3 (2.9 kg per m^3) of space and above 4,500 ft^3 (127 m^3), 1 lb per 20 ft^3 (3.2 kg per m^3) of space.

2. Volumes given in the table are based upon a flooding factor of 5 percent at 32°F (0°C) which is 0.026 lb/ft^3 (0.0042 kg/m^3) for Halon 1211, and 0.023 lb/ft^3 (0.0037 kg/m^3) for Halon 1301.

3. When computing the net cubic volume to be protected, due allowance should be made for permanent nonremoveable impermeable structures, which materially reduce the volume.

4. Warning: Discharge of these agents in a confined space can be hazardous to personnel. When the system discharges, the protected space should be evacuated immediately of all personnel.

A-10-3.2

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*, and NFPA 17, *Standard for Dry Chemical Extinguishing Systems*, are examples of applicable NFPA standards.

A-10-3.2.2 Well-separated dual manual controls are recommended, whether the system is designed for manual or automatic operation.

Appendix B Portable Fire Extinguishers and Fixed Systems

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

B-1 Classification of Fires.

Detailed information on portable fire extinguishers can be found in NFPA 10, *Standard for Portable Fire Extinguishers*.

For all practical purposes, the four general classes of fire are as follows:

Class A Fires. Fires in ordinary combustible material such as wood, cloth, paper, rubber, and many plastics.

Class B Fires. Fires in flammable liquids, oils, greases, tars, oil base paints, lacquers, and flammable gases.

Class C Fires. Fires involving energized electrical equipment where the electrical nonconductivity of the extinguishing media is of prime importance. (When electrical equipment is deenergized, extinguishers for Class A or Class B fires can be used safely.)

Class D Fires. Fires in combustible metals such as magnesium, titanium, zirconium, sodium, or potassium.

B-2 Classification of Fire Extinguishers.

B-2.1

Based on the classification of fires described above and on fire extinguishing potential as determined by physical testing by organizations acceptable to the authority having jurisdiction, classifications have been established for portable fire extinguishers. The U.S. Coast Guard also classifies portable fire extinguishers based on the classification of fires found in Section B-1 but uses a different method of indicating extinguishment potential. (*See Title 46, Code of Federal Regulations*.)

The relative extinguishment potential of various sizes and types of extinguishers as determined by Underwriters Laboratories Inc. is expressed by a numeral, and the class of fire for which the agent is suitable is represented by the letters in Section B-1. Size or weight alone does not necessarily indicate the effectiveness of the extinguisher, and this should be understood when choosing an extinguisher to ensure the best value and the maximum protection. Because of the regulatory responsibility of the U.S. Coast Guard in the field of boating safety, U.S. Coast Guard designations are followed in this standard. (*See Table B-2.1*.)

Table B-2.1 Fire Extinguishers

Type of Extinguisher	Fire Suitability A	Fire Suitability B	Fire Suitability C	Subject to Freezing	Annual Maintenance Required[1]	Operating Precautions
Carbon dioxide	No	Yes	Yes	No	Weigh and tag	Smothering in high concentrations. Avoid contact with discharge horn.
Dry chemical	No	Yes	Yes	No	Weigh to manufacturer's instructions; verify pressure if gauge is provided and seal integrity; tag	None
Multipurpose dry chemical A, B, C	Yes	Yes	Yes	No	Weigh to manufacturer's instructions; verify pressure if gauge is provided and seal integrity; tag	None
Halon 1211 or 1301	See Note 2	Yes	Yes	No	Weigh to manufacturer's instructions; verify pressure if gauge is provided and seal integrity; tag	Avoid high concentrations

[1] In addition, inspect frequently to detect tampering, obstruction of discharge orifice, or other condition. (See NFPA 10, *Standard for Portable Fire Extinguishers.*)
[2] Certain extinguishers of this type are listed for Class A fires. Check label for suitability for Class A fires.

B-3 Fire Extinguisher Rating System.

B-3.1

Although currently using a rating system based on the size and weight of the extinguishing agent, the U.S. Coast Guard also considers extinguisher performance on marine-type fires. Extinguishers not labeled with a U.S. Coast Guard approval classification should be listed and labeled by Underwriters Laboratories Inc., have a minimum rating of 5 B:C, and have a minimum capacity as specified in Table B-3.1. Those of inadequate performance are not classified as approved by the Coast Guard. Table B-3.1 provides the Coast Guard classification and relative unit size for the minimum size approved portable and semiportable fire extinguisher acceptable for use on flammable liquid fires.

Table B-3.1 U.S. Coast Guard Classification of Fire Extinguishers

Classification Type	Size	Halon 1211 (lb)	Carbon Dioxide (lb)	Dry Chemical (lb)
B	I	$2^1/_2$	5	2
B	II	10	15	10
B	III		35	20

B-4 Portable Fire Extinguishers and Fixed Systems — Maintenance.

B-4.1

All fire extinguishers should be examined at regular intervals several times each year to make certain that they have not been tampered with and have not suffered corrosion or damage. Seals should be inspected to determine that the extinguishers have not been operated since last being charged. This examination can be carried out by most boat owners or operators; however, for more than casual inspection for obvious deficiencies, it is recommended that a qualified fire extinguisher service person service fire extinguishers at least once a year and after each use.

B-4.2

All fire extinguishers should be recharged after each use, even if only partly discharged.

B-4.3

Dry chemical fire extinguishers should be kept filled with the specified weight of chemical at all times. Cartridges, in cartridge-type extinguishers, should be reweighed annually and, if found to weigh less than the minimum weight stamped thereon, should be replaced with a full cartridge or recharged. The gauge on stored pressure units should be examined and the unit serviced if the pressure is outside the operating limits.

B-4.3.1 After discharge, and before recharging, the discharge hose should be cleaned of all chemicals.

B-4.4

Carbon dioxide fire extinguishers should be reweighed semiannually, and cylinders in fixed carbon dioxide systems should be reweighed at least annually but preferably every 6 months. If found to be lighter than the weight indicated on the nameplate, cylinders should be recharged.

B-4.4.1 Carbon dioxide fire extinguishers always should be recharged after each use, even if only partly discharged.

B-4.4.2 Carbon dioxide extinguishers and cylinders in fixed systems should be provided with tags indicating the date weighed, current weight, and weigher's signature.

B-4.5

Portable extinguishers should be hydrostatically tested in accordance with the requirements of NFPA 10, *Standard for Portable Fire Extinguishers*.

B-4.6

All fixed systems, if installed, should be maintained on at least an annual basis in accordance with the manufacturer's maintenance manual. It is recommended that a fixed system be maintained by a qualified fixed system service person.

B-5 Fire Extinguishers and Fixed Systems — Operations.

B-5.1

For Class A fires, such as those in bedding, cushions, acoustic materials, and wood, the extinguishing agent should be water, multipurpose dry chemical, Halon 1211, or Halon 1301 (if listed for Class A fires). Action should be taken to extinguish completely any burning or smoldering embers, or the smoldering material should be thrown overboard. Alcohol fuel galley fires also can be extinguished with water.

B-5.2

Carbon dioxide, Halon 1211, Halon 1301, and dry chemical are the most effective means of extinguishment for Class B fires in flammable liquids such as gasoline, diesel fuel, or kerosene.

B-5.2.1 Dry chemical fire extinguishers are provided with a nozzle for distributing the dry chemical in a dense cloud from about 5 ft to 15 ft (1.5 m to 4.5 m), depending upon the capacity of the extinguisher. For open fires in flammable liquids, the discharge should be applied in a rapid, sweeping motion to the near edge of the flames at their base and continued toward the far edge. For fires caused by running or dripping fuel from leaks in fuel tanks or lines, extinguishment should begin at the lower part of the fire and work upward. Leaks should be stopped as quickly as possible. For use on obstructed fires, such as in engine rooms, the discharge should be applied near the base of the fire to be effective. Such applications are not always possible.

B-5.2.2 Carbon dioxide fire extinguishers are provided with a horn for applying the discharge close to the base of the flames. For open fires in flammable liquids, the discharge should be applied in a slow, sweeping motion to the near edge of the flames at their base and continued toward the far edge. For fires caused by running or dripping fuel from leaks in fuel tanks or lines, extinguishment should begin at the lower part of the fire and work upward. Leaks should be stopped as quickly as possible.

B-5.3

For Class C fires involving electrical equipment, circuits should be deenergized first by opening main switches, pulling shore line plugs, or other means. Dry chemical, carbon dioxide, Halon 1211, or Halon 1301 extinguishers should be used. Water or foam extinguishers should not be used due to the danger of electrical shock to the operator or shorting of the electrical circuits.

B-5.4

Fixed fire extinguishing systems provide manual, automatic, or combined manual and automatic operation. The manual release should be used without waiting for the automatic release to operate if a fire occurs aboard an attended vessel. Personnel should be evacuated prior to discharge where using carbon dioxide and Halon 1211 systems, as their effects are dangerous to life. All hatches, ports, doors, or other openings to areas covered by a fixed system should be closed prior to release, if possible.

Appendix C Operation and Maintenance

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

C-1

The fire and explosion hazards of inboard powered boats should be emphasized because of their basic design and construction. While ventilation for the removal ashore of heavier-than-air flammable vapors is provided at floor level, similar provisions are obviously impossible for boats. Accordingly, the operation and maintenance recommendations included in this appendix are intended to supplement the standard.

C-2 Hull.

C-2.1

The entire boat should be kept clean and shipshape.

C-2.1.1 Frequent flushing and cleaning of bilges is recommended.

C-2.1.2 Clean waste and rags should be stowed in metal containers or in metal-lined lockers. Waste and rags coated with oil, paint, paint remover, or polish should be disposed of ashore immediately and should not be stored onboard.

C-2.1.3 Foul weather clothing should be hung loosely in well-ventilated lockers.

C-2.1.4 Paint and varnish removers and the materials they remove are generally highly flammable. Particular caution should be exercised during their use to ensure ample ventilation, to prohibit open lights, fires, and smoking, and to ensure that the removed material is disposed of ashore as quickly as possible.

C-2.1.5 Naked lights and open flames, however small, should not be carried into compartments where gasoline vapor might be present.

C-2.1.6 Gasoline or other flammable solvents should not be used for cleaning purposes.

C-2.2

The ventilation system should be maintained at top efficiency.

C-2.2.1 Ventilation ducts should never be blocked off, and any screening used in cowl or duct openings should be kept clear.

C-2.2.2 If hazardous vapors are present, the entire boat should be opened to free all vapors, and no equipment should be operated until the problem has been corrected.

C-2.3 Precautions During Lightning Conditions.

C-2.3.1 Since the basic purpose of protection against lightning is to ensure the safety of personnel, it is appropriate that the following precautions should be followed:

(a) Boat occupants should remain inside a closed boat to the degree practical during a lightning storm and should not dangle arms or legs in the water.

(b) To the extent consistent with safe handling and navigation of the boat during a lightning storm, contact with any items connected to a lightning protection system should be avoided, especially in such a way as to create a bridge between the items. For example, an operator should not be permitted to be in contact with the reversing gear levers and the spotlight control handle at the same time.

(c) No occupant should be in the water during a lightning storm.

C-2.3.2 Maintenance Suggestions for Lightning Protection Systems.

(a) A whip-type radio antenna should not be tied down during a lightning storm if it has been designed as a part of the lightning protection system.

(b) If a boat has been struck by lightning, compasses and electrical gear should be checked to determine whether damage or change in calibration has occurred.

C-3 Engines.

C-3.1

Engines, including their fuel, electric, and cooling systems, always should be maintained in satisfactory operating condition in accordance with the manufacturer's instructions.

C-3.1.1 Before starting any engine, the following procedures should be performed:

(a) Ventilate the engine compartment.

(b) Open the hatches to any compartment into which vapors can flow, and make particular use of the senses of sight and smell to detect fuel leaks.

(c) Check that the lubrication oil reservoir is full.

(d) Check that the engine-cooling water intakes are open.

C-3.1.2 When engine starts:

(a) Check the oil pressure.

(b) Verify the cooling-water circulation (e.g., check exhaust discharge).

C-3.1.3 During operation, frequent observation checks should be made of oil pressure and cooling-water temperature.

C-4 Fuel Systems.

C-4.1

Gasoline vapors are heavier than air and cannot escape from low-lying pockets such as bilges unless drawn or forced out. An atmospheric concentration of gasoline vapor as low as 1.25 percent is sufficient to create a mixture that can explode by means of only a slight spark.

The entire fuel system, including tanks, piping (including tank vent line), and accessories, should be checked frequently for leaks or evidence of corrosion.

C-4.1.1 All connections should be maintained tight at all times.

C-4.1.2 Fuel carried onboard outside of a fixed fuel system should be stored in an approved container or in a portable tank such as is provided for outboard engines and should be stowed safely outside of engine or living compartments.

C-4.2

Utmost care should be exercised during fueling operations.

C-4.2.1 Fueling should never be done at night except under well-lighted conditions.

C-4.2.2 During fueling operations, smoking should be forbidden onboard or anywhere nearby.

C-4.2.3 Before opening tanks, the following procedures should be performed:

(a) Shut down engines, motors, and fans.

(b) Extinguish all open flames, including open pilot lights.

(c) Close all ports, windows, doors, and hatches.

(d) Determine the quantity of fuel to be taken aboard in advance of fueling operations.

C-4.2.4 The fuel delivery nozzle should be put in contact with the fill pipe before the flow of fuel is begun, and this contact should be maintained continuously until fuel flow has stopped. There is a serious hazard posed by static discharge unless this practice is observed.

C-4.2.5 Tanks should not be filled completely. Allow a minimum of 2 percent of tank space for expansion. The space allowance should be 6 percent if the temperature of the fuel taken aboard is 32°F (0°C) or lower.

C-4.2.6 The following should be performed after fuel flow has stopped:

(a) Secure the fill cap tightly.

(b) Wipe up any spillage completely and dispose of the rags or waste on shore.

(c) Ventilate all spaces, and check for gasoline vapors before starting any engines or operating any appliances.

C-5 Cooking, Heating, and Auxiliary Appliances.

C-5.1

All flame operated equipment should be kept clean and maintained in accordance with the manufacturer's instructions.

C-5.1.1 Gasoline should not be used for priming alcohol or kerosene burners, nor should gasoline or other flammable liquids be used for lighting coal, charcoal, or wood stoves.

C-5.1.2 Alcohol, kerosene, and fuel-oil burner tips should be kept clean to avoid choking, extinguishment, and consequent flooding.

C-5.1.2.1 Burners should not be primed when hot.

C-5.1.2.2 Reserve fuel should be limited to minimum needs, and should be carried only in approved containers stowed in a safe location outside the engine compartment.

C-5.2

Printed instructions and labeled diagrams for the operation and maintenance of propane systems should be available onboard for ready reference.

C-5.2.1 Only the specific gas for which the system is designed should be used.

C-5.2.2 Particular care should be taken to protect flames from being blown out by boilovers, gusts of wind, or other causes.

C-5.2.3 Containers should be changed in accordance with the following instructions and under the supervision of licensed personnel, when such officers are onboard, or by other responsible persons when no such officers are onboard.

C-5.2.3.1 For single-container systems, the following procedures should be performed:

(a) Close stop valves on container and burn out gas content in the line by lighting burners.

(b) Important — When burners go out, shut them off.

(c) Disconnect empty container, leaving stop valve closed and plugged. Connect the full container.

C-5.2.3.2 For multicontainer systems, the following procedures should be performed:

(a) Close container stop valves.

(b) Burn out gas content in low-pressure lines and proceed with container change as described in C-5.2.3.1(c).

C-5.2.3.3 For both types of systems, the following procedures should be performed:

(a) After turning on the full container, light all burners and allow to burn for a sufficient length of time to ensure that there is no air in the lines to interrupt a continuous flow of gas.

(b) Shut off burners and container stop valves, and test for leaks with soapy water solution.

C-5.2.4 Frequent (at least twice per month) tests of the entire system, performed at service pressure, should be made by closing container valves and observing the gauge. If tight, there should be no noticeable drop in 10 min. A test for location of leaks should be made with soapy water solution never — with flame.

C-6 Electrical System.

Frequent inspection should be made of all electrical equipment and wiring to ensure against deterioration and faulty conditions such as loose connections, insulation failure, burned switch contacts, fuse replacements, and bonding effectiveness. Battery terminals should be kept clean of corrosive deposits.

C-7 Emergency Equipment.

Pyrotechnics should be stored in a dry place in a suitable waterproof container and should be inspected frequently for signs of deterioration. Any sign of deterioration should be cause for replacement.

Appendix D Referenced Publications

D-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.

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*, 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 17, *Standard for Dry Chemical Extinguishing Systems*, 1994 edition.

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, 1992 edition.

NFPA 70, *National Electrical Code*, 1993 edition.

NFPA 780, *Lightning Protection Code*, 1992 edition.

D-1.2 Other Publications.

D-1.2.1 ASTM Publication. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM E380, *Standard Practice for Use of the International System of Units (SI) (the Modernized Metric System)*, 1991 edition.

D-1.2.2 SAE Publications. Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.

SAE J378-88, *Recommended Practice for Marine Engine Wiring.*

SAE J1171-86, *Recommended Practice for External Ignition Protection of Marine Electrical Devices.*

SAE J1191-86, *Recommended Practice for High Tension Cable Assemblies—Marine.*

SAE J1223-91, *Recommended Practice for Marine Carburetors.*

SAE J1294-86, *Recommended Practice for Ignition Distributors—Marine.*

SAE J1428-85, *Recommended Practice for Marine Circuit Breakers.*

D-1.2.3 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 1129-88, *Standard for Safety Wet Exhaust Components for Marine Engines.*

UL 1426-86, *Standard for Safety Electric Cables for Boats.*

UL 2006-91, *Standard for Safety Halon 1211 Recovery/Recharge Equipment.*

D-1.2.4 U.S. Government Publications. U.S. Government Printing Office, Superintendent of Documents, Washington, DC 20402.

Title 46, *Code of Federal Regulations*, Subpart 110.15-65(e) of Coast Guard 259.

Title 46, *Code of Federal Regulations*, Parts 110-113.

Title 46, *Code of Federal Regulations*, Subpart 111.80-5(a)(3) of Coast Guard 259.

1995 Edition

This edition of NFPA 303, *Fire Protection Standard for Marinas and Boatyards*, was prepared by the Technical Committee on Marinas and Boatyards 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 303 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 303

This first NFPA standard on the subject of marinas and boatyards was adopted by the Association in 1940 on recommendation of the Committee on Boat Basins and Municipal Marinas of the then NFPA Marine Section. The following year the scope of the recommendations was enlarged to include boat service and storage yards. Minor amendments were adopted in 1952 and 1957. A revised edition was produced in 1960 by the Committee on Motor Craft and Marinas. In 1961, the Sectional Committee on Marinas and Boatyards was established to deal exclusively with these matters. A complete revision of NFPA 303 was developed and adopted in 1963, amendments to which were adopted in 1966, 1975, and 1984. In 1986 a complete revision of NFPA 303 was adopted; it incorporated boat condominiums and multiple berthing facilities and provided updated electrical and fire protection requirements. The 1990 edition of NFPA 303 contained amendments to the previous edition, while the 1995 edition contains amendments to Chapters 1, 2, 3, and 4 of the 1990 edition.

Technical Committee on Marinas and Boatyards

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Committee Scope: This Committee shall have primary responsibility for documents on fire prevention and protection in the design, construction and operation of marinas and boatyards.

NFPA 303
Fire Protection Standard for Marinas and Boatyards

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 Introduction

1-1 Scope.

This standard applies to the construction and operation of marinas, boatyards, yacht clubs, boat condominiums, docking facilities associated with residential condominiums, multiple-docking facilities at multiple-family residences, and all associated piers, docks, and floats. Single family residences with docking facilities for private, non-commercial use are not intended to be covered by this standard, but use of the standard by the authority having jurisdiction or by single-family residences shall be permitted.

1-1.1

This standard also applies to support facilities and structures used for construction, repair, storage, hauling and launching, or fueling of vessels if fire on a dock would pose an immediate threat to these facilities, or a fire at a referenced facility would pose an immediate threat to a dock area.

1-1.2

This standard applies to marinas and facilities:

(a) Servicing small recreational and commercial craft, yachts, and other craft of not more than

300 gross tons, and

(b) Not covered by NFPA 307, *Standard for the Construction and Fire Protection for Marine Terminals, Piers, and Wharves*; or NFPA 30A, *Automotive and Marine Service Station Code*.

1-1.3

No requirement in this standard shall be construed as reducing applicable building, fire, and electrical codes.

1-2 Purpose.

This standard is intended to provide a minimum acceptable level of safety to life and property from fire and electrical hazards at marinas and related facilities. The standard recognizes the following circumstances.

1-2.1

Electrical wiring on and about piers and floats, and connected to craft, presents exceptional fire and shock hazard. This standard emphasizes, and in some cases exceeds, the requirements of NFPA 70, *National Electrical Code®*.

1-2.2

Marinas and related facilities frequently are located in remote areas, isolated from public protection, or with dock areas not easily accessible to community fire equipment. Hence, the selection, location, and maintenance of fire-fighting equipment, and adequate training in its use, are essential.

1-2.3

Continuing operations such as fiberglassing, woodworking, painting and paint removing, welding and cutting, and handling gasoline and other highly flammable liquids are hazardous operations that require careful vigilance and fire prevention effort by management.

1-3 Retroactivity.

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 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 which 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.

Additional definitions specific to certain chapters of this standard are contained within the appropriate chapter.

Approved.* Acceptable to the authority having jurisdiction.

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

Berth. The water space to be occupied by a boat or other vessel alongside or between bulkheads, piers, piles, fixed and floating docks, or any similar access structure. (*See also Slip.*)

Boatyard. A facility used for constructing, repairing, servicing, hauling from the water, storing (on land and in water), and launching of boats. Boatyards are usually, but not necessarily, waterfront facilities. Boatyards provide facilities and services, as described above, that exceed the basic berthing or mooring of boats.

Building. A roofed-over structure with or without enclosed walls.

Bulkhead. A vertical structural wall, usually of stone, timber, metal, concrete or synthetic material, constructed along, and generally parallel to, the shoreline to retain earth as an extension of the upland, and often to provide suitable water depth at the waterside face.

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).

Covered Dock. A fixed or floating dock structure that is provided with a roof system to protect berthed boats from the weather. (*See also Covered Slip.*)

Covered Slip. A building that contains slips.

Covered Storage. A structure or building capable of receiving and storing boats for extended periods of time while protecting the boats from exposure to the weather. The structure might or might not be heated or cooled.

Crane. A mechanical device used for lifting or moving boats. A crane can be fixed in position or mobile. Generally refers to a device having a movable projecting arm (boom), or a horizontal beam which translates on an overhead support.

Dock. A fixed or floating structure that provides access to boats in associated berths, and where boats are secured during periods of inactivity.

Dry Stack Storage. A facility, either covered or uncovered, constructed of horizontal and vertical structural members designed to allow placement of small boats in defined slots arranged both horizontally and vertically. Vertically, the boats are placed in tiers, or racks, 2 or more levels high. Boats are placed in the racks by use of a forklift or mobile crane. Also known as Dry Rack Storage or Stack Storage.

Flammable Liquid. A liquid having a flash point below 100°F (37.8°C) and having a vapor pressure not exceeding 40 lb per sq in. (absolute) (2,068 mm Hg) 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).

Floating Piers or Floating Docks. Piers or docks designed with inherent flotation capability that allows the structure to float on the water surface and rise and fall with water level changes.

Fixed Piers or Fixed Docks. Piers or docks constructed on a permanent, fixed foundation, such as on piles, that permanently establishes the elevation of the structure deck with respect to land.

Fuel Product Lines. Piping that connects the fuel storage tanks to the fuel dispensing pumps. Piping can be located above or below ground or a combination of above and below ground. General term includes associated fittings, valves, and hardware.

Fuel Storage. An area or structure (i.e., tanks) that contains fuel products in storage for subsequent dispensing.

Fueling Station or Pier. An area on a pier, dock, bulkhead, or similar structure that is specifically used for the dispensing of fuel products. Also known as a Marine Service Station, Fuel Dispensing Facility, or Fuel Dock.

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.

Marina. A facility, generally on the waterfront, that stores and services boats in berths, on moorings, and in dry storage or dry stack storage. A dry land marina would provide similar services, but might not be located on the waterfront. The services provided by a marina are those generally associated with active boat use, such as: berthing of boats, fueling, sanitary sewage pumpout, seasonal boat storage or short-term storage, seasonal boat painting, boat engine maintenance, and voyage repairs. Servicing of a greater nature is generally associated with boatyard facilities. A marina can also incorporate recreational facilities, ship's stores, offices, restaurants, or other upland amenities.

Marine Railway. A device used for hauling boats out of the water or placing boats into the water. Generally a structure comprised of a movable cradle, it is capable of accommodating a range of vessel sizes and types and operates on fixed, inclined tracks (ways) extending from the upland into the water. The cradle is moved up or down the tracks by a winched cable or chain.

Monorail. Overhead track and hoist system for moving material around the boatyard or moving and launching boats.

Mooring(s). Any place where a boat is wet stored or berthed. Locally, can be used to differentiate between permanent anchored moorings and slips.

Pier. A structure extending over the water and supported on a fixed foundation (fixed pier), or on flotation (floating pier), that provides access to the water.

Power Outlet. An enclosed assembly that can include receptacles, circuit breakers, fused switches, fuses and watt-hour meter, and mounting means approved for marine use.

Seasonal Storage. Storage of boats for extended periods when not in use, i.e., winter storage.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Slip. A berthing space between or adjacent to piers, wharves, or docks. The water areas associated with boat occupation. (*See also Berth.*)

Stack Storage. *See Dry Stack Storage.*

Standpipe System. An arrangement of piping, valves, hose connections, and allied equipment with the hose connections located in such a manner that water can be discharged in streams or spray patterns through attached hose and nozzles, for the purpose of extinguishing a fire and so protecting designated buildings, structures or property in addition to providing occupant protection as required.

Classes of Standpipe Systems:

Class I Systems. A Class I standpipe system shall provide $2^1/_2$-in. (63.5-mm) hose connections to supply water for use by fire departments and those trained in handling heavy fire streams.

Class II Systems. A Class II standpipe system shall provide $1^1/_2$-in. (38.1-mm) hose stations to supply water for use primarily by the building occupants or by the fire department during initial response.

Wet Storage. A term used to indicate that a boat is stored afloat in a partly or completely laid-up status.

Chapter 2* Management

2-1 Smoking Restrictions.

Smoking shall be prohibited and “NO SMOKING” signs shall be posted in all areas where fuels and other flammable liquids are stored or dispensed, in all covered or enclosed boat storage areas, in battery rooms, and in other such locations as management or the authority having jurisdiction shall designate.

2-2 Maintenance of Fire-Fighting Equipment and Systems.

A maintenance program that requires periodic inspection, testing, and operation of fire-fighting equipment and systems, and that assures access to all parts of the facility for fire-fighting personnel, shall be adopted.

2-2.1

All fire-fighting equipment and systems shall be inspected and tested at regular intervals. As part of this requirement, fire extinguishers shall be inspected at least annually and provided with a tag showing the last date of inspection, and shall be emptied at the end of their service period, preferably as part of a training exercise (*see Section 2-3*).

2-2.2

Hoses shall be unrolled, inspected, and tested (in accordance with the manufacturer's instructions) at least once a year.

2-2.3

The fire department shall have access to fenced, gated, or locked grounds or piers. Appropriate means of access (including keys, cardkeys, and combinations) shall be provided to the fire department or shall be permitted to be secured in a lock box on the premises accessible to the fire department. The fire department shall be notified immediately of any changes in the means of access.

2-3 Employee Training.

The initial minutes are the most vital in fighting a fire. In order to ensure effective application of the available fire-fighting equipment, it is essential that employees of the facility be trained in the equipment's use. This can only be achieved through regular training and practice. The interest taken by management through active leadership and participation in the training of their personnel in fire protection duties will have the effect of bringing and keeping all employees up to a high standard of responsibility relative to both fire prevention and fire protection.

2-3.1

Practice drills shall be held at frequent intervals, preferably once a month and at a minimum of twice a year.

2-3.2

All employees shall be given instruction in the procedures for response to a fire alarm, in reporting a fire to the proper authorities (and to designated facility employees), and in such matters as location of fire hydrants.

2-3.3

Selected employees shall be given training in the use of fire-fighting equipment such as portable pumps, standpipe systems, wheel mounted extinguishers, auxiliary water sources, etc.

2-3.4

All employees, including office personnel, shall be given training in the use of portable fire extinguishers and hoses in the fighting of fires.

2-4 Fire Department Liaison.

The local fire department shall be encouraged to visit the facility annually to become acquainted with every part of the plant and to conduct employee training sessions. Management shall assist the fire department in prefire planning for:

(a) Entries and access routes for equipment within the premises.

(b) Location, construction, use, and accessibility of all buildings and all their subdivisions including basements, storage lockers, etc.

(c) Location and extent of outside working areas.

(d) Location and means of access to both dry and wet boat-storage areas.

(e) Type and capacity of water lines on piers and walkways, including all points where connection of hydrant or pumper supplies can be effected.

(f) Types and capacities of facility equipment, including work or tow boats, portable pumps, pier-mounted hose cabinets, all portable fire extinguishers, etc.

(g) Voltages and capacities of electrical systems, and location of electrical disconnecting means.

2-5* Watch Service.

If a watch person is employed, the route shall be laid out to include every important and potentially hazardous area within the premises. These areas shall be incorporated in a recognized watch person's recording system, such as a portable watch clock or a computerized reporting system. The watch person's first round shall consist of a complete inspection immediately at the close of the working day. Subsequent rounds shall be scheduled so that the interval between visiting each area shall not exceed one hour.

2-6 Boat Owners and Guests.

A high percentage of fires in marinas and related facilities are attributable to boat owners and guests who cannot be expected to be aware of fire hazards to the level of a professional. Signs, posters, or posted instructions shall be provided where practicable to remind the public of basic fire safety practices and to warn of unusual or extreme fire hazards. All boat owners at the marina shall be provided with written instructions for reporting fires and other emergencies and actions to be taken in the event of a fire.

Chapter 3 Electrical Wiring and Equipment

3-1 General.

Electrical systems and electrical equipment in the marina and boatyard require special consideration because of the existence of some, or all, of the following conditions in these locations:

(a) Locations are wet or continuously damp, and are exposed to rain, wind-driven spray, atmospheric moisture, and severe corrosive effects including, but not limited to, salt contamination;

(b) Locations are exposed to excessively high or low temperatures;

(c) Locations are subject to flooding by abnormally high water;

(d) Locations where flammable or combustible liquids or gases are stored, dispensed, or used;

(e) Locations where electrical equipment and facilities are used by persons not under the control of the management, many of whom are unfamiliar with the possible hazards associated with such use, and the means to avoid them. Those persons need to be protected from electrical hazards when they are on the land, on boats, in storage or repair facilities, or going from one to the other.

(f) Locations where boats are moved to and from the water, and to and from storage or repair stations;

(g) Locations, e.g., floating pier, that are subject to movements such as mechanical shock and vibration.

3-2 National Electrical Code.

NFPA 70, *National Electrical Code*, provides basic provisions to be observed in the design, selection, and installation of electrical wiring and equipment. The recommendations set forth herein supplement and relate the requirements of NFPA 70, *National Electrical Code*, to the specific conditions and combinations of conditions found in marinas and boatyards and shall be adhered to in addition to any requirements found in NFPA 70, *National Electrical Code*, including, but not limited to, Article 555.

3-3 Listed or Labeled.

All electrical materials, devices, appliances, fittings, and other equipment shall be listed or labeled by a qualified testing agency and shall be installed and connected in accordance with listing requirements and/or manufacturer's instructions.

3-4 Electrical Datum Plane.

The electrical datum plane is defined as follows:

(a) In land areas subject to tidal fluctuation, the electrical datum plane is a horizontal plane 2 ft (0.606 m) above the highest tide level for the area occurring under normal circumstances, i.e., highest high tide.

(b) In land areas not subject to tidal fluctuation, the electrical datum plane is a horizontal plane 2 ft (0.606 m) above the highest water level for the area occurring under normal circumstances.

(c) The electrical datum plane for floating piers and landing stages that are (a) installed to permit rise and fall response to water level, without lateral movement, and (b) that are so equipped that they can rise to the datum plane established for 3-4(a) or 3-4(b) is a horizontal plane 30 in. (0.762 m) above the water level at the floating pier or landing stage and a minimum of 12 in. (0.305 m) above the level of the deck.

3-4.1

A bench mark indicating the electrical datum plane of the land area shall be permanently located on shore in the marina or boatyard.

3-4.2

Electrical services shall be disconnected from the power source when the water level reaches the bench mark for the electrical datum plane.

3-4.3

All electrical connections shall be located at least 12 in. (0.305 m) above the deck of a floating pier. All electrical connections shall be located at least 12 in. (0.305 m) above the deck of a fixed pier, but not below the electrical datum plane. See 3-14.1 for receptacle locations.

3-5 Power Supply.

3-5.1

Poles or structures used to support electrical service shall be used for that purpose only.

Exception: These poles or structures shall be permitted to be used to support communications and television cables and lighting fixtures.

3-5.2

Primary power, when introduced in excess of 250 volts phase to phase, shall be transformed to reduce the marina or boatyard system to be not in excess of 250 volts phase to phase.

Exception No. 1: 600 volts maximum shall be permitted to be used for a yard's distribution system where approved by the authority having jurisdiction.

Exception No. 2: 600 volts maximum shall be permitted to be carried to piers where design considerations require more than 250 volts maximum due to load requirements where approved by the authority having jurisdiction, provided that transformers are in locked vaults of design appropriate for the environment and all cable connections are in accordance with the National Electrical Code (NFPA 70).

3-5.3

Transformers shall be installed, where located within the marina or boatyard property area, in compliance with the requirements of Article 450, NFPA 70, *National Electrical Code*, with the additional requirement that transformers shall not be located in a wet location as herein described.

3-5.4

Transformers shall be permitted to be installed in locations exposed to weather and unprotected if they are specifically approved for that use.

3-5.5

Service equipment, including service disconnecting equipment, meters, and associated equipment, and the main switchboard or panel, shall not be installed in wet locations, and shall be protected against access by unauthorized persons. In all other respects, the service installation shall be in compliance with the requirements of Article 230, NFPA 70, *National Electrical Code*.

Exception: Equipment shall be permitted to be installed in locations exposed to weather and unprotected if they are specifically approved for that use.

3-5.6

Where auxiliary emergency standby power supply equipment with an output rating in excess of 5 kW is provided and is driven by an internal combustion engine, the emergency electric system shall be arranged as required by Article 700, NFPA 70, *National Electrical Code* and NFPA 110, *Standard for Emergency and Standby Power Systems.* The engine and generator shall be housed in a well-ventilated, fire-resistive enclosure that shall contain only the auxiliary power unit and the necessary controls. The engine and generator shall not be located below the electrical datum plane. Interior areas of the enclosure shall be lighted by a fixture connected to the normal power supply.

3-6 Grounding.

3-6.1

Grounding of all noncurrent-carrying metal parts of the electrical system, and provision of suitable equipment-grounding facilities at all outlets provided for the connection of portable equipment and all outlets provided for the connection of shore power to vessels afloat, are of utmost importance in marinas, boatyards, boat basins, and similar establishments. The means and methods of grounding the noncurrent-carrying metal parts of the electrical system and for equipment and portable appliances connected thereto shall comply with the requirements of NFPA 70, *National Electrical Code* (Article 250).

3-6.2

There shall be installed a common grounding conductor of not less than No. 12 AWG, arranged in accordance with the requirements of NFPA 70, *National Electrical Code* (Article 250), properly attached to the interior of all metallic boxes, housings, and enclosures and properly connected to the grounding facility of all receptacles. Metal inserts and metal attachments that are externally and internally exposed on nonmetallic boxes and enclosures shall be connected to the common ground. Said grounding conductor shall terminate at the distribution panel ground and shall specifically conform to the requirements of NFPA 70, *National Electrical Code* (Section 555-7).

3-6.3

The partial or complete burial of a metal enclosure in earth shall not be accepted as a substitute for the grounding requirements as provided herein with respect to such enclosure, as required by NFPA 70, *National Electrical Code* (Section 250-51).

3-6.4

Metal poles, lighting standards, and other metal supports that carry or enclose electrical wiring shall be grounded in accordance with NFPA 70, *National Electrical Code* (Section 250-51).

3-7 Dry Locations.

The entire electrical system installed in a dry location shall comply with the requirements of NFPA 70, *National Electrical Code*.

3-8 Damp Locations.

The entire electrical system installed in a damp location shall be composed of materials suitable for the purpose as defined in Article 100, NFPA 70, *National Electrical Code*.

3-9 Wet Locations.

The entire electrical system in a wet location shall be suitable for wet locations as defined in Article 100, NFPA 70, *National Electrical Code*.

3-10 Hazardous Locations.

The entire electrical system installed in a hazardous (classified) location shall comply with the requirements given in Article 500, NFPA 70, *National Electrical Code*, and where required by the conditions, to the requirements of this standard related to damp and wet locations.

3-11 Electrical Installation.

Wiring electrical equipment and materials installed on piers, wharves, docks, or similar locations, and wiring methods shall specifically conform to the requirements of Article 555, and any other applicable requirements of NFPA 70, *National Electrical Code*.

3-11.1

Electrical wiring shall be installed to avoid possible contact with masts and other parts of boats being moved in the yard. Underground electrical installations shall comply with the requirements of Section 230-30, 230-31, 230-48, and 230-49, NFPA 70, *National Electrical Code*. It shall be permitted to utilize "extra hard usage" cables (see Table 400-4, NFPA 70, *National Electrical Code*), such as Type G and Type W, as permanent wiring on the underside of piers (floating or fixed) provided that such cables are properly supported, are not subject to physical damage, and are installed in compliance with any listing requirements, manufacturer's recommendations, and any applicable sections of NFPA 70, *National Electrical Code*.

Exception: Temporary wiring shall not be used to supply power to boats.

3-11.2

If electrical wiring is not installed underground, the wiring within yard areas shall be routed to:

(a) Avoid wiring within or across any portion of the yard that might be used for moving vessels.

(b) Avoid wiring closer than 20 ft (6.1 m) from the outer edge or any portion of the yard that might be used for moving vessels or stepping or unstepping masts.

(c) Clearance for wiring in other portions of the yard, not inclusive of the areas described in (a) and (b) above, shall be:

1. Not less than 18 ft (5.49 m) above grade in open areas, and
2. Not less than 8 ft (2.44 m) above highest point of roof when above buildings.

(d) Proper warning signs to warn operators of the wire clearance to be encountered shall be located so as to be clearly visible.

3-11.3

Wiring installed over and under navigable water shall be subject to approval by the authority having jurisdiction. Proper warning signs to warn operators and boaters of the wire clearance to be encountered shall be placed in suitable locations.

3-11.4

Where flexibility is necessary as on piers composed of floating sections, the feeder conductors, if installed in a wet location, shall be cable listed for "extra hard usage" as identified in Table 400-4, NFPA 70, *National Electrical Code*, and rated not less than 167°F (75°C), 600 volts, of the required ampacity and shall include a common grounding conductor with an outer jacket rated to be resistant to temperature extremes, oil, gasoline, ozone, abrasion, acids, and chemicals. The cable shall be securely fastened by nonmetallic clips to structural members of the pier other than the deck planking.

(a) Where flexible cable passes through structural members it shall be protected against chafing by a permanently installed oversized sleeve of nonmetallic material.

(b) There shall be an approved junction box of corrosion-resistant construction with permanently installed terminal blocks on each pier section to which the feeder and feeder extensions are to be connected. Metal junction boxes and their covers, and metal screws and parts that are exposed externally to the boxes, shall be of corrosion-resisting materials, or protected by material resistant to corrosion.

3-11.5*

All exterior wiring and equipment shall have copper conductors and all connectors, bus bars, or splicing means shall be made of copper or copper with a plating of silver, tin, or zinc.

3-12 Circuit Breakers, Switches, Panels, and Power Outlets (Damp and Wet Locations).

3-12.1

Overcurrent protection as required by NFPA 70, *National Electrical Code*, shall be provided by the use of circuit breakers to avoid the difficulty of fuse replacement in gasketed enclosures.

3-12.2

Circuit breakers and switches installed in gasketed enclosures shall be arranged to permit required manual operation without exposing the interior of the enclosure. All such enclosures shall be arranged with a weep hole to discharge condensation.

3-13 Power Outlet.

A manufactured power outlet shall comply with ANSI/UL 231, *UL Standard for Safety Power Outlets*.

3-14 Receptacles.

3-14.1

Receptacles intended to supply shore power to boats:

(a) Shall be housed in power outlets approved for wet locations, and shall be in a weatherproof enclosure, the integrity of which is not affected when the receptacle is in use (attachment plug/cap inserted). The weatherproof receptacle covers of manufactured power outlets with more than one receptacle shall be capable of full closure when in use.

(b) Shall be mounted in power outlets or in other weatherproof enclosures at an angle to reduce the strain caused by the weight and catenary of the shore power cable. The receptacle face shall face downward at any angle from horizontal to 55 degree above horizontal.

(c) Shall not be mounted less than 24 in. (0.610 m) above the deck surface of the pier, and not below the electrical datum plane on a fixed pier.

3-14.2

Receptacles that provide shore power for boats shall be rated not less than 20 amperes and shall be single outlet type.

(a) Receptacles rated no less than 20 amperes nor more than 50 amperes shall be of the locking type and shall conform to the configurations of ANSI/NEMA WD 6, *Wiring Devices - Dimensional Requirements*, as shown in Figure 1, Appendix B.

(b) Receptacles rated for 60 amperes or 100 amperes shall be of the pin and sleeve type and shall conform to the configurations of UL 1686, *UL Standard for Safety Pin and Sleeve Configurations*, as shown in Figure 2, Appendix B.

3-14.3

Each single receptacle that supplies shore power for boats shall be supplied by an individual branch circuit of the voltage class and rating corresponding to the voltage class and rating of the receptacle.

3-14.4

Fifteen- and 20-ampere outdoor receptacles, other than those supplying shore power to boats, shall be protected by ground-fault circuit-interrupters. They shall be permitted to be housed in power outlets with the receptacles that provide shore power to boats, provided a marking clearly indicates that they are not to be used to supply power to boats.

3-15 Disconnects.

3-15.1

A readily accessible disconnecting means shall be provided by which each boat can be isolated from its supply circuit.

3-15.2 Disconnecting Means.

The necessary equipment consisting of a circuit breaker or switch, or both, shall be located within 50 ft (15.25 m) of the shore power connection and is intended to constitute the means of cutoff of the supply to the boat.

3-16 Lighting Fixtures.

3-16.1

Lighting fixtures shall conform to the requirements of NFPA 70, *National Electrical Code* (Sections 410-4, 410-5, and 410-6), and, additionally, shall be located to prevent damage by contact with stored or moving material.

3-16.2

Switches for control of individual lighting fixtures that are exposed to the weather or splash shall be of a type approved for that location.

3-17 Electrical Equipment Enclosures.

3-17.1

Electrical equipment enclosures installed on piers above deck level shall be securely and substantially supported by structural members, independent of any conduit connected to them. If enclosures are not attached to mounting surfaces by means of external ears or lugs, the internal screw heads shall rest on gaskets to prevent seepage of water through mounting holes.

3-17.2

Electric equipment enclosures on piers shall be located so as not to interfere with mooring lines.

3-18 Feeders and Branch Circuits on Piers.

3-18.1

The load for each ungrounded feeder and service conductor supplying receptacles for the connection of power to boats shall be calculated in accordance with Article 555 of NFPA 70, *National Electrical Code*.

General lighting and other loads shall be calculated, and the voltage drop based on the total load calculated as above shall be as required by Section 215-1, NFPA 70, *National Electrical Code*.

3-18.2

Feeder circuits extending from the main service equipment that are intended for use in providing shore power to one or more boats, shall be of the 3-wire, grounded neutral, single-phase type of 110/220 volts, 115/230 volts, 120/240 volts, or 120/208 volts 3-phase Y, according to availability from the local public power source. The minimum feeder conductor size shall be No. 10 AWG; the minimum service conductor size shall be No. 8 AWG.

3-18.3

Where feeder circuits extend on a pier to serve a group of shore power receptacles, the connecting wiring leading to individual devices that contain one or more such receptacles shall be considered feeder taps, coming under Exception No. 2, Section 240-21, NFPA 70, *National Electrical Code*. The branch circuits connecting the receptacles to the feeder tap shall be equipped with circuit breakers for overcurrent protection, located at the receptacle, with not more than one receptacle connected beyond the required circuit breaker. Rigid metallic or nonmetallic conduit shall be installed to protect wiring above the decks of piers and landing stages and below the enclosure that it serves. The conduit shall be connected to the enclosure by full standard threads. The use of special fittings of nonmetallic material to provide a threaded connection into enclosures on rigid nonmetallic conduit, employing joint design as recommended by the conduit manufacturer for attachment of the fitting to the conduit, will be acceptable provided the equipment and method of attachment are approved and the assembly meets the requirements of installation in a damp location.

3-18.4

The disconnects for feeder circuits and branch circuits exceeding from the main service equipment shall be readily accessible and clearly marked.

3-19 Hazardous (Classified) Locations.

3-19.1

Only qualified persons, as defined in Article 100, NFPA 70, *National Electrical Code*, shall be permitted to use, handle, install, or repair electrical systems or facilities within any area classified as “Hazardous.”

3-19.2

Only the electrical equipment and wiring necessary for the handling and dispensing of the fuels shall be installed within the hazardous area at any outdoor storage or dispensing station. Lighting fixtures for such locations, and the switches controlling them, shall be located beyond the hazardous area unless of a type approved for the location.

3-19.3

The grounding wire of the electrical system, or other approved grounding connection, shall be arranged to provide adequate grounding protection to the metal nozzle of all fuel-dispensing equipment.

3-19.4

When electrical equipment is installed in a location that is classified as both “Hazardous” and “Damp,” the construction shall include approved methods of meeting the requirements of both locations.

3-20 Tests.

The following tests shall be conducted upon completion of the installation.

3-20.1

The electrical system shall be subjected to an insulation test in the presence of the representative of the authority having jurisdiction. Such tests shall meet the requirements of Section 110-7, NFPA 70, *National Electrical Code*.

3-20.2

All receptacles shall be tested for ground integrity and polarity. All improper conditions shall be corrected prior to use. Standard ground and polarity connections are as detailed in Section 200-10, NFPA 70, *National Electrical Code*.

3-21 Marine Hoists, Railways, Cranes, and Monorails.

3-21.1

Motors and controls for marine hoists and railways shall not be located in a wet location as defined in Section 3-4.

3-21.2

Where it is necessary to provide electric power to a mobile crane or hoist in the yard, and a trailing cable is involved, it shall consist of listed portable power cables with ground conductors rated for the conditions of use and provided with a jacket of distinctive color for safety.

3-22 Maintenance of Electrical Wiring and Equipment.

3-22.1

An inspection of all electrical wiring, ground connections, conduit, hangars, supports, connections, outlets, appliances, devices, and portable cables installed or used in a marina, boatyard, boat basin, or similar establishment shall be made at regular intervals to ensure a complete inspection at least annually. Such an inspection shall include a ground integrity test and a polarity test. All corroded, worn, broken, or improper materials shall be replaced or repaired before further use. The use of tape to repair broken or cracked insulation of jackets on flexible cables or cords shall be prohibited. Splicing of flexible cord or cable shall be prohibited. The inspection shall take particular notice of the following conditions, and corrective action shall be taken as appropriate:

(a) Areas being used for purposes not originally contemplated and that introduce hazards greater than those for which the electrical system was designed.

(b) Locked or otherwise restricted areas or equipment being left open.

(c) The use of grounding-type portable electrical equipment that is not properly and adequately grounded.

(d) Special attention shall be given to shore power cable sets used by vessels for connection to shore power outlets. Shore power cable sets that lie across the surface of pier walkways shall be protected from mechanical abuse and shall be secured so as not to trail into the water.

(e) Flexible cords being used for purposes not in accordance with NFPA 70, *National Electrical Code*, i.e., used for permanent wiring.

Exception: See Section 3-11.1.

(f) Damaged or inoperative switches, lighting fixtures, and receptacle outlets.

(g) Overloading of electrical circuits.

(h) The introduction of unsuitable appliances into a hazardous area.

Chapter 4 Fire Protection

4-1 General.

Due to the unusually high concentration of combustibles and the presence of ordinary combustibles (Class A), flammable liquids (Class B), and electrical (Class C) fire hazards within virtually every area of the facilities covered by this standard, the placement and maintenance of both fixed and portable fire extinguishment equipment are extremely important.

4-2 Planning.

Careful planning in the placement of fire extinguishment equipment shall be made in cooperation with the authority having jurisdiction and the local responding fire departments at least annually in order to accommodate changing conditions and personnel responsible for the fire control in the facility.

4-3 Portable Fire Extinguishers.

4-3.1

Placement of portable fire extinguishers shall be in accordance with Chapter 3, NFPA 10, *Standard for Portable Fire Extinguishers*.

4-3.2

Placement of portable fire extinguishers on piers and along bulkheads where vessels are moored or are permitted to be moored shall be as follows.

4-3.2.1 Extinguishers listed for Class A, Class B, and Class C fires shall be installed at the pier/land intersection on a pier that exceeds 25 ft (7.6 m) in length. Additional fire extinguishers shall be placed such that the maximum travel distance to an extinguisher does not exceed 75 ft (22.9 m).

4-3.2.2 All extinguishers installed on piers shall meet the rating requirements set forth in Chapter 3 of NFPA 10, *Standard for Portable Fire Extinguishers*, for ordinary (moderate) hazard type.

4-3.3

Portable fire extinguishers that meet the minimum requirements of Chapter 3, NFPA 10, *Standard for Portable Fire Extinguishers*, for extra (high) hazard type shall be installed on two sides of a fuel-dispensing area. On piers or bulkheads where long fueling hoses are installed for fueling vessels, additional extinguishers installed on the pier shall meet the requirements of

Chapter 3, NFPA 10, *Standard for Portable Fire Extinguishers*, for extra (high) hazard type and 4-3.2.1 of this standard.

4-3.4

All portable fire extinguishers shall be maintained in accordance with Chapters 4 and 5, NFPA 10, *Standard for Portable Fire Extinguishers*, and shall be clearly visible and marked.

4-4 Fixed Fire Extinguishment Systems.

4-4.1

Combustible buildings in excess of 500 ft^2 (46.45 m^2) that are constructed on piers shall be protected by a fixed automatic sprinkler system installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

Noncombustible buildings in excess of 500 ft^2 (46.45 m^2) that are constructed on piers, and contain combustible materials, the amount of which presents a hazard equal to a building of combustible construction as determined by the authority having jurisdiction, shall be protected by a fixed automatic sprinkler system installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

Exception: In existing facilities, considering water supply availability and adequacy, and size of facility, where clearly impractical for economic or physical reasons.

4-4.2*

Marina and boatyard buildings in excess of 5,000 ft^2 (464.5 m^2) in total area shall be protected by a fixed automatic sprinkler system installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*. (*See Section 5-2 for requirements for rack storage buildings.*)

Exception: In existing facilities, considering water supply availability and adequacy, and size of facility, where clearly impractical for economic or physical reasons.

4-4.3

Combustible piers and substructures in excess of 25 ft (7.6 m) in width or in excess of 5,000 ft^2 (464.5 m^2) in area, or within 30 ft (11.4 m) of other structures or superstructures required to be so protected shall be protected, in accordance with Section 3-3, NFPA 307, *Standard for the Construction and Fire Protection of Marine Terminals, Piers, and Wharves*.

Exception No. 1: In the case of fixed piers, where the vertical distance does not exceed 36 in. (0.91 m) from the surface of mean high water level to the underside of the pier surface. In the case of floating piers, where the vertical distance does not exceed 36 in. (0.91 m) from the surface of the water to the underside of the pier surface.

Exception No. 2: In existing facilities, considering water supply availability and adequacy, and size of facility, where clearly impractical for economic or physical reasons.

4-4.4*

An approved water supply shall be provided within 100 ft (30.5 m) of the pier/land intersection or fire department connection serving fire protection systems. Access between water supplies and pier/land intersections or fire department connections shall be by roadway acceptable to the authority having jurisdiction.

4-5 Fire Standpipe Systems.

4-5.1

Standpipe systems, where installed, shall be in accordance with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*. Class I standpipe systems shall be provided for piers, bulkheads, and buildings where the hose lay distance from the fire apparatus exceeds 150 ft (45.8 m). Supply piping for standpipes on piers and bulkheads shall be sized for the minimum flow rate for Class II systems.

Exception: Hose racks, hoses, and standpipe cabinets shall not be required on piers and bulkheads.

4-5.2

Manual dry standpipes shall be permitted.

4-5.3

Flexible connections shall be permitted on floating piers subject to approval by the authority having jurisdiction.

4-5.4

Listed nonferrous piping shall be permitted to be used in accordance with its listing.

4-6 Hydrants and Water Supplies.

Hydrants and water supplies for fire protection in marinas and boatyards shall be provided in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*; NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*; and NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*.

4-7 Fire Pumps.

Fire pumps when required shall be installed in accordance with NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps.* Electrical components shall be installed in accordance with 3-5.6.

4-8 Maintenance.

Portable fire extinguishers shall be maintained in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*.

4-8.1

All sprinkler systems, standpipe systems, water supply facilities and fire pumps shall be maintained in accordance with NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*.

4-9 Exposure Protection.

The hazards of fire exposure and appropriate protection methods shall be evaluated. (*See NFPA 80A, Recommended Practice for Protection of Buildings from Exterior Fire Exposures.*)

4-10 Transmittal of Fire Emergency.

All marinas and boatyards shall have a means to rapidly notify the fire department in the event of an emergency. If a telephone is used for this purpose, it shall be available for use at all times and shall not require the use of a coin.

The street address of the facility and the emergency telephone number(s) shall be prominently displayed on a sign at the telephone.

NOTE: EMS and police numbers should be displayed in addition to fire department numbers unless 9-1-1 (E-9-1-1) is in use.

4-11 Fire Detectors.

4-11.1

Fire detection devices and installation shall be in accordance with NFPA 72, *National Fire Alarm Code*.

4-11.2

Fire detectors shall be installed in the following interior or covered locations unless protected by a fixed automatic sprinkler system installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*:

(a) Rooms containing combustible storage or goods.

(b) Rooms containing flammable liquid storage or use.

(c) Rooms containing battery storage or maintenance.

(d) Rooms containing paint and solvent storage or use.

(e) Enclosed or covered storage of vessels.

(f) Areas used for enclosed or covered maintenance of vessels.

(g) Areas used for public assembly, dining, or lodging.

(h) Kitchens and food prep areas.

(i) Dust bins and collectors.

(j) Inside trash storage areas.

(k) Rooms used for janitor supplies or linen storage.

(l) Laundry rooms.

(m) Furnace rooms.

Chapter 5 Berthing and Storage

5-1 Wet Storage and Berthing.

5-1.1

Each berth shall be arranged such that a boat occupying the berth can be readily removed in an emergency without the necessity of moving other boats.

5-1.2

Ready access to all piers, floats, and wharves shall be provided for municipal fire-fighting equipment.

5-1.3*

Electrical lighting shall be provided to assure adequate illumination of all exterior areas, piers, and floats, but positioned so as not to interfere with navigation or aids to navigation.

5-1.4

Only listed 120/240 volts ac electrical equipment shall be operated unattended.

5-2 Dry Storage.

5-2.1 General.

(a) The use of portable heaters in a boat storage area shall be prohibited except where necessary to accomplish repairs, in which case they shall be used only when personnel are in attendance. No open flame heaters of any sort shall be used.

(b) Ladders long enough to reach the deck of any stored boat shall be located so as to be readily available.

(c) The use of blow torches or flammable paint remover shall be prohibited.

Exception: Flammable solvents can be used as provided in 6-6.1.

(d) The use of gasoline or other flammable solvents for cleaning purposes shall be prohibited.

(e) Where a boat is to be dry-stored for the season or stored indoors for an extended period of time, e.g., while awaiting repairs, the following precautions shall be taken:

1. The vessel shall be inspected for any hazardous materials or conditions that might exist and corrective action shall be taken.

2. LPG and CNG cylinders, reserve supplies of stove alcohol or kerosene and charcoal shall be removed from the premises or stored in a separate, designated safe area.

3. All portable fuel tanks shall be removed from the premises or emptied. If portable fuel tanks are emptied, the cap shall be removed and the tank left open to the atmosphere.

4. Permanently installed fuel tanks shall be stored approximately 95 percent full.

(f) No unattended electrical equipment shall be in use aboard boats.

(g) All storage areas shall be routinely raked, swept, or otherwise policed to prevent the accumulation of rubbish.

(h) Ready access of fire-fighting equipment shall be provided at all times for boats stored both inside and outside. In the case of inside storage areas, the local fire department authorities shall be appraised of the quickest way to gain access to the building in case of emergency.

5-2.2 Indoors.

(a) When work is being carried out on board a vessel in an unsprinklered storage building, management shall require an inspection of the vessel at the end of the day to ensure that there are no hazards present resulting from the day’s work. If a guard is employed, the vessel shall be included in the regular rounds.

(b) No Class I flammable liquids shall be stored in an indoor boat storage area.

(c) All work performed on boats stored indoors shall be performed by qualified personnel only. Facility management shall maintain control over all personnel access to storage facilities and boats stored indoors.

5-2.3 In-Out Dry Storage or Rack Storage.

(a) Any facility utilizing a rack storage system of more than one level shall be considered to fall under the definition of "in-out dry storage facility."

(b) Water supply and hoses, or portable fire extinguishers and wheeled cart assemblies equipped with discharge nozzles capable of reaching all boats on the highest racks shall be provided.

(c) Boats stored either inside or outside in single or multiple-level racks shall have unimpeded vehicular access at one end and shall have equipment available to remove any stored boat.

(d)* Where boats are stored on multilevel racks in buildings, automatic sprinkler protection shall be installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

Exception No. 1: Buildings under 5,000 ft^2 (464.5 m^2) provided with an automatic fire detection and alarm system supervised by a central station complying with NFPA 72, National Fire Alarm Code. If such a system is not technically feasible, an automatic fire detection and alarm system supervised by a local protective signaling system complying with NFPA 72, National Fire Alarm Code, or a full-time watch service shall be utilized.

Exception No. 2: In existing facilities, considering water supply availability and adequacy and size of facility, where clearly impractical for economic or physical reasons.

(e) Where boats are stored in multilevel racks, either inside or outside, for seasonal storage or for in-out operation, the following precautions shall be taken:

1. Drain plugs shall be removed (in sprinklered buildings).

2. Batteries shall be disconnected or the master battery switch turned off.

3. Fuel tank valves shall be closed.

4. For seasonal storage, the requirements of 5-2.1 shall apply.

(f) All repair operations while boats are on racks or inside an in-out dry storage building shall be prohibited.

(g) All portable power lines, such as drop cords, shall be prohibited from any boat in an in-out dry storage building. Portable battery chargers shall also be prohibited aboard any boat.

5-2.4 Battery Storage.

(a) Lead-acid type batteries shall be removed for storage and recharging wherever practical. Where, due to size and weight, it is impractical to remove them for storage, batteries may be permitted to remain on board provided:

1. The battery compartment is arranged to provide adequate ventilation.

2. A listed battery charger shall be used to provide a suitable charge.

3. The power connection to the charger consists of a three-wire cord of not less than No. 14 AWG conductors connected to a source of 110-volt to 125-volt single phase current, with a

control switch and approved circuit protection device designed to trip at not more than 125 percent of the rated amperage of the charger.

4. There is no connection on the load side of this device from this circuit to any other device and the boat battery switch shall be turned off.

5. The battery is properly connected to the charger and the grounding conductor effectively grounds the charger enclosure.

6. Unattended battery chargers are checked at intervals not exceeding 8 hours while in operation.

Chapter 6 Operational Hazards

6-1 Conditions on Individual Boats.

6-1.1

The management shall have an inspection made of boats received for major repair or storage. This shall be accomplished as soon as practicable after arrival of a boat and before commencement of any work aboard for the purpose of determining:

(a) Presence of combustible vapors in any compartment.

(b) General maintenance and cleanliness, and location of any combustible materials that require removal or protection for the safe accomplishment of the particular work involved.

(c) Quantity, type, and apparent condition of fire extinguishing equipment on board.

(d) Presence of appropriate listed shore power inlet(s) and listed ship-to-shore cable(s).

6-1.2

The management shall, as a condition to accepting a boat received for major repair or storage, require the owner to correct any discrepancies found in 6-1.1 or to authorize management to do so.

6-1.3

The following general precautions shall be observed:

(a) Smoking in the working area shall be prohibited.

(b) Loose combustibles in the way of any hazardous work shall be removed.

(c) Unprotected battery terminals shall be suitably covered to prevent inadvertent shorting from dropped tools or otherwise. The ungrounded battery lead shall be disconnected.

(d) Only experienced personnel shall be employed in the removal or installation of storage batteries.

(e) Precautions recommended herein for specific kinds of work shall be followed.

(f) When electric service is provided to boats in storage, the receptacle providing the power shall be protected with a ground-fault circuit-interrupter.

6-1.4

The marina or boatyard operator shall post in a prominent location or provide to boat operators using a marina or boatyard for mooring, repair, servicing, or storage, a list of safe operating procedures containing such information as:

(a) The use of hibachis or any type of portable charcoal or wood cooking equipment shall be limited to specifically authorized areas where they can be used safely (not on the docks or near flammables).

(b) Procedures for disposal of trash.

(c) Nonsmoking areas.

(d) Location of fire extinguishers and hoses.

(e) Procedures for turning in fire alarm.

(f) Fueling procedures.

6-1.5

The information on fueling procedures referred to in 6-1.4(f) shall be as a minimum the following:

Before Fueling

1. Stop all engines and auxiliaries.
2. Shut off all electricity, open flames, and heat sources.
3. Check bilges for fuel vapors.
4. Extinguish all smoking materials.
5. Close access fittings and openings that could allow fuel vapors to enter the boat's enclosed spaces.
6. Remove all personnel from the boat except the person handling the fueling hose.

During Fueling

1. Maintain nozzle contact with fill pipe.
2. Fuel filling nozzle must be attended at all times.
3. Wipe up spills immediately.
4. Avoid overfilling.

After Fueling and Before Starting Engine

1. Inspect bilges for leakage or fuel odors.
2. Ventilate until odors are removed.

6-2 Heating.

6-2.1

Heating equipment shall be installed in accordance with local ordinances and the following standards as appropriate:

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*

NFPA 90B, *Standard for the Installation of Warm Air Heating and Air Conditioning Systems*

NFPA 211, *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances*.

6-2.2

Adequate and suitable fire extinguishing equipment shall be supplied, installed, and maintained in an approved manner in proximity to heating equipment in accordance with Section 4-3.

6-2.3

Heat generating plants for steam, hot water, or forced air systems shall be located in detached buildings or rooms separated from other areas by fire walls.

6-2.4

Coal and wood burning stoves shall not be used unless such installations are periodically checked and found to possess adequate safeguards by the local fire authority having jurisdiction. If such stoves are used, the following precautions shall be in effect unless the authority having jurisdiction modifies the precautions specifically for each installation:

(a) A radial clearance of 36 in. (0.91 m) shall be maintained from any combustible material unless such material is effectively protected in accordance with NFPA 211, *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel Burning Appliances*.

(b) Combustible flooring under stoves shall be protected in accordance with NFPA 211, *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel Burning Appliances*.

(c) Chimney connectors shall be substantially supported and have a clearance of at least 18 in. (0.46 m) from all combustible material. Connectors passing through a combustible partition shall be protected at the point of passage by a metal ventilated thimble not less than 12 in. (0.31 m) larger in diameter than the protector, or in accordance with Chapter 5 of NFPA 211, *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel Burning Appliances*. Chimney connectors shall not pass through concealed spaces.

(d) Ready fuel supplies, particularly if scrap wood is used, shall be neatly stowed to maintain safe clearance from stoves.

(e) Substantial metal cans shall be provided for handling ashes. These cans shall not be used as receptacles for combustible waste.

6-2.5

Heating devices employing a flame or exposed hot wires shall not be used in areas where flammable vapors or combustible dusts might be present.

6-3 Storage and Handling of Fuels.

6-3.1

The fueling station shall be located to minimize the exposure of all other plant facilities. All fueling stations shall be accessible by boat without entering or passing through the main berthing area.

Exception: Where inside fueling stations are made necessary by prevailing sea conditions (wake, surge, tide, etc.) such stations shall be located near an exit by water from the berthing area or at some other location from which, in case of fire aboard a boat alongside, the stricken craft can be quickly removed without endangering other boats nearby.

6-3.2

All boat fueling operations shall be carefully accomplished in accordance with NFPA 302, *Fire Protection Standard for Pleasure and Commercial Motor Craft*, at the fueling station or other specifically designated remote location.

6-3.3

No tank barge or other fuel supply boat shall be permitted within the berthing area. Outside berths and connections shall be provided for the use of tank barges or fuel supply boats.

6-3.4

Fuel storage tanks shall be installed in accordance with NFPA 30A, *Automotive and Marine Service Station Code*, and in accordance with all state and local ordinances.

6-3.5

Fuel storage tanks shall be securely anchored where they are located subject to flooding or tidal conditions, and the applicable precautions outlined in Chapter 2 of NFPA 30A, *Automotive and Marine Service Station Code*, shall be observed.

6-3.6

Fuel storage tanks and pumps, other than those integral to approved dispensing units supplying gasoline, Class I, or Class II flammable liquids at marine service stations, shall be located only on shore, or with the express permission of the authority having jurisdiction on a pier of solid-fill type. Approved dispensing units with or without integral pumps shall be permitted to be located on shore, on piers of solid-fill type, or on open piers, wharves, or floating piers.

6-3.7

Tanks and pumps supplying diesel Class III flammable liquids at marine service stations shall be permitted to be located on shore, on piers of solid-fill type, or on open piers, wharves, or floating piers. Class III flammable liquid tanks that are located elsewhere than on shore or on piers of the solid-fill type shall be limited to 550 gal (2.08 m^3) aggregate capacity. Pumps not a part of the dispensing unit shall be located adjacent to the tanks.

6-3.8

Fuel pipelines shall be installed in accordance with the provisions of NFPA 30A, *Automotive and Marine Service Station Code*.

6-3.9

Dispensing units for transferring fuels from storage tanks shall be in accordance with provisions of NFPA 30A, *Automotive and Marine Service Station Code*. Gasoline delivery nozzles shall be equipped with a self-closing control valve that will shut off the flow of fuel when the operator’s hand is removed from the nozzle. The use of any device to override this safety feature is prohibited. The nozzle shall be inspected daily for proper operation. Any nozzle that shows evidence of possible malfunction or leaking shall be removed from service. The use of any automatic nozzle with a latch-open device is prohibited for the delivery of gasoline. In the construction of the fuel hose assembly, provision shall be made so the fuel delivery nozzle is properly bonded to the shore electric grounding facilities as required in Section 3-6 of this standard.

6-3.10

Gasoline and other flammable liquids stored in drums or cans shall be kept separate from other plant facilities, and stored and dispensed in accordance with applicable requirements of NFPA 30A, *Automotive and Marine Service Station Code*.

6-3.11

Hand carriage of gasoline within the plant area shall be restricted to containers designed for carrying and storage of such fuel. Open buckets, cans, or glass jars shall not be used.

6-3.12

Only soaps, detergents, and approved solvents shall be used for cleaning purposes on the premises or on board boats. Gasoline or Class I flammable liquids shall not be used.

6-4 Storage and Handling of Paints and Solvents.

Paint storage and mixing shall be segregated from other working and storage areas, preferably by provision of a well-separated and ventilated building of noncombustible construction, but otherwise by provision of a ventilated fire-resistive room with properly protected openings.

6-5 Storage and Handling of Fiberglass Reinforced Plastic Materials.

Liquid materials used for the construction and repair of fiberglass reinforced plastic boats such as resins, catalysts, oxidizers, and solvents are usually flammable or combustible. Areas in which these materials are stored or used shall be well ventilated, constructed of noncombustible materials, and shall have particular attention paid to provisions for fire protection of such areas. Catalyzed resins shall be set and cooled before disposal of excess material or waste.

6-6 Paint Removal and Painting.

6-6.1

Removal of paint or other finishes by use of flammable solvents shall be restricted to exterior surfaces of boats and shall be conducted only out-of-doors and well separated from other craft and adjacent (hazardous) operations.

6-6.2

An adequate supply of approved fire extinguishing equipment of suitable type shall be readily accessible to all areas where paint removal, painting, or refinishing is in process.

6-6.3

The operation of open-flame devices shall not be permitted where painting, sanding, scraping, or wire brushing is being performed in confined areas such as boat interiors. The operation of spark-producing equipment shall not be permitted where painting is being performed in confined areas such as boat interiors.

6-6.4

Portable electric lamps used in areas where flammable vapors may be encountered, such as in paint removal and painting locations, shall be of the explosionproof type and shall be equipped with guards.

6-6.5

Only such quantities of paint and solvent as required for one day’s operations shall be permitted in the work area.

6-6.6

Where spray finishing is performed indoors repeatedly at a fixed location, it shall be conducted in accordance with NFPA 33, *Standard for Spray Application Using Flammable and Combustible Materials*. Where such spray finishing is performed occasionally and in varying locations either indoors or outdoors, suitable precautions shall be taken to assure that all possible sources of ignition are eliminated throughout and near to the area wherein the spray finishing is to be performed. Ample ventilation of the area shall be provided.

6-7 Lumber Storage.

6-7.1

Main stocks of lumber shall be stored in a segregated area.

6-7.2*

Piles of lumber shall be neatly stacked, and unobstructed aisles of adequate width shall be maintained between individual piles, to limit spread of fire and permit access for fire-fighting personnel and equipment.

6-8 Welding, Brazing, Soldering, and Metal Cutting.

6-8.1

These operations shall be restricted to a shop specifically provided for the purpose, or in an open area. The shop shall be of noncombustible or fire-resistive construction, including its flooring, and all combustibles shall be kept well away from the shop or area.

6-8.2

Only experienced personnel shall be permitted to perform welding, brazing, soldering, and cutting work.

6-8.3

When welding or cutting in or on a boat, the following precautions shall be taken:

(a) Before starting operations a proper fire watch equipped with appropriate fire extinguishers shall be established.

(b) All combustible materials in proximity to hazardous repair work shall, if possible, be moved to a safe location aboard or ashore. Noncombustible material or properly flameproofed tarpaulins shall be used to protect combustible materials that cannot be moved.

(c) The area shall be free of combustible vapor and flammable liquids.

(d) All hatches, ports, tank openings, etc., through which sparks might pass shall be protected.

(e) Noncombustible or properly flameproofed tarpaulins or metal shields shall be set around the work in progress to restrict the travel of sparks.

(f) Before welding or cutting is begun on decks or bulkheads, a careful check shall be made of conditions on the opposite side thereof to eliminate the possibility of damage by heat or fire.

(g) Safeguards shall be taken with any fuel tanks to prevent vapors from creating a fire hazard.

6-8.4

Neither welding nor cutting shall be attempted on a fuel tank unless the tank has been cleaned or otherwise safeguarded in accordance with NFPA 327, *Standard Procedures for Cleaning or Safeguarding Small Tanks and Containers Without Entry*.

6-8.5

All welding and cutting equipment shall be maintained in the best condition. Oxyacetylene hose shall be neatly coiled and stored in a cool location, free from grease, oil, etc. Spare gas cylinders shall be limited to five and kept in a well-ventilated locker. Electric welding equipment shall conform to the provisions of NFPA 70, *National Electrical Code*.

6-8.6

Wherever welding or cutting operations are in process, adequate and suitable fire extinguishing equipment shall be supplied, installed, and maintained in an approved manner and a competent fire watch provided where deemed advisable.

6-9 Woodworking.

Good housekeeping and clean premises being essential to health and safety, woodworking equipment and machinery shall be arranged in a manner to prevent accumulations of sawdust, shavings, and wood waste. The interior of woodworking areas shall be constructed so as to minimize pockets and ledges inaccessible to cleaning, and the following precautions shall be observed:

(a) Sawdust, waste, and refuse shall be removed daily, or more often if necessary, and safely disposed of.

(b) Exhaust systems shall be installed for automatic removal of sawdust and shavings from planers.

(c) Machines shall never be left unattended while in operation.

(d) The area provided to accommodate boats undergoing construction or repair shall be large enough to permit free access around and under them. A check shall be made of all boats in this area to make certain the area is free of flammable vapors and other hazards.

(e) All volatile liquids required shall be kept to a minimum and handled only in approved safety cans.

(f) Adequate and suitable fire extinguishing equipment shall be supplied, installed, and maintained in an approved manner.

(g) Open flames, lights, and smoking shall be prohibited.

6-10 Machine Shop.

6-10.1

The machine shop shall be housed in a separate noncombustible or fire-resistive building or effectively segregated by means of a fire wall when it shares a building with other facilities. If a means of egress is necessary in the separating fire wall, it shall comply with the requirements of NFPA 80, *Standard for Fire Doors and Fire Windows*.

6-10.2

Machines and motors shall be kept clean and in good repair at all times.

6-10.3

All flammable liquids required shall be kept at a minimum and handled only in approved safety cans.

6-10.4

Gravity feed from fuel tanks to test stands shall not be permitted.

6-10.5

An adequate supply of approved portable fire extinguishers of suitable type shall be installed and maintained in an approved manner.

6-11 Battery Service and Storage.

6-11.1

Hydrogen gas is formed during the functioning of wet cell storage batteries. Hydrogen gas is highly flammable, is much lighter than air, and will rise to the highest available space. The area used for service or storage of such batteries shall be designed to:

(a) Vent the gas to the exterior atmosphere, and

(b) Prevent ignition of such gas that might not be completely vented.

6-11.2

A separate room or completely closed area shall be provided for battery charging and storage. The room shall be used for no other purpose, and materials not required for the designated use shall not be placed or stored therein. The access door and windows (if any) shall be kept locked when the room is unattended.

6-11.3

The battery room shall be ventilated in the following manner: air inlets shall be provided at, or below, the level of the battery racks with adequate exhausts at the ceiling. A vent stack equipped with natural draft exhaust head shall be installed to aid in providing an upward draft.

6-11.4

The room and the electrical equipment located within the described space shall conform to the applicable requirements of NFPA 70, *National Electrical Code*, for Class I, Division I, Group B, Hazardous Area.

6-11.5

To minimize the hazard, switches for control of services and illumination shall be permitted to be located on the exterior of the room or enclosure, and, in such location, need not be rated explosionproof.

6-11.6

Battery chargers used shall have separate control switches in addition to a master switch to control all units.

6-11.7

Charging equipment shall be well secured, protected from physical damage, and so located as to permit good ventilation all around it. Metal enclosures of battery charging devices shall be bonded to the equipment grounding conductor of the electrical system (green wire).

6-11.8

Racks for storing and charging use shall be substantial, suitably insulated, reasonably open, and shall permit the setting of batteries so that no pockets where gases might accumulate can be formed, and shall conform to the requirements of Section 480-7, NFPA 70, *National Electrical Code*.

6-11.9

Insulated tools and battery clips equipped with insulated cuffs shall be used to avoid short circuits.

6-11.10

All battery servicing work shall be conducted by experienced personnel only. The following specific precautions shall be followed:

(a) Smoking shall be prohibited in the battery room.

(b) No open flame or spark producing work shall be undertaken in the battery room.

(c) No volatile liquids shall be stored or used in the battery room.

(d) Cell caps shall be kept tight while connecting or disconnecting batteries, but shall be removed whenever possible while charging.

(e) Battery tongs or other appropriate carrying devices shall be used when removing or lifting batteries.

(f) Wiring connections shall never be connected or disconnected if power is being supplied to or released by batteries.

(g) When nickel-cadmium batteries are to be charged or serviced in the reserved area, the work shall be done in a separate work area from which servicing or charging is done on lead-acid types of storage batteries. Tools and equipment used in servicing or charging nickel-cadmium batteries shall be distinguished by an appropriate color applied to them and shall be at all times reserved only for such usage.

6-11.11

One (or more) approved dry chemical portable fire extinguisher(s) shall be provided in a readily accessible location within the enclosed area and shall be maintained in an approved manner.

6-12 Servicing Liquefied Petroleum and Compressed Natural Gas Systems.

6-12.1

Utmost care shall be exercised at all times in the servicing of liquefied petroleum gas and compressed natural gas systems and equipment.

6-12.2

Changing of cylinders shall be performed in accordance with NFPA 302, *Fire Protection Standard for Pleasure and Commercial Motor Craft*.

6-12.3

Checks for leaks in liquefied petroleum gas and compressed natural gas systems shall never be made with a flame.

6-13* Maintenance.

The marina or boatyard facility shall be maintained at all times in a state of general order and cleanliness.

6-13.1

Covered metal containers approved for the purpose shall be provided at convenient locations in shop areas used for boat construction, service, or repair for storage of oily and soiled rags and other refuse subject to spontaneous combustion. These containers shall be clearly marked as to their purpose and the contents disposed of at least daily in a safe manner.

6-13.2

Separate metal containers shall be provided in shop areas used for boat construction, service, or repair for storage of sawdust, wood chips, and other residue, and trash that is not readily subject to spontaneous combustion. These containers shall be emptied at least daily.

6-13.3

Shop floors shall be swept at least once a day, and with greater frequency as necessary, to prevent accumulation of easily ignited residue such as sawdust, wood chips, scraps of fiberglass reinforced plastic (FRP) materials, etc., and to prevent accumulation of metal chips and other residue that presents hazards including fire hazards.

6-13.4

Where tar paper, roofing paper, or similar floor covering is used for floor protection in shops where FRP work takes place, the floor covering shall be promptly removed and properly disposed of at the end of the specific job or on a regular schedule.

6-13.5

Covered containers shall be provided throughout the facility, including locations convenient to moored boats, for garbage and trash. These containers shall be located in areas where ignition of contents will not pose a hazard to the surroundings. Emptying and cleaning of these containers shall be performed regularly.

6-13.6

Walkways, piers, access roads, and other parts of the facilities shall be maintained free of obstructions at all times so as to provide safe and reasonable access to all parts of the facility by fire-fighting personnel and equipment.

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.

NOTE: It is not the intent of this standard that the marina or boatyard owners/operators maintain copies of these standards as a requirement of this standard, nor is it expected that they be knowledgeable as to their detailed contents. The inclusion of these reference standards provides a ready source for specifying compliance in procurement of equipment, systems, and design or installation services. Key requirements of the referenced standards as they apply to marinas and boatyards have been included in Chapters 1 to 6 inclusive with reference to the appropriate NFPA or ANSI standards.

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 20, *Standard for the Installation of Centrifugal Fire Pumps*, 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 30A, *Automotive and Marine Service Station 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*, 1995 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 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 90B, *Standard for the Installation of Warm Air Heating and Air Conditioning Systems*, 1993 edition.

NFPA 110, *Standard for Emergency and Standby Power Systems*, 1993 edition.

NFPA 211, *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances*, 1992 edition.

NFPA 302, *Fire Protection Standard for Pleasure and Commercial Motor Craft*, 1994 edition.

NFPA 307, *Standard for the Construction and Fire Protection of Marine Terminals, Piers, and Wharves*, 1995 edition.

NFPA 327, *Standard Procedures for Cleaning or Safeguarding Small Tanks and Containers Without Entry*, 1993 edition.

7-2 ANSI Publications.

American National Standards Institute, 1430 Broadway, New York, NY 10018.

ANSI/UL 231, UL *Standard for Safety Power Outlets*, 1994.

ANSI/NEMA WD6, *Wiring Devices-Dimensional Requirements*, 1988.

7-3 UL Publication.

Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 1686, UL *Standard for Safety Pin & Sleeve Configurations*, 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-1-4 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

While design of the marina or boatyard can reduce certain hazards, the fact remains that proper management of the facility or boatyard is an important element for reducing the risk of fire, electrical, and other hazards that threaten life and property. The guidelines in this chapter are specifically addressed to those management functions where implementation can significantly reduce the specific and overall hazard.

The marina or boatyard management should adopt procedures to show that facility and equipment comply with the requirements of this standard and to show that maintenance and inspection functions are carried out as specified in this standard.

A-2-5 Watch Service.

A watch service has been shown to be one of the most important means for early detection of a fire during hours when marina or boatyard personnel are not working, and is required under certain circumstances in 5-2.3(d).

If a watch person is employed, he or she should be physically active, have good eyesight and hearing, and have a good record of health and sobriety. It is particularly important that the watch person have a reasonable familiarity with boats.

A-3-11.5

The exterior environment in marinas and boatyards exposes electrical equipment and wiring to the highly corrosive conditions of acid rain, salt spray, and temperature extremes. These conditions greatly enhance the galvanic corrosion where dissimilar metals are used in the electrical circuitry, which can cause high resistance connections and the possibility of fires.

A-4-4.2

The combustibility of the boats in storage should be considered in determining the hazard classification for appropriate sprinkler system design.

A-4-4.4

In order to comply with this requirement, water supplies may consist of a hydrant that is part of an approved water supply system, drafting hydrant, or drafting site.

A-5-1.3

It is recommended that an auxiliary power supply be provided to ensure lighting in the event of a power failure.

A-5-2.3

(d) Multilevel racks with height of storage not exceeding 12 ft (3.66 m) are covered by NFPA 13, *Standard for the Installation of Sprinkler Systems*. The combustibility of the boats in storage should be considered in determining hazard classifications. Where boats are stored on racks and storage height exceeds 12 ft (3.66 m), guidance for the design of automatic sprinkler protection should be taken from NFPA 231C, *Standard for Rack Storage of Materials*. Combustibility of boat construction should be used in determining the appropriate commodity class for fire protection system selection and design. Plan view configuration of the boats in storage should be reviewed in determining whether in-rack sprinklers are needed and, to aid in the proper design of the in-rack portion of the sprinkler system. Sound engineering judgment is necessary in selecting sprinkler spacing, placement and design criteria.

A-6-7.2

See NFPA 46, *Recommended Safe Practice for Storage of Forest Products*, for additional guidance.

A-6-13

The following list contains examples of conditions that should be eliminated or controlled:

(a) Uncontained trash, wood scraps, sawdust, rags, etc.

(b) Used engines and engine parts, miscellaneous metal, unused machinery, and similar items placed other than in a specifically designated and fenced area.

(c) Unswept floors, particularly in shop areas.

(d) Open paint cans or other flammable or combustible liquids.

(e) Spills of oil, paint, or fuel.

(f) Unmowed grass or weeds, brush, dead or dying trees, and other debris.

Appendix B

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

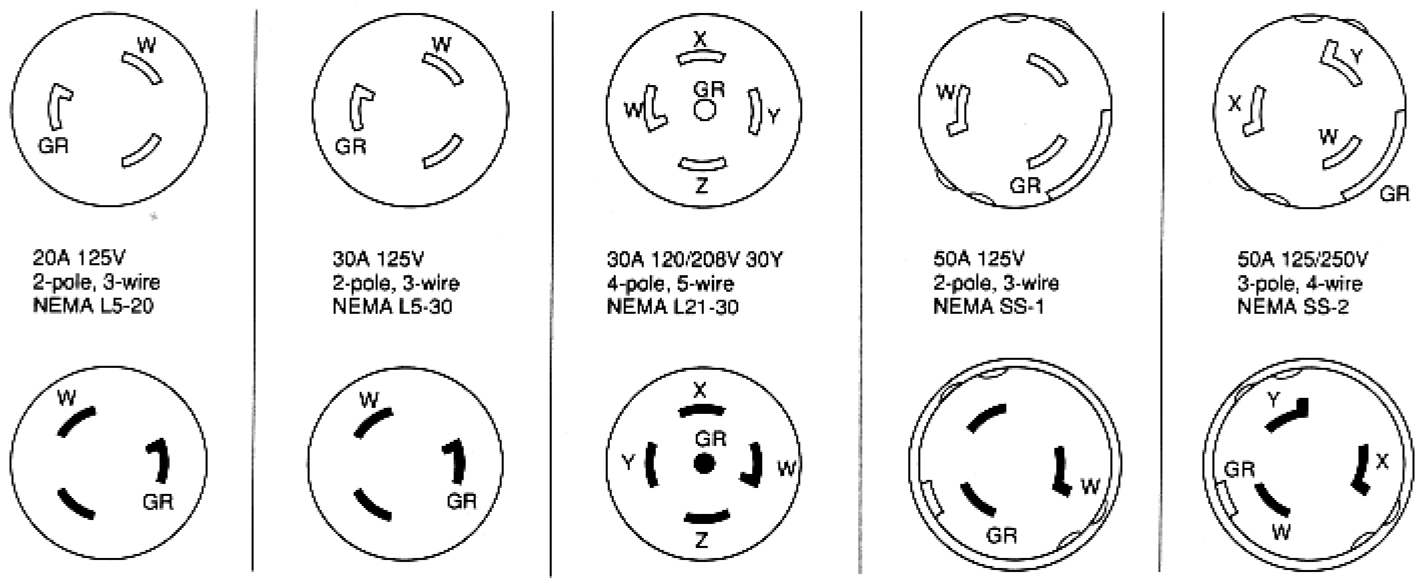
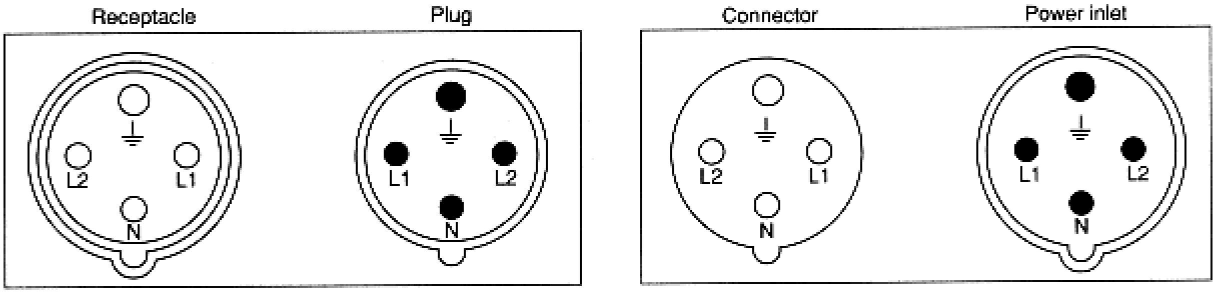


Figure B-1 Receptacle configurations, 20 amperes to 50 amperes.

Shore connection, front view

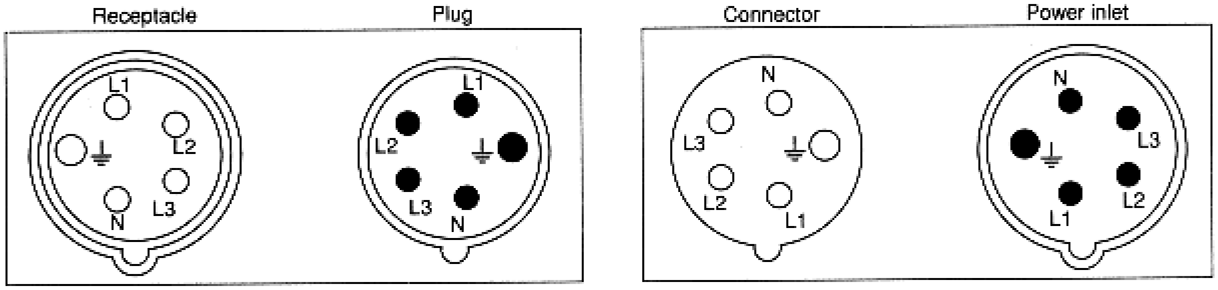
Boat connection, front view

Receptacle Plug Connector Power inlet



100A 125/250V, 3-pole, 4-wire

Receptacle Plug Connector Power inlet

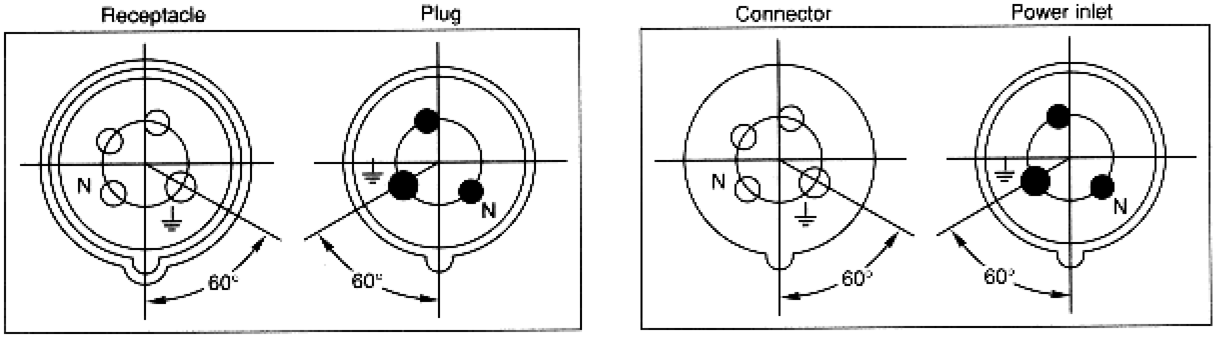


100A 120/208V, 30-wye, 4-pole, 5-wire

Shore connection, front view

Boat connection, front view

Receptacle Plug Connector Power inlet

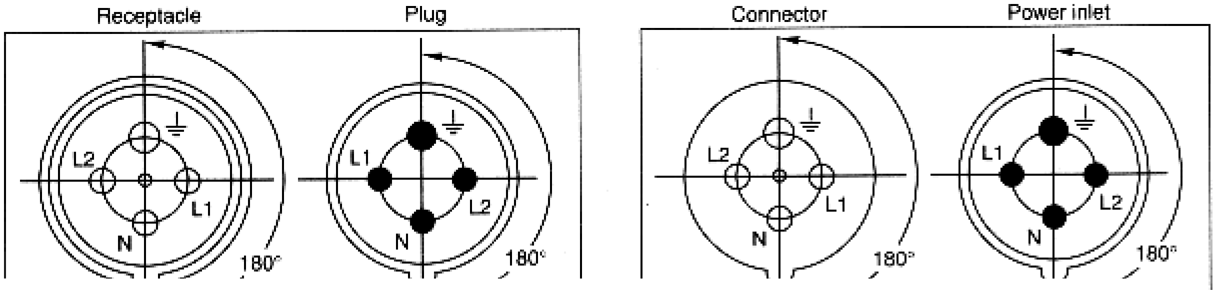


1P + N + ground, 60A, 125VAC

Shore connection, front view

Boat connection, front view

Receptacle Plug Connector Power inlet



(Views are of mating faces of devices) 2P + N + ground, 60A, 125/250VAC

Figure B-2 Safety pin and sleeve configurations, 60 amperes or 100 amperes.

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*, 1994 edition.

NFPA 46, *Recommended Safe Practice for Storage of Forest Products*, 1990 edition.

NFPA 231C, *Standard for Rack Storage of Materials*, 1995 edition.

Tentative Interim Amendment

NFPA 303

Fire Protection Standard for Marinas and Boatyards

1995 Edition

Reference: 3-14.1(a) and (b), 3-11.5

TIA 95-1 (NFPA 303)

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 303, *Fire Protection Standard for Marinas and Boatyards*, 1995 edition. The TIA was processed by the Marinas and Boatyards Committee, and was issued by the Standards Council on October 1, 1996, with an effective date of October 21, 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. Delete 3-14.1 as presently written and replace it with the following language from the 1990

edition:

"3-14.1 Receptacles intended to supply shore power to boats shall be housed in power outlets approved for marine use."

2. Delete 3-11.5.

NFPA 306

1993 Edition

Standard for the Control of Gas Hazards on Vessels

1993 Edition

This edition of NFPA 306, *Standard for the Control of Gas Hazards on Vessels,* was prepared by the Technical Committee on Gas Hazards, released by the Correlating Committee on Marine Fire Protection, 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 306

The original standard on this subject was developed by the NFPA Committee on Marine Fire Hazards in 1922 in cooperation with the NFPA Committee on Flammable Liquids. It was adopted by the Association and published as Appendix A of the “Regulations Governing Marine Fire Hazards.” Further editions with minor changes were published in 1923, 1926, and 1930. In 1947, a completely revised standard was prepared by a joint committee of the American Bureau of Shipping and the National Fire Protection Association. A revised edition was developed by the NFPA Sectional Committee on Gas Hazards, approved by the Committee on Marine Fire Protection, and adopted in 1962, amended in 1963, 1969, 1971, 1972, 1975, 1980, and 1984.

In 1988 a complete revision was prepared by the Committee. It added a new safety designation, a safe condition for vessels in lay-up, and a section on military unique vessels. Chapters 2, 3, and 4 were restructured to present the sequence for obtaining a Marine Chemist Certificate.

The 1993 edition contains amendments to the 1988 edition.

Committee on Marine Fire Protection

Correlating Committee

Robert Loeser, *Chairman*
Underwriters Laboratories Inc., FL

Guy R. Colonna, *Secretary*
National Fire Protection Assn., MA
(Nonvoting)

Howard C. Blanding, American Bureau of Shipping, NY

Richard A. Comstock, Fire Prevention & Engineering Bureau of Texas, TX

Joseph J. Cox, American Inst. of Merchant Shipping, DC

Bolling F. Douglas, Marine Assoc., Inc., GA

Warren E. Jackson, Glastonbury, CT

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Rep. American Petroleum Inst.

W. B. Hataway, Marine Chemists Inc. of TX
Rep. Marine Chemists Assn. Inc.

James R. Herndon, Marine Hydraulics Int'l Inc., VA

Charles K. Klein, Newport News Shipbuilding, VA
Rep. Shipbuilders Council of America

Kathy J. Metcalf, Sun Refining & Marketing Marine Dept., PA
Rep. American Inst. of Merchant Shipping

Frank G. Monaghan, Mare Island Naval Shipyard, CA
Rep. U.S. Navy

Peter A. Popko, U.S. Coast Guard Headquarters, DC

Winston A. Smith, Norshipco, VA
Rep. Shipbuilders Council of America

Charles C. Thornton, Thornton Laboratories Inc., FL
Rep. Marine Chemists Assn. Inc.

Kenneth M. Vogel, M&M Protection Consultants, NJ

Chester H. Walters, Nat'l Marine Service Inc., IL
Rep. American Waterways Operators Inc.

Alternates

John T. Bell, Marine Inspection Services Inc., TX
(Alt. to W. B. Hataway)

Danny R. Joyce, Avondale Shipyards Inc., LA
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Robert H. Walker, Marine Chemist Service Inc., VA
(Alt. to C. C. Thornton)

Nonvoting

Richard L. Swift, Pittsburgh, PA
(Member Emeritus)

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 prevention of fire and explosion of flammable vapors in compartments or in spaces on board vessels and on the conditions that must exist in those compartments or spaces in order that workers can safely enter them.

NFPA 306
Standard for the
Control of Gas Hazards on Vessels

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 Appendix D.

Chapter 1 General

1-1 Scope.

1-1.1

This standard applies to vessels carrying or burning as fuel flammable or combustible liquids. It also applies to vessels carrying or having carried flammable compressed gases, chemicals in bulk, or other products capable of creating a hazardous condition.

1-1.2

This standard describes the conditions required before a space may be entered or work may be started on any vessel under construction, alteration, repair, or for shipbreaking.

1-1.3

This standard applies to cold work, application or removal of protective coatings, and work involving riveting, welding, burning, or like fire-producing operations.

1-1.4

This standard applies to vessels while in the United States, its territories and possessions, both within and outside of yards for ship construction, ship alteration, ship repair, or shipbreaking.

1-1.5

The standard applies specifically to those spaces on vessels that are subject to concentrations of combustible, flammable, and toxic liquids, vapors, gases, and chemicals as hereinafter described. This standard is also applicable to those spaces on vessels that may not contain sufficient oxygen to permit safe entry.

1-2 Purpose.

The purpose of this standard is to provide minimum requirements and conditions for use in determining that a space or area on a vessel is safe for entry or work.

1-3* Emergency Exception.

Nothing in this standard shall be construed as prohibiting the immediate drydocking of a vessel whose safety is imperiled (the vessel is sinking or is seriously damaged), making it impracticable to clean and gas free in advance.

1-4* Governmental Regulations.

Nothing in this standard shall be construed as superseding existing requirements of any governmental or local authority. Attention of owners, repairers, and chemists is directed to the “Rules and Regulations for Tank Vessels” and other rules and regulations for vessel inspection of the United States Coast Guard and the “Occupational Safety and Health Standards” of the United States Department of Labor, which prescribe an inspection prior to making repairs involving riveting, welding, burning, or similar fire-producing operations, and prior to entering spaces where oxygen deficiency may exist. Those standards provide, under the conditions stated therein, for inspection by a Marine Chemist certificated by the National Fire Protection Association or, alternatively, for inspection by certain other persons.

1-5 Definitions.

Unless expressly stated elsewhere, the following terms shall, for the purpose of this standard, have the meanings indicated below.

Adjacent Spaces. Those spaces in all directions from subject space, including all points of contact, corners, diagonals, decks, tank tops, and bulkheads.

Certificate. See “Marine Chemist’s Certificate.”

Chemical. Any compound, mixture, or solution in the form of a solid, liquid, or gas that may be hazardous by virtue of its properties other than or in addition to flammability, or by virtue of the properties of compounds that might be evolved from hot work or cold work.

Coiled Vessels. Tank vessels using a closed system of heating coils that use thermal oil as the heating medium.

Flammable. The words “flammable” and “inflammable” are interchangeable or synonymous terms for the purpose of this standard.

Flammable Compressed Gas. Any flammable gas that has been compressed, liquefied, or compressed and liquefied for the purpose of transportation and has a Reid vapor pressure exceeding 40 psia (2.76×10^5 Pa).

Hollow Structures. Rudders, rudder stocks, skegs, castings, masts and booms, rails, and other attachments to a vessel that enclose a void space.

Marine Chemist. The holder of a valid Certificate issued by the National Fire Protection Association in accordance with the “Rules for Certification of Marine Chemists,” establishing him as a person qualified to determine whether construction, alteration, repair, or shipbreaking of vessels, which may involve hazards covered by this standard, can be undertaken with safety.

Activities of a Marine Chemist, as defined in this section, are limited to the inspection and certification procedures described in this standard and consulting services connected therewith.

Marine Chemist's Certificate (Certificate). A written statement issued by a Marine Chemist in the form and manner prescribed by this standard. It states the conditions that the Marine Chemist found at the time of his inspection.

Materials.

(a) **Flammable Liquid.** Any liquid having a flash point (closed cup) below 80°F (26.6°C) and having a vapor pressure not exceeding 40 psi absolute (2068.6 mm Hg) at 80°F (26.6°C).

1. *Grade A.* Any flammable liquid having a Reid vapor pressure of 14 lb (9.6×10^4 Pa) or more.

2. *Grade B.* Any flammable liquid having a Reid vapor pressure under 14 lb (9.6×10^4 Pa) and over $8^1/_2$ lb (5.9×10^4 Pa).

3. *Grade C.* Any flammable liquid having a Reid vapor pressure of $8^1/_2$ lb (5.9×10^4 Pa) or less and a flash point of 80°F (26.6°C) or below.

(b) **Combustible Liquid.** Any liquid having a flash point (open cup) at or above 80°F (26.6°C).

1. *Grade D.* Any combustible liquid having a flash point below 150°F (65.5°C) and above 80°F (26.6°C).

2. *Grade E.* Any combustible liquid having a flash point of 150°F (65.5°C) or above.

(c) **Toxic Materials.** Any material whose properties contain the inherent capacity to produce injury to a biological system. This is dependent on concentration, rate, method, and site of absorption.

Repair Classifications.

(a) **Hot Work.** Any construction, alteration, repair, or shipbreaking operation involving riveting, welding, burning, or similar fire-producing operations. Grinding, drilling, abrasive blasting, or similar spark-producing operations shall be considered hot work unless deemed otherwise by a Marine Chemist.

(b) **Cold Work.** Any construction, alteration, repair, or shipbreaking that does not involve heat-, fire-, or spark-producing operations.

(c) **Work Below Deck.** Work in or on enclosed spaces surrounded by shell, bulkheads, and overheads.

(d) **Work in the Open.** Work performed from open decks or in spaces from which the overhead has been completely removed.

Secured. Closed in a manner to avoid accidental opening or operation.

Shipbreaking. The breaking down of a vessel's structure for the purpose of scrapping the vessel; includes the removal of gear, equipment, or any component part of a vessel.

Tanker Designations.

(a) **Tank Vessel.** Any vessel especially constructed or converted to carry liquid bulk cargo in tanks.

(b) **Tank Ship.** Any tank vessel propelled by power or sail.

(c) **Tank Barge.** Any tank vessel not equipped with a means of self-propulsion.

Vessel. Includes every description of watercraft used, or capable of being used, as a means of transportation on water.

Chapter 2 Minimum Requirements for Issuance of Marine Chemist's Certificate and Maintenance Conditions

2-1 The Marine Chemist Shall Personally Determine Conditions.

A Marine Chemist shall be permitted to issue a Certificate setting forth in writing that the prescribed work to a vessel can be undertaken with safety. The Marine Chemist shall physically inspect the conditions and carry out tests within each compartment or space, ensuring compliance with the minimum applicable requirements to his satisfaction prior to issuing a Certificate.

2-2 Procedures Prior to Issuance of a Certificate.

2-2.1

The calibration of all instruments used by the Marine Chemist shall be checked before and after each day's use. A record shall be maintained of all calibration checks.

2-2.2

The Marine Chemist's determinations shall include an internal inspection and tests of the spaces to be certified and spaces adjacent thereto. The determinations shall also include:

(a) the three previous cargoes carried,

(b) the nature and extent of the work,

(c) starting time and duration of the work,

(d) tests of cargo and vent lines at manifolds and accessible openings,

(e) verification that cargo valves in prescribed areas of work are tagged and positioned in a manner to avoid accidental operation, and

(f) tests of cargo heating coils.

2-3 Standard Safety Designations and Conditions Required.

The following standard safety designations shall be used where applicable in preparing Certificates, cargo tank labels, and other references.

2-3.1 SAFE FOR WORKERS.

Means that in the compartment or space so designated:

(a)* The oxygen content of the atmosphere is at least 19.5 percent and not greater than 22 percent by volume;

(b)* The concentration of flammable materials is below 10 percent of the lower explosive limit;

(c)* Any toxic materials in the atmosphere associated with cargo, fuel, tank coatings, inerting mediums, or fumigants are within permissible concentrations at the time of the inspection; and

(d)* The residues or materials associated with the work authorized by the Certificate will not produce uncontrolled toxic materials under existing atmospheric conditions while maintained as directed on the Certificate.

(e) If any of the conditions of 2-3.1(a), (b), (c), or (d) do not exist, then the designation “Not Safe for Workers” or “Enter with Restrictions” shall be used.

2-3.2 NOT SAFE FOR WORKERS.

Means that in the compartment or space so designated, personnel shall not be allowed to enter.

2-3.3 ENTER WITH RESTRICTIONS.

Means that in any compartment or space so designated, entry for work shall be permitted only if conditions of proper protective equipment, clothing, and time are as specified.

2-3.4 SAFE FOR HOT WORK.

Means that in any compartment or space so designated:

(a)* The oxygen content of the atmosphere is not to exceed 22 percent by volume,

(b)* The concentration of flammable materials in the atmosphere is less than 10 percent of the lower explosive limit,

(c) The residues are not capable of producing a higher concentration than permitted by 2-3.4(a) or (b) under existing atmospheric conditions in the presence of hot work and while maintained as directed on the Certificate, and

(d) All adjacent spaces, including diagonal spaces, containing or having contained flammable or combustible materials, are sufficiently clean to prevent the spread of fire; or are inerted; or, in the case of ship’s fuel oil tanks or lube tanks, or engine room or fire room bilges or other machinery spaces, have been treated in accordance with the Marine Chemist’s requirements.

(e) If any of the conditions of 2-3.4(a), (b), (c), or (d) do not exist, the designation “Not Safe for Hot Work” must be used.

2-3.5 NOT SAFE FOR HOT WORK.

Means that in the compartment so designated, hot work shall not be permitted.

2-3.6 SAFE FOR SHIPBREAKING.

Means that the compartment so designated shall meet the requirements of 2-3.4(a) through (d). The residual combustible materials designated are not capable of producing fire beyond the extinguishing capabilities of the equipment on hand.

2-3.7 INERTED.

Means that one of the following procedures has been completed in the compartment or space so designated:

(a)* Carbon dioxide or other nonflammable gas acceptable to the Marine Chemist has been introduced into the space in sufficient volume to maintain the oxygen content of the atmosphere of the enclosed space at or below 8.0 percent or 50 percent of the amount required to support combustion, whichever is less.

(b) The space has been flooded with water, provided that any hot work is performed at least 3 ft (0.9 m) below the water level and, further, provided that the gas content of the atmosphere above the water does not exceed l0 percent of the lower explosive limit and such procedure is approved by a Marine Chemist.

(c) The kind of gas and the safe disposal and securing of gas inerting media shall be noted on the Certificate by the Marine Chemist upon completion of repairs. Closing and securing of hatches and other openings, except vents, may be considered as “safe disposal” by the Marine Chemist.

2-3.8 INERTED FOR FLAMMABLE COMPRESSED GAS.

Means that individual pressure tanks with a working pressure of 50 psi (3.45×10^5 Pa) or more are considered in a safe condition for such work not directly involving these tanks or their pipelines when a positive pressure is maintained on the tanks by the flammable vapors and when special precautions are observed under carefully controlled conditions as specified on the Certificate.

2-3.9 SAFE FOR LAY-UP.

Means that for any tank ship so designated, any of the following conditions has been met:

(a) The vessel has been cleaned in accordance with the provisions in Section 3-1, and the vessel is inspected weekly by the responsible owner’s representative to ensure that no change in conditions occurs.

(b) All the cargo tanks have been discharged of cargo, the residues are not capable of producing more than 10 percent of the lower explosive limit, and the vessel is inspected weekly by the responsible owner’s representative to ensure that no change in conditions occurs.

(c) All the cargo tanks have been inerted to less than 8 percent oxygen or 50 percent of the amount to support combustion, whichever is less; a responsible owner’s representative is in constant attendance, and the vessel is reinspected daily until stabilized; and, thereafter, the responsible owner’s representative is to maintain daily inspections and records of oxygen content.

2-4 Preparation of Certificates.

When the Marine Chemist is satisfied that the requirements of this standard and any other requirements necessary in order that the prescribed work can be undertaken with safety have been carried out or have not been met, a Certificate shall be prepared in form and manner prescribed by this standard.

2-4.1

The Certificate shall include the frequency and type of such additional tests, inspections, qualifications, and other instructions as the Marine Chemist specifies.

2-4.2

The Certificate shall state conditions under which the Marine Chemist should be consulted or recalled.

2-4.3

Such qualifications and requirements shall include precautions, including protective equipment and devices, necessary to eliminate or minimize hazards that may be present from protective coatings or residues from cargoes.

2-5 Issuance of Certificates.

The Certificate shall be completed, and a signature for receipt of the Certificate shall be obtained, signifying the understanding of the conditions and limitations under which it is issued.

2-5.1

If the Certificate is issued in connection with commencement of repair work, it shall be delivered to and signed for by the ship repairer or his authorized representative.

2-5.2

If the Certificate is issued for purposes other than the commencement of repair work, it shall be delivered to and signed for by the person who authorized the inspection or his authorized representative.

2-6 Responsibility for Obtaining Certificate and Maintaining Conditions.

2-6.1

Work authorized by the Certificate shall commence within 24 hours unless otherwise noted on the Certificate.

2-6.2

It is the responsibility of the vessel repairer, shipbreaker, or vessel builder to retain the services of the Marine Chemist, to secure copies of his Certificate, and to provide the master of the vessel and the representatives of the vessel owner with copies of such Certificate. Receipt and understanding of the Certificate shall be acknowledged by signature of the person designated in 2-5.1 or 2-5.2.

2-6.3

Throughout the course of repairs or alterations, conditions on the Certificate shall be maintained on the vessel by full observations of all qualifications and requirements.

2-6.4

It is the responsibility of the vessel repairer, shipbreaker, or vessel builder to ensure that the prescribed work is carried out at the original location within the facility for which the Certificate was issued, unless movement is authorized within that facility by the Marine Chemist on the Certificate.

2-6.5

It is the responsibility of the person signing for receipt of the Certificate to securely post the Certificate in a conspicuous place aboard the vessel before a space may be entered or work may be started.

2-6.6

All access openings to spaces designated “Not Safe for Workers,” including inerted spaces, shall be appropriately labeled with a warning sign “Not Safe for Workers,” which shall remain in place unless recertificated.

Chapter 3 Preparing Vessels for Issuance of a Marine Chemist’s Certificate

3-1 Where a Safe Condition Is to Be Obtained Entirely by Cleaning.

(*See Appendix B.*)

3-1.1

All cargo pumps, cargo lines, inert gas lines, crude oil wash lines, piped cargo fire extinguishing systems, and vent lines shall have been flushed with water, blown with steam or air, or inerted.

3-1.2

Compartments concerned shall be so cleaned that the atmosphere in all cargo compartments and adjacent spaces, including those diagonally adjacent to the cargo compartments, is in accordance with 2-3.1, 2-3.4, or 2-3.1 and 2-3.4, as applicable.

3-1.3

Tanks or compartments with residues whose flash point is 180°F (82.2°C) or above may be partially cleaned for minor hot work. The residue in the subject space shall be cleaned back a sufficient distance from the hot work area to prevent the spread of fire. All other requirements of 2-3.4, as applicable, shall be met.

3-1.4

The residue in all compartments concerned (with the exception of tanks described in 3-1.3) shall be such that the conditions of 2-3.1, 2-3.4, or 2-3.1 and 2-3.4, as applicable, shall be met.

3-2 Where a Safe Condition Is to Be Obtained by Both Cleaning and Inerting or Entirely by Inerting.

(*See Appendix B.*)

3-2.1

The Marine Chemist shall approve the use of the inerting medium and shall personally supervise introduction of the inerting medium into the space to be inerted, except in situations where an inerting medium has been introduced prior to the vessel’s arrival at the repair facility. A Marine Chemist, in all cases, shall personally conduct tests to determine that the oxygen content of the inerted space is at or below 8 percent or 50 percent of the amount required to support combustion, whichever is less. The Marine Chemist shall be readily available during the entire period of work, and he shall determine that the oxygen level in the inerted space is maintained at or below 8 percent or 50 percent of the amount required to support combustion, whichever is lower. On vessels not utilizing cargo space inerting systems, a Marine Chemist shall specify the safe disposal and securing of the inerting medium following completion of the repair work on the inerted space and adjacent spaces.

3-2.2

All piped cargo fire extinguishing systems within the cargo tanks and vent lines, except those in the inerted spaces, shall have been flushed with water, blown with steam or air, or inerted. (All valves to the inerted spaces shall be tagged and secured in such a manner as to avoid accidental opening or operation.) All cargo pumps and cargo lines, inert gas lines, and crude oil wash lines shall have been flushed with water, blown with steam or air, or inerted.

3-2.3

All spaces to be inerted shall be sufficiently intact to retain the inerting medium. All valves, hatches, and other openings to the inerted spaces, except those controlling the inerting medium, shall be closed and secured.

3-2.4

Compartments or spaces in which internal repairs or alterations are to be undertaken shall be cleaned to comply with the requirements of Section 3-3, and all other spaces (with the exception of tanks described in 3-1.3) shall be inerted in accordance with the requirements of 2-3.7 or 2-3.8.

3-2.5

Compartments or spaces on which external repairs or alterations are to be undertaken on the external boundaries (deck or shell) may be inerted by gas instead of being cleaned as described in this section, and all other spaces (with the exception of tanks described in 3-1.3) shall be inerted in accordance with the requirements of 2-3.7 or 2-3.8.

3-3 Where a Safe Condition Is to Be Obtained Entirely by Cleaning Certain Compartments and by Securing the Other Compartments.

(*See Appendix B.*)

3-3.1

Nonadjacent spaces containing atmospheres exceeding l0 percent of the lower explosive limit shall be closed and secured, and those spaces noted on the Certificate.

3-3.2

All piped cargo fire extinguishing systems and vent lines to the spaces involved shall have been flushed with water, blown with steam or air, or inerted, and the valves to all other compartments closed and secured. All cargo pumps and cargo lines, inert gas lines, and crude oil wash lines shall have been flushed with water, blown with steam or air, or inerted, and the valves closed and secured in a manner to avoid accidental opening or operation.

3-3.3

Compartments or spaces in which internal repairs or alterations are to be undertaken and all adjacent compartments, including those diagonally adjacent thereto, shall be cleaned to comply with the applicable requirements of Section 3-1. All other applicable spaces shall be closed and secured in a manner to avoid accidental opening or operation.

3-4 Where a Safe Condition Is to Be Obtained by Both Cleaning and Inerting or Entirely by Inerting Certain Compartments and by Securing the Other Compartments.

(*See Appendix B.*)

3-4.1

All piped cargo fire extinguishing systems and vent lines to the spaces involved, except those to the inerted spaces, shall have been flushed with water, blown with steam or air, or inerted, and the valves to all other compartments closed and secured in a manner to avoid accidental opening or operation. All cargo pumps and cargo lines, inert gas lines, and crude oil wash lines shall have been flushed with water, blown with steam or air, or inerted, and the valves closed and secured in such a manner as to avoid accidental opening or operation.

3-4.2

Nonadjacent spaces containing atmospheres exceeding l0 percent of the lower explosive limit shall be closed and secured in a manner to avoid accidental opening or operation, and those spaces noted on the Certificate.

3-4.3

Compartments or spaces in which internal repairs or alterations are to be undertaken shall be cleaned to comply with the requirements of Section 3-1, and all adjacent compartments, including those diagonally adjacent thereto, shall be inerted to comply with the applicable requirements of 2-3.7. All other compartments shall be closed and secured in compliance with 3-3.1. With respect to inerted spaces, the requirements of 3-2.1 apply.

3-4.4

Compartments or spaces on which external repairs or alterations are to be undertaken on the external boundaries (deck or shell) may be inerted by gas instead of being cleaned as described in Section 3-1. All adjacent compartments, including those diagonally adjacent thereto, shall be inerted or cleaned to comply with applicable requirements of Section 3-2. All other applicable spaces shall be closed and secured in compliance with 3-3.1.

3-5 Cargo Heater Coils.

3-5.1

All steam supplied cargo heater coils to the spaces involved, except those to the inerted spaces, shall have been made safe by one of the following means: steaming, flushing with water, blowing with air, or inerting.

3-5.2

Coils in cargo tanks that have been used for chemicals that may react with water or steam shall be cleaned in accordance with the requirements of 5-3.2.

3-5.3

On coiled vessels using thermal heating oils [FP 500°F+ (260°C+) or above], the Marine Chemist shall satisfy himself as to the integrity of the heater coils in the prescribed work areas.

3-6 Electric Welding Operations.

When determined to be necessary by the Marine Chemist, electrical welding ground cables shall be connected to the ship’s structure, as close as possible to the point of welding, with a safe current-carrying capacity equal to or exceeding the specified maximum output capacity of the unit that it services.

3-7 Requirements for Use of a Designated Berthing Area for Cleaning, Gas Freeing, or Inerting.

3-7.1

Vessels that have not been cleaned, gas freed, or inerted shall proceed to a designated berth, selected and set apart with due regard to the hazards of the location and to the hazards to adjacent property.

3-7.2

The degassing, cleaning, or inerting of vessels at such designated berths shall be carried out in accordance with the requirements of Section 3-1 or Section 3-2 before they are shifted to other berths. No repairs involving hot work, other than in boiler or machinery spaces when specifically certified by a Marine Chemist, shall be undertaken on any vessel in such designated berth until it has been degassed and cleaned or inerted in accordance with the requirements of Section 3-1 or Section 3-2, nor shall such repairs be then undertaken if another vessel that has not complied with these requirements is in the designated berth at the same time.

3-8 Adjacent Ship's Fuel Oil Tanks.

No hot work shall be permitted within 3 ft (0.9 m) of any ship's fuel oil tanks unless these tanks have been cleaned, inerted, or the work is authorized by the Marine Chemist.

Chapter 4 Vessels Required to Have Marine Chemist's Certificate

4-1 Tank Vessels.

Tank vessels shall be permitted to be repaired when cleaned, or cleaned and inerted, in accordance with the provisions in Section 3-1 or Section 3-2, respectively. A Certificate to this effect shall be required. Repairs or alterations involving hot work shall not be undertaken unless specifically authorized by the Certificate.

Exception No. 1: Tank vessels shall be permitted to enter a repair yard for examination, afloat or in dry dock, provided that all bulk cargo compartments and cofferdams are kept closed.

Exception No. 2: Tank vessels shall be permitted to enter a repair yard for scraping, washing down, and painting, afloat or in dry dock, provided that all bulk cargo compartments and cofferdams are kept closed.

Exception No. 3: Tank vessels shall be permitted to enter a repair yard for work (hot or cold) to be performed outside of the vessel, afloat or in dry dock, on the propeller, tailshaft, or rudder, or for work to be performed off the vessel, such as on the anchors or chains, provided that all bulk cargo compartments and cofferdams are kept closed.

Exception No. 4: Tank vessels shall be permitted to enter a repair yard, afloat or in dry dock, for work within boiler and machinery spaces and other locations provided that, where hot work is to be undertaken, a Certificate shall be required. This Certificate shall set forth each specific location for which hot work is approved. All bulk cargo compartments, cofferdams, and other areas where the flammable content of the atmosphere is above l0 percent of the lower explosive limit shall be kept closed and secured. The securing of the compartments, cofferdams, and other areas shall be noted on the Certificate.

Exception No. 5: Tank vessels that proceed to a dry dock or designated berth selected with due regard to the hazards of the location and to the hazards to adjacent property shall be permitted to undergo specific limited repairs of a local nature when the compartments or spaces involved *and the adjacent compartments or spaces are prepared in accordance with the provisions of Section 3-3 and Section 3-4.*

4-2 Vessels Other Than Tank Vessels.

On any vessels that have carried flammable or combustible liquid in bulk as fuel or cargo, or that have carried cargoes that may produce hazardous atmospheres (including, but not limited to, those of decomposition or reaction with oxygen from the atmosphere), no repairs involving hot work shall be made in or on the external boundaries (shell, tank top, or deck) of cargo tanks, fuel tanks, oil pipelines, heating coils or hollow structures, and machinery spaces, unless such compartment and pipelines, as deemed necessary by the Marine Chemist, have been cleaned or inerted to meet the appropriate designation requirements of 2-3.4 and 2-3.7. Repairs and alterations shall not be undertaken until a Certificate is obtained.

4-3 Military Unique Vessels (i.e., U.S. Navy, Coast Guard, Army).

4-3.1

Oilers and tank barges shall be treated as “Tank Vessels” in accordance with Section 4-1.

4-3.2

All ammunition shall be removed from any space requiring hot work. Adjacent spaces containing ammunition shall be treated in accordance with Marine Chemist requirements. Adjacent spaces containing flammable or combustible liquids shall be treated in accordance with 2-3.4.

4-3.3

Adjacent tanks used for radiation shielding on nuclear-powered vessels shall be treated in accordance with the Marine Chemist’s requirements.

4-3.4

All other types of military vessels shall be treated in accordance with Section 4-2.

4-3.5

All tanks, confined spaces, and machinery compartments in which “internal” repairs or alterations are to be undertaken shall be cleaned to comply with the requirements of 2-3.1 or 2-3.3 and 2-3.4, and adjacent compartments shall be cleaned to meet the requirements of 2-3.4 or shall be permitted to be inerted to meet the requirements of 2-3.7.

Exception: Spaces covered by 3-1.3, Section 3-8, and 4-3.3.

4-3.6

All tanks, confined spaces, and machinery compartments in which “external” repairs or alterations are to be undertaken shall be cleaned to comply with the requirements of 2-3.4, or any tanks shall be permitted to be inerted to comply with the requirements of 2-3.7; and adjacent compartments shall be cleaned to meet the requirements of 2-3.4 or shall be permitted to be inerted to meet the requirements of 2-3.7.

Exception: Spaces covered by 3-1.3, Section 3-8, and 4-3.3.

4-4 Vessels in Lay-up.

A tank ship in lay-up shall be treated in accordance with Section 4-1. No repairs or alterations involving hot work shall be made unless authorized by the Marine Chemist in accordance with the provisions of 2-3.9.

4-5 Vessels Carrying Flammable Compressed Gas.

On any vessels that have carried flammable compressed gas in bulk, no repairs or alterations involving hot work shall be made unless the provisions of Section 4-1 have been complied with, provided individual pressure tanks, inerted in accordance with 2-3.8, are considered in a safe condition for such work not directly involving these tanks or their pipelines.

Chapter 5 Additional Requirements for Bulk Chemical Cargo Tanks

5-1 Scope.

5-1.1

This section describes the conditions required before repairs can be made in spaces that have carried or have been exposed to chemicals in bulk. The remaining spaces in the vessel shall comply with the applicable provisions in Chapter 4.

5-1.2

The definitions set forth in Section 1-5 shall apply to this chapter.

5-2 Minimum Requirements.

5-2.1

All minimum requirements for issuance of the Certificate set forth in Chapter 2 of this standard are applicable to spaces that have carried or have been exposed to chemicals in bulk.

5-2.2

The designation “Not Safe for Workers” shall be used for spaces that have carried material of unknown chemical hazards. (*See 2-4.3.*)

5-2.3

Results of any chemical hazard tests shall be permitted to be noted on the Certificate.

5-3 Minimum Conditions.

5-3.1

Minimum conditions that shall prevail prior to the issuance of a Certificate for spaces that have contained chemicals in bulk shall be as set forth in Chapter 3, insofar as they are applicable, and as set forth in this section.

5-3.2

All pipelines, including heating coils, fire extinguishing systems, and vents, together with the cargo pumps and cargo lines serving the chemical-carrying spaces, shall be initially dealt with to the satisfaction of the Marine Chemist. Care shall be exercised in the selection of methods and materials used for cleaning or inerting to avoid noncompatibility with previous cargoes.

5-3.3

Compartments having carried chemicals in bulk and that are to be cleaned shall be so cleaned that the atmosphere in those compartments is in accordance with 2-3.1 and 2-3.4, as applicable.

5-3.4

The residues in the compartments concerned shall be such that the conditions of 2-3.1 and 2-3.4, as applicable, will be met.

Chapter 6 Additional Requirements for Flammable Cryogenic Liquid Carriers

6-1 Scope.

6-1.1

The design and operational characteristics of tank, cargo-handling, and related systems on vessels carrying flammable cryogenic liquid cargoes shall be fully appreciated by the Marine Chemist in making the determinations required by Section 2-1 of this standard. This chapter describes the conditions required before repairs can be made in spaces that have carried or have been exposed to flammable cryogenic liquid cargoes in their liquid or vapor form.

6-1.2

This chapter supplements the factors to be considered prior to issuance of the Certificate in accordance with Section 2-1.

6-1.3

Only those Marine Chemists who have evidenced the required additional experience, training, and knowledge shall be authorized to issue Certificates under the requirements of this chapter. Such Chemists shall receive a special endorsement on the Marine Chemist's Certificate issued them by the National Fire Protection Association.

6-2 Definitions.

6-2.1

The definitions set forth in Section 1-5 shall apply to this chapter.

6-2.2

The following additional definitions are applicable:

Cargo Area. That part of the ship that contains the cargo containment system, cargo pump room, and compressor room and includes deck areas over the full beam and length of the ship above the foregoing. Where fitted, the cofferdams, ballast, or void spaces at the after end of the aftermost hold space, or the forward end of the forwardmost hold space, are excluded from the cargo area.

Cargo Containment System. The arrangement for containment of cargo including, where fitted, a primary and secondary barrier, associated insulation, and any intervening spaces and adjacent structures if necessary for the support of these elements. If the secondary barrier is part of the hull structure, it may be a boundary of the hold space.

Cryogenic Liquid. A refrigerated liquefied gas having a boiling point lower than –130°F (–90°C).

Gas-Dangerous Space.

(a) A space in the cargo area that is not arranged or equipped in an approved manner to ensure that its atmosphere is at all times maintained in a gas-safe condition.

(b) An enclosed space outside the cargo area through which any piping that could contain liquid or gaseous products passes, or within which such piping terminates, unless approved arrangements are installed to prevent any escape of product vapor into the atmosphere of that space.

(c) A cargo containment system and cargo piping.

1. A hold space where cargo is carried in a cargo containment system requiring a secondary barrier.

2. A hold space where cargo is carried in a cargo containment system not requiring a secondary barrier.

(d) A space separated from a hold space described in (c) 1, above, by a single gastight steel boundary.

(e) A cargo pump room and cargo compressor room.

(f) A zone on the open deck or semienclosed space on the open deck within 9.84 ft (3 m) of any cargo tank outlet, gas or vapor outlet, cargo pipe flange, cargo valve, or entrance and ventilation opening to cargo pump rooms and cargo compressor rooms.

(g) The open deck over the cargo area and 9.84 ft (3 m) forward and aft of the cargo area on the open deck up to a height of 7.88 ft (2.4 m) above the weather deck.

(h) A zone within 7.88 ft (2.4 m) of the outer surface of a cargo containment system where such surface is exposed to the weather.

(i) An enclosed or semienclosed space in which pipes containing products are located.

(j) A compartment for cargo hoses.

(k) An enclosed or semienclosed space having a direct opening into any gas-dangerous space or zone.

Hold Space. The space enclosed by the ship’s structure in which a cargo containment system is situated.

Interbarrier Space. That space between a primary and secondary barrier, whether or not completely or partially occupied by insulation or other material.

Primary Barrier. The inner element designed to contain the cargo when the cargo containment system includes two boundaries.

Secondary Barrier. The liquid-resisting outer element of a cargo containment system designed to afford temporary containment of any envisaged leakage of liquid cargo through the primary barrier and to prevent the lowering of the temperature of the ship’s structure to an unsafe level.

6-3 Minimum Requirements.

6-3.1

All minimum requirements for issuance of the Certificate as set forth in Chapter 2 of this standard shall be met prior to commencement of hot work or entry in spaces that have carried or been exposed to flammable cryogenic liquids or their vapors.

6-3.2

The special safety designation “SAFE FOR REPAIR YARD ENTRY” applies only to flammable cryogenic liquid carriers and describes vessels whose compartments and spaces either have been tested by sampling at remote sampling stations, with results indicating that the atmosphere tested is above 19.5 percent oxygen and less than 10 percent of the lower explosive limit, or have been inerted in accordance with 2-3.7.

6-3.3

Vessels whose cargo containment systems have not met the criteria of 6-3.2 may undergo specific limited repairs in locations outside the “gas-dangerous spaces.” However, such repairs or alterations shall not be undertaken until a Certificate is obtained. When undergoing such repairs, the vessel shall be berthed in a special location selected with due regard to the hazards of the location and to hazards to adjacent property. Should the Marine Chemist have reason to question the safety of any aspect of the site selection, he shall consult the proper governmental authorities.

6-3.4

Interbarrier spaces or insulation could contain pockets of cargo vapors that can be released over varying time periods. The Marine Chemist shall inspect for gas concentration and combustible materials before work in or on the boundaries of such places is begun.

6-3.5

The following information shall be used by the Marine Chemist as a guide for making his inspection:

(a) Description and schematic arrangement of provisions for inerting cargo tanks, hold spaces, or interbarrier spaces, as applicable;

(b) Description and instruction manual for calibration of the cargo leak detector equipment;

(c) Schematic plan showing locations of leak detector(s) and sampling points;

(d) Schematic plan(s) of liquid and vapor cargo piping;

(e) U.S. Coast Guard Letter of Compliance and Certificate of Fitness for foreign flag vessels or the Certificate of Inspection and Certificate of Fitness for U.S. flag vessels; and

(f) The recent history of cargoes handled with special reference to outturn and any pertinent unusual incidents encountered.

6-4 Minimum Conditions.

6-4.1

Minimum conditions that shall prevail prior to the issuance of a Certificate for spaces that have contained or been exposed to flammable cryogenic liquids or their vapors shall be as set forth in Chapter 3, insofar as they are applicable, and as set forth in this section.

6-4.2

When vessels are undergoing repairs, no venting of cargo tanks, systems, or other spaces that could contain inert gas or flammable vapors shall take place without approval of the Marine Chemist. Any other activity that could similarly alter the atmosphere in the vicinity of the repair work shall be permitted to be undertaken only with such approval.

6-4.3

Vessels that are capable of burning cargo boil-off as a fuel for their main propulsion system or for other purposes shall be inspected to ensure that gas supply lines to the fire room or other spaces have been properly secured, inerted, or otherwise properly treated prior to repairs to this system.

6-4.4

Prior to the opening of cargo machinery or systems for repairs, such equipment shall have been purged and ventilated to remove cargo vapor or inert gas.

Appendix A

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

A-1-3

In all emergency situations, all necessary precautionary measures should be undertaken as soon as is practical to provide safe conditions satisfactory to the Marine Chemist.

A-1-4

All applicable regulations, requirements, and standards should be consulted.

A-2-3.1

(a) It is important that any change from ambient air, either above or below, should be investigated. Even though any change from ambient air is undesirable, the range of 19.5 percent to 22 percent has been selected for reasons of the accuracy of the meter and the precision with which it can be read. The setting of the instrument for 20.8 percent should be made in ambient air under the conditions of temperature and humidity within the compartment or space to be tested.

A-2-3.1

(b) The level of 10 percent lower explosive limit should not be used to determine the toxic level. It is to be used in those instances where a fire hazard would be present, i.e., with propane, methane, etc., but not a toxic hazard.

A-2-3.1

(c) Permissible concentrations can be found in the latest version of *Threshold Limit Values for Chemical Substances*, published by the American Conference of Governmental Industrial Hygienists, the *Permissible Exposure Limit Value* in Subpart Z of 29 CFR 1910.1000, or the value listed in the Manufacturers Safety Data Sheet (MSDS).

A-2-3.1

(d) See A-2-3.1(c).

A-2-3.4

(a) See A-2-3.1(a).

A-2-3.4

(b) The terms “lower flammable limit” and “lower explosive limit” are used synonymously. Refer to NFPA 325M, *Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids*.

It is important that any change from the levels found by the Marine Chemist be investigated. A positive change in the lower explosive limit would indicate the presence of flammable contaminants in the atmosphere.

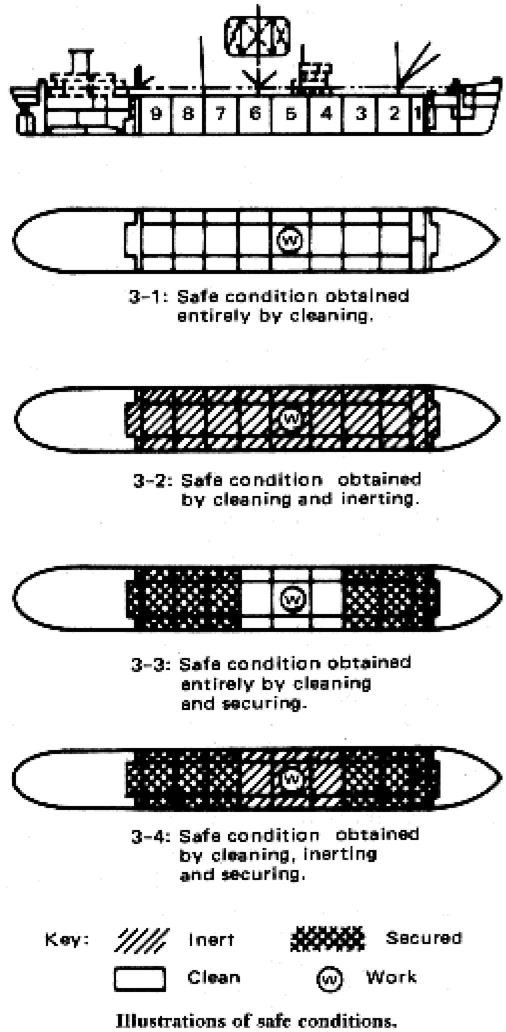
A-2-3.7

(a) The improper introduction of an inerting gas can generate sufficient static electricity for ignition. Refer to NFPA 69, *Standard on Explosion Prevention Systems*, for level of oxygen to support combustion.

Appendix B

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

These illustrations are examples of safe conditions discussed in Chapter 3 of this standard. The conditions shown in the drawings correspond to Sections 3-1 through 3-4 of the standard. Although the single plane drawings show horizontal separations only, vertical compartmentation should be similarly treated.



Illustrations of safe conditions.

Appendix C

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

MARINE CHEMIST CERTIFICATE
SERIAL NO. A 00000

Survey Requested by	Vessel Owner or Agent	Date
Vessel	Type of Vessel	Specific Location of Vessel
Last Three (3) Cargoes	Tests Performed	Time Survey Completed

In the event of any physical or atmospheric changes adversely affecting the STANDARD SAFETY DESIGNATIONS assigned to any of the above spaces, or if in any doubt, immediately stop all work and contact the undersigned Marine Chemist.

QUALIFICATIONS: Transfer of ballast or manipulation of valves or closure equipment tending to alter conditions in pipe lines, tanks or compartments subject to gas accumulation, unless specifically approved in this Certificate, requires inspection and endorsement or reissue of Certificate for the spaces so affected. All lines, vents, heating coils, valves, and similarly enclosed appurtenances shall be considered "not safe" unless otherwise specifically designated.

STANDARD SAFETY DESIGNATIONS (partial list, paraphrased from NFPA 306 Subsections 2-3.1 through 2-3.4, and Subsection 6-3.2).

SAFE FOR WORKERS: Means that in the compartment or space so designated: (a) the oxygen content of the atmosphere is at least 19.5 percent by volume; and that, (b) toxic materials in the atmosphere are within permissible concentrations; and that, (c) the residues are not capable of producing toxic materials under existing atmospheric conditions while maintained as directed on the Marine Chemist's Certificate.

NOT SAFE FOR WORKERS: Means that in the compartment or space so designated, the requirements of Safe for Workers have not been met.

ENTER WITH RESTRICTIONS: Means that in any compartment or space so designated, entry for work may be made only if conditions of proper protective equipment, clothing, and time are as specified.

SAFE FOR HOT WORK: Means that in the compartment so designated: (a) oxygen content of the atmosphere is at least 19.5 percent by volume, with the exception of inerted spaces or where external hot work is to be performed; and that, (b) the concentration of flammable materials in the atmosphere is below 10 percent of the lower flammable limit; and that, (c) the residues are not capable of producing a higher concentration than permitted by (b) above under existing atmospheric conditions in the presence of fire, and while maintained as directed on the Marine Chemist's Certificate; and further, that, (d) all adjacent spaces containing or having contained flammable or combustible materials have been cleaned sufficiently to prevent the spread of fire, or are satisfactorily inerted, or, in the case of fuel tanks or lube oil tanks, or engine room or fire room bilges, have been treated in accordance with the Marine Chemist's requirements.

NOT SAFE FOR HOT WORK: Means that in the compartment so designated, the requirements of Safe for Hot Work have not been met.

SAFE FOR REPAIR YARD ENTRY: Means that the compartments and spaces of the flammable cryogenic liquid carrier so designated: (a) have been tested by sampling at remote sampling stations, and results indicate the atmosphere tested to be above 19.5 percent oxygen, and less than 10 percent of the lower flammable limit, or (b) are inerted.

CHEMIST'S ENDORSEMENT. This is to certify that I have personally determined that all spaces in the foregoing list are in accordance with NFPA 306, *Standard for the Control of Gas Hazards on Vessels*, and have found the condition of each to be in accordance with its assigned designation.

"The undersigned acknowledges receipt of this Certificate under Section 2-3 of NFPA 306 and understands conditions and limitations under which it was issued."

This Certificate is based on conditions existing at the time the inspection herein set forth was completed and is issued subject to compliance with all qualifications and instructions.

NOTE THIS CERTIFICATE IS VALID ONLY ON MARINE VESSELS

20M-5-84-UDP **VESSEL POSTING** Printed in U.S.A.

Appendix D Referenced Publications

D-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.

D-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 325M, *Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids*, 1991 edition

D-1.2 Other Publications.

Threshold Limit Values for Chemical Substances and Physical Agents (latest edition), American Conference of Governmental Industrial Hygienists, P.O. Box 1937, Cincinnati, OH 45201.

US DOL-OSHA, *Permissible Exposure Limit Value*, Subpart Z, 29 CFR 1910.1000, U.S. Government Printing Office, Superintendent of Documents, Washington, DC 20402.

Formal Interpretation

NFPA 306

Control of Gas Hazards on Vessels

1993 Edition

Reference : 2-2.2
F.I. 80-2

Question: Was it the Committee’s intention for 2-2.2 that all adjacent spaces to an engine or fire room, that is to be certified for hot work in a central area of the room and the work is not going to be on or near a fuel tank, be inspected or tested?

Answer: No.

Issue Edition: 1980
Reference:– 2-1.2

Date: August 1983

Control of Gas Hazards on Vessels

1993 Edition

Reference : 2-3.4(d)
F.I. 80-1

Question: May a product such as No. 6 Fuel Oil with a flash point of 150°F be left in a space adjacent to a cargo space in which hot work is being done?

Answer: No.

Issue Edition: 1980
Reference:– 1-6.3(d)
Date: October 1982

NFPA 307

1995 Edition

Standard for the Construction and Fire Protection of Marine Terminals, Piers, and Wharves

1995 Edition

This edition of NFPA 307, *Standard for the Construction and Fire Protection of Marine Terminals, Piers, and Wharves*, was prepared by the Technical Committee on Marine Terminals 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 307 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 307

This document replaces NFPA 307-1967, which was withdrawn by the Standards Council in October of 1980, and NFPA 87-1980. NFPA 307-1967, *Recommendations for the Operation of Marine Terminals*, was adopted by NFPA in 1951 with amendments adopted in 1961 and 1967.

NFPA 87-1980, *Standard for the Construction and Protection of Piers and Wharves*, was first initiated by the Committee on Piers and Wharves during the period from 1919 to 1925, and was first adopted by the NFPA in 1925. Revised editions were adopted in 1931, 1935, 1954, 1963, 1968, 1971, 1975, and 1980. NFPA 307-1985 represents a combination of NFPA 307-1967 and NFPA 307-1980 including amendments to both. NFPA 307-1990 consists of amendments to NFPA 307-1985. NFPA 307-1995 consists of amendments to NFPA 307-1990.

Technical Committee on Marine Terminals

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Domenick A. Serrano, Jr., S&S Fire Suppression Systems Inc., NY
Rep. Nat’l Fire Sprinkler Assn.

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Alternate

Robert E. Keenan, Jr., Industrial Risk Insurers, NC
(Alt. to M. L. Jones)

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 relating, generally, to the fire safe construction and fire protection of piers and wharves and of structures thereon. It shall also be responsible for documents relating to the fire safety that is unique to marine terminal facilities and operations but avoiding duplicating and overlapping the scopes of other NFPA Committees that may have primary jurisdiction.

NFPA 307
Standard for the
Construction and Fire Protection of
Marine Terminals, Piers, and Wharves

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 E.

NOTE: All weights and measures used in this standard will be expressed in standard international units (SIU) followed by approximate conversions in the English system. Although some rounded SIU's are slightly more stringent than existing values, this change is not intended to apply to existing installations.
In addition, actual numerical values obtained directly from referenced documents such as NFPA 70, *National Electrical Code*®, will not be changed or rounded, although the SIU equivalent will be placed first in the text.

Chapter 1 Introduction

1-1 Scope.

1-1.1

This standard shall apply to marine terminals as defined herein. Special use piers and wharf structures that are not marine terminals, such as public assembly, residential, business, or recreational occupancies that differ in design and construction from cargo handling piers, require special consideration. The general principles of this standard for the construction and fire protection of piers and wharves shall be applicable to such structures.

1-1.2*

This standard shall not apply to marinas and boatyards.

1-1.3*

This standard shall not apply to the handling of flammable or combustible liquids in bulk.

1-1.4*

This standard shall not apply to the handling of liquefied gases in bulk.

1-2 Purpose.

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 in marine terminals, piers, and wharves. They reflect situations and the state of the art 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 in which it shall be determined by the authority having jurisdiction that the existing situation involves a distinct hazard to life or property.

Chapter 2 Definitions

2-1 Definitions.

The following terms are used herein with the meanings indicated. See illustrations in Appendix B for additional definitions.

Approach Way. A structure used to gain access to a pier or wharf, but not used to moor barges or vessels.

Approved.* Acceptable to the authority having jurisdiction.

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

Bent. A main supporting framework consisting of a transverse row of piling with interconnecting pile cap and bracing. A bent normally extends the full width across the pier. Depending upon deck design and load requirements, bents are usually spaced 3 m to 4 m (10 ft to 13 ft) apart. Short bents, not extending across the full width of the pier, used for intermediate or supplementary supports for concentrated loads, rail or crane tracks, etc., are commonly referred to as pony bents.

Berth. The water area at the side of a pier or wharf where vessels shall be permitted to remain afloat when moored at the pier or wharf.

Bulkhead Building. A structure generally having a solid-fill-type substructure and forming the land end of one or more piers.

Bulkhead Wall. A retaining wall of timber, stone, concrete, steel, or other material built along, or parallel to, navigable waters.

Cargo. Commodities in transit.

Bulk. Unpackaged commodities carried in the holds or tanks of cargo vessels and tankers and generally transferred by such means as conveyors, clamshells, pipeline, etc.

Breakbulk. Commodities packaged in bags, drums, cartons, crates, etc., commonly, but not always, palletized and conventionally stevedored and stowed.

Containerized. Commodities stowed and transported in a container.

Chassis. Special trailer or wheeled undercarriage on which containers or roll-on/roll-off (RO/RO) cargoes are moved.

Container. A standard, reusable box-like structure having a volume of 1.81 m^3 (64 ft^3) or more, designed and constructed to permit lifting with its contents intact, and intended primarily for containment of packages (in unit form) during transportation.

Container Freight Station (CFS). A transload facility used primarily for loading and unloading cargo from containers. Also used for temporary storage, receipt, and delivery of cargo.

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 which has been so designated.

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.

Marine Terminal. A facility comprising one or more berths, slips, piers, wharves, loading and unloading areas, warehouses, and storage yards used for transfer of people and/or cargo between waterborne carriers and land.

Pier. A structure, usually of greater length than width, and projecting from the shore into a body of water. A pier may be either open deck or provided with a superstructure. Used interchangeably with “wharf.”

Protected Steel. Structural steel protected by the application of a material such as concrete to maintain the stability of the steel under fire conditions for a specified period of time.

Roll-On/Roll-Off (RO/RO). A form of cargo handling utilizing a vessel designed to load or unload cargo by using wheeled vehicles that roll-on or roll-off.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Slip. A berth formed by an extension, artificial or otherwise, of a navigable water into the space between adjacent structures, where vessels shall be moored.

Substructure. That portion of the construction of a pier or wharf below, and including, the deck. (*See Appendix B.*)

Superstructure. That portion of the construction of a pier or wharf above the deck.

Terminal Operator. The owner or other person, such as the leasee, who is responsible for the operation of the facility.

Terminal Yard. Those open areas at a marine terminal site provided for the temporary storage of cargo, containers, and cargo-handling equipment, and areas devoted to the maintenance of the terminal and equipment. As used herein, the term does not include open pier and wharf areas, except that solid-fill-type wharves that are contiguous to and form a part of yard areas shall be considered part of the terminal yard.

Transit Shed. A transload facility for cargoes, usually located on a pier or wharf, and primarily used for transfer of breakbulk-type cargo.

Transload Facility. A building or structure used for loading and unloading cargo from containers, trucks, railcars, and vessels; the classification and consolidation of commodities; and the temporary storage of commodities (e.g., a transit shed or container freight station).

Warehouse. A building used for long-term storage of commodities as contrasted with temporary storage in container freight stations and transit sheds.

Water Level and Tide Terminology:

Low Water. In nontidal locations, the normal low water level; in single tidal areas, mean low water; and in dual tidal areas, mean lower low water.

Mean Low Water, Mean High Water, Mean Lower Low Water, or Mean Higher High Water. A tidal datum. A long-term arithmetic mean of the named tidal levels as promulgated for a given location in the tables and charts of the National Ocean Survey of the National Oceanic and Atmospheric Administration.

Tidal Range. The difference in height between mean lower low water and mean higher high water or, in places having only one tide daily, between mean low water and mean high water.

Wharf. A structure having a platform built along and parallel to a body of water. A wharf can be either open deck or provided with a superstructure. Used interchangeably with “pier.”

Chapter 3 Piers and Wharves

3-1 General.

Design, all materials, and the workmanship elements of pier and wharf construction shall conform to standards and construction practices that will ensure a durable and safe structure that will withstand the forces of nature to which it is likely to be exposed, the deteriorating influences of its environment, the expected wear and tear of operation and use, and will provide a safe place for its occupants.

3-2 Substructure Construction.

3-2.1* Substructure Construction.

This chapter contains construction and protection standards for the three basic construction types of pier substructures: namely, fire-resistive, noncombustible, and combustible substructures, and also any combination of these materials in a fourth construction type defined herein as composite construction.

3-2.2 Protection Against Mechanical Damage.

Concrete or other portions of pier or wharf structures that are exposed to impact or abrasion by vessels, or are subject to damage by floating ice or debris shall be protected by an open-fender system constructed of wood or other material approved by the authority having jurisdiction.

Provisions shall be made to reduce the impact force exerted on the pier with details of construction that prevent excessive damage from ordinary operations.

3-2.3 Support for Walls.

When piers or wharves are located in soft or yielding bottoms where unequal loading results in unequal settlement, the substructure for supporting division walls and walls enclosing stairs, elevators, escalators, and chutes shall be separate and distinct from the structure of the pier.

3-2.4 Fire-Resistive Substructures.

3-2.4.1 General. A fire-resistive substructure shall be one having a fire resistance rating in all of its parts of not less than 4 hr.

Exception: If wood piles, wood cribwork, or unprotected steel piles are used, they shall not extend above low water or, in tidal waters, they shall not extend more than one-half the tidal range or a maximum of 1 m (3 ft) above low water.

3-2.4.2 Pier Deck. Pier decks shall be reinforced concrete, or equivalent construction, to afford a 4-hr fire resistance rating. Where railroad tracks extend onto the pier deck and are at a lower level than the deck, the sides and bottom of the depressed section shall be of the same construction as the pier deck, or of equivalent fire resistance rating.

When used on the underside of the pier deck, vapor barriers, moisture shields, coatings, or finishes shall conform to the definition of noncombustible or limited combustible as defined in NFPA 220, *Standard on Types of Building Construction*.

3-2.4.3 Aprons. Pier aprons or platforms built along the sides or ends of the pier shall have the substructure and deck constructed to have a 4-hr fire resistance rating.

3-2.5 Noncombustible Substructures.

3-2.5.1* General. A noncombustible substructure is one that meets the requirements for fire-resistive substructures in accordance with 3-2.4.

Exception: Structural steel and steel piles above the critical level in relation to low water specified in 3-2.4.1 are not provided with fireproofing equivalent to a 4-hr fire resistance rating; or one of reinforced concrete for which a 4-hr resistance rating has not been established by standard test.

3-2.5.2 Pier Deck. Pier decks shall conform to the requirements of 3-2.4.2.

Exception: The fire resistance rating requirement of fire-resistive substructures shall not apply to noncombustible pier decks.

3-2.5.3 Aprons. Pier aprons or platforms built along the sides or ends of the pier shall have the substructure and deck constructed so as to have a fire resistance rating equal to that of the pier substructure and deck.

3-2.6 Combustible Substructures.

3-2.6.1* Piles and Stiffening Members. The substructure shall be constructed of wood piles extending to the pier deck. Stiffening of the piling shall be by the use of inclined bracing piles or cross braces of timber of not less than 100 mm (4 in.) nominal minimum dimension and 20,000 mm^2 (32 $in.^2$) minimum cross-sectional area. The cross bracing shall be designed to offer a minimal surface exposed to fire, and the smallest possible obstruction to the distribution of water in fighting fires under the pier deck. Deep narrow spaces between timbers shall be fire-stopped over each bent, or at least once in each timber length.

3-2.6.2 Pier Deck and Supports. The following provisions shall apply:

(a) Pile caps shall consist of sawed timber not less than 200 mm (8 in.) nominal minimum dimension and 62,000 mm^2 (96 in.^{2}) minimum cross-sectional area, and the deck stringers of not less than 150 mm (6 in.) nominal minimum dimension and 46,000 mm^2 (72 in.^{2}) minimum cross-sectional area. Deck planking on stringers shall be not less than 100 mm (4 in.) in thickness, and on this shall be laid a wearing surface of 50 mm (2 in.) of wood sheathing, or a layer of concrete or asphalt, or other material of equivalent durability. The sheathing and deck planks shall be laid at right angles, except that in the driveways the sheathing shall be permitted to be laid diagonally. Joists 100 mm (4 in.) or less in thickness shall not be used in this type of construction.

(b) Pier decks without superstructures shall have deck planking not less than 76 mm (3 in.) thick.

(c) Pier decks of composite laminated timber and concrete construction shall be acceptable, provided that timbers used shall be not less than 50 mm (2 in.) in nominal thickness, and shall be treated for protection against decay, termites, or attack by marine life.

(d) Any openings in pier decks, such as spaces between bullrail and pier deck, alongside railroad or crane tracks, and others made necessary for operations or equipment, shall be suitably closed to prevent debris from falling through and accumulating on substructure members. Steel angle iron, steel plate, or equivalent noncombustible material of a thickness that will resist damage and fire spread shall be used for closures, and shall be permanently installed in such a manner as to accommodate operations and accomplish these objectives. (*See examples in Appendix B.*)

(e) Where railroad tracks extend onto a pier at a lower level than the deck, the sides and bottom of the depressed section shall be of the same construction as the pier deck, or of equal or greater fire resistance. Side hatches shall be permitted in the walls of such depressed sections, for fire-fighting purposes, with openings normally closed by hatch covers having a fire resistance rating equivalent to the walls.

3-2.6.3 Aprons. Pier aprons or platforms built along the sides or ends of the pier shall have the substructure and deck constructed to have fire-resistive qualities equal to that of the pier substructure and deck, except that at every fire wall of the substructure and superstructure, a section of the apron or platform and its substructure shall be of fire-resistive construction, as defined in 3-2.4. This fire-resistive section shall extend for a distance of at least 3 m (10 ft) on each side of the fire wall.

3-2.7 Composite Substructures.

3-2.7.1 General. Composite construction shall mean any combination of combustible and noncombustible materials (with or without fire resistance rating), described in 3-2.4, 3-2.5, and 3-2.6, not meeting the limitations of the Exception under 3-2.4.1.

3-2.7.2 Pier Decks, Supports, Bracings, and Aprons. Pier decks, supports, bracings, and aprons shall conform to the construction requirements of 3-2.4, 3-2.5, and 3-2.6 for the respective type of construction used for the various portions of the substructure.

3-3 Substructure Protection and Subdivision.

3-3.1 Protection and Subdivision of Noncombustible Substructures.

The provision of fire walls, fire-stops, automatic sprinklers, and other fire-extinguishing facilities under the pier deck shall depend upon the amount of exposed steel, the fire resistance ratings of reinforced concrete construction or assemblies, and the fire hazard as determined by the authority having jurisdiction.

3-3.2* Protection and Subdivision of Composite Substructures.

The provision of fire walls and fire-stops, automatic sprinklers, and other fire-extinguishing facilities shall conform to the requirements for combustible substructures as provided in 3-3.3.

Exception: Where exposed combustible structural materials are limited to piling and intrabent bracing, and the height from low water to the top of combustible construction does not exceed the typical distance between bents, the provision of fire walls and fire-stops and the installation of automatic sprinklers or other fire-extinguishing facilities under the pier deck shall depend upon the amount and concentrations of all exposed combustible materials, fire resistance rating of the pier deck, configuration of and access to the substructure, and the fire hazard.

3-3.3 Protection and Subdivision of Combustible Substructures.

3-3.3.1 Automatic Sprinklers. A complete system of automatic sprinklers shall be installed for the protection of all combustible substructures.

Exception: The requirement of a complete automatic sprinkler system shall be permitted to be waived for those existing substructures as specified in 3-3.3.5 and for piers and wharves that:

(a) have solid decking 7.5 m (25 ft) or less in width; and that

(b) are 465 m^2 (5,000 ft^2) in area or smaller, exclusive of approach ways 7.5 m (25 ft) or less in width; and that

(c) are separated by at least 9 m (30 ft) from other structures; and that

(d) have no superstructures exceeding 46.5 m^2 (500 ft^2) in individual area nor 140 m^2 (1,500 ft^2) in aggregate area, and such superstructures are not less than 9 m (30 ft) apart.

3-3.3.2 Installation of Sprinklers. Installation of sprinkler equipment shall be in accordance with the applicable provisions of NFPA 13, *Standard for the Installation of Sprinkler Systems*. Where there is danger of damage to sprinkler equipment by floating objects, physical barriers shall be provided to exclude such objects.

3-3.3.3 Additional Installation Requirements. In addition to the applicable provisions of NFPA 13, *Standard for the Installation of Sprinkler Systems*, the following provisions shall apply:

(a) Where narrow horizontal channels or spaces are caused by caps, stringers, ties, and other structural members, the standard upright sprinkler might not project sufficient water upward to extinguish or control fires on the underside of the pier or wharf deck. In these cases, a sprinkler that projects water upward to wet the overhead, such as a pendant sprinkler installed in an upright position, or the old-style sprinkler shall be used. Location, spacing, and deflector position shall be governed by the discharge pattern of the sprinkler and the structure being protected. The following design and installation guides shall apply where pendant sprinklers in the upright position or old-style sprinklers are to be utilized:

1. The maximum coverage per sprinkler head shall be limited to 7.5 m^2 (80 ft^2).

2. Where spacing or arrangement of stringers constitutes typical open-joist construction directly supporting the deck, sprinkler branch lines shall be installed between the bents at right angles to the stringers. Spacing between branch lines shall not exceed 3 m (10 ft). Sprinklers on branch lines shall be staggered and spaced not to exceed 2.5 m (8 ft) on centers.

3. Where crisscross construction (typically ties on stringers — see diagram in Appendix B) is involved, closer spacing of sprinklers shall be permitted as necessary to provide wetting of the entire structure.

4. The deflectors of sprinklers on lines under stringers shall be located not less than 100 mm (4 in.) nor more than 250 mm (10 in.) below the bottom plane of the stringer, and not more than 450 mm (18 in.) below the underside of the pier or wharf deck.

5.* The sprinkler system shall be hydraulically designed in accordance with the requirements of NFPA 13, *Standard for the Installation of Sprinkler Systems*. Sprinklers shall be 12.7-mm ($^1/_2$-in.) orifice and shall discharge at a minimum pressure of 85 kPa (12.5 psi). Design area shall be based upon the largest area between fire-stops plus an additional area embracing at least two branch lines on opposite sides of the fire-stop. Minimum design area shall be not less than 465 m^2 (5,000 ft^2).

6. The temperature rating of the sprinkler shall not exceed 74°C (165°F).

7. The maximum area to be protected by any one system shall be limited to 2325 m^2 (25,000 ft^2).

(b) Sprinklers designed and approved specifically for protection of combustible substructures shall be installed in conformity with their listing.

(c) The pipe hangers shall be placed in a location where they will be in the wetting pattern of the sprinkler to prevent the lag screws from burning or charring out, dropping sprinkler piping, and bleeding the system. The distance from the sprinkler to the hanger shall not exceed 460 mm (18 in.).

(d) Horizontal and vertical bracing shall be provided at not more than 6-m (20-ft) intervals on all sprinkler piping 76 mm (3 in.) or larger that is parallel to and within 15 m (50 ft) of the face of the pier or wharf and where it might be subjected to heavy fireboat nozzle streams.

(e) Sprinkler systems, including hanger assemblies and bracing, in underdeck areas shall be properly protected throughout against corrosion. Sprinklers shall be of corrosion-resistant type. When the fire protection design for substructures involves the use of detectors or other electrical equipment for smoke or heat detection, pre-action or deluge-type sprinkler protection, all detectors and wiring systems shall be moisture- and corrosion-proof to protect against unfavorable atmospheric conditions that exist beneath these structures. Frequent inspection and testing of these systems shall be conducted in accordance with applicable NFPA standards.

(f) Water supply systems, hydrants, fire hose valves, and sprinkler systems shall be installed with adequate protection against freezing and physical damage.

3-3.3.4 Other Extinguishing Facilities. Deck openings to permit the use of revolving nozzles and other fire-fighting devices shall be provided for all combustible substructures in accordance with the following:

(a) Openings in the pier deck shall be provided at intervals not exceeding 7.5 m (25 ft) on centers to enable the fire department to place in operation, with the least possible delay, devices suitable for extinguishing underdeck fires. Openings shall be over clear spaces to avoid interference by the substructure with effective operation of extinguishing devices. The effective arrangement of these openings shall not exceed 64,500 mm^2 (100 $in.^2$) and shall be not less than 230 mm (9 in.) in the smallest dimension, so as to readily pass the appliances for which they are intended. The openings shall be provided with covers that can be removed easily. Covers shall be constructed of such material, or so insulated, that they will resist the passage of heat and fire in a manner equivalent to that of the pier deck. Location of openings shall be conspicuously indicated. [*See also 3-2.6.2(e).*]

(b) All parts of the deck, including aprons, where fire fighters shall be expected to work shall be solid and continuous, have no uncovered openings, and be virtually smoketight.

(c) There shall be maintained on the pier or wharf, preferably at the land end, in readily accessible locations, a sufficient number of revolving nozzles, cellar pipes, and other devices of appropriate type with the necessary supply of hose to permit establishing two complete water curtains across the pier or wharf, and at least two additional nozzles for extinguishing purposes. In determining the number of devices that are required, consideration shall be given to the amount of such equipment carried on fire apparatus due to respond.

(d) To supply water for the devices covered by this section, there shall be installed an adequate water supply and adequate hydrants or hose connections.

3-3.3.5* Other Extinguishing Facilities — Existing Substructures. In existing substructures where, in the opinion of the authority having jurisdiction, it is clearly impractical to install and maintain an automatic sprinkler system, deck openings and revolving nozzles, as specified in 3-3.3.4 in conjunction with the required structural barriers of 3-3.3.6 through 3-3.3.9, shall be permitted to be provided as alternate protection. Consideration shall be given to any built-in extinguishing equipment that is practical to install and maintain, such as partial automatic sprinkler equipment or manual sprinkler equipment with particular emphasis on preserving the integrity of the required structural barriers under fire conditions.

3-3.3.6 Subdivision of Combustible Substructures. All substructures of combustible construction shall have the underdeck area subdivided by the following:

(a) Transverse fire walls extending to low water and the full width of the pier, including aprons or platforms, at intervals not exceeding 137 m (450 ft). A section of the entire pier deck over the fire wall, including any aprons or platforms, shall be of fire-resistive construction, as defined in 3-2.4, to preserve the effectiveness of the fire wall. This fire-resistive section shall extend for a distance of at least 3 m (10 ft) on each side of the fire wall.

Exception: The 6-m (20-ft) fire-resistive cap [3 m (10 ft) on each side of the fire wall] is not *required when the fire walls constitute a continuation of the fire walls in a superstructure.*

(b) Transverse fire-stops located between fire walls. Spacing between fire walls and fire-stops or between fire-stops shall not exceed 46 m (150 ft). Fire-stops shall fit tightly up against the pier deck and around any structural members or pipes that pass through the fire-stop so that an effective barrier to fire and draft will be maintained. Fire-stops shall extend to the low water line. Where aprons or platforms are built along the sides of the pier, fire-stops shall extend to the outside edge of such platforms.

NOTE: The requirements set forth in subsections (a) and (b) above shall be permitted to be modified where floods, tidal, or wave action render such fire walls or fire-stops structurally impracticable, provided equivalent protection is obtained by other means.

3-3.3.7 Types of Fire Walls. Substructure fire walls shall have a fire resistance rating of at least 4 hr and shall be constructed of reinforced concrete, or of other materials that are equivalent in stability and have an equivalent fire resistance rating. Walls shall be free of holes and shall extend to low water.

3-3.3.8* Types of Fire-Stops. Fire-stops shall have a fire resistance rating of not less than 1 hr and shall be constructed of 150 mm (6 in.) of reinforced concrete, or other materials that are equivalent in stability and resistance to physical damage.

3-3.3.9 Existing Substructures. For existing substructures where, in the opinion of the authority having jurisdiction, the standard fire walls required in 3-3.3.7 are impractical, approved fire-stops installed every 46 m (150 ft), and constructed as specified in 3-3.3.8, shall be permitted to be used as alternate protection.

3-4 Superstructure Construction.

3-4.1* Material Requirements.

The type of material or combination of materials used in superstructure construction shall meet the general construction provisions of 3-1.1, and when protected in accordance with this standard shall be of any of the types of construction described in NFPA 220, *Standard on Types of Building Construction*.

3-4.2 Exterior Wall Requirements.

Exterior walls that are less than 9 m (30 ft) from other buildings or from property lines shall be constructed of not less than 4-hr fire resistive construction, and openings in such walls shall be protected by labeled protective devices in accordance with NFPA 80, *Standard for Fire Doors and Fire Windows*. Exterior walls shall be provided with suitable access to the building interior at intervals not exceeding 60 m (200 ft) for the use of fire fighters, guards, and workers.

3-5 Superstructure Protection.

3-5.1 Automatic Sprinklers.

All superstructures shall be provided with a complete system of automatic sprinklers installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

Exception: Sprinklers shall not be required in small superstructures located over unsprinklered fire-resistive substructures (a) if such superstructures do not exceed 46.5 m^2 *(500* ft^2*) in* *individual area, (b) if the total area of all such structures does not exceed 139.4 m^2 (1,500 ft^2), and (c) if the separation between any two such structures is not less than 9 m (30 ft).*

3-5.2* First Aid Fire Appliances.

Portable fire appliances and 38-mm ($1^1/_2$-in.) standpipe connections shall be installed, distributed, and their locations marked in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*; NFPA 13, *Standard for the Installation of Sprinkler Systems*; and NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*.

Chapter 4 Terminal Buildings

4-1 General.

This chapter applies to buildings and structures located on marine terminal premises other than the piers and wharves and their superstructures described in Chapter 3.

4-2 Construction Requirements.

NFPA 220, *Standard on Types of Building Construction*, shall be referred to when constructing or modifying marine terminal buildings.

4-3* Additional Requirements.

All terminal buildings shall be separated from other buildings as necessary to minimize the effects of fire exposure, giving consideration to the construction, protection, and separation distances of the respective buildings. Outside storage of cargo shall not be within 6 m (20 ft) of the exterior of the building.

Exception: This section does not apply to containers, railroad cars, and vehicles that are parked for the purpose of loading or unloading cargo. Containers, railroad cars, and vehicles shall only remain parked within 6 m (20 ft) of a building as long as is necessary to meet cargo loading, unloading, and handling requirements.

4-4 Automatic Sprinklers.

4-4.1

Buildings used for the handling or storage of combustible cargo shall be provided with a complete system of automatic sprinklers.

Exception: Buildings not exceeding 465 m^2 (5,000 ft^2) total floor area.

4-4.2

Due to the widely varying nature of commodities that might pass through transit sheds, container freight stations, transload facilities, and similar buildings used for handling and temporary storage of general cargo, minimum sprinkler design criteria shall be based upon Ordinary Hazard Group 2 classification under the provisions of NFPA 13, *Standard for the Installation of Sprinkler Systems*.

4-4.3

If the maximum storage height that the building will permit exceeds 3.7 m (12 ft), the requirements of NFPA 231, *Standard for General Storage*, shall be followed for protection of Class IV commodities piled to the maximum height permitted by building construction, and the clearance requirements of 8-5.6.

4-4.4

If racks or shelving are present or likely to be present, the requirements of NFPA 231C, *Standard for Rack Storage of Materials*, shall be followed for protection of Class IV commodities. Protection in warehouses for the long-term storage of specific commodities shall be designed for the specific use.

Exception: Buildings not exceeding 465 m^2 (5,000 ft^2) total floor area.

4-4.5

Warehouses used for the storage of hazardous materials shall be protected by a complete system of automatic sprinklers installed in conformity with the standard applicable to the type of hazardous material being stored.

4-4.6

Warehouses and lockers rented as secured spaces, and not directly controlled by the terminal operator, shall be protected by a complete system of automatic sprinklers installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*. Such systems shall be designed and installed with all control valves, drains, and alarms located in an area accessible to terminal personnel for inspection and operation.

4-5 Temporary Storage of Explosives.

Buildings used for the temporary storage of explosives or fireworks shall conform to the appropriate provisions of NFPA 495, *Explosive Materials Code*; NFPA 1124, *Code for the Manufacture, Transportation, and Storage of Fireworks*; NFPA 498, *Standard for Explosives Motor Vehicle Terminals;* and regulations of the United States Bureau of Alcohol, Tobacco and Firearms.

4-6 Miscellaneous Service Operations.

Where miscellaneous service operations such as office, maintenance and repair, and vehicle service are conducted in buildings used for receiving, delivering, and storage of cargo, the requirements of NFPA 513, *Standard for Motor Freight Terminals*, apply when they are appropriate and are not covered by this standard. In addition, see Chapter 8.

4-7 Manufacturing and Processing Operations.

Manufacturing and processing operations conducted on the premises of marine terminals shall be confined to separate buildings that are designed, constructed, and protected for that purpose.

4-8 Structures Located Inside Terminal Buildings.

Structures, permanent or temporary, placed inside larger terminal buildings, such as those used for offices and tool sheds, shall be sprinklered.

Chapter 5 Terminal Yards

5-1* General.

Marine terminal yards are those open areas, yards, and lots provided for the temporary storage of cargo and cargo handling equipment, and areas devoted to the maintenance of the terminal and equipment. As used herein, the term does not include pier and wharf areas.

Exception: Solid-fill-type wharves that are contiguous to, and form a part of, yard areas shall be considered a part of the terminal yard.

5-2 Terminal Yard Surfaces and Markings.

Yards shall be paved, or otherwise suitably surfaced, to permit all-weather operations of heavy equipment with appropriate marking of roadways, access lanes, parking and storage areas; to facilitate the confinement and recovery of spills; and to control the growth of vegetation and minimize upkeep and maintenance. (*For yard areas used for the storage of forest products, see Section 5-6*.)

5-3 Containment and Access.

The entire property shall be surrounded by a fence, or other suitable means, to prevent access by unauthorized persons. An adequate number of gates shall be provided in the surrounding fence or other barriers to permit ready access of fire apparatus in case of fire.

5-4 Vehicular Routes, Traffic, and Parking.

Vehicular routes, traffic rules, and parking areas shall be established, identified, and used. Private vehicle parking in marine terminals shall be permitted only in designated areas.

5-5 Fire Lanes.

5-5.1

Access for fire-fighting operations shall be provided by means of fire lanes spaced at such intervals that no portion of any storage or parking area will be over 15 m (50 ft) from the fire lane.

Exception: Block stowage of empty containers, provided containers with combustible exteriors are interspersed to reduce fire spread.

5-5.2

Fire lanes that are U-shaped, do not exceed 90 m (300 ft) in length, and are adjacent to cargo piled less than 5 m (16 ft) high shall be a minimum of 4 m (12 ft) wide. All other fire lanes shall be a minimum of 6 m (20 ft) wide. Fire lanes shall not dead-end unless designed with a turnaround at the end. Such turnarounds shall have an inside radius of not less than 7.5 m (25 ft) and an outside radius of not less than 15 m (50 ft).

Exception: Where there are practical difficulties in meeting the requirements of Section 5-5, the authority having jurisdiction shall be permitted to approve alternative fire lane arrangements, provided the intent of reasonable emergency access is achieved.

5-6 Container Storage.

Storage in excess of five containers high shall be permitted only with the coordination of the local authority having jurisdiction.

The local authority having jurisdiction shall consider the need for aerial fire-fighting techniques, improved access for mobile fire-fighting apparatus, and pile stability before permitting this arrangement.

Chapter 6 Water Supply for Fire Protection

6-1 Hydrants and Hose Connections.

There shall be provided on, or immediately adjacent to, every pier, wharf, or marine terminal property a sufficient number of accessible hydrants or 64-mm ($2^1/_2$-in.) hose outlets for use by public or private fire departments for extinguishing large structure and contents fires, and for use in providing exposure protection. The number and location of hydrants and hose connections shall be determined by the authority having jurisdiction, but shall not be spaced further apart than 90 m (300 ft) nor more than 45 m (150 ft) from a dead-end area.

6-2 Water Supply.

The water supply requirement for hydrants shall be in addition to that required for automatic sprinklers. The capacity of the water system shall be sufficient to deliver the quantity of water determined by the authority having jurisdiction, giving due consideration to the relative fire hazard to the property involved and the availability of marine fire-fighting equipment. Fire flow shall be designed for not less than a 4-hr duration. Piping, pumps, and other facilities shall be designed and installed in accordance with the requirements of 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*. When water is supplied through connections to public water systems, the installation of additional water supplies, such as private pumping systems, dry hydrants (as described in Appendix B of NFPA 1231, *Standard on Water Supplies for Suburban and Rural Fire Fighting*), fire department pumper connections, and similar supplemental or auxiliary supplies that utilize nonpotable water or water sources other than the public water system, shall conform to local and state laws and regulations.

Chapter 7 Hazardous Materials Storage

7-1 Hazardous Materials.

Includes any 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 which has been so designated.

7-2 Processing and Placarding.

Hazardous materials shall not be processed for further shipment at marine terminals unless packed, labeled, and placarded in accordance with applicable regulations of the U.S. Department of Transportation.

7-3* Handling, Storage, and Loading.

Hazardous materials at terminals shall be handled, stored, loaded, and unloaded in accordance with applicable federal regulations, as well as the authority having jurisdiction.

7-4* Bulk and General Cargo Operations.

Combined bulk cargo and general cargo operations shall not be permitted where, in the opinion of the authority having jurisdiction, joint operations increase the fire hazard inherent in each operation.

7-5 Written Procedures.

A written plan shall be developed and implemented for the handling and temporary storage of hazardous materials at all general cargo terminals.

Exception: For those terminals where operations are limited to specific types of commodities only and no hazardous materials are being received or delivered a written plan shall not be required.

The plan shall be developed in cooperation with the authority having jurisdiction, and the location, quantity, methods, and time of handling and storing hazardous materials shall be limited and controlled in accordance with such plan. (*See Appendix D for example.*)

NOTE: Compliance with the provisions of this chapter shall include, as a minimum, means by which to provide ready access to information concerning the quantity, location, and nature of any hazardous material stored at terminal facilities.

7-6 Designated Storage Areas.

The plan of Section 7-5 shall require establishment and use of designated areas for temporary storage of hazardous materials except that containerized cargo operations may intersperse individual containers containing hazardous materials with containers containing general cargo, provided storage conforms to the requirements of Section 7-7.

Exception: Hazardous materials specified in 7-8.1.

7-7 Hazardous Material and General Cargo Containers.

The procedure to be followed where containers with hazardous materials are interspersed with general cargo containers shall be detailed in the written plan of Section 7-5, and shall be based upon the following general guidelines:

(a) To minimize concentration and exposure problems, the interspersal plan shall ensure that containers of incompatible materials and containers of the more highly combustible, toxic, or reactive materials are kept well separated from each other.

(b) Sufficient access space shall be provided for effective use of hose streams and for movement of exposed containers under emergency conditions. Containers of hazardous materials shall remain parked or stored on chassis where operations permit.

7-8 Designated Hazardous Materials Storage Areas.

7-8.1*

Containers with the following types of hazardous materials shall not be interspersed with general cargo containers. Storage shall be confined to designated hazardous materials storage areas.

(a) Explosive materials as defined in NFPA 495, *Explosive Materials Code*. (*Also see Sections 7-15 and 7-16.*)

(b) Organic peroxides.

(c) Liquid oxygen.

(d) Oxidizing materials.

(e) Poisonous gases (Division 2.3 materials).

(f) Chlorine, fluorine, sulfur dioxide, and anhydrous ammonia.

(g) Flammable solids that are dangerous when wet.

(h) Radioactive materials.

(i) Other types of hazardous materials, as designated by the authority having jurisdiction.

Exception: Alternative storage location and handling procedures shall be authorized by the authority having jurisdiction where, in his or her judgment, equivalent safety can be provided by such alternatives.

7-8.2

Outside hazardous materials storage areas designated under the provisions of Sections 7-5 and 7-6 shall be located on land, not less than 15 m (50 ft) from buildings and other cargo storage areas, 6 m (20 ft) from property lines, and 30 m (100 ft) from other designated hazardous materials storage areas. Separation distances to buildings and property lines shall be maintained as open space and kept clear of storage of any kind at all times.

7-8.3

Access to designated outside hazardous materials storage areas shall be by means of fire lanes. Such fire lanes shall be not less than 6 m (20 ft) wide, and located in such a manner that no part of the storage area is over 15 m (50 ft) from a fire lane. Such fire lanes shall not dead-end.

7-8.4

Designated hazardous materials storage areas shall not be located within the following distances of electrical installations, unless such installations comply with the requirements for Class I Division 2 of Articles 500-501 of NFPA 70, *National Electrical Code*: horizontal separation distances shall not be less than 6.1 m (20 ft); and vertical separation distance shall not be less than 6.1 m (20 ft), or 3.05 m (10 ft) above the highest point of storage, whichever is greater.

Exception: Areas where the materials stored or handled are limited to a type or class of cargo not requiring the foregoing electrical installation classification as determined by the authority having jurisdiction. (See Articles 500-1, 2 and 3 of NFPA 70, National Electrical Code.)

7-8.5

Designated outside hazardous materials storage areas shall be constructed and situated to prevent runoff or drainage toward building, storage, and storage areas.

7-8.6

Designated outside hazardous materials storage areas shall be enclosed with a 1.8-m (6-ft) high wire or chain link fence, unless the entire terminal is surrounded by such a fence and the fence is in sound condition.

7-8.7

Designated hazardous materials storage areas shall be posted with signs. Such signs shall be easily visible, not obstructed by cargo storage, and contain the words HAZARDOUS

MATERIALS — NO SMOKING in capital letters not less than 150 mm (6 in.) in height.

7-9

Areas used to store hazardous materials in a liquid state shall have materials available for blocking drains. Hazardous materials shall not be permitted to enter waterways.

7-10

Areas used to store hazardous materials shall be free of grass, weeds, debris, and other combustible waste matter.

7-11

Containers loaded with hazardous materials shall not be stacked except as permitted by the authority having jurisdiction.

7-12

Placards shall be removed from containers that no longer contain hazardous materials.

7-13

Terminals handling hazardous materials shall prepare a "Hazardous Materials Emergency Operations Plan." This plan shall detail the actions to be taken by responsible managers, employees, and agents of the terminal in the event of a leak, spill, explosion, fire, or damage to a container. This plan shall be prepared in cooperation with the authority having jurisdiction, and shall incorporate provisions of OSHA and EPA requirements.

7-14

Information concerning the location, amount, and type of hazardous materials located within the confines of the marine terminal yard, buildings, piers, and wharves shall be readily available for reference by responding emergency personnel. This information shall be kept at the main gate security office, or other location approved by the authority having jurisdiction.

7-15

Marine terminals that receive and deliver explosive materials shall establish and operate an explosives interchange lot and, if transload operations are performed, a less-than-truckload explosives lot, in accordance with the requirements of NFPA 498, *Standard for Explosives Motor Vehicle Terminals*, and NFPA 495, *Explosive Materials Code*.

7-16

No vehicles or containers transporting hazardous materials other than explosives shall be parked in an explosives interchange lot except as permitted by NFPA 498, *Standard for Explosives Motor Vehicle Terminals*, and the authority having jurisdiction.

Chapter 8 General Terminal Operations

8-1 General.

The period of time necessary for cargo to be temporarily stored upon the pier or wharf in a transit shed, transfer building, or the terminal yard shall be kept as short as possible. Particular attention shall be directed to the safe storage and handling of highly combustible or hazardous materials.

8-2 The Terminal Operator.

8-2.1

The terminal operator shall establish and enforce fire prevention regulations and be responsible for the provision and maintenance of fire protection equipment. This responsibility requires an understanding of all applicable laws, ordinances, and regulations.

8-2.2

The terminal operator shall be responsible for the training of employees in fire prevention and the proper emergency action in the event of fire or other emergency, for providing the necessary equipment to control the spread of fire, and for handling any necessary movement or evacuation of vessels. The terminal operator shall prepare and implement an emergency operations plan detailing action to be taken in the event of fire, explosion, leak, spill, or damage to container or cargo.

8-3 Fire Organization.

8-3.1 Fire Safety Plan.

8-3.1.1* The terminal operator shall designate a competent and reliable employee(s) who shall be responsible for ensuring that all standpipe, fire hose, sprinkler equipment, portable fire extinguishers, and other fire protection devices and equipment are properly maintained. This employee(s) shall be familiar with proper maintenance procedures and standards. Such devices shall be maintained in accordance with applicable NFPA standards.

8-3.1.2 The designated employee(s) shall be familiar with the location of all telephones, valves, alarm boxes, fire hose stations, portable fire extinguishers, and other fire-fighting equipment.

8-3.1.3 The designated employee(s) shall have ready access to information concerning the fire hazard characteristics of the cargoes in the terminal and the location of all cargo that is exceptionally hazardous.

8-3.1.4 The designated employee(s) shall enforce all firesafety regulations and instruct employees in the proper use of fire alarm boxes.

8-4 Vessels.

8-4.1 Maneuverability.

All vessels shall be moored in an orderly manner. When mooring the vessel due regard shall be given to rapid removal in the event of a fire originating on either the pier or the vessel.

8-4.2 Mooring of Vessels.

Vessels that, in the opinion of the authority having jurisdiction, pose a substantial potential fire hazard due to the cargo they are carrying or the location they are moored shall rig fire warps. Fire warps shall consist of hawsers of sufficient size to take the vessel under tow in the event of an emergency. Fire warps shall be secured to the deck of the vessel and shall hang over the outboard side to within 1.8 m (6 ft) of the surface of the water. An eye shall be spliced into the outboard end of the warp of sufficient size to permit the rapid attachment of a towing shackle.

8-4.3 Mooring of Vessels Carrying Hazardous Materials.

Vessels carrying hazardous materials capable of posing a risk to the terminal, as determined by the authority having jurisdiction, shall not moor in a manner that would require turning the vessel prior to an emergency movement.

8-4.4 Cutting, Welding, or Other Hot Work.

8-4.4.1 Repairs involving cutting, welding, or other hot work shall be limited, as far as practical, while the vessel is at a marine terminal. Such hot work shall not be permitted while the vessel is fueling, loading, or unloading hazardous materials, or when explosives, Division 1.1, 1.2, or 1.3 are on board or within 30 m (100 ft). (*See 9-9.3.1 for terminal hot work requirements.*)

Exception: When approved by the authority having jurisdiction.

8-4.4.2 When such hot work is performed, it shall be conducted in accordance with the regulations of the U.S. Department of Transportation, U.S. Department of Labor, U.S. Coast Guard, and the authority having jurisdiction.

8-4.5 Bunkering (Refueling).

Bunkering of vessels at a marine terminal shall be done in accordance with regulations of the U.S. Coast Guard, the authority having jurisdiction, or both.

8-4.6 Shipboard Cargo Handling.

8-4.6.1 Smoking shall be prohibited except in designated areas.

8-4.6.2 Cargo handling equipment (lifts, carriers, conveyors, etc.) used aboard ship, and the refueling of such equipment, shall conform to regulations of the U.S. Department of Labor and U.S. Coast Guard as prescribed for the type of cargo handled and the requirements of the authority having jurisdiction.

8-5 Terminal Cargo Handling and Storage.

8-5.1

All placement of cargo shall be in accordance with the regulations of the U.S. Coast Guard, the authority having jurisdiction, and terminal operating orders.

8-5.2

Container handling and storage areas shall be suitably identified, including marking of travel lanes, to indicate direction of travel. All necessary traffic control measures shall be taken.

8-5.3 Transload Facilities.

At least one main aisle shall extend the length of the pier or transit shed. As a minimum, the aisle shall be of sufficient width to permit trucks to maneuver and pass one another.

Exception: Where cargo is transferred directly to or from railroad cars or vehicles and it is unnecessary to use trucks within the structure, an aisle shall not be required.

8-5.3.1 Aisle spaces shall be established between cargo piles extending from the main aisle to the sides of the transit shed or transload facility. Aisles shall be so arranged that, in addition to separating the cargo piles, they will give ready access to sprinkler control valves, fire hose stations, portable fire extinguishers, and the deck openings for fire-fighting purposes. Cargo shall not interfere with ready access to such equipment.

8-5.3.2 Aisle or access space of at least 600 mm (2 ft) shall be maintained between cargo piles and the side walls, fire walls, or fire-stops in transit sheds, container freight stations, or similar transload structures.

8-5.4

Clearance between cargo piles and sprinkler deflectors, roof supports, and other building structural members and ignition sources, such as lighting equipment, heating devices, and ductwork, shall be maintained in conformity with the requirements of NFPA 231, *Standard for General Storage*.

8-5.5

Care shall be exercised to ensure that fire-protection facilities, such as automatic sprinklers, will not be overtaxed in the event of fire due to the concentration and high-piling and palletizing of combustible cargoes. The adequacy of the sprinkler system shall be reevaluated when the fire hazard of the commodity in storage, or the method of storage, changes. If found deficient, such system shall be brought into compliance as determined by the authority having jurisdiction.

8-5.6* Fibers.

Sisal or other combustible fibers shall be handled in the open or in buildings protected by automatic sprinklers.

8-5.6.1 Fibers shall be piled with at least a 600-mm (2-ft) clear space to side walls and a 300-mm (1-ft) space at supporting columns for material expansion. Proper aisle space for fire department access and fire control by sprinklers and hose stream water penetration shall be maintained. Block piling shall not exceed 12 m × 15 m (40 ft × 50 ft) with stacks no higher than 4 m (12 ft), and palletized storage shall be limited to 3 pallets high unless the sprinkler system is designed to protect other configurations.

8-5.6.2 Access to the fiber, and to the aisles between the fiber stacks, shall be restricted to the personnel handling the fiber and other authorized personnel.

8-6 Time Limitation of Storage.

A pier or wharf shall not be used as a warehouse unless the structure was specifically designed for that purpose.

8-7 Separation of Passenger and Cargo Service.

Where piers are used for both passengers and cargo, the movement of passengers in or near any cargo area shall be regulated to eliminate any additional fire hazard, and passengers shall be subject to the same “No Smoking” rule as terminal personnel.

8-8 International Shore Connection.

International shore connection, as required by the International Safety of Life at Sea Convention, shall be available at the marine terminal to enable local fire-fighting equipment to be connected to a vessel’s fire main system. The threads on the shore-side connection shall conform to NFPA 1963, *Standard for Screw Threads and Gaskets for Fire Hose Connections*.

8-9* Guard Service.

Security personnel shall be provided by the terminal for the protection of the terminal in such numbers and of such qualifications as to ensure adequate surveillance, prevent unauthorized entrance, and detect fire hazards.

8-10 Notification.

The terminal shall have a means to rapidly notify the fire department in the event of an emergency. If a telephone is used for this purpose, such phone shall not require the use of a coin.

Chapter 9 Miscellaneous Installations and Operations

9-1 Tractors, Lift Trucks, Dock Cranes, and Other Material-Handling Equipment.

9-1.1

Material-handling equipment operated by internal combustion engines shall be of approved design and construction and be stored in a separate designated location, not on a combustible pier or wharf.

9-1.2

Unless fire extinguishers are readily accessible, each vehicle shall be provided with an extinguisher approved for Class B and Class C fires.

9-1.3*

All fueling and repairs shall be conducted at designated and properly protected locations. All fueling shall be from approved dispensing devices. Emergency refueling shall not be performed on a combustible pier or wharf, nor inside buildings where combustible cargo is stored or handled.

9-1.4

Electrically operated equipment shall be permitted to be stored on the pier or wharf in a segregated area. Battery charging equipment shall be installed in accordance with NFPA 70, *National Electrical Code*.

9-1.5

Material-handling equipment operated aboard ships or in areas where hazardous materials are being stored or handled shall be suitable for such use, as required by the regulations of the U.S. Department of Transportation, the U.S. Coast Guard, the U.S. Department of Labor, and the authority having jurisdiction.

9-2 Automotive and Railroad Equipment.

9-2.1

Transient trucks and automobiles shall be permitted to remain on piers and wharves only long enough to load and unload cargo. The number of vehicles permitted upon the pier or wharf at any one time shall be limited to a number that enables free traffic flow. Such vehicles shall not be permitted to interfere with the access of emergency response equipment. They shall be parked in such a way that they can be promptly driven off the pier in the event of emergency. Fueling and repair operations shall conform to 9-1.3.

9-2.2

RO/RO operations involving self-propelled motor vehicle cargo shall conform to requirements of the U.S. Coast Guard and the authority having jurisdiction.

9-2.3

Locomotives operated within the area of a marine terminal where combustible fibers or lumber are stored shall be fitted with approved and properly maintained spark arresters.

9-2.4

Diesel locomotives shall not be fueled within a marine terminal except at a properly located and designed fueling station.

9-2.5

Rail cars or trucks containing hazardous materials prohibited for shipment over the pier or wharf of a marine terminal shall not be permitted within the marine terminal.

9-2.6

Fueling and service of vehicles and equipment shall conform to the applicable requirements of NFPA 513, *Standard for Motor Freight Terminals*.

9-3 Electrical Installations.

9-3.1

Electrical installations shall be in accordance with NFPA 70, *National Electrical Code*.

9-3.2

Temporary lighting, when required, shall be obtained from battery-powered hand lamps or floodlights powered by portable generators. Generators shall be operated outside the building, warehouse, pier, or transit shed, and temporary heavy-duty wiring shall be run into the area served. The temporary wiring shall be adequately supported and properly fused.

9-4 Heating.

9-4.1

Gas-burning equipment shall be installed in accordance with NFPA 54, *National Fuel Gas Code*.

9-4.2

Electric heaters shall be of approved design, and installed in accordance with NFPA 70, *National Electrical Code*.

9-4.3

Oil burning heaters shall be installed in accordance with NFPA 31, *Standard for the Installation of Oil-Burning Equipment*.

9-4.4

Solid fuel burning equipment shall be installed in accordance with the requirements of NFPA 211, *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances*.

9-4.5

Boilers and heating equipment used for power or heat shall be located in buildings detached from the pier, or shall be enclosed on the pier by wall, floor, and ceiling materials having not less than a 2-hr fire resistance rating. Floors or decks immediately beneath and extending for a distance of 1 m (3 ft) from boilers, furnaces, and other heat-producing appliances shall be entirely noncombustible, and no combustible material shall be permitted in contact with the top or bottom surfaces of such portion of a floor or deck.

Exception: Hot water heaters, space heaters, and other small appliances if such appliances are of a type listed for mounting on a combustible floor or a protected combustible floor.

9-4.6

Portable heaters shall be used only when the device is approved for the specified use by the authority having jurisdiction. Portable heaters shall not be used in cargo handling or storage areas except for emergencies.

9-5 Processes.

9-5.1

Processes involving the use of flammable liquids shall be prohibited, except when permitted by the authority having jurisdiction.

9-5.2

Ripening or coloring of fruits or vegetables by means of direct heat or flammable gas shall not be conducted on the pier or wharf unless the process is segregated and protected by automatic sprinklers.

9-5.3

Warm rooms or areas temporarily heated to protect cargo from freezing shall be arranged with heating facilities as described in Section 9-4. Where a temporary form of closure is used, the enclosing material shall have a flamespread rating not exceeding 50 when tested in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*. Heating equipment for the temporary area shall be electric, gas, or fuel oil fired, with proper clearance to combustible materials. The heaters shall be approved for space or construction heating. Fuel-fired heaters shall have a listed flame failure shutoff device and temperature controls. Heaters shall not be refueled while operating, and shall be fueled from approved fuel handling devices only.

9-6 Fumigation.

9-6.1*

Fumigation shall, where practical, be conducted in buildings designed and constructed for that purpose. When conducted in warehouses, transit sheds, or piers, the fumigation shall be conducted in rooms segregated from the balance of the area by a wall or partition having a fire resistance rating of not less than 1 hr. Fumigating gases or chemicals shall be stored outside in a properly marked noncombustible building and secured from fire exposure or accidental release.

9-6.2

The authorities having jurisdiction shall be notified in advance of any fumigation operation.

9-7 Pallets and Dunnage.

9-7.1

Pallets and dunnage shall, where practical, be stored outdoors, arranged to minimize the exposure hazard to other property, and be readily accessible for fire fighting. Such storage shall conform to the requirements of NFPA 231, *Standard for General Storage*.

9-7.2

Where pallets and dunnage must be stored indoors, that storage shall be in accordance with NFPA 231, *Standard for General Storage*.

9-8 Packaging and Recoopering.

All packaging shall be done in a segregated area. Incidental recoopering and repackaging shall be conducted at a safe distance from other cargo working areas. Refuse materials resulting from recoopering shall be promptly removed.

9-9 Incinerators.

Incinerators shall be constructed as required in NFPA 82, *Standard on Incinerators and Waste and Linen Handling Systems and Equipment*.

9-10 Maintenance, Repairs, and Housekeeping.

9-10.1

Special periodic inspections shall be made beneath the pier deck to determine conditions relating to fire prevention and protection in the substructure. Heavy incrustation of oil shall be removed from all combustible members. Floating combustible debris shall be removed. Fire protective devices, such as automatic sprinklers, nonautomatic sprinklers, piping, and fire-stops, shall be carefully examined and promptly repaired, if repairs are necessary. Covers for nozzle openings in the pier deck for the use of substructure fire protection equipment shall be kept accessible and in good order so that they will not stick when speedy removal is essential.

9-10.2

All buildings and yard areas shall be kept free of debris and waste materials. Such materials shall be kept in metal containers and removed or emptied at sufficiently frequent intervals to prevent dangerous accumulations. Yard areas shall be kept free of grass and weeds.

9-11 Cutting, Welding, or Other Hot Work.

9-11.1

Repairs involving cutting, welding, or other hot work shall be limited, as far as practical, at a marine terminal. Such hot work shall not be permitted:

(a) During gas freeing operations;

(b) Within 30 m (100 ft) of bulk cargo operations involving the loading or unloading of flammable or combustible materials;

(c) Within 30 m (100 ft) of fueling (bunkering) operations; or

(d) Within 30 m (100 ft) of explosives or 15 m (50 ft) of other hazardous materials.

9-11.2

When such hot work is performed, it shall be conducted in accordance with NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, and with the regulations of the U.S. Department of Transportation, U.S. Department of Labor, U.S. Coast Guard, and the authority having jurisdiction.

9-11.3

Open flame lights or lanterns using kerosene, gasoline, LPG, or calcium carbide fuel shall not be used.

9-11.4

Smoking shall be permitted only in posted designated areas as approved by the authority having jurisdiction. Smoking and open flames shall not be permitted within 15 m (50 ft) of hazardous materials storage.

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 13, *Standard for the Installation of Sprinkler Systems*, 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 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 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 54, *National Fuel Gas Code*, 1992 edition.

NFPA 70, *National Electrical Code*, 1996 edition.

NFPA 80, *Standard for Fire Doors and Fire Windows*, 1995 edition.

NFPA 82, *Standard on Incinerators and Waste and Linen Handling Systems and Equipment*, 1994 edition.

NFPA 211, *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances*, 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 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, 1990 edition.

NFPA 495, *Explosive Materials Code*, 1992 edition.

NFPA 498, *Standard for Explosives Motor Vehicle Terminals*, 1992 edition.

NFPA 513, *Standard for Motor Freight Terminals*, 1994 edition.

NFPA 1124, *Code for the Manufacture, Transportation, and Storage of Fireworks*, 1995 edition.

NFPA 1231, *Standard on Water Supplies for Suburban and Rural Fire Fighting*, 1993 edition.

NFPA 1963, *Standard for Fire Hose Connections*, 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

See NFPA 303, *Fire Protection Standard for Marinas and Boatyards*.

A-1-1.3

See NFPA 30, *Flammable and Combustible Liquids Code*.

A-1-1.4

See NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas [LNG]*, or NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*.

A-2-1 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-2-1 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-2-1 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-3-2.1

Combustible substructures, due to their inherent combustibility and structural configuration, present substructure fire protection problems different from those of fire-resistive or noncombustible construction. This standard requires properly designed and installed fixed fire extinguishing equipment and appropriate structural barriers to minimize the spread of fire.

It is essential that all equipment be continuously maintained in good working condition. Similar fire protection problems may exist with composite construction. Special provisions have accordingly been provided in 3-3.2 for such construction.

A-3-2.5.1 See NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*.

A-3-2.6.1 Deep narrow spaces between timbers present ideal conditions for the accumulation of extraneous material and are also natural channels for the rapid spread of fire.

A-3-3.2 Protection and Subdivision of Composite Substructures.

The provisions of 3-3.2 are based upon consideration of the amount and arrangement of exposed combustible materials. When the underside of the pier deck is combustible, or when the pier deck is noncombustible on combustible supports with the distance from low water to top of combustible material exceeding the typical distance between bents, then the requirements for protection and subdivision of combustible substructures apply. When the above distance to low water is equal to or less than the typical distance between bents, and the pier deck and pile caps are noncombustible with no exposed combustible inter-bent bracing, protection and subdivision requirements for combustible substructures would normally apply only if other combustible materials, unusual conditions, or hazards were present. If other combustible materials (e.g., catwalks, decks, vapor barriers, fender systems) are present, or unusual conditions or hazards (e.g., concentrations of combustible structural supports, flammable liquid hazards) exist, then consideration should be given to the type, quantity, and arrangement of all exposed combustible material, the fire resistance rating of the pier deck, and the configuration and access to the substructure for manual fire-fighting operations.

A-3-3.3.3(a)(5) The use of fire-stops for draft control to bank heat, facilitate the opening of sprinkler heads, and prevent the overtaxing of the sprinkler system is particularly important in the design of sprinkler protection for combustible substructures. The fire walls and fire-stops of 3-3.3.6 should be incorporated into the sprinkler system design for this purpose to the maximum extent practical; however, due to limitations in the size of the design area for the sprinkler system, additional fire-stops will normally be needed. These additional or supplemental fire-stops need only have limited fire resistance but should be as deep as possible and be of substantial construction, such as double 76.2-mm (3-in.) planking where exposed to the elements. Where not exposed to physical damage, 19.05-mm ($^3/_4$-in.) treated plywood extending 1219.2 mm (48 in.) below stringers with solid blocking between stringers should provide adequate durability and reasonable effectiveness.

A-3-3.3.5 It should be recognized, however, that this alternate protection contemplates manual fire-fighting operations that will be effective only under the most favorable of physical arrangements and conditions at the time of the fire.

A-3-3.3.8 Fire-stops may be of wood planking built up to a thickness of 150 mm (6 in.), or of wrought iron plate 12.7 mm ($^1/_2$ in.) thick, or other equivalent construction, provided that each side of the wood or exposed metal fire-stops are protected by automatic sprinklers and by deck openings for the use of revolving nozzles.

A-3-4.1 Subdivision of Pier Superstructures.

It is recommended that fire walls be installed for the subdivision of superstructures and that the area between fire walls not exceed 4,650 m^2 (50,000 ft^2). These walls should be continuous with the substructure fire walls required in 3-3.3.6. In addition, it is recommended that, in open area superstructures, curtain boards or draft stops of noncombustible construction be installed between the fire walls at intervals not exceeding 30 m (100 ft). When construction permits, these curtain boards should be carried down to the lower chord of the roof trusses.

A-3-5.2

If hose lines needed for fire fighting on the pier cannot be adequately supplied from hydrants located in the yard or adjacent city streets, pipelines equipped with approved 64-mm ($2^1/_2$-in.) outlets for fire department use should be extended onto the pier. In such cases, the 38-mm ($1^1/_2$-in.) standpipe connections should also be made to this pipeline.

For evaluation of the hazards of fire exposure and protection methods, refer to NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*.

A-4-3

For guidance on construction, protection, and separation distances refer to NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*.

A-5-1

Yard storage of logs, lumber, and other forest products should be in accordance with NFPA 46, *Recommended Safe Practice for Storage of Forest Products*.

A-7-3

The loading, unloading, handling, and storage of hazardous materials is an inherent part of most marine terminal operations. Particular attention should be given to facilities, procedures, and operations that will minimize dangerous concentrations, avoid the mixing of incompatible materials, ensure safe operations, and permit effective fire control in the event of an accident. Over the years a large body of regulations has evolved that is specifically applicable to such operations.

Marine terminal owners and operators, shippers, and others responsible for the transportation and handling of hazardous materials, as well as local authorities responsible for the regulation of such operations for public safety, should be familiar with all applicable federal regulations. A summary of U.S. Coast Guard regulations, hazardous materials regulations of the U.S. Department of Transportation, occupational safety and health standards of the U.S. Department of Labor, and the regulations of the U.S. Department of Treasury, along with recommended good practice in administration of local regulations, is found in Appendix D.

A-7-4

Operations involving the loading, unloading, handling, and storage of bulk cargoes of certain hazardous materials present special problems, especially if conducted at a general cargo marine terminal. Such general cargo terminals regularly handle a variety of other hazardous materials, including explosives and chemicals, subject to explosive decomposition. The handling of bulk "cargo of particular hazard," as defined in U.S. Coast Guard Regulations Title 33 Part 126.10(d), tanker moorage, pipeline transfer and storage of flammable liquids, liquefied natural gas, and similar products is incompatible with general cargo marine terminal operations. Separate terminal facilities that are designed, constructed, operated, and protected as required for the particular bulk cargo are needed.

A-7-8.1

The hazardous materials listed in 7-8.1 include generic names that embrace a range of hazards. Individual container shipments of such materials will involve various quantities and will be subject to differing local conditions. An exception to required storage in a designated hazardous materials storage area is provided to permit recognition of these differences for such shipments. It is recommended that approval of any alternative by the authority having jurisdiction be based upon the principles of Chapter 7 and the procedures outlined in Appendix D.

A-8-3.1.1 Fire problems involving marine terminals and vessels present significantly different challenges from those normally faced by land-based fire-fighting organizations. Pre-fire plans, routine drills, and coordination with local mutual-aid organizations are all essential to effective fire fighting in marine facilities. (*See NFPA 1405, Guide for Land-Based Fire Fighters Who Respond to Marine Vessel Fires.*)

Where a trained public fire department is not readily available, a fire brigade consisting of selected employees should be organized. The efficiency of the brigade depends on thorough drilling in the location and proper use of fire-fighting equipment, including operation of portable fire extinguishers, laying of hose lines, and application of hose streams. It is recommended that there be a special detail assigned to close all fire doors in times of fires and drills. (*See NFPA 600, Standard on Industrial Fire Brigades.*)

A-8-5.6

The storage of cotton should comply with NFPA 231E, *Recommended Practice for the Storage of Baled Cotton*.

A-8-9

See NFPA 601, *Standard for Guard Service in Fire Loss Prevention*.

A-9-1.3

See NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance, and Operation;* NFPA 30, *Flammable and Combustible Liquids Code;* and NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*.

A-9-6.1 Fumigation.

1. It is recommended that, wherever possible, nonflammable fumigants be used.
2. Fumigation of imported cargo should, preferably, be conducted in detached buildings under competent supervision.

3. No fumigant should be used that has a flammability rating greater than 2; a reactivity rating greater than 1, as outlined in NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials*; or a flashpoint less than 60°C (140°F).

4. All flammable or combustible fumigants should be stored in sealed metal containers and in accordance with the requirements of NFPA 30, *Flammable and Combustible Liquids Code*.

5. Where other than nonflammable fumigants are used, electric wiring and equipment for fumigating chambers or enclosures should be installed in accordance with Chapter 5 of NFPA 70, *National Electrical Code*.

6. Adequate ventilation facilities should be provided to remove the fumigant from the chamber or enclosure, and must be of good design and arranged to safely vent or release spent gases after dilution at altitudes or locations that protect persons and property in the area.

7. Fumigants should be used only as recommended by the manufacturer.

8. Where other than nonflammable fumigants are used, piping valves and fittings should conform to the requirements of Chapter 3 of NFPA 30, *Flammable and Combustible Liquids Code*.

9. Where pesticides are required to be stored on the premises, especially for long periods of time, such storage should conform to the requirements of NFPA 43D, *Code for Storage of Pesticides*.

10. Pesticides should be stored so as to prevent deleterious contact with moisture.

11. Pesticides should be stored in a manner to prevent accidental release.

12. Suitable gas masks should be provided for fumigation operations. The gas masks should be prominently displayed and adequately labeled.

13. Federal, state, or local governmental regulatory agencies, such as the U.S. Department of Labor, may have additional requirements that should be followed when applicable.

14. The use of products generally distributed with instructions for use in households, such as paradichlorobenzene or naphthalene crystals or pellets used for fabric pest control, is acceptable as fumigants not needing any special requirements other than those recommended by the manufacturer.

Appendix B Substructure Nomenclature

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

There being no so-called typical construction, substructures vary widely by the type and the combination of materials used and the arrangement of structural members. The following illustrations are provided to clarify terminology used:

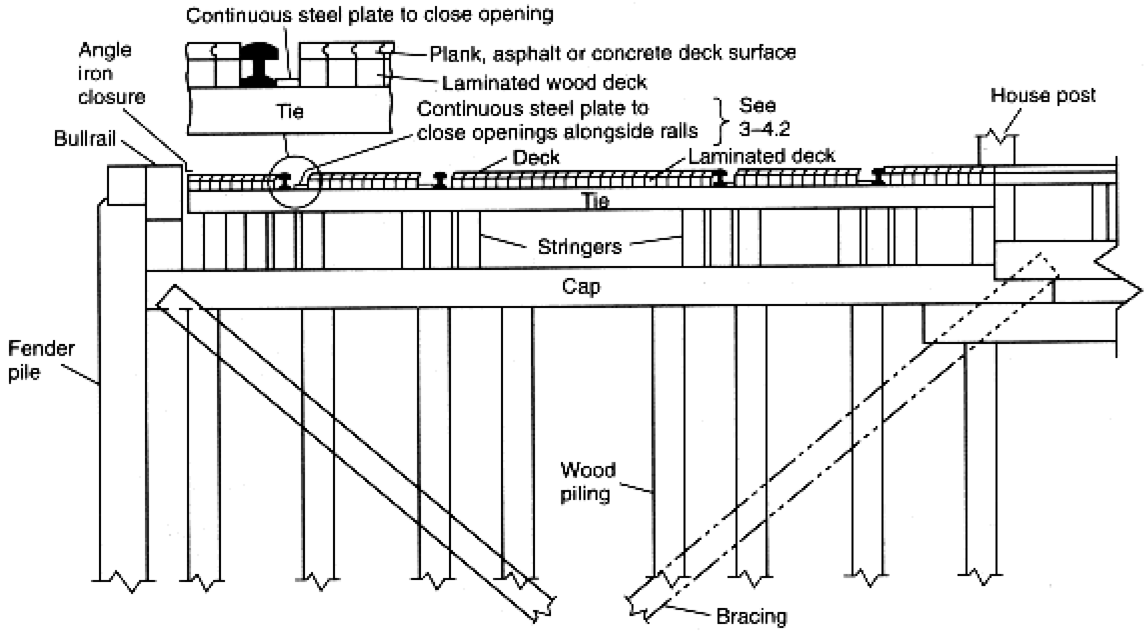

Figure B-1 Illustration of a combustible substructure with railroad tracks.

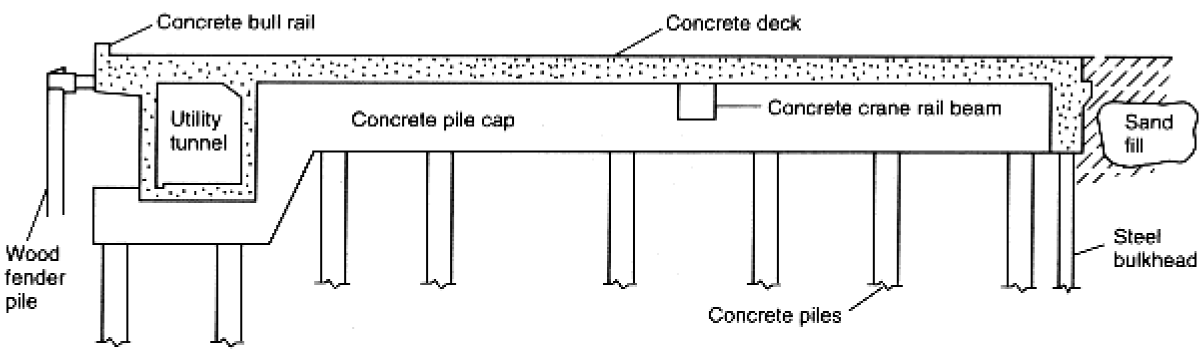

Figure B-2 Fire-resistive concrete wharf substructure.

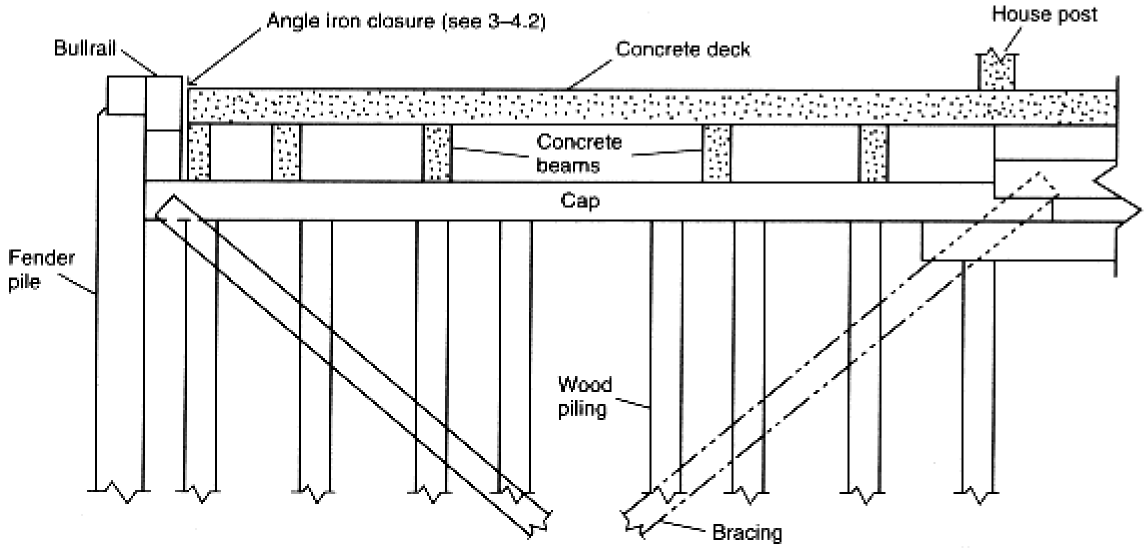

Figure B-3 Wharf substructure with fire-resistive, reinforced concrete deck and beams over combustible piles and pile caps.

Appendix C Additional Fire Protection Facilities

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

C-1 Sprinkler Supervision and Alarm.

It is recommended that sprinkler systems be provided with sprinkler supervisory and water flow alarm service through a central station where available, and as remote station, auxiliary, or proprietary systems where not available. (*See NFPA 72, National Fire Alarm Code.*)

C-2 Fire Alarm.

It is recommended that an approved system of manual fire alarms arranged to sound local alarms and summon the private brigade and public fire department be installed at marine terminals. (*See NFPA 72, National Fire Alarm Code; and NFPA 1221, Standard for the Installation, Maintenance, and Use of Public Fire Service Communication Systems.*)

The installation of automatic fire alarm equipment in substructures should be approached with due regard to maintenance and possibility of false alarms.

U.S. Coast Guard Regulations Title 33, Part 126.16 requires “designated waterfront facilities” authorized to handle cargo of particular hazard, as defined in Part 126.10, to be equipped with approved warning alarms at the waterside of the facility to warn approaching or transiting water traffic of immediate danger in the event of fire or cargo release.

Appendix D Regulations — References

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

D-1 Federal Regulations.

D-1.1 Code of Federal Regulations:

Title 33, Part 126 issued by the U.S. Coast Guard contains regulations covering the handling of explosives or other dangerous cargoes within or contiguous to waterfront facilities.

D-1.2 Code of Federal Regulations:

Title 49, Chapter I, Parts 170-179 issued by the U.S. Department of Transportation covers preparation of hazardous materials for transportation by common carriers by rail freight, rail express, rail baggage, highway, or water; construction of containers, packaging, weight, marking, and labeling when required; billing; and shippers' certificate of compliance with these regulations; also covers cars, loading, storage, billing, placarding, and movement thereof by carriers by rail.

D-1.3 Code of Federal Regulations:

Title 49, Chapter III, Parts 390-397 administered by Federal Highway Administration, U.S. Department of Transportation, applies to every common carrier by motor vehicle, contract carrier by motor vehicle, and private carrier of property by motor vehicle engaged in interstate or foreign commerce, with respect to the transportation by motor vehicle of explosives and other dangerous articles. Parts 390-397 cover qualifications of drivers, driving rules, parts and accessories for safe operation, recording and reporting accidents, hours of service of drivers, inspection and maintenance of motor vehicles.

D-1.4 Occupational Safety and Health Standards of the U.S. Department of Labor. Code of Federal Regulations:

Title 29, (Labor), Chapter XVII, Parts 1910, 1917 and 1918. The Occupational Safety and Health Act of 1970 (Public Law 91-596) authorizes the secretary of labor to set mandatory occupational safety and health standards applicable to businesses affecting interstate commerce. These parts contain safety and health standards that were established under federal or national consensus rules, adopted under Section 6(a) of the Act and standards of specific design, and adopted under Section 6(b) of the Act.

D-1.5 Commerce in Explosives Regulations of the U.S. Department of the Treasury. Code of Federal Regulations:

Title 26, Part 181. This part contains regulations promulgated to implement Title XI, Regulations of Explosives of the Organized Crime Control Act of 1970. It contains requirements pertaining to interstate and foreign commerce in explosive materials; licensing of manufacturers and importers of, and dealers in, explosive materials; the issuance of user permits; the conduct of business by licensees and operations by permittees; the storage of explosive materials; the records and reports required by licensees and permittees; relief from disabilities under this part; and exemptions, unlawful acts, penalties, seizures, and forfeitures.

D-2 Local Regulations.

D-2.1

The administration of local codes, ordinances and regulations is usually handled under various permit systems with the authority having jurisdiction granting permission to load, unload, transport, store, handle, and use hazardous materials in accordance with specific provisions stipulated in the permit. Because marine terminal operations involve such a wide range of hazardous materials and large number of movements, it is impractical to issue individual permits for each movement. Accordingly, it is recommended that local regulations be adopted authorizing a master harbor permit system for marine terminal operators.

D-2.2

Under such a system, the marine terminal is issued a master permit that is renewed annually or when conditions at the terminal change substantially. The master permit should specify maximum limitations on the quantities for specific types of hazardous materials that can be handled at the terminal, and should set forth conditions under which the materials can be moved and stored. Such permits should have provisions under which the authority having jurisdiction may issue excess quantity permits for the handling of occasional shipments that exceed master permit quantity limits, and special handling permits for shipments of exceptional hazard. Since the master permit is a long-term device intended to assist day-to-day safe operations in the storage and handling of hazardous cargoes, it is important for the authority having jurisdiction to monitor operations through frequent inspections.

D-2.3

In determining the maximum quantities and the storage and handling conditions for the various hazardous materials to be specified in the master permit for a given marine terminal, due consideration should be given to:

(a) The location of the terminal in relation to large population centers, in conjunction with the types and quantities of hazardous materials that are proposed to be stored.

(b) The speed and direction of prevailing winds.

(c) The type of construction of the terminal and its condition and maintenance. This factor should consider such items as the condition of the superstructure and substructure, the condition of electrical services, water and fuel lines, and the level of difficulty in gaining access to the structure for purposes of fire fighting.

(d) Emergency access to the terminal and the hazardous materials storage area.

(e) The physical size of the marine terminal and whether or not there is sufficient room for proper segregation of incompatible materials.

(f) The provisions that have been made for the fire protection of the terminal. These would include whether or not the terminal is sprinklered, fire-fighting access, and water supplies.

(g) The capability of the local emergency services agencies, including available equipment, manpower, and training.

D-2.4

It would be appropriate to make the storage plan of Section 7-5 a part of the master permit details either by reference or otherwise. These details of storage, handling, quantities, and types of hazardous materials will vary by terminal, by locality, and by systems or procedures adopted pursuant to the general considerations listed above. All such plan and permit details should be based upon the goal of safe handling with storage quantities and types controlled so as to prevent an unmanageable situation in the event of fire or accident.

D-2.5

The following examples of plan and master permit details being used at certain terminals illustrate methods that may be of assistance to those responsible for developing such plans. Illustrations cover both container yard and breakbulk operations. Quantities specified in these examples reflect availability of strong public and private fire control facilities.

Container Yard Operations

The terminal should designate three hazardous materials storage areas known as Areas A, B, and C. Each area should be located:

(a) 15 m (50 ft) from buildings and other general cargo storage areas.

(b) 6 m (20 ft) from property lines.

(c) 30 m (100 ft) from other hazardous materials temporary storage areas.

The maximum dimensions for these areas should be:

(a) Area A: 12.5 m × 40 m (40 ft × 125 ft) with access for fire department vehicles.

(b) Area B: 12.5 m × 44 m (40 ft × 144 ft) with access for fire department vehicles.

(c) Area C: 12.5 m × 10.5 m (40 ft × 34 ft) with access for fire department vehicles.

Containers should be placed no closer than 1.5 m (5 ft) from any other container in the storage area. Unoccupied space in the hazardous material storage area may be used to store empty chassis. Designated separation distances between storage areas should be kept open at all times and storage of any kind should be prohibited.

Storage areas should be surrounded by a 75-mm (3-in.) wide painted line 6 m (20 ft) out from the storage area. Such lines should be of contrasting color to the surface. The words “HAZARDOUS CARGO AREA — NO SMOKING — NO FLAMES” should be painted on the surface in letters not less than 150 mm (6 in.) high every 9 m (30 ft) adjacent to the perimeter line.

The terminal operator should be responsible for all hazardous materials at the terminal regardless of ownership. Operating plans should identify the individuals who have this responsibility and the authority for liaison with authorities having jurisdiction.

The following chart is an example of master harbor permit system limitations for the outside storage of hazardous materials in containers. Except as permitted by the authority having jurisdiction, the terminal should not exceed the maximum quantities set forth in the column designated “Maximum Quantities” in the chart. Nor should the terminal accept hazardous materials labeled as “Call for Permit” in the same column of the chart, without first obtaining a permit to accept such hazardous materials.

If the terminal operator wishes to apply for an exempted commodity classification for a commonly transported hazardous material, a letter should be sent to the authority having jurisdiction. Letters will be reviewed annually for possible inclusion into the exempted commodity category.

HAZARDOUS MATERIALS CONTAINER YARDS

Temporary Storage Conditions and Limitations

HAZARDOUS MATERIAL D.O.T. CLASS	MAXIMUM QUANTITIES	STORAGE AREA	ADDITIONAL CONDITIONS
Flammable liquids	Not to exceed 45,400 kg (100,000 lb)	A	May stack containers 2 high. No other commodity may be stored in Area "A"
Flammable compressed gas	20 containers	B	No other hazardous material may be stored within 15 m (50 ft)
Combustible liquids	Unlimited	*	*May be stored with general cargo. See Note 2
Flammable solids	3 containers not to exceed 20,450 kg (45,000 lb)	B and/or C	No other hazardous material may be stored within 30 m (100 ft). May stack 2 high
Flammable solids - dangerous when wet	Call for a permit		
Oxidizing material	10 containers	B and/or C	No other hazardous material may be stored within 15 m (50 ft). May stack containers 2 high
Corrosive material	10 containers	B and/or C	No other hazardous material may be stored within 15 m (50 ft). May stack containers 2 high
Nonflammable compressed gas	10 containers	B and/or C	No other hazardous material may be stored within 15 m (50 ft). May stack containers 2 high EXCEPT: nitrogen, argon, and carbon dioxide. Helium may be stored with general cargo. See Note 2
Chlorine, fluorine, sulfur dioxide or ammonia (may be one type or any combination of)	3 containers	B and/or C	Maximum container size for chlorine is 910 kg (1 ton). No other hazardous material may be stored within 30 m (100 ft)
Poisonous Gases, Division 2.3	Call for a permit		
Poisons, Division 6.1	2 containers not to exceed 18, 150 kg (40,000 lb)	B and/or C	No other hazardous material may be stored within 15 m (50 ft). May stack containers 2 high
Irritating material	2 containers not to exceed 4,550 kg (10,000 lb)	B and/or C	No other hazardous material may be stored within 15 m (50 ft). May stack containers 2 high
Radioactive material	Call for a permit		

Explosives: Division 1.1 and 1.2	1 container not to exceed 91 kg (200 lb)	C	
Division 1.3	1 container not to exceed 910 kg (2,000 lb)	C	No other commodity may be stored in this area at the same time
Division 1.4	3 containers not to exceed 45,400 kg (100,000 lb)	C	Remove from terminal within 48 hours
Division 1.5	3 containers not to exceed 45,400 kg (100,000 lb)	C	
Oxygen, liquid	3 containers not to exceed 18,150 kg (40,000 lb)	B and/or C	No other commodity may be stored in this area at the same time
Organic Peroxides	1 container not to exceed 45.5 kg (100 lb)	B and/or C	No other commodity may be stored in this area at the same time
ORM A ORM B ORM C ORM D	No restriction	*	*May be stored with general cargo. See Note 2
Other: Pyrophoric materials Etiologic agent Cryogenic material	Call for a permit		

Exception: Placarded containers containing less than 455 kg (1,000 lb) gross weight of a hazardous material listed in 49 CFR 172.101 Hazardous Materials Table may be stored with the general cargo, provided the hazardous materials temporary storage areas are full.

Note 1: Maximum total quantities are listed by the total number of containers allowed in an area and the maximum total gross weight of the hazardous material in pounds (kilograms) permitted in the area. The total gross weight figure is the sum of all containers in the area and must not be exceeded.

Note 2: Exempted commodities by proper shipping name may be stored with the general cargo. All other conditions of this permit and city, state, and federal law should be strictly adhered to.

Breakbulk Operations

The following is an example of storage requirements for the storage of hazardous materials in breakbulk form. See preceding example for storage or operating provisions that may also be appropriate.

Indoor storage and handling of hazardous materials should be confined to structures that are sprinklered as required in Section 4-5. Sprinkler systems having more than 100 heads should be supervised by an approved central, proprietary, or remote station service, or provided with a local alarm that will give an audible signal at a constantly attended location.

Overnight indoor storage of hazardous materials as indicated in the following table should be stored in predesignated locations or areas within the building. These areas should be posted with signs. Such signs should contain the words "HAZARDOUS MATERIALS — NO SMOKING" in red capital letters 150 mm (6 in.) or more in height.

Smoking within such buildings should be limited to predesignated locations. In no case should smoking or open flames be allowed within 15 m (50 ft) of the hazardous materials storage locations.

Buildings used for the storage of hazardous materials should be secured when not occupied or under the interior surveillance of security personnel. (*See Section 8-9.*)

Storage (including general cargo) should be so placed as to provide at least one aisle 6 m (20 ft) wide running the length of the building, and cross aisles 1.5 m (5 ft) wide at least every 23 m (75 ft).

Designated separation distances between storage areas should be kept open at all times and storage of any kind should be prohibited.

The following chart is an example of master permit specification limitations for the storage of hazardous materials in breakbulk form.

BREAKBULK CARGO

TEMPORARY STORAGE CONDITIONS AND LIMITATIONS

HAZARDOUS MATERIAL D.O.T. CLASS	OUTDOOR MAXIMUM QUANTITIES	INDOOR MAXIMUM QUANTITIES	COMMENT	SEPARATIONS OUTSIDE
Flammable liquids	Not to exceed 22,700 kg (50,000 lb)	20,850 L (5,500 gal) business hours, 685 L (180 gal) non- business hours unless sprinkler system is supervised, then 9,465 L (2,500 gal)		15 m (50 ft) from other hazard m (25 ft) from general cargo. configurations to comply with 55 gal drums — In piles, 2 hig per pile, 18 m (60 ft) from pro occupied buildings, 12 m (40 piles. 5 gal pails — In piles, 5 per pile, same separation dista for 55 gal drum storage
Flammablecompressed gas	2 groupings of 100 cylinders	20 cylinders		15 m (50 ft) from other hazard m (25 ft) from general cargo. storage to comply with the fol cylinders to be placed in grou greater than 100 per group: 6- between groups 15 m (50 ft) f lines and occupied buildings
Combustibleliquids	Not to exceed 45,400 kg (100,000 lb)	62,500 L (16,500 gal) business hours, 2,000 L (500 gal) non-business hours unless sprinkler system is supervised, then 30,300 L (8,000 gal)		Breakbulk storage to comply following: 5 gal drums — In p maximum 300 drums per pile from property lines and occup 12 m (40 ft) between piles. 5 g piles, 5 high, no limit on pile s separation distance as required drum storage
Flammable solids	Not to exceed 6,810 kg (15,000 lb)	455 kg (1,000 lb)		General
Flammable	Call for a permit	Call for a permit		

solids—dangerous when wet				
Oxidizing material	Not to exceed 4,550 kg (10,000 lb)		910 kg (2,000 lb)	Breakbulk storage to be 15 m hazardous cargo, 7.5 m (25 ft) cargo. Dry storage should be p moisture. Liquid storage shou over organic surfaces, to inclu surfaces
Corrosive material	Not to exceed 11,400 L (3,000 gal)	2,300 L (600 gal)	General. Dry commodities-permitted unlimited amounts in storage	General.Dry commodities may general cargo, to be protected
Nonflammable compressed gas	5 groupings of 100 cylinders per grouping	100 cylinders		May be stored with general ca following: oxygen (oxidizer), fluorine, sulfur dioxide, ammo
Chlorine, fluorine, sulfur dioxide, ammonia (may be one type or any combination of)	50 cylinders chlorine, max.cylinder size:910 kg (1 ton)	10 cylinders aggregate,max. size:140 kg (300 lb)		General. Storage may be placed with P 6.1. Note: Chlorine cylinder m 910 kg (1 ton)
Poisonous Gases, Division 2.3	Call for a permit	Call for a permit		
Poisons, Division 6.1 & irritants	Not to exceed 9,100 kg (20,000 lb)	910 kg (2,000 lb)		General
Radioactive material	Call for a permit	Call for a permit		
Explosives Division 1.1 and 1.2	Not to exceed 91 kg (200 lb)	Storage limit to 2 hrs, 91 kg (200 lb)	Call for a permit	To be stored in an approved m location approved by the auth jurisdiction
Explosives Division 1.4	Not to exceed 45,400 kg (100,000 lb)	18,200 kg (40,000 lb)		To be stored at least 15 m (50 property lines, occupied build hazardous storage. Individual separation should be in accord 49, Code of Federal Regulatio

Division 1.5	Not to exceed 45,400 kg (100,000 lb)	18,200 kg (40,000 lb)		
Ammonium nitrate, fertilizer grade	Not to exceed 140,000 kg (300,000 lb)	18,200 kg (40,000 lb)		
Organic peroxides	Call for a permit	Call for a permit		
ORM A ORM B ORM C ORM D ORM E	No restriction	No restriction		Storage with general cargo
Other: Pyrophoric materials Etiologic agent Cryogenic material	Call for a permit	Call for a permit		
Oxygen liquid	Not to exceed 4,540 kg (10,000 lb)	3 cylinders	Not to remain inside enclosed buildings overnight	Nonliquefied oxygencylinders form should be stored with ox Liquefied oxygen should be s all other hazardous materials (50 ft), from general cargo by Combustible material and deb stored within 7.5 m (25 ft) of cylinders

General — Where general is listed under storage conditions, the following separations should be adhered to: Outside breakbulk 6 m (20 ft) from fence lines, property lines; 7.5 m (25 ft) from other hazardous cargo, 3 m (10 ft) from general cargo. Inside 7.5 m (25 ft) from other hazardous cargo, 3 m (10 ft) from general cargo. Storage should be placed along outside walls.

Note: For those hazard classes listed as “Call for a permit” and Explosives, Division 1.1, 1.2 and 1.3, a special permit is required. Specific storage conditions and restrictions should be established based on the relative hazard of the actual commodity and the facility’s capability to handle that commodity.

For SI Units: 1 gal = 0.00379 m^3, 1 lb = 0.454 kg, 1 ft = .305 m.

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*, 1993 edition.

NFPA 43D, *Code for Storage of Pesticides*, 1994 edition.

NFPA 46, *Recommended Safe Practice for Storage of Forest Products*, 1990 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 72, *National Fire Alarm Code*, 1993 edition.

NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*, 1993 edition.

NFPA 231E, *Recommended Practice for the Storage of Baled Cotton*, 1989 edition.

NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*, 1995 edition.

NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance and Operation*, 1992 edition.

NFPA 600, *Standard on Industrial Fire Brigades*, 1992 edition.

NFPA 601, *Standard for Guard Service in Fire Loss Prevention*, 1992 edition.

NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials*, 1990 edition.

NFPA 1221, *Standard for the Installation, Maintenance, and Use of Public Fire Service Communication Systems*, 1994 edition.

NFPA 1405, *Guide for Land-Based Fire Fighters Who Respond to Marine Vessel Fires*, 1990 edition.

E-1.2 U.S. Government Publications.

U.S. Government Printing Office, Superintendent of Documents, Washington, DC 20402.

Title 33, *Code of Federal Regulations*, Part 126.

Title 49, *Code of Federal Regulations*, Parts 170-179.

Title 49, *Code of Federal Regulations*, Parts 390-397.

Title 29, *Code of Federal Regulations*, Parts 1910, 1917, 1918.

Title 26, *Code of Federal Regulations*, Part 181.

Title 46, *Code of Federal Regulations*, Part 146.

NFPA 312

1995 Edition

Standard for Fire Protection of Vessels During Construction, Repair, and Lay-Up

1995 Edition

This edition of NFPA 312, *Standard for Fire Protection of Vessels During Construction, Repair, and Lay-Up*, was prepared by the Technical Committee on Shipbuilding, Repair and Lay-Up 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 312 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 312

The first standard on these subjects was adopted by the NFPA in 1933 on recommendation of its Marine Committee, predecessor of the Marine Section. It was further considered in 1935, 1936, and 1937 and was finally adopted by the Association in 1938 on recommendation of the Marine Section Committee on Builders' Risk, Repair and Lay-Up. Editorial changes were made in 1942.

With the reorganization of NFPA marine activities in 1948, responsibility for the standard fell to the Committee on Shipbuilding, Repair and Lay-Up. Their recommendations were adopted by the Association in 1950 (Parts I and II) and 1951 (Part III), and revised editions were adopted in 1964, 1968, 1976, and 1984.

The 1990 edition of NFPA 312 was a complete revision that incorporated expanded requirements for vessel lay-up and an update of the fire protection requirements for vessels undergoing construction, conversion, and repair.

NFPA 312-1995 consists of amendments and editorial changes to NFPA 312-1990.

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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.

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 prevention and fire protection of vessels in course of construction, under repair and during lay-up.

NFPA 312
Standard for
Fire Protection of Vessels During Construction, Repair, and Lay-Up

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 Introduction

Due to the quantity and character of combustible materials used, many vessels undergoing construction, conversion, or repairs, and vessels laid up in a shipyard or elsewhere are readily vulnerable to fire. Long passageways, unenclosed stairways, hatches, and hoistways facilitate the rapid spread of fire throughout the vessel. The location of the vessel is often so isolated that private protection is the main source of fire-fighting services. Even where major municipal protection is available, the possible delayed response due either to lateness in the discovery of the fire or the absence of means for quick notification, lack of special equipment in many municipal fire departments for combating shipboard fires, or an unfamiliarity with ship construction due to the transitory nature of the risk can cause material damage or complete destruction before effective means of extinguishment can be brought into action. Therefore, every reasonable means of preventing fire shall be provided and supplemented by means of detection and protection equipment that permit the prompt discovery, retard the spread, and permit extinguishment of any fire before it has passed the incipient stage. This includes full coordination and cooperation with municipal fire departments.

1-1 Scope.

This standard shall apply to vessels during the course of construction, conversion, repairs, or while laid up. It shall not apply to situations where it is in conflict with or superseded by requirements of any government regulatory agency.

1-1.1 Emergency Exception.

Nothing in this document shall be construed as prohibiting the immediate drydocking of a vessel whose safety is imperiled, as by being in a sinking condition or by being seriously damaged. In such cases, all necessary precautionary measures shall be taken as soon as practicable.

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.

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.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Chapter 2 Construction, Conversion, and Repair

2-1 Inspection.

2-1.1

Regular inspections shall be made by a responsible person representing the shipyard during the entire construction, conversion, or repair period to note and initiate actions to eliminate fire hazards or to implement work procedures to keep these hazards to a minimum.

2-1.2

An inspection of a vessel shall be made by a yard representative to evaluate potential fire hazards as soon as practicable after the vessel enters a repair yard, but before any work is started. It shall be conducted jointly with a representative of the owner. Such inspections shall note housekeeping conditions, including location of dunnage and trash; the kind and amount of cargo aboard; and the type, amount, and condition of the vessel's fire protection equipment.

2-1.3

The types and approximate amounts of fuel oils and other flammable liquids in all cargo, bunker, deep, settler, and double bottom tanks shall be determined. Such determination shall include all associated piping systems.

2-1.4

The information obtained shall be distributed to the departments responsible for the fire safety of vessels while in the yard and to the various production departments involved.

2-1.5

For minor repairs, the inspection shall be permitted to be limited to the actual working area and adjacent compartments. Supplementary information necessary for fire and explosion prevention shall be obtained.

2-2 Rubbish, Waste Materials, Oil Spills, and General Care.

2-2.1

Work areas shall be kept clean. All accumulations, and particularly combustible rubbish, refuse, and waste materials, shall be collected and safely disposed of as they accumulate.

2-2.2

Uncrating of equipment or working materials shall be accomplished before taking the contents aboard ship unless there is a risk of damage from handling, in which case the consignment shall be taken aboard to be uncrated. All crating and packing material shall be removed immediately to a remote location ashore.

2-2.3

Protective coverings, e.g., tarpaulins, used to protect machinery and equipment shall be either noncombustible or fire retardant approved material.

2-3 Smoking.

Smoking shall not be permitted in designated hazardous areas. “No Smoking” signs shall be prominently posted in all prohibited areas.

2-4 Storage of Explosives, Flammable Material, and Dangerous Cargo.

2-4.1*

The storage of explosive, flammable, or combustible materials shall not be permitted on or in close proximity to vessels in course of construction, conversion, or repair.

Exception: Ship’s fuel and standard ship’s stores stowed in specifically designated spaces.

2-4.2

Vessels carrying explosives or other dangerous cargo such as flammable gases, hazardous chemicals, and flammable liquids, but excepting ship’s fuel and storage in specifically designated spaces, shall not be permitted to enter a repair yard until such materials have been removed. NFPA 306, *Standard for the Control of Gas Hazards on Vessels*, outlines the circumstances under which exceptions to this requirement shall be permitted to be exercised with respect to gas hazards.

2-5 Use of Open-Flame or Spark-Emitting Devices.

2-5.1

It shall be the responsibility of yard management to determine that any hot work or other fire- or spark-producing operations proceed with safety.

2-5.2

Where there is any danger of fire caused by hot work, despite the fact that ordinary precautions are employed, a fire watch with suitable portable fire-fighting equipment shall be provided to stand by during such operations ready to extinguish any incipient fire that might occur. The employees acting as the fire watch shall be instructed as to the fire hazards anticipated and how to use the fire extinguishing equipment provided. Special attention shall be paid to opposite sides of the bulkheads or decks where hot work is to be done to be certain that there are no combustible materials, painted surfaces, wiring runways, etc., in contact with, or in close proximity to, such bulkheads or decks that can be damaged by heat or fire.

2-5.2.1 When it is necessary to remove combustible insulation to a safe distance from the location where welding or burning is to be done, special care shall be taken to prevent sparks or hot slag from entering exposed insulated spaces. Doorways, hatch and tank openings, portholes, etc., shall be protected where there is a danger of sparks or hot slag dropping or ricocheting into such openings and igniting combustible materials. Hot work shall not be done on vessels where there is a danger of sparks or hot slag falling into oil slicks on the waters beneath.

2-5.2.2 Where hot work processes cannot be properly safeguarded for making necessary repairs, such repairs shall be accomplished by safer means, such as by drilling, sawing, bolting, or other appropriate means.

2-5.3

The riveting of furnaces shall not be permitted in confined spaces or in close proximity to combustible materials.

2-5.4

Before any hot work involving riveting, welding, burning, heating, or other fire- or spark-producing operations is started in or on any fuel spaces, including fuel tanks of motor-driven lifeboats, or other areas that contain or have contained flammable or combustible liquids or vapors, including freshly painted areas, certification shall be obtained in accordance with NFPA 306, *Standard for the Control of Gas Hazards on Vessels*.

2-5.5

Equipment such as blow torches and cutting and welding apparatus shall be stored so as to prevent tampering by unauthorized persons. Oxygen, acetylene, and other flammable gas lines shall be disconnected at the source of supply at the end of each working shift, and the discharge end of the hose removed from below decks or enclosed spaces. During meal periods or other extended nonwork periods, lines shall be disconnected at the source of supply.

2-5.5.1 Only oxygen, acetylene, and other flammable gas hoses in good repair shall be used. Where gases are supplied from portable cylinders, the portable cylinders shall not be placed below the main deck, in confined spaces, or under overhanging decks. Portable outlet headers from piped systems shall comply with the provisions of NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*.

2-5.6

Electric welding cables shall be inspected frequently and cables with damaged insulation shall be reinsulated or replaced. Cables shall be triced-up off steel decks, bulkheads, or wherever possible to reduce the possibility of short-circuiting or grounding. Where cables must be run in areas of personnel or vehicular traffic, suitable protection shall be provided to prevent crushing the cables. When not in use, electrodes shall be removed from holders and the holders so placed that they will not cause arcing or electrical short circuits.

2-5.7

Vessels in drydock shall be suitably grounded.

2-5.8

Heating for the personal comfort of employees or for other reasons shall be done by means of steam, hot water, or electricity using the vessel's heating facilities as far as practicable. Where salamanders must be used, they shall be mounted on 4-in. (102-mm) legs and shall be permitted only where someone is constantly in attendance and where adequate ventilation is provided. They shall be located a safe distance from combustible materials and so arranged as to avoid any danger of upset. Use of wood kindling fuel shall not be permitted. Under no conditions shall compressed air or oxygen be discharged into salamanders to increase the rate of burning.

2-6 Temporary Electrical Installations.

2-6.1

Electrical wiring and equipment of a temporary nature shall be substantially installed in such a manner as to be safe from physical damage and shall be frequently inspected. Defects in wiring, fixtures, or equipment of a type liable to create dangerous conditions shall be promptly remedied. Portable equipment shall be grounded and provided with overcurrent protection and shall be disconnected when not in use.

2-6.1.1 When temporary wiring and equipment is needed in hazardous locations, such wiring and equipment shall conform to the provisions of Articles 500 through 503 of NFPA 70, *National Electrical Code*.®

2-6.2

Electric current to the vessel's lighting system shall be cut off when no work is being done.

Exception: Where lights are required for inspection and safety purposes, the vessel's lighting system shall remain active.

2-6.3

The vessel's permanent lighting system shall be used when conditions permit.

2-6.4

Temporary, portable electric lights shall be used in accordance with NFPA 70, *National Electrical Code*.

2-6.5

Temporary electrical wiring shall be installed and maintained in a safe manner and shall be provided with overcurrent protection; installations in accordance with the provisions of Article 305 of NFPA 70, *National Electrical Code*, shall constitute compliance with this requirement. Such wiring and lamps shall not be placed in direct contact with combustible materials. Makeshift hangers, such as nails, which might damage wiring insulations, shall not be used. Where temporary wiring cables are run in areas of personnel or vehicular traffic, they shall be triced-up to prevent physical damage. Protective guards shall be installed on all lights subjected to physical damage.

2-7 Application of Paints and Other Flammable Compounds.

2-7.1

No welding, burning, or other open-flame or spark-producing machines or operations such as chipping, grinding, etc., shall be permitted in close proximity to the application of flammable paints or other flammable compounds. Adequate ventilation shall be provided to maintain the atmosphere at no more than 10 percent of the lower explosive limit or below the lower limit of toxicity for that particular material, as determined by a certificated marine chemist. In all instances, precautions and application instructions of the manufacturer shall be obtained and observed. Monitoring of these areas shall be carried out by a designated competent person.

2-8 Protection to Door Openings.

2-8.1

As work advances, so far as practicable, all door openings shall be provided with permanent doors.

2-8.2

In order to minimize the spread of fire, all doors and personnel accesses shall be kept completely closed except as required by the work. All other openings, e.g., vent ducts, shall be kept completely closed wherever practicable.

2-8.3

Where doors are kept locked to prevent theft or unauthorized entry, the keys shall be made available to the guard and fire brigade, or shall be located at a designated place aboard where they can be obtained without delay in emergencies by such personnel.

2-9 Staging and Miscellaneous Structures.

2-9.1

Staging other than metal or fire retardant treated wood shall be removed as soon as its purpose has been served.

2-9.2

Small buildings on or under shipways shall be restricted to those absolutely necessary and shall be of noncombustible construction.

2-10 Watch Service.

2-10.1

During the outfitting of new vessels, or in the case of vessels berthed for construction, conversion, or repair operations, a competent guard shall be on duty at all times when work is not in progress.

2-10.2

Where central station systems are not feasible or are not deemed necessary, an approved portable clock system shall be provided on the vessel during the outfitting, repair, or conversion period.

2-10.3

Watch service shall also be provided on the shipways during earlier stages of construction if a fire hazard exists due to completion of another vessel, combustibility of ways, stocks, and staging, and any significant obstruction or congestion caused by the proximity of adjacent structures.

2-10.4

Before going on duty, guards shall be informed of locations where riveting, welding, burning, or other hot work has been performed in the vicinity of combustible material while work is in progress. They shall also be advised of the locations of freshly painted areas, tanks containing oil, or other hazardous conditions. All such locations shall be inspected while work is in progress and as soon as practicable after work has been stopped. The regular watch force shall be assisted by other competent persons when necessary in order to complete the inspection within a reasonable period. The guards shall be required to give further special attention to these locations during their rounds so as to ensure against the spread of any previously undetected fires.

2-10.5

Guards shall be familiar with the location of all items of fire equipment on vessels, inspect them during their daily tours of inspection, and know how to use them.

2-11 Fire Alarm Service.

2-11.1

A suitable means of alerting all persons aboard the vessel shall be provided and clearly identified. Instructions on what to do in case of fire shall be posted at points of vessel access.

2-11.2

Where central station or fire alarm supervised guard service is not provided, telephones shall be available at convenient locations on or near vessels and connected to a central office where someone is constantly on duty.

2-11.3

Provisions shall be made for the establishment, marking, and maintenance of proper fire lanes at ways and berths.

2-11.4

Ways, hulls, and berths shall be prominently identified. Yard layout diagrams shall be provided for public fire fighting whenever the yard is primarily dependent upon those facilities for fire protection.

2-12 Fire Protection Equipment.

2-12.1*

Water with adequate pressure for fire extinguishing purposes shall be available to all parts of vessels in the course of construction, conversion, and under repair. One-and-one-half-inch (38.1 mm) and $2^1/_2$-in. (63.5 mm) lines of adequate length connected to shore hydrants for hose connections shall lead to points on vessels convenient for use in an emergency. Adequate supplies of spare hose and nozzles shall be readily available. Due regard shall be given to the capacity of existing shore hydrants to ensure that an adequate water supply is available.

2-12.2

Temporary pipe risers with hose connections supplied by shore lines shall be installed at the shipways, and a supply of hose shall be available at such connections on the various decks of vessels under construction. These risers shall be installed in the ratio of one for each 200 ft (62 m) of vessel length.

2-12.3*

While vessels are at berths or in drydock, temporary hose lines supplied by shore connections shall be placed aboard the vessels connected and ready for use, in the ratio of at least one hose line for each 200 ft (62 m) of vessel length. Where this is deemed unnecessary due to the size and type of vessel involved, hose lines shall be provided at the berthing spaces or drydocks.

2-12.4

Hose line connections or hydrants shall be provided with adapters to permit the connection of shore fire department hose.

2-12.5

On vessels under repair, the vessel's fire system piping, where the system is intact and capable of being used, shall be connected to water supplies from the yard by means of temporary shore to ship connections.

2-12.6

Hose lines or approved portable fire-fighting and extinguishing appliances such as hand extinguishers, in suitable numbers for Class A, Class B, and Class C fires, shall be provided at convenient locations throughout vessels. Portable extinguishers shall be provided and used in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*.

2-12.7

Alternate means shall be available for extinguishing Class A, Class B, and Class C fires that cannot be controlled by the limited capacity of portable hand extinguishers.

2-13* Fire Brigade.

Designated employees shall form the nucleus of a fire brigade and shall be thoroughly drilled in the use of extinguishing equipment provided, including the laying of hose lines, the handling of hose streams and special extinguishing equipment, and the use of self-contained breathing apparatus. Drills shall be held at least once a month.

Exception: This does not apply where a shipyard fire department with paid members is maintained.

2-14 Vessel Stability during Fire Fighting.

2-14.1

After an outbreak of fire, at the first indication of lack of stability, the discharge of fire streams shall be reduced to the minimum necessary to prevent the spread of fire. Effective means shall be taken to prevent capsizing of the vessel as soon as the extent of the flooding indicates there could be danger from lack of stability.

2-14.2

On vessels under repair, the vessel's pumping facilities, or a shore substitute, shall be in condition and ready to free the bilges of water whenever it tends to accumulate. Scuppers leading from all decks below the main deck to the bilge shall be maintained free.

2-14.3

Provision shall be made for the withdrawal of any vessel in the event that fire makes withdrawal necessary.

2-15 Testing of Fire Protection Equipment.

2-15.1

Water-based fire protection systems shall be tested in accordance with NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*.

2-15.2

Protected spaces shall be evacuated prior to performing testing or maintenance on a gaseous fire extinguishing system.

Exception: Unless suitable safeguards are in place, such as physical isolation of the system or the provision of breathing apparatus to persons within the space.

Chapter 3 Lay-Up

3-1 Application.

3-1.1

This chapter applies to all vessels declared as laid up by the owner or operator, without a full crew, but with equipment either in operable condition or requiring a minimum of work to restore it to service. This chapter does not apply to vessels in a long term inactive status (“mothballed”), requiring extensive work to return to active service, or to vessels in a reduced operating status. It also does not apply to those vessels in routine shipyard maintenance availability (e.g., two year drydock) or to those in emergency availability for repairs.

3-1.2

This chapter is primarily intended for large self-propelled vessels, although it is applicable to all other vessels to varying degrees. Where a vessel cannot satisfy a requirement either because of its design (barges typically do not have fire mains) or because the vessel is not required to have equipment or systems on board (not all vessels are required to have an International Shore Connection), it need not satisfy that requirement.

3-1.3

All repairs, reconstruction, conversion, and alteration performed during lay-up shall satisfy the requirements of Chapter 2 of this standard.

3-2 Governmental Authorities.

Lay-up locations and procedures shall satisfy the current Coast Guard Captain of the Port requirements. All U.S. flag vessels that maintain their Certificate of Inspection shall continue to satisfy all applicable Coast Guard regulations.

3-3* General Considerations for Lay-Up Locations.

The following factors shall be considered in choosing a lay-up site:

3-3.1

Sufficient water depth at all tidal stages year round.

3-3.2

The presence of a fire alarm box, telephone, or other reliable means of communication.

3-3.3

Freedom from high humidity, and very low temperature extremes, which could affect the fire main system.

3-3.4*

The arrangement of vessel moorings, singly or in groups, to facilitate vessel movement in case of fire or other emergency.

3-3.5

The availability of fenders or camels of ample size alongside at areas of possible or actual contact with other vessels or land structures.

3-3.6*

The availability of towing craft and waterborne or land-based fire-fighting assistance, or both.

3-3.7

The availability of anchors not already in use for emergency deployment.

3-3.8

The arrangement of the vessel's equipment so that personnel can part or slip the anchor chain.

3-4 Lay-Up Berths at Dock.

3-4.1

Where the lay-up berth is adjacent to a wharf, pier, or other land-connected structure, it shall be free from exposure to potential fire and explosion hazards and provide ready access for fire-fighting equipment. Piers shall satisfy the requirements of NFPA 307, *Standard for the Construction and Fire Protection of Marine Terminals, Piers, and Wharves*.

3-4.2

Vessels shall be moored singly at the lay-up berth unless there is access for shore-based fire-fighting and salvage equipment to the outboard nested vessels.

3-5 Vessel Preparation.

3-5.1 Sea Valves.

Sea suction for fire mains intended for immediate use shall not be covered and shall be kept clear from fouling.

3-5.2 Escape Preparation.

Tow wires (fire warps) shall be secured at the bow and stern of each vessel and paid out through suitable hawse pipes or chocks so that the free end of the wire is readily accessible to tug boats for towing purposes. NFPA 307, *Standard for the Construction and Fire Protection of Marine Terminals, Piers, and Wharves*, contains specifications for fire warps.

3-6 Power Source.

3-6.1

There shall be a source of power that might be from land, from another vessel, or on the vessel for lighting, flooding alarms, fire fighting, fire detection systems, and bilge pumping through the ship. This source shall be maintained and immediately available. The power source shall not be a battery.

3-6.2

Where the service or emergency source of power is a portable generator set located on the weather deck, selection and placement shall take into account fire safety considerations of the fuel system, exhaust system, fire-fighting systems, weather protection, and electrical installation and electrical protection devices.

3-7 Planning and Station Bills.

3-7.1

There shall be standard and emergency communication plans between vessel and shore.

3-7.2

There shall be contingency plans for fire fighting (including coordination with local fire departments), heavy weather, use of tug boats, movement of the vessel, and emergency evacuation of personnel.

3-7.3

A fire station bill must be conspicuously posted for all personnel on the vessel, and safety observers for each work party shall be identified. Personnel shall be trained to perform their safety and emergency duties.

3-7.4

Fire control plans showing general arrangements, fire-fighting equipment (including clear indication of which systems are operational), fire detection systems, ventilation systems, fire-resistant boundaries, and means of escape shall be available in a prominently marked weathertight enclosure outside the deckhouse.

3-8 General Care and Cleanliness.

3-8.1

Vessels laid up shall be kept thoroughly clean throughout. Any accumulations, particularly combustible rubbish, refuse, and waste material, shall be collected and disposed of promptly.

3-8.2

Galley exhaust grease traps shall be cleaned prior to lay-up. If in use by watch personnel, the traps shall be inspected at least monthly and cleaned as necessary.

3-8.3

Smoking shall not be permitted aboard laid up vessels except at locations specifically designated and approved as smoking areas.

3-8.4

Protective coverings, e.g., tarpaulins, used to protect machinery and equipment shall be either noncombustible or fire retardant approved material.

3-8.5

All liquid and gaseous cargoes shall be offloaded from the vessel, and all vessels shall be certified in accordance with NFPA 306, *Standard for the Control of Gas Hazards on Vessels*, immediately prior to being laid up and weekly thereafter until conditions are stabilized, subject to requirements of regulatory authorities.

3-8.6

Machinery space bilges shall be clear of all debris, oil, and other flammable materials.

3-9 Ventilation — Closure of Openings.

3-9.1

All spaces, except those that are sealed, shall be ventilated and accessible for ready inspection.

3-9.2

All cargo and ship's service tanks, double bottom, deep, peak, settling, day, and all other miscellaneous tanks used for the vessel's fuel oil and lubricants shall have their manhole cover plates closed and secured and all exterior traces of oil or lubricants removed.

3-9.3

All vents serving tanks used for the vessel's fuel and lubricants, and all vents serving adjacent cofferdams, shall be fitted with flame screens or flame arresters, as appropriate, and left open.

3-9.4

Except where required for distribution of humidified air, all closures, including fire dampers (but not automatic fire dampers), in ventilation systems shall be closed. All automatic fire dampers shall be maintained in operating condition.

3-9.5

All ports, doors, and other openings in the vessel's shell or deck houses, and all hatches shall be kept closed, covered, or sealed. All interior doors shall be kept closed.

Exception: Hatches used for ventilation and access to holds shall be permitted to be open.

3-10* Storage of Explosive and Flammable Materials.

3-10.1

Explosives, flammable gases, hazardous chemicals, and flammable liquids, other than ship's fuel, shall not be retained aboard vessels if the lay-up is intended to exceed 60 days.

3-10.2

Fuel shall be drained from tanks and fuel systems of auxiliary motor craft and removed from the vessel if lay-up is intended to exceed 60 days.

3-10.3

When fuel is transferred, unless the fueling system is hard piped, the tank, hose, and machinery shall be bonded.

3-11 Temporary Heating Arrangements.

Open-flame heaters are prohibited. Temporary heating sources shall be disconnected when the vessel is unattended. When heat tracing cable is used in a hazardous area, a ground-fault circuit-interrupter shall be used in conjunction with the overcurrent device.

3-12 Temporary Electrical Wiring.

3-12.1

Electrical wiring for temporary use shall comply with the requirements of 2-6.1.

3-12.2

Portable electrical equipment shall be the double insulated type or provided with a grounding conductor in the supply cable and disconnected when not in use.

3-13 Watches.

3-13.1

There shall be a watch maintained whenever there is no functioning automatic fire detection and alarm system.

3-13.2

Watch service shall be established to monitor the vessel's condition and to detect unauthorized access.

3-13.3

The watch personnel shall be capable of performing emergency procedures, operating fire protection equipment, and assisting in removing the vessel from the lay-up location. Oxygen breathing apparatus or similar device shall be provided and maintained for immediate use.

3-13.4

The watch service shall be equipped for and satisfy the requirements of 2-10.5.

3-14 Fire Detection and Fire Alarms.

3-14.1

Where automatic fire detection and fire alarm systems are not installed or operable, the requirements of 2-11 shall be satisfied.

3-14.2

Vessels shall maintain the capability of two-way voice radio or telephone emergency communication. Portable radios satisfy this requirement.

3-14.3

If fire detection and fire alarm equipment is installed in lieu of the requirements of 3-13, it shall be capable of notifying appropriate personnel.

3-15 Fire Protection.

3-15.1 Access.

Gangways, ladders, or other facilities providing access to the vessel or vessels for fire-fighting purposes shall be available at all times.

3-15.2 Vessel Stability.

The applicable requirements of 2-14 shall be satisfied in the event of fire.

3-15.3 Fire Protection Equipment.

Any onboard equipment that is necessary for protection of the vessel shall be maintained in proper operating condition.

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 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, 1995 edition.

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1994 edition.

NFPA 70, *National Electrical Code, 1996 edition.*

NFPA 306, *Standard for the Control of Gas Hazards on Vessels*, 1993 edition.

NFPA 307, *Standard for the Construction and Fire Protection of Marine Terminals, Piers, and Wharves*, 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 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-1-2 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 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-2-4.1

Flammable and inflammable have the same meaning. The term "flammable liquids" in this instance includes all flammable and combustible liquids having a flash point below 140°F (60°C) closed cup test. Reference OSHA regulations for this definition.

A-2-12.1

The minimum nozzle residual pressure should be 60 psi (4.14×10^{5} Pa) at 100 gpm (6.3×10^{-3} m^3/s). The minimum total flow should be 500 gpm (3.15×10^{-2} m^3/s) for ships approximately 300 ft (93 m) in length, having small interior compartments such as small passenger vessels. The minimum total flow for larger ships having 2000 ft^2 (186 m^2) in area or smaller compartments should be 1000 gpm (6.3×10^{-2} m^3/s). Ships, such as cargo ships, having compartments larger than 2000 ft^2 (186 m^2) should have at least 1500 gpm (9.45×10^{-2} m^3/s) available. Ships having large cargo holds may require higher capacities.

A-2-12.3

The hose lines should be nominal $1^1/_2$ in. (38.1 mm) or $2^1/_2$ in. (63.5 mm) in size, or a combination of both sizes, and of sufficient length so that any part of the vessel may be reached by at least one line.

A-2-13

For further details, refer to NFPA 600, *Standard on Industrial Fire Brigades*.

A-3-3

In addition to the fire related considerations for selecting a site for lay-up, the following general safety guidelines should also be considered: protection from open seas and surge; good holding ground for anchors, clear of wrecks, cables, or other obstacles; clear of known cyclone or tidal wave danger; clear of open roadstead anchorages or shipping channels; clear of high velocity or turbulent tidal or river currents; clear of floating hazards or significant amounts of moving ice; clear of hazardous shore facilities; and clear of industrial waste discharges.

A-3-3.4

The following guidelines should be considered when mooring vessels: the number, size, arrangement, and condition of the mooring lines shall be sufficient to hold the vessel secure, based on the vessel's freeboard and draft, and the extreme climatic, tidal, and current conditions in the area.

For vessels at anchorage the following guidelines should be considered: the size and scope of anchor chain and number and size of anchors shall be based on the freeboard, depth of water, type of bottom, and extreme climatic, tidal, and current conditions in the area.

A-3-3.6

The fire risk, proximity to port facilities, and location (relative to the pier or waterway) should be considered when determining the reasonable distance and time for availability of assistance.

A-3-10

Flammable and inflammable have the same meaning. The term "flammable liquids" in this instance includes all flammable liquids having a flash point below 140°F (60°C) closed cup and having a vapor pressure not exceeding 40 psi absolute (2068.6 mm Hg) at 140°F (60°C). Reference Coast Guard regulations for this definition.

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 600, *Standard on Industrial Fire Brigades*, 1992 edition.

B-1.2 Other Publications.

B-1.2.1 U.S. Government Publications. USGPO Superintendent of Documents, Washington DC 20402.

Code of Federal Regulations

33 CFR

46 CFR 49 CFR

29 CFR Part 1915.

B-1.2.2 American Bureau of Shipping. ABS, 45 Eisenhower Dr., Paramus, NJ 07652.

"Guide for Lay-Up and for Reactivation of Laid-up Ships" 1986.

NFPA 318

1995 Edition

Standard for the Protection of Cleanrooms

1995 Edition

This edition of NFPA 318, *Standard for the Protection of Cleanrooms*, was prepared by the

Technical Committee on Cleanrooms 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.

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 318

The Committee on Cleanrooms was formed in 1988 and held its first meeting during May of that year. The Committee was organized into Chapter Subcommittees that separately prepared individual chapters and related appendix material for review by the full Committee at meetings held October 1988, March 1989, September 1989, March 1990, September 1990, and June 1991.

The standard was submitted and adopted at the Fall Meeting in Montréal, Quebéc, Canada, November 18-20, 1991. The 1992 edition was the first edition of this standard.

The standard was revised in 1995.

Technical Committee on Cleanrooms

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Dennis Kirson, *Vice Chair*
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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.

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 cleanrooms.

NFPA 318

Standard for the Protection of Cleanrooms

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.

This standard applies to all semiconductor facilities containing what is herein defined as a cleanroom or clean zone, or both.

1-2* Purpose.

This standard is intended to provide reasonable safeguards for the protection of facilities containing cleanrooms from fire and related hazards. These safeguards are intended to provide protection against injury, loss of life, and property damage.

1-3 Applicability.

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 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 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.

Access Floor System. An assembly consisting of panels mounted on pedestals to provide an under-floor space for the installations of mechanical, electrical communication, or similar systems or to serve as an air-supply or return-air plenum.

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.

Clean Zone. A defined space in which the concentration of airborne particles is controlled to specified limits.

Cleanroom. A room in which the concentration of airborne particles is controlled to specified limits.

Compressed Gas. Any material or mixture having in the container an absolute pressure exceeding 40 psi (pounds per square inch) at 70°F (275.8 kPa at 21.1°C) or, regardless of the pressure at 70°F (21.1°C), having an absolute pressure exceeding 104 psi at 130°F (717 kPa at 54.4°C), or flammable liquid having a vapor pressure exceeding 40 psi absolute at 100°F (275.8 kPa at 37.8°C) as determined by ASTM D323, *Standard Test Method for Vapor Pressure of Petroleum Products*.

Explosion. An effect produced by the sudden violent expansion of gases, which can be accompanied by a shockwave or disruption, or both, of enclosing materials or structures. An explosion might result from chemical changes such as rapid oxidation, deflagration, or detonation; decomposition of molecules, and runaway polymerization (usually detonations); or physical changes (e.g., pressure tank ruptures).

Flammable Vapors. A concentration of flammable constituents in air that exceeds 10 percent of its lower flammable limit (LFL).

Hazardous Chemical.* Any solid, liquid, or gas that has a degree-of-hazard rating in health, flammability, or reactivity of Class 3 or 4 as ranked by NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials*.

Interface. That place at which independent systems meet and act on or communicate with each other.

Interlock. An arrangement in which the operation of one part or mechanism automatically brings about or prevents the operation of another.

Liquid. For the purpose of this code, any material that has a fluidity greater than that of 300 penetration asphalt when tested in accordance with ASTM D5, *Standard Test Method for Penetration of Bituminous Materials*. When not otherwise identified, the term liquid shall mean both flammable and combustible liquids.

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).

Flammable Liquid. A liquid having a flash point below 100°F (37.8°C) and having a vapor pressure not exceeding 40 psia (2 068 mm Hg) at 100°F (37.8°C) shall be known as a Class I liquid.

Class I liquids shall be subdivided as follows:

Class IA liquids 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 liquids 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 liquids shall include those having flash points at or above 73°F (22.8°C) and below 100°F (37.8°C).

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 Degrees C*, shall be considered noncombustible. (*See NFPA 220, Standard on Types of Building Construction.*)

Pass-through. An enclosure installed in a wall with a door on each side that allows chemicals, production materials, equipment, and parts to be transferred from one side of the wall to the other.

Pyrophoric. A chemical with an autoignition temperature in air at or below 130°F (54.4°C).

Restricted Flow Orifice. A device located in the gas cylinder valve body that restricts the maximum flow rate to 1.06 ft^3/min (30 L/min).

Smoke. The airborne solid and liquid particulates and gases evolved when a material undergoes pyrolysis or combustion, together with the quantity of air that is entrained or otherwise mixed into the mass.

Standby Mode. A mode wherein all flow of flammable gas or liquid ceases and heaters have power removed.

Third Party. A professional, qualified as the result of training, education, and experience, who can perform a compliance and hazardous analysis of process equipment in accordance with this standard.

Tool. Any device, storage container, work station, or process machine used in the cleanroom.

Work Station. A defined space or an independent principal piece of equipment using hazardous chemicals within a cleanroom or clean zone, where a specific function, a laboratory procedure, or a research activity occurs. The work station might include connected cabinets and contain ventilation equipment, fire protection devices, sensors for gas and other hazards, electrical devices, and other processing and scientific equipment.

Chapter 2 Fire Protection

2-1 Automatic Fire Extinguishing Systems.

2-1.1 General.

Wet pipe automatic sprinkler protection shall be provided throughout facilities containing cleanrooms and clean zones.

2-1.2 Automatic Sprinkler Systems.

2-1.2.1* Automatic sprinklers for cleanrooms or clean zones shall be installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, and shall be hydraulically designed for a density of 0.20 gpm/ft^2 [8.15 (L/min)/m^2] over a design area of 3000 ft^2 (278.8 m^2).

2-1.2.2* Approved quick response sprinklers shall be utilized for sprinkler installations within down-flow airstreams in cleanrooms and clean zones.

2-1.2.3* Sprinklers shall be installed in gas cylinder cabinets containing flammable gases.

2-1.2.4* Automatic deluge water spray protection shall be provided over silane gas cylinders in open dispensing systems described in 6-4.2.1(b). This protection shall be activated by ultraviolet/infrared detectors.

Exception: Where the open dispensing system is remotely located from structures and designed to mitigate the effects of detonation, the automatic deluge water spray system shall not be required.

2-1.2.5 Automatic sprinkler protection shall be designed and installed in the plenum and interstitial space above cleanrooms in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, for a density of 0.20 gpm/ft^2 [8.15 (L/min)/m^2] over a design area of 3000 ft^2 (278.8 m^2).

2-1.2.6 All combustible exhaust ducts shall have interior automatic sprinklers when the largest interior cross-sectional diameter is equal to or greater than 10 in. (254 mm).

Exception: Ducts approved for use without internal automatic sprinklers.

2-1.2.6.1* Sprinklers installed in duct systems shall be hydraulically designed to provide 0.5 gpm (1.9 L/min) over an area derived by multiplying the distance between the sprinklers in a horizontal duct by the width of the duct. Minimum discharge shall be 20 gpm (76 L/min) per sprinkler from the five hydraulically most remote sprinklers. Sprinklers shall be spaced a maximum of 20 ft (6.1 m) apart horizontally and 12 ft (3.7 m) apart vertically.

2-1.2.6.2 A separate indicating control valve shall be provided for sprinklers installed in ductwork.

2-1.2.6.3* Drainage shall be provided to remove all sprinkler water discharged in ductwork.

2-1.2.6.4 Where corrosive atmospheres exist, duct sprinklers and pipe fittings shall be manufactured of corrosion resistant materials or coated with approved materials.

2-1.2.6.5 The sprinklers shall be accessible for periodic inspection and maintenance.

2-1.2.7* Automatic sprinklers shall be provided in pass-throughs used to convey combustible chemicals.

2-1.2.8* Combustible Tools.

2-1.2.8.1 Where the horizontal surface of a combustible tool is obstructed from ceiling sprinkler discharge, automatic sprinkler protection that covers the horizontal surface of the tool shall be provided.

Exception: An automatic gaseous-fire-suppression local surface application system shall be permitted as an alternative to sprinklers. Gaseous extinguishing systems shall be actuated by IR or UV/IR optical detectors. Detectors shall be tested monthly.

2-1.2.8.2 Where the work station is of combustible construction, automatic sprinkler protection shall be provided in the exhaust transition piece.

Exception: An automatic gaseous-fire-suppression interior application system shall be permitted as an alternative to sprinklers.

2-1.2.8.3* Where the branch exhaust ductwork is constructed of combustible material, automatic sprinkler protection shall be provided within the work station transition piece or the branch exhaust duct.

2-1.2.8.4 Where the branch exhaust ductwork is subject to combustible residue buildup, regardless of the material of construction, automatic sprinkler protection shall be provided.

2-2 Alarm Systems.

2-2.1

The discharge of an automatic fire suppression system shall activate an audible fire alarm system on the premises and an audible or visual alarm at a constantly attended location.

2-2.2*

Where the potential exists for flammable gas concentrations to exceed 20 percent of the LFL, a continuous gas detection system shall be provided.

2-2.3

Signal transmission for alarms designed to activate signals at more than one location shall be verified at each location during each test of the alarm system.

2-2.4

A manual notification system shall be provided to result in an audible alarm as in 2-2.1.

2-3 Detection Systems.

2-3.1*

A listed or approved air sampling smoke detection system shall be provided in the cleanroom return airstream at a point before dilution from make-up air occurs. The system shall have a minimum sensitivity of 0.03 percent per ft obscuration. The system shall be capable of monitoring particles to 10 microns or less. Where the system is of the light-scattering type, it shall have a minimum sensitivity of 0.03 percent per ft obscuration; where the system is of the cloud chamber type, it shall have a minimum sensitivity of 50,000 particles per millimeter.

2-3.2*

Smoke detection within a cleanroom air system shall result in an alarm transmission to a constantly attended location as well as a local alarm signal within the cleanroom that is distinctive from both the facility evacuation alarm signal and any process equipment alarm signals in the cleanroom.

2-3.3

Detection shall be provided at silane gas cylinders in open dispensing systems described in 6-4.2.1(b). Activation of detectors shall result in the closing of the cylinder automatic shutoff valves described in 6-1.2.

Chapter 3 Ventilation and Exhaust Systems

3-1 Air Supply and Recirculation Systems.

3-1.1

The location of outside air intakes shall be chosen to avoid drawing in hazardous chemicals or products of combustion coming either from the building itself or from other structures and devices.

3-1.2

High Efficiency Particulate Air (HEPA) and Ultra Low Penetration Air (ULPA) filter modules shall meet the combustibility requirements outlined in UL 586, *High-Efficiency, Particulate, Air Filter Units*.

3-1.3

Air supply and recirculation ducts, connectors, and appurtenances shall be constructed of noncombustible material such as aluminum steel or of Class 0 or Class 1 materials as tested in accordance with UL 181, *Standard for Safety Factory-Made Air Ducts and Air Connectors*.

3-1.4

Supply air ducts shall have a flame spread index of not more than 25 and a smoke-developed rating of not more than 50 when tested in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*.

3-2 Local Exhaust System.

3-2.1

Exhaust air discharged from cleanrooms shall not be recirculated. Ducts shall lead to the outside as directly as practicable and shall discharge above the roof at a location, height, and velocity sufficient to prevent reentry of hazardous chemicals.

3-2.2

Energy conservation devices that create a risk of returning contaminants to the cleanroom air supply shall not be used in fume exhaust systems.

3-2.3

Air containing hazardous chemicals shall be conveyed through duct systems maintained at a negative pressure relative to the pressure of normally occupied areas of the building.

Exception: Downstream of fans, scrubbers, and treatment devices.

3-2.4

Work station exhaust ventilation shall be designed to capture and exhaust contaminants generated in the station.

3-3 Local Exhaust System Construction.

3-3.1*

Ribbed flexible connections shall not be used in exhaust duct connected to combustible work stations nor to work stations where combustible chemicals are used.

3-3.2

The entire exhaust duct system shall be self-contained. No portions of the building shall be used as an integral part of the system.

3-3.3

Two or more operations shall not be connected to the same exhaust system when the combination of the substances removed might create a fire, explosion, or chemical reaction hazard within the duct system.

3-3.4

Exhaust ducts penetrating fire resistance-rated construction shall be contained in an enclosure of equivalent fire-resistive construction.

3-3.5

Fire dampers shall not be installed in exhaust ducts.

3-3.6*

Exhaust duct systems shall be constructed of noncombustible materials or protected with sprinklers in accordance with 2-1.2.6.

Exception: Ducts approved for use without automatic sprinklers.

3-3.7

The exterior surface of nonmetallic exhaust ducts shall have a smoke developed rating of 25 or less when either the interior or exterior of the duct is exposed to fire, when tested in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*.

3-4 Duct Velocities.

Airflow in cleanroom exhaust systems shall be designed to ensure dilution such that flammable vapors are not conveyed in the ducts. (*See definition of flammable vapors.*)

3-5 Controls.

3-5.1

The exhaust ventilation system shall have an automatic emergency back-up source of power. The emergency power shall be designed and installed in accordance with NFPA 70, *National Electrical Code®*.

3-5.2*

The emergency power shall operate the exhaust system at not less than 50 percent capacity when it is demonstrated that the level of exhaust maintains a safe atmosphere.

3-5.3

Fire detection and alarm systems shall not be interlocked to shut down local exhaust fans automatically.

3-5.4

Dampers, where required for balancing or control of the exhaust system, shall be of a locking type.

3-5.5

The air-handling system shall be designed to provide smoke exhaust, or a dedicated smoke control system shall be provided.

Exception No. 1: Where contamination within the cleanroom is limited and recirculation will not affect adjoining areas, the above shall not be required.

Exception No. 2: Where the cleanroom is not Class 1000 or cleaner as defined in Federal Standard 209E, Cleanroom and Work Station Requirements, Controlled Environment, the above shall not be required.

Exception No. 3: Where the fume exhaust system is capable of smoke removal or preventing smoke migration, the above shall not be required.

3-5.6

A manually operated remote switch(es) to shut off the affected areas of the cleanroom air recirculation system(s) shall be provided at an approved location(s).

Chapter 4 Construction

4-1*

Cleanrooms rated Class 100 or cleaner in accordance with Federal Standard 209E, *Cleanroom and Work Station Requirements, Controlled Environment*, or cleanrooms having clean zones rated Class 100 or cleaner, shall have approved, noncombustible components for walls, floors, ceilings, and partitions.

4-2

Cleanrooms shall be separated from adjacent occupancies by 1-hour fire resistance-rated construction.

4-3

Cleanroom access floors shall be designed to resist a force of 0.5 G magnitude in seismic zones 1, 2, and 3, depicted in Figure 4-3.

Earthquake Zones

1-Maximum potential for earthquake damage — 3-Slight potential

2-Reasonable potential — 4 and 5-Earthquake protection not required

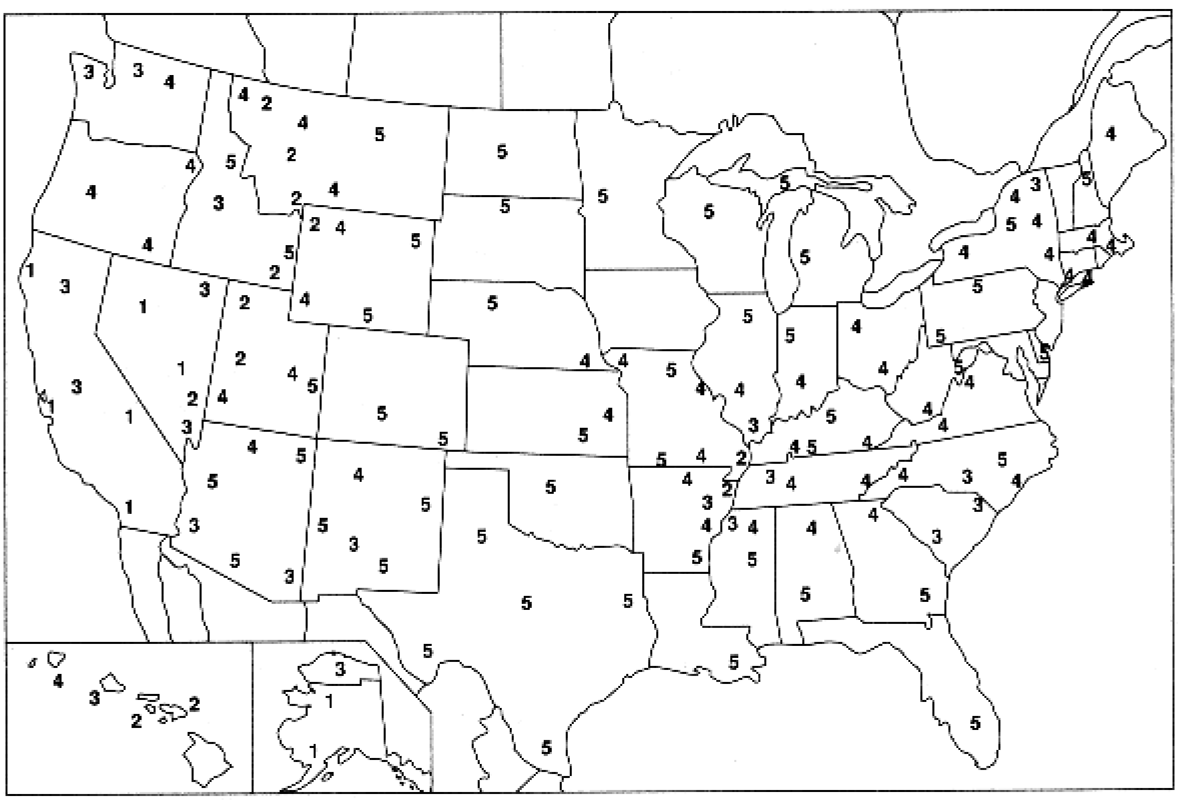

Figure 4-3 Seismic map.

Chapter 5 Chemical Storage and Handling

5-1 Hazardous Chemicals.

5-1.1*

Storage and handling of hazardous chemicals shall comply with applicable NFPA standards, including the following:

NFPA 30, *Flammable and Combustible Liquids Code;*

NFPA 33, *Standard for Spray Application Using Flammable and Combustible Materials;*

NFPA 43A, *Code for the Storage of Liquid and Solid Oxidizers;*

NFPA 43B, *Code for the Storage of Organic Peroxide Formulations;*

NFPA 70, *National Electrical Code;*

NFPA 385, *Standard for Tank Vehicles for Flammable and Combustible Liquids;* and

NFPA 386, *Standard for Portable Shipping Tanks for Flammable and Combustible Liquids*.

5-1.1.1 Hazardous chemicals storage and dispensing rooms shall be separated from the cleanroom by 1-hour fire resistance-rated construction.

5-1.1.2 Hazardous chemicals storage and dispensing rooms shall have a drainage system to an approved location, or the room shall serve as secondary containment for a hazardous chemical spill and fire protection water for a period of 20 minutes.

5-1.1.3 Hazardous chemicals in the cleanroom shall be limited to those needed for operations and maintenance. Quantities of hazardous chemicals shall be limited to those within the tool or the daily (24 hours) supply of chemicals needed.

5-1.1.4 Hazardous chemicals storage and dispensing rooms shall have mechanical exhaust ventilation as follows:

(a) Mechanical exhaust ventilation shall be at a minimum rate of one cu ft per min (cfm) per sq ft of floor area.

(b) Exhaust and inlet openings shall be arranged to prevent accumulation of vapors.

(c) For dispensing rooms, the mechanical exhaust ventilation system shall be connected to an automatic emergency back-up source of power.

5-1.1.5 Accidental Mixing.

5-1.1.5.1 Hazardous chemicals shall be stored within enclosed storage cabinets or work stations.

Exception: Within hazardous materials storage or dispensing rooms.

5-1.1.5.2 Incompatible chemicals shall not be stored in the same cabinet.

5-1.1.5.3 Storage cabinets shall be constructed of not less than 18 gauge steel. Doors shall be self-closing and shall be provided with a latching device.

5-1.1.6 Approved safety containers shall be used to store flammable liquids.

Exception: Where needed for purity, glass or plastic containers shall be permitted for quantities of 1 gal (4 L) or less per individual container.

5-1.1.7 Containers of chemicals shall be labeled as to their contents.

5-2 Flammable and Combustible Liquid Delivery Systems.

5-2.1

Class I and II liquids shall not be piped to deliver by gravity from tanks, drums, barrels, or similar containers. Dispensing devices for flammable and combustible liquids shall be of an approved type.

5-2.2

When pressurized systems are utilized, all materials used in the system will be compatible with the chemicals being dispensed.

5-2.3

The pressurized system shall be equipped with the following safeguards:

(a) Automatic depressurization vents in the case of fire. Vent to a safe location.

(b) Manual vents to allow for the removal of canisters. Vent to a safe location.

(c) Manual shutoff valves at the point of use.

(d) Only inert gas shall be used.

5-2.4

For pressurized delivery systems of 10 gal (38.8 L) or less, inert gases shall be used at 15 psi (1 bar) or less.

5-2.5

Pressurized delivery systems for flammable or combustible liquids shall be hydrostatically tested to 150 percent of the working pressure for 2 hours with no visible leakage or loss of pressure.

Exception: An inert gas shall be permitted to be used to pressure test systems in which water or water residue would be damaging or cost restrictive.

5-2.6

Pressurized delivery systems for flammable and combustible liquids shall be constructed of a ferrous metal.

5-2.7

Delivery pressure at the tool shall not exceed 15 psi (103 kPa).

5-2.8

Bulk delivery systems shall be equipped with the following safeguards:

(a) Excess flow protection.

(b) Secondary containment for spills.

(c) Manual shutdown at point of use and dispensing.

(d) Fill level monitors and automatic shutoff.

(e) Preset meter for automated delivery systems.

5-3 Container Delivery.

5-3.1*

In new buildings, hazardous chemicals shall not be permitted within an exit corridor. In existing buildings, hazardous chemicals shall be transported in approved chemical carts.

5-3.2

Hazardous chemicals shall not be dispensed or stored in exit access corridors.

5-3.3*

Chemical carts transporting or containing hazardous chemicals shall be designed so that the contents will be fully enclosed. They shall be capable of containing a spill from the largest single container transported, with a maximum individual container size of 5 gal (19 L). The capacity of carts used for transportation of hazardous chemicals shall not exceed 55 gal (208 L).

5-3.4

Incompatible chemicals shall not be transported simultaneously on the same hazardous chemical cart.

5-4 Waste Disposal.

5-4.1

Separate drainage systems shall be provided for incompatible materials.

5-4.2*

Drainage systems shall be labeled as to their intended contents in an approved manner.

5-4.3

Collection of chemicals shall be directed to containers compatible with the material being collected.

5-4.4

Flammable liquids shall be collected in approved containers.

5-4.5

During collection of flammable liquids the waste container shall be within secondary containment.

5-4.6

Chemical containers shall be labeled as to their contents in an approved manner.

5-4.7

Incompatible chemicals shall not be transported simultaneously on the same hazardous chemical cart.

5-5 Spill Protection.

5-5.1

Spill protection for liquid hazardous chemicals shall be provided where leakage from a fitting or tool terminates in an unoccupied or below-grade area.

5-5.2

Spill protection shall include secondary containment and a method of detecting a spill.

Chapter 6 Hazardous Gas Cylinder Storage and Distribution

6-1 Packaging.

6-1.1 Container Data.

The supplier shall accumulate and provide upon request the following information:

(a) Cylinder contents with description of the components.

(b) Cylinder serial number, material of construction, and standards used for construction and testing.

(c) Cylinder valve with restricted orifice, when provided. Date of manufacture, material of construction, and flow curve for the orifice.

(d) Description and date of last hydrostatic test.

6-1.2*

Cylinders containing pyrophoric gases shall be equipped with normally closed automatic shutoff valves that incorporate restricted flow orifices.

6-2 Transport to the Semiconductor Facility.

The operator of a vehicle transporting hazardous compressed and liquefied gases shall be trained in the handling of containers and the use of portable fire extinguishers. The operator shall be familiar with the site gas delivery procedures.

6-2.1

A leak check shall be performed on all gas cylinders prior to unloading from the transport vehicle.

6-2.2*

An emergency response program shall be developed to handle accidents connected with the delivery of gases.

6-3 Distribution Systems.

6-3.1

Material for tubing, piping, and fittings used for distribution of compressed and liquefied gases shall be compatible with those gases. The entire system shall be subjected to a pressure test at a minimum pressure of 20 percent over the maximum pressure available to the system but not less than 80 psi (552 kPa) for 2 hours with no discernible pressure drop.

6-3.2*

Materials for tubing, piping, and fittings used for the distribution of compressed and liquefied gases shall be of noncombustible construction or of combustible construction contained in a noncombustible outer jacket.

Exception: When double containment of highly corrosive gases is used, the use of combustible piping and a combustible outer jacket shall be permitted.

6-3.3

Tubing, piping, and fittings shall be welded.

Exception: Nonwelded connections and fittings shall be permitted to be used when housed in an exhausted enclosure or in an outside enclosure.

6-3.4

Distribution piping shall be leak tested in accordance with SEMI F1-90, *Specification for Leak Testing Toxic Gas Piping Systems*.

6-3.5*

Welders and pipefitters shall be trained and qualified for the specific function they are performing.

6-3.6*

Purge panels shall be provided at the cylinders on all compressed hazardous process gases when in use. (*See 6-4.3(j) for silane and silane mixes.*)

6-3.7

Gas cabinets or purge panels not located in gas cabinets shall be labeled with the process tools they serve, the type of gas, and the type of purge gas.

6-3.8*

Purge panels shall be constructed of materials compatible with gases conveyed, minimize leakage potential, provide for control of excess flow, and be equipped with an appropriate emergency shutoff.

6-3.9

Purge panels shall be designed to prevent backflow and cross contamination of purge gas or other process gases.

6-3.10

Check valves shall not be exposed to cylinder pressure if a cylinder has a pressure greater than 80 psi (552 kPa).

6-3.11

A manual isolation valve shall be provided on the process delivery line at the purge panel to permit removal of the purge panel for repair and maintenance.

6-3.12

Incompatible process gases shall not occupy the same gas cabinet.

6-3.13

Hazardous gas cylinder purge panels shall be provided with dedicated purge gas cylinders. Only purge panels serving compatible gases shall be permitted to share a purge cylinder.

6-3.14

Bulk gas systems shall not be used as the purge source for hazardous gas cylinder purge panels.

6-4 Silane and Silane/Nontoxic Mixes Storage and Dispensing Areas.

6-4.1

Cylinders shall be stored in storage areas external to the building.

6-4.1.1 Cylinders not located in bunkers shall be provided with a security open chain-link fence. The cylinders shall be separated from adjacent structures and the fence by a minimum distance of 9 ft (2.7 m).

6-4.1.2 The storage area shall be open on at least three sides with cylinders secured to steel frames. Where a canopy is provided, the height shall be a minimum of 12 ft (3.7 m).

6-4.2

Gases shall be dispensed from open dispensing racks.

6-4.3

Dispensing areas shall be provided with the following safeguards:

(a) Dispensing racks shall be located external to the building.

Exception: Where the weather conditions do not permit, the dispensing racks shall be in an approved bunker.

(b) Cylinders shall be separated from each other by a steel plate $^1/_4$ in. (6.3 mm) thick, extending 3 in. (76 mm) beyond the footprint of the cylinder. The steel plate shall extend from the top of the purge panel to 12 in. (305 mm) below the cylinder valve.

(c) Mechanical or natural ventilation at a minimum of 1 cfm/ft^2 (0.00047 m^3/s per 0.09 m^2) of storage and dispensing area shall be provided.

(d) Cylinders shall be provided with protection and detection in accordance with 2-1.2.5 and 2-3.3.

(e) Remote manual shutdown of process gas flow shall be provided near each gas panel. The dispensing area shall have an emergency shutdown for all gases that can be operated at a minimum distance of 15 ft (4.6 m) from the dispensing area.

(f) Exterior dispensing areas shall be separated from structures in accordance with Figure 6-4. The dispensing area shall be open on at least three sides with cylinders secured to steel frames. Where a canopy is provided, the height shall be a minimum of 12 ft (3.7 m).

(g) Gas vent headers or individual purge panel vent lines shall have a continuous flow of nitrogen. To prevent back diffusion of air into the vent line, a nitrogen flow shall be introduced. The nitrogen shall be introduced upstream of the first vent or exhaust connection to the header.

(h) Cylinders not located in bunkers shall be provided with a security open chain-link fence. The cylinders shall be separated from adjacent structures and the fence by a minimum distance of 9 ft (2.7 m).

(i) If mechanical ventilation is provided, the ventilation system shall be provided with an automatic emergency back-up source of power to operate at full capacity.

(j) Silane and silane mixes shall be equipped with automated purge panels.

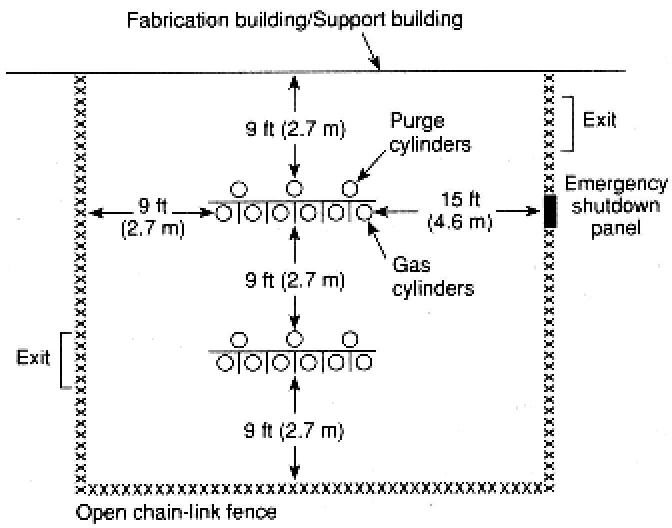

Figure 6-4 Silane dispensing area.

6-5* Silane/Toxic Mixes Storage and Dispensing Areas.

6-5.1

The storage area shall be located external to the building.

6-5.1.1 Cylinders not located in bunkers shall be provided with a security open chain-link fence. The cylinders shall be separated from adjacent structures and the fence by a minimum distance of 9 ft (2.7 m).

6-5.1.2 The storage area shall be open on at least three sides with cylinders secured to steel frames. Where a canopy is provided, the height shall be a minimum of 12 ft (3.7 m).

6-5.1.3 Where gas cabinets are used, only single-cylinder cabinets shall be used.

6-5.2

Silane/toxic mixes shall be dispensed from single-cylinder gas cabinets.

6-5.3

Dispensing areas shall be provided with the following safeguards:

(a) The dispensing areas shall be located external to the building.

Exception: Where the weather conditions do not permit, the dispensing area shall be in an approved bunker.

(b)* Silane/toxic mixes located in cabinets shall be provided with mechanical ventilation at a minimum of 200 ft per min (fpm) (0.762 m/s) across the cylinder neck and the purge panel. The ventilation system shall be provided with an automatic emergency back-up source of power to operate at full capacity.

(c) Remote manual shutdown of process gas flow shall be provided outside each gas cabinet.

(d) Gas vent headers or individual purge panel vent lines shall have a continuous flow of nitrogen. To prevent back diffusion of air into the vent line, a nitrogen flow shall be introduced. The nitrogen shall be introduced upstream of the first exhaust connection to the header.

(e) Exterior dispensing areas shall be separated from structures in accordance with Figure 6-5. The dispensing area shall be open on at least three sides with cylinders in single-cylinder cabinets. Where a canopy is provided, the height shall be a minimum of 12 ft (3.7 m).

(f) Gas cabinets not located in bunkers shall be provided with a security open chain-link fence. Cabinets shall be separated from adjacent structures and the fence by a minimum of 12 ft (3.7 m).

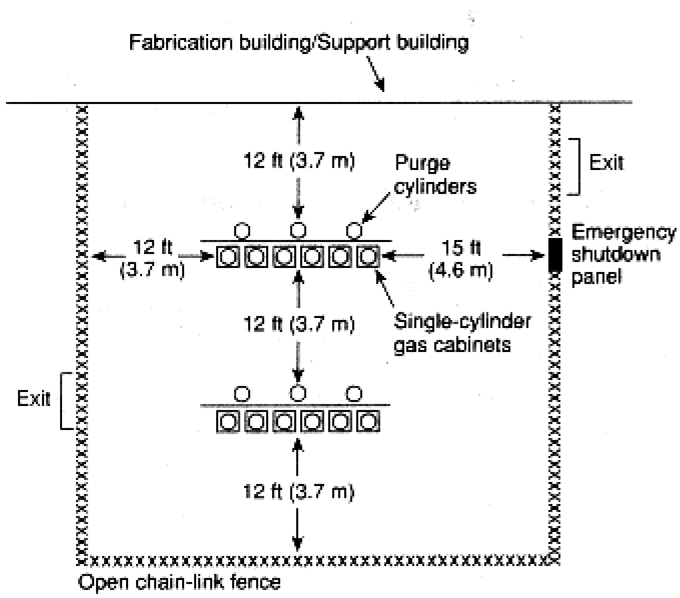

Figure 6-5 Silane/toxic mixes dispensing area.

6-6 Flammable or Toxic Gases.

6-6.1*

Toxic or flammable gases in use shall be contained in cabinets provided with exhaust ventilation. Cabinets shall be provided with gas detection and automatic shutdown of the gas supply. Exhaust ventilation shall be continuous or activated automatically by gas detection.

Exception: Lecture cylinders in ion implanters need not be in gas cabinets. They shall be located in exhausted enclosures with gas detection and automatic shutdown of the gas supply.

6-6.2

Exhaust ventilation shall be provided where there is potential for gas release and for the area containing valves, fittings or connections, transfer stations, or vacuum pumps. Detection of toxic or flammable gases shall activate a local alarm and shut down the gas supply. Alarms shall be monitored continuously.

6-6.3

Exhaust ventilation, detection, and shutdown systems shall be provided with an automatic emergency source of back-up power.

6-6.4

Welding and other activities that might produce ignition shall be minimized in areas where there is potential flammable gas release. Welding or other activities that might produce a spark shall be allowed only through a special internal permit procedure that calls for monitoring in the area for 20 percent of the LEL and a fire watch and ventilation to reduce the potential of explosive concentrations.

6-6.5

"No Smoking" signs shall be provided in the flammable gas storage area, in areas where there is a potential for flammable gas release, and within 25 ft (7.6 m) of those areas.

6-6.6

Open flames shall not be used in the flammable gas storage or dispensing areas. All sources of electrical heat shall comply with NFPA 70, *National Electrical Code*. Compressed and liquefied gases in storage or dispensing shall be protected from uncontrolled heat sources.

6-7 Vent Headers.

6-7.1

Purge panel vent line headers, where used, shall be designed to prevent the mixing of incompatible gases and silane with air. Vent header inert gas purge shall be monitored and provided with a local alarm when flow falls below a required set point.

6-7.2

Silane vent headers or individual purge panel vent lines shall have a continuous flow of nitrogen. To prevent back diffusion of air into the vent line, a nitrogen flow shall be introduced. The nitrogen shall be introduced upstream of the first exhaust connection to the header.

6-7.3

Vents shall terminate at a safe location or in treatment systems.

6-7.4

Process delivery lines used for hazardous gases shall be dedicated to those gases.

6-8* Training.

Operators working with hazardous gases and handling hazardous compressed and liquefied gas containers shall be trained for that function. Training shall be provided annually.

Chapter 7 Production and Support Equipment

7-1* General.

Production and support equipment shall be designed and installed in accordance with Sections 7-2 through 7-8.

7-2 Interlocks.

7-2.1*

Hardware interlocks that will automatically bring the tool to standby mode shall be interfaced with the tool's operating system.

7-2.2

A local visual and audible alarm shall be provided to indicate activation of any interlock.

Exception: Panel interlocks.

7-2.3

Each interlock and its operation shall be described in both the operations and maintenance manuals for the tool.

7-2.4

Tools utilizing hazardous chemicals shall be designed to accept inputs from monitoring equipment. An alarm signal from the monitoring equipment shall automatically stop the flow of hazardous chemicals to the tool.

7-2.5

Interlocks shall be designed to require manual reset and to permit restart only after fault correction.

7-3 Electrical Design.

7-3.1

Electrical components and wiring shall be in accordance with NFPA 70, *National Electrical Code*, and NFPA 79, *Electrical Standard for Industrial Machinery*. The tool or associated equipment as a complete system shall be approved.

7-3.1.1 Process tools and associated equipment shall meet the requirements of NFPA 70, *National Electrical Code*, Section 90-7, Examination of Equipment for Safety.

7-3.1.2 All electrical components and wiring shall be listed.

7-3.2

Electrical equipment and devices within 5 ft (1.5 m) of work stations in which flammable liquids or gases are used shall comply with the requirements of NFPA 70, *National Electrical Code*, for Class I, Division 2 locations.

Exception: The requirements for Class I, Division 2 locations shall not apply when the air removal from the work station or dilution will ensure nonflammable atmospheres on a continuous basis.

7-3.3

Work stations using flammable chemicals shall not be capable of being energized without adequate exhaust ventilation.

7-4 Process Liquid Heating Equipment.

Electric immersion heaters and hot plates shall not be used in combustible tools or tools using combustible or flammable liquids.

Exception: Stand-alone electric water heaters, external to combustible wet stations, or bonded heaters shall be permitted.

7-4.1

Where stand-alone electric water heaters are used, they shall include:

(a) Ground fault interrupters,

(b) Overcurrent protection,

(c) Power interrupts,

(d) Manual resets,

(e) Temperature controllers,

(f) Redundant liquid level sensors,

(g) Redundant over-temperature protection.

7-4.2

Electrically heated baths shall have the following interlocks to activate both shutdown and alarms:

(a) Ground fault interrupters,

(b) Overcurrent protection,

(c) Power interrupts,

(d) Manual resets,

(e) Temperature controllers,

(f) Redundant liquid level sensors,

(g) Redundant over-temperature protection.

7-4.3*

Those baths heating flammable or combustible liquids shall have high-temperature limit switches.

7-4.4*

Liquid level sensors shall be tested after maintenance but at least monthly.

7-5 Materials of Construction.

Tools shall be of noncombustible construction.

Exception: That part of the work station that comes into contact with corrosive materials.

7-6 Vacuum Pumps.

7-6.1*

Vacuum pumps using combustible oils shall use a control device to remove oils prior to their discharge into the exhaust duct system.

7-6.2 Exhaust Conditioning.

7-6.2.1* Vacuum pumps that handle flammable gases in excess of 20 percent of LFL shall discharge into a control device to treat the flammable gases from the airstream prior to discharge into exhaust system ductwork.

7-6.2.2 Vacuum pumps handling flammable or pyrophoric chemicals or high concentration oxygen shall not use combustible pump oils.

7-6.2.3 Vacuum pumps that handle flammable or pyrophoric gases shall be equipped with a nitrogen purge and interlocked with the process tool operating system.

7-7 Hazardous Gas Delivery Systems.

7-7.1

Hazardous gas piping, controls, and valves that are internal to tools using hazardous gases shall be contained within a noncombustible enclosure that is exhausted at a minimum airflow of 100 cfm per ft^2 (0.047 m^3/s per 0.09 m^2) of average transverse cross-sectional area of the enclosure.

7-7.2

Mass flow controller bypass valves shall be designed to prevent excess flow of silane and to prevent them from being left in the open position.

7-8* Tools Using Flammable or Combustible Chemicals.

All tools using flammable or combustible chemicals shall be provided with exhaust to reduce the concentration of flammable gases and vapors to less than 20 percent of the LFL.

Chapter 8 Means of Egress

8-1*

Means of egress shall be designed in accordance with NFPA *101®*, *Life Safety Code®*, Chapters 5 and 28.

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*, 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 43A, *Code for the Storage of Liquid and Solid Oxidizers*, 1990 edition.

NFPA 43B, *Code for the Storage of Organic Peroxide Formulations*, 1993 edition.

NFPA 70, *National Electrical Code*, 1993 edition.

NFPA 79, *Electrical Standard for Industrial Machinery*, 1994 edition.

NFPA *101*, *Life Safety Code*, 1994 edition.

NFPA 220, *Standard on Types of Building Construction*, 1992 edition.

NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, 1990 edition.

NFPA 385, *Standard for Tank Vehicles for Flammable and Combustible Liquids*, 1990 edition.

NFPA 386, *Standard for Portable Shipping Tanks for Flammable and Combustible Liquids*, 1990 edition.

NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials*, 1990 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 D5-1986, *Standard Test Method for Penetration of Bituminous Materials.*

ASTM D323-1990, *Standard Test Method for Vapor Pressure of Petroleum Products.*

ASTM E136-1993, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750 Degrees C.*

9-1.2.2 FED STD Publication. Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

FED STD 209E, 1992, *Cleanroom and Work Station Requirements, Controlled Environment.*

9-1.2.3 SEMI Publication. Semiconductor Equipment and Materials International, 805 East Middlefield Road, Mountain View, CA 94043-4080.

SEMI F1-90, *Specification for Leak Testing Toxic Gas Piping Systems.*

9-1.2.4 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 181-1990, *Standard for Safety Factory-Made Air Ducts and Air Connectors.*

UL 586-1990, *High-Efficiency, Particulate, Air Filter Units.*

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

A systems approach to risk management was attempted throughout this standard. These fire safety objectives are achieved through the proper management of fire prevention and fire response activities.

A-1-4 Hazardous Chemical.

The terms "hazardous materials," "hazardous chemicals," and "hazardous wastes" are often used interchangeably, and in most context, it is properly understood that they have the same meaning. In the United States, however, these terms actually have quite different definitions under the U.S. Code of Federal Regulations (CFR):

(a) Hazardous materials are raw materials in transit to the user and are governed by the U.S. Department of Transportation (DOT) under Title 49 CFR, Transportation.

(b) By definition, a hazardous material becomes a hazardous chemical once it arrives at a plant and is used in the work place, at which time its use is governed by the Occupational Safety and Health Administration (OSHA) under Title 29 CFR, Labor.

(c) Waste is generated by a process. A chemical becomes waste once it completes its useful life in-plant, and disposal is classified as ignitible, corrosive, reactive, or toxic. Where it is considered hazardous waste it is regulated by the Environmental Protection Agency (EPA) under Title 40 CFR, Protection of the Environment.

While ignitible wastes are of particular interest to NFPA, all hazardous waste should be protected to avoid adverse impact to the environment.

A-2-1.2.1 Typical configurations of cleanrooms and their chases and plenums create numerous areas that might be sheltered from sprinkler protection. These areas can include air-mixing boxes, catwalks, hoods, protruding lighting, open waffle slabs, equipment, piping, ducting, and cable trays. Care should be taken to relocate or supplement sprinkler protection to ensure that sprinkler discharge covers all parts of the occupancy. Care should also be taken to ensure that sprinklers are located where heat will be satisfactorily collected for reliable operation of the sprinkler.

Gaseous fire suppression systems are not substitutes for automatic sprinkler protection. The large number of air changes in cleanrooms can cause dilution or stratification of the gaseous agent.

It is recommended that sprinkler systems be inspected at least semiannually by a qualified inspection service. (See NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems.*) The length of time between such inspections can be decreased due to ambient atmosphere, water supply, or local requirements of the authority having jurisdiction.

Prior to taking a sprinkler system out of service, one should be certain to receive permission from all authorities having jurisdiction and notify all personnel who might be affected during system shutdown. A fire watch during maintenance periods is a recommended precaution. Any sprinkler system taken out of service for any reason should be returned to service as promptly as possible.

A sprinkler system that has been activated should be thoroughly inspected for damage and components replaced or repaired promptly. Sprinklers that did not operate but were subjected to corrosive elements of combustion or elevated temperatures should be inspected, and replaced if necessary, in accordance with the minimum replacement requirements of the authority having jurisdiction. Such sprinklers should be destroyed to prevent their reuse.

A-2-1.2.2 The use of quick response sprinklers, while still delayed in opening by the downward airflow, would respond to a smaller size fire quicker than conventional sprinklers. (Glass bulb-type quick response sprinklers might be preferable to other types of quick response sprinklers.)

A-2-1.2.3 It is recommended that an approved 135°F (57°C) $^3/_8$-in. (9.5-mm) orifice sprinkler be used. It is recommended that a sprinkler be installed in all gas cylinder cabinets.

A-2-1.2.4 The UV/IR detectors could also serve the function required in 2-3.3.

A-2-1.2.6.1 Small orifice sprinklers, $^3/_8$ in. (9.5 mm) or larger, can be used.

A-2-1.2.6.3 Drainage and placement of sprinklers should be designed to prevent water from flowing back into process equipment or the ductwork from collapsing under the weight of the water or both. Since water discharged into exhaust ductwork will most likely be contaminated, outflow from the drain lines should be piped in accordance with local environmental regulations.

A-2-1.2.7 It is recommended that an approved $^3/_8$-in. (9.5-mm) orifice sprinkler be used. Drainage should be provided to remove all sprinkler water discharged in the pass-through.

A-2-1-2.8

Figure A-2-1.2.8 from FM Loss Prevention Data Sheet 7-7 "Semiconductor *Fabrication Facilities*" August 1991 illustrates various arrangements of a wet bench work station, the associated fume exhaust ductwork, and possible locations of fire protection devices. (*See Figure A-2-1.2.8.*)

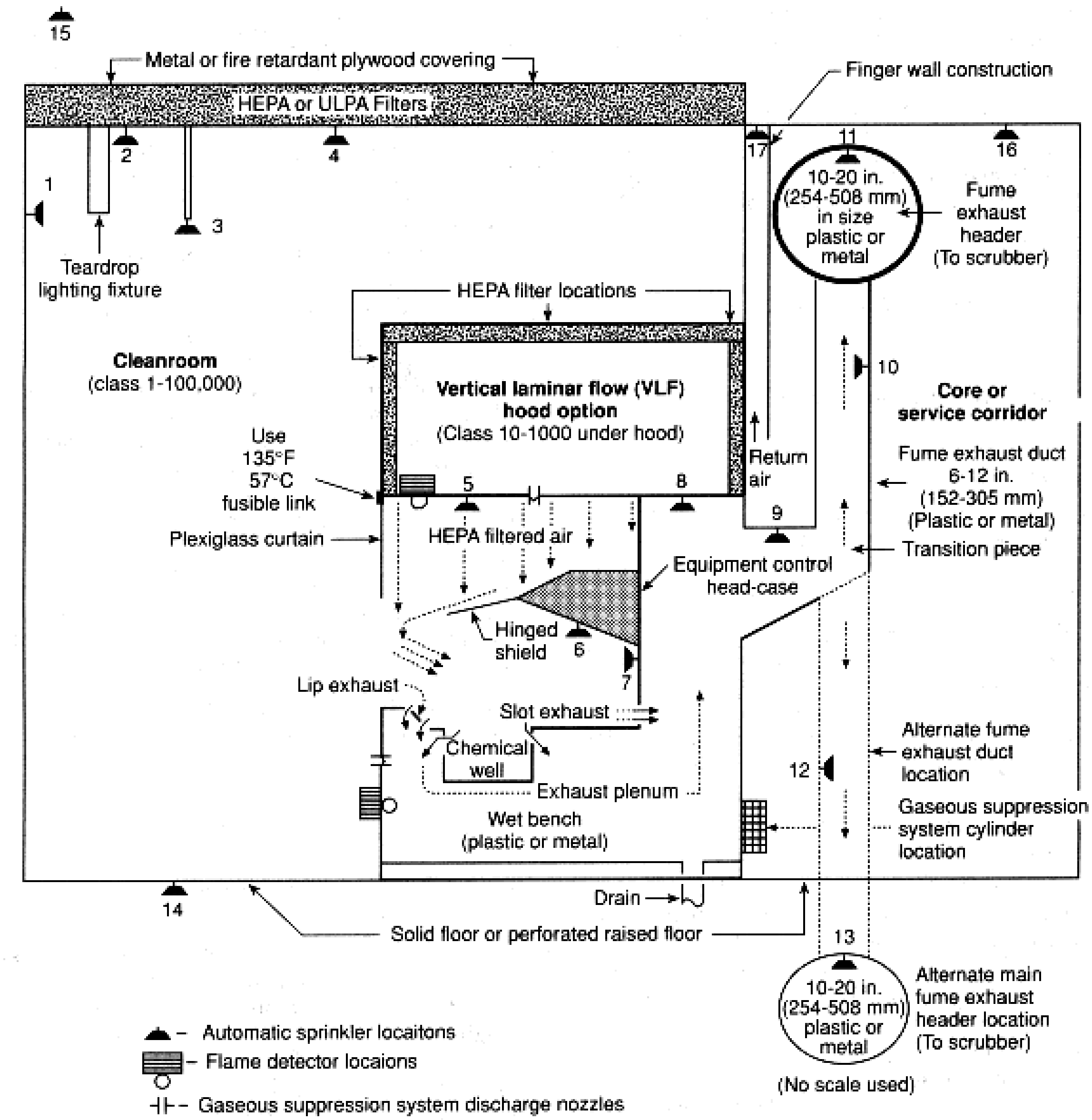

Figure A-2-1.2.8 Example of sprinkler locations for combustible tools.

A-2-1.2.8.3 To minimize the effect of automatic sprinkler water discharge on airflow in exhaust ducts, it is preferable to locate the sprinkler head in the work station transition piece. It is also acceptable to use a $^3/_8$-in. (9.5-mm) orifice sprinkler.

A-2-2.2

Cleanroom hydrogen monitoring should use parts per million detectors to provide alarm and detection for hydrogen leaks.

A-2-3.1

The detectors may also be used to shut down the recirculating fans or activate a dedicated smoke control system, or both. See NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*.

A-2-3.2

Smoke detection need not result in an automatic facility evacuation alarm signal.

A-3-3.1

Ribbed flex duct is frequently used to connect a piece of equipment to the exhaust duct system. Trapped sections occur where ducts are routed under structural members or other mechanical ducts or piping. Transport velocities that are adequate in straight sections of ductwork might not be adequate in the above sections due to turbulence, and as a result, hazardous chemicals can deposit in the ductwork. Ribbed flex duct is frequently used to connect a piece of equipment to the exhaust duct system. Ribbed flex duct has the undesirable property of very rapid burn-through or collapse in the event of internal fire exposure.

The duct system should be designed and constructed to minimize the collection of hazardous chemicals.

A-3-3.6

Considering fire protection issues only, duct materials listed in descending order of preference are:

(a) Metallic.

(b) Approved coated metallic or nonmetallic not requiring fire sprinklers, fire dampers, or interrupters of any kind.

(c) Combustible with internal automatic sprinkler protection.

A-3-5.2

Emergency power systems are not intended to keep production equipment operating except in limited cases. When electrical utility power in a facility fails, most production equipment will shut down, thereby reducing the hazardous fumes transported in the fume exhaust duct system.

A-4-1

Buildings housing these cleanrooms should be of noncombustible or fire-resistive construction.

A-5-1.1

The following documents should be consulted for storage and handling of hazardous chemicals.

NFPA 68, *Guide for Venting of Deflagrations*, 1994 edition.

NFPA 329, *Recommended Practice for Handling Underground Releases of Flammable and Combustible Liquids*, 1992 edition.

A-5-3.1

New buildings are designed to provide chemical handling corridors.

A-5-3.3

Breakable individual chemical containers should be separated to avoid breakage.

A-5-4.2

Labeling of contents should be in accordance with ANSI B31.3, *Chemical Plant and Petroleum Refinery Piping*.

A-6-1.2

If a flow restricted orifice is placed in a system with an excess flow device, the excess flow device might not shut off.

A-6-2.2

This program should be coordinated with the fire department, the plant emergency response team, and the gas supply organization. A response time for all parties concerned should be a part of the procedure. Periodic drills should be performed with all parties involved to handle simulated accidents.

A-6-3.2

If the distribution piping is of noncombustible construction, a combustible outer jacket can be used for secondary containment.

A-6-3.5

Training should be as outlined in SEMI F3, *Guideline for Welding Stainless Steel Tubing for Semiconductor Manufacturing Applications*.

A-6-3.6.1 Automated purge panels are recommended because they reduce the potential for human error.

A-6-3.8

The basic components of purge panels should incorporate the following features:

(a) Tied diaphragm regulators should be used.

(b) All piping/tubing connections should be welded or of a metal gasket face seal fitting with zero clearance, except valve connection to cylinder.

(c) Burst pressure components should be rated to at least 50 percent over the maximum pressure available to all components.

(d) All components should have a helium leak rate no greater than 0.00001 cc/hr.

(e) Regulators should be of the hand-loaded type. Dome loaded regulators should not be used on hazardous gases. Remotely operated gas delivery systems can use dome loaded regulators.

(f) No check valves should be used as a primary control of potential cross contamination and backflow.

(g) Electrical components on purge panels should be intrinsically safe.

(h) Excess flow control (valve or switch) should be provided on the high pressure side of the purge panel.

(i) Emergency high pressure shutoff valves should be provided and should operate upon the activation of an emergency off button, gas monitoring alarm (high alarm), or electronically monitored excess flow control switch.

(j) All systems should be equipped with an emergency shutoff.

A-6-5

The use of silane/toxic mixes is discouraged due to the dangers inherent in these materials. Alternative methods should be sought to eliminate the use of these chemicals.

A-6-5.3 (b) Exhaust airflow should be calculated by multiplying 200 fpm by the cross-sectional area of the cabinet.

A-6-6.1

Alternate substances should be considered for replacement of hazardous gases.

A-6-8

A certification program should be used to ensure adequate training.

A-7-1 Introduction.

This chapter can be used to minimize known fire hazards inherent in the construction and operation of cleanroom tools.

Proper materials, regulatory requirements, and good practices should be considered in design, use, and maintainability of all tools.

Where hazards cannot be eliminated, no single failure should result in an exposure situation that places people in jeopardy. All fire prevention or protection systems used internal to, or with, equipment should be fail-safe.

General Recommendations. Tools should be designed to achieve fire prevention, or in the event of fire, to provide early detection and suppression adequate to prevent fire spread, explosion, or threat to life safety.

The completed system should have third-party review based on the requirements of this chapter.

Where available, components and subassemblies used should be listed.

Listed below is a guideline setting forth areas of consideration when tool design drawings are being reviewed. This list includes only recommendations. Design review should not be limited by, or to, these items:

(a) Materials of construction (flammability, combustibility, and compatibility);

(b) Electrical components, their mounting, and enclosures;

(c) Electrical circuit protection;

(d) Access to components within equipment;

(e) Minimization and control of pyrophoric chemicals;

(f) A review of process piping, connectors, and materials;

(g) Methods of preventing excess flow of gases;

(h) Earthquake stability where and when applicable;

(i) Redundant controls of electrical heaters;

(j) Software interlocks.

Tools should bear a nameplate identifying the manufacturer by name and address, and the model and serial number of the tool.

Tool manufacturers should notify owners of inherent defects that affect fire and safety, when they become known. Likewise, users should notify tool manufacturers of potential fire and safety considerations.

Tool manufacturers should conduct ongoing programs of quality assurance, safety research, and investigation to identify, correct, and inform users of any potential operating malfunctions that might constitute fire safety hazards that could exist in their products.

All known hazards that cannot be engineered out of a tool should be clearly identified and controlled. These conditions should be specifically addressed in the tool's operation and maintenance manuals or in a notice accompanying the tool.

Plans and specifications for tools, prior to their fabrication or use or both, should be reviewed and signed by a trained employee or independent third party using the requirements of Chapter 7.

The maintenance and operation manuals should provide guidance for the posting of appropriate signs on tools to indicate that maintenance is in process.

Administration. Owners should designate a responsible individual in their employ to review drawings of tool and system designs to ensure that tools will be in conformance with these requirements.

Owners should perform physical inspection of tools on receipt to ensure that the tool is in conformance with their design/review documents.

Owners should ensure that the tool is accompanied with adequate installation, maintenance, and operating instructions, which will include appropriate wiring details and facilitizing of the tool.

Owners should ensure that a proper hands-on training program is instituted in the safe operation of the tool and that standardized examinations are given to test knowledge and ability.

Owners should institute an appropriate maintenance program to ensure that all safety controls will work in a proper manner when required. Inspection and maintenance should be done on a sufficiently frequent basis against a checklist by qualified personnel to ensure continued safe operation of the tool. The name of the inspector should be posted on or close to the tool, as well as the date of last inspection.

Production and support equipment can be designed to comply with SEMI S2, *Product Safety Guidelines*, and designed and installed in accordance with Sections 7-2 through 7-8.

A-7-2.1

Interlock systems should be designed to prevent override during normal operation.

A-7-4.3

Wet benches that use combustible chemicals, heated above their flash points, or flammable chemicals should be provided with devices to detect fire.

A-7-4.4

A convenient way in which to test low liquid level sensors is to use them at least weekly to shut down the process by removing them from the bath; if they fail to shut off equipment, they prove they are not operating properly.

A-7-6.1

Such devices can be traps, condensers, demisters, or coalescing filters. As an alternative, noncombustible oils should be used, or dry-type pumps not requiring lubricant should be used.

A-7-6.2.1 Vacuum pumps whose construction is susceptible to backstreaming oil into tools should have foreline traps on their inlets.

A-7-8

Exhaust flow should be monitored and controlled by a sensor set at a negative static pressure to provide the minimum airflow specified in Chapter 5.

As an alternative to the above, the minimum airflow can be monitored by periodic inspection to preclude changes caused by modifications to the exhaust duct system.

In the event a low airflow condition results, a local audible and visual alarm should provide a signal at the tool. The sensor and alarm should be of the manual reset type.

Exhaust static pressure or flow monitoring should be provided on all exhausted tools. Local visual and audible alarms should also be provided. The sensor and alarm should be of the manual reset type.

A-8-1

Semiconductor facilities can be considered to be special purpose industrial occupancies containing ordinary hazard manufacturing operations. NFPA *Fire Protection Handbook*, 17th ed, Section 9, Chapter 14, Industrial Occupancies, points out that high hazard occupancies are limited to those industrial facilities that house extremely hazardous operations and do not include those buildings in which there is incidental or restricted use of chemicals and gases, such as semiconductor cleanrooms designed in accordance with this standard.

Appendix B

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

B-1

The following appendix contains useful and explanatory information about subjects related to the installation of fire protection systems that are not covered in the text.

B-2 Seismic Protection.

B-2.1

In seismic zones, where required by the authority having jurisdiction, approved seismic warning and control systems should be installed to mitigate the damage of an earthquake.

B-2.2

An approved seismically activated valve should be provided to automatically shut off piping systems conveying hazardous chemicals during significant seismic events. It should generate a signal to activate emergency shutoff valves on gas cabinets, hazardous gas supply lines, and appropriate utility services, such as natural or LP-Gas.

B-2.3

Seismic warning and control systems should be able to discriminate actual seismic activity from background industrial interference, such as a forklift operating in the area of the seismic sensors.

B-2.4

The optimal seismic warning and control system should react only to a ground acceleration of 0.05G - 0.25G at the specific frequencies inherent to earthquakes (0.5 Hz-15 Hz).

B-2.5

Electrically operated seismic warning systems should be powered by an uninterruptible power supply.

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 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, 1995 edition.

NFPA 68, *Guide for Venting of Deflagrations*, 1994 edition.

NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, 1993 edition.

NFPA 329, *Recommended Practice for Handling Underground Releases of Flammable and Combustible Liquids*, 1992 edition.

Fire Protection Handbook, 17th edition.

C-1.2 Other Publications.

C-1.2.1 ANSI Publication. American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

ANSI B31.3-1993, *Chemical Plant and Petroleum Refinery Piping.*

C-1.2.2 Factory Mutual Engineering Corp. Publication. 1151 Boston-Providence Turnpike, Norwood, MA 02062.

FM Loss Prevention Data Sheet 7-7, *Semiconductor Fabrication Facilities*.

C-1.2.3 SEMI Publications. Semiconductor Equipment and Materials International, 805 East

Middlefield Road, Mountain View, CA 94043-4080.

SEMI F3-90, *Guideline for Welding Stainless Steel Tubing for Semiconductor Manufacturing Applications.*

SEMI S2-93, *Product Safety Guidelines*.

C-1.2.4 U.S. Government Publications. Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

Code of Federal Regulations, Title 29, Labor, 1993.

Code of Federal Regulations, Title 40, Protection of Environment, 1993.

Code of Federal Regulations, Title 49, Transportation, 1993.

Formal Interpretation

NFPA 318

Protection of Cleanrooms

1995 Edition

Reference : 5-2.7
F.I. 92-1

Question: Is double-walled piping intended to be the only method of secondary containment of piping systems?

Answer: No.

Issue Edition: 1992
Reference: 5-2.7
Issue Date: August 3, 1992
Effective Date: August 24, 1992

NFPA 325

1994 Edition

Guide to Fire Hazard Properties of Flammable Liquids, Gases,

1994 Edition

This edition of NFPA 325, *Guide to Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids*, 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 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 325

The first edition of NFPA 325, 325M, was presented to the Association in 1930. Successively revised and enlarged editions were published in 1935, 1941, 1945, 1947, 1951, 1954, 1960, 1965, 1969, 1977, and 1984.

This 1994 edition is an amended version of the 1991 edition. The hazard identification ratings of NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials*, have been updated to be consistent with changes made to chemicals listed in NFPA 49, *Hazardous Chemicals Data*. These are indicated by a vertical rule in the left-hand margin.

This document is not a code, standard, or recommended practice, as these terms are defined by NFPA. It is only a compilation of basic fire protection properties of various materials, prefaced by an explanation of the properties covered. The data contained have been collected from numerous authoritative sources, including the U.S. Bureau of Mines, Factory Mutual Research Corporation, and Underwriters Laboratories Inc., as well as from the manufacturers of the materials. The originating source of the data is on file at NFPA headquarters and may be obtained upon request.

The table presented here summarizes available data on the fire hazard properties of about 1,500 substances, listed alphabetically by their chemical name. In addition, about 500 synonyms are listed alphabetically and cross-referenced to their proper entries.

The values for any given property are representative and deemed suitable for general use. Where differences exist in reference sources, the value selected for inclusion in this compilation is conservative. Slight differences are to be expected between data sources, due to differences in the purity of test samples, minor differences in test apparatus, and minor differences in technique and observation. In almost all cases, these minor variations have little practical significance.

Where there is difference of opinion as to the actual value of a property of a given material or where the validity of the data presented is questioned, further tests should then be conducted on representative samples of the specific material in question by a qualified testing laboratory.

Curtis G. Payne, U.S. Coast Guard (G-MTH-1), DC

Gary Robinson, Liberty Mutual Insurance Co., IL
Rep. The Alliance of American Insurers

William J. Satterfield, Hartford Steam Boiler Inspection & Insurance Co., CT

James Saylor, Aetna Life & Casualty,
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Nonvoting

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 325

Guide to Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids

1994 Edition

Chapter 1 General

1-1 Scope.

This guide applies to flammable liquids, flammable gases, and volatile flammable solids.

1-2 Purpose.

The purpose of this guide is to provide the user with basic fire hazard information on the materials covered by the scope.

1-3 Definitions of Fire Hazard Properties.

1-3.1

No single fire hazard property, such as flash point or ignition temperature, should be used to describe or appraise the fire hazard or fire risk of a material, product, assembly, or system under actual fire conditions. The fire hazard properties given in this guide have been determined under controlled laboratory conditions and may properly be used to measure or describe the response of materials, products, assemblies, or systems under these conditions. Properties measured under these conditions may be used as elements of a fire risk assessment only when such assessment takes into account all of the factors that are pertinent to the evaluation of the fire hazard of a given situation.

1-3.2

The pertinent literature seldom mentions the degree of purity of the material being tested; even boiling point or melting point data are frequently missing. These data, if available, would permit judging the purity of the material and, hence, the reliance to be placed on the values reported, particularly with respect to flash point and flammable range. Finally, it must be remembered that there is little industrial use of high purity materials. As a consequence of these considerations, no values of purity are given in this compilation. The melting points and boiling points should be regarded as approximations.

1-3.3 Flash Point.

The flash point of a liquid is the minimum temperature at which the liquid gives off sufficient vapor to form an ignitible mixture with air near the surface of the liquid or within the test vessel used. By "ignitible mixture" it is meant a mixture that is within the flammable range (between the upper and lower limits) and, thus, is capable of propagation of flame away from the source of ignition. Some evaporation takes place below the flash point, but not in quantities sufficient to form an ignitible mixture. Flash point applies mostly to flammable and combustible liquids, although certain solids, such as camphor and naphthalene, that slowly volatilize at ordinary room temperature, or certain liquids, such as benzene, that freeze at relatively high temperatures, will exhibit a flash point in the solid state.

The flash points given in this manual are, for the most part, closed cup flash points. Where the only available data is based on open cup tests, this is designated by the initials "oc" after the entry. In the case of some of the older data in this manual, it could not be determined whether a closed cup or open cup procedure had been used. In these cases, it has been assumed that the data is based on closed cup tests. For further information on the flash point test procedures used, see NFPA 321, *Standard on Basic Classification of Flammable and Combustible Liquids.*

1-3.4 Ignition Temperature.

The ignition temperature of a substance, whether solid, liquid, or gas, is the minimum temperature required to cause self-sustained combustion, independently of the heating or heated element. Ignition temperatures observed under one set of conditions may differ markedly from those observed under another set of conditions. For this reason, ignition temperatures should be regarded as approximations. Some of the variables known to affect ignition temperature are the percentage of the gas or vapor in the mixture, the shape and size of the test vessel, the rate and duration of heating, the kind and temperature of the ignition source, and catalytic or other effects of materials that may be present. As there are many differences in ignition temperature test methods, such as the size and shape of the test vessel, the material of construction of the test vessel, method and rate of heating, residence time, and method of flame detection, it is not surprising that reported ignition temperatures may differ for the same material.

The majority of the data reported in this manual have been obtained by one of two methods: ASTM D286 and ASTM D2155. Both have been withdrawn by the American Society for Testing and Materials. ASTM D2155 has been replaced by ASTM E659, *Standard Test Method for Autoignition Temperatures of Liquid Chemicals*. An earlier test method, ASTM D2883, *Test Method for Reaction Threshold Temperature of Liquid and Solid Materials*, provides for the study of autoignition phenomena at reduced and elevated pressures. Federal Test Method Standard 791B, Method 5050, is another current test method that provides for the measurement of autoignition properties in the same terms used by the ASTM procedures.

Previous test methods relied only on visual detection of flame. Consequently, the ignition temperatures obtained by these procedures were the minimum temperatures at which hot-flame ignition occurred. The current test methods employ thermoelectric flame detection, thus permitting the detection of nonluminous or barely luminous reactions that were difficult or impossible to detect by the older procedures. As a result, the following terms have come into use:

Hot-Flame Ignition. A rapid, self-sustaining, sometimes audible gas-phase reaction of the sample or its decomposition products with an oxidant. A readily visible yellow or blue flame usually accompanies the reaction.

Cool-Flame Ignition. A relatively slow, self-sustaining, barely luminous gas-phase reaction of the sample or its decomposition products with an oxidant. Cool flames are visible only in a darkened area.

Pre-Flame Reaction. A slow, nonluminous gas-phase reaction of the sample or its decomposition products with an oxidant.

Catalytic Reaction. A relatively fast, self-sustaining, energetic, sometimes luminous, sometimes audible reaction that occurs as a result of the catalytic action of any substance on the sample or its decomposition products, in admixture with an oxidant.

Non-Combustive Reaction. A reaction other than combustion or thermal degradation that is undergone by certain substances when they are exposed to heat. Thermal polymerization is an example of this type of reaction.

Reaction Threshold. The lowest temperature at which any reaction of the sample or its decomposition products occurs, for any sample/oxidant ratio.

Autoignition Temperature (AIT). The currently accepted term for the Hot-Flame Ignition Temperature.

Cool-Flame Reaction Threshold (CFT). The lowest temperature at which cool-flame ignitions are observed for a particular system. Previously undefined.

Preflame-Reaction Threshold (RTT). The lowest temperature at which exothermic gas-phase reactions are observed for a particular system. Previously undefined.

Previously, reported ignition temperatures, including those given in this manual, have corresponded roughly to the autoignition temperature (AIT), provided that proper allowances were made for empirical differences in the measurement technique. In the future, it is expected that CFT and RTT will routinely be reported. Both are lower than AIT and are significant factors to be evaluated in the assessment of the overall ignition risk of a given system. Cool flames are self-sustaining, exothermic ignition reactions that, under proper circumstances, may act as the initiator of more energetic hot-flame reactions. Pre-flame reactions have the capacity, under adiabatic or near-adiabatic conditions, to elevate the temperature of a fuel/air mixture to the point where cool- or hot-flame ignition may occur.

As an illustration of the effects of test methods, the ignition temperature of hexane, as determined by three different methods, are 437°F (225°C), 637°F (336°C), and 950°F (510°C). The effect of percentage composition is shown by the following ignition temperatures for pentane: 1018.4°F (548.4°C) at 1.5 percent, 935.6°F (502.4°C) at 3.75 percent, and 888.8°F (476.3°C) at 7.65 percent. The following ignition temperatures for carbon disulfide demonstrate the effect of the size of the test vessel: 248°F (120°C) in a 200 ml flask, 230°F (110°C) in a 1 liter flask, and 205°F (96°C) in a 10 liter flask. The effect of the material of construction of the test vessel is shown by the following ignition temperatures for benzene: 1060°F (572°C) in a quartz vessel and 1252°F (678°C) in an iron vessel.

The ignition temperature of a combustible solid is influenced by the rate of air flow, rate of heating, and size of the sample. Small sample tests have shown that, as the rate of air flow or the rate of heating is increased, the ignition temperature decreases to a minimum value, then increases.

1-3.5 Flammable (Explosive) Limits.

In the case of gases or vapors that form flammable mixtures with air, oxygen, or other oxidizers, such as chlorine and nitrous oxide, there is a minimum concentration of the material below which propagation of flame does not occur. Similarly, there is a maximum concentration above which propagation of flame does not occur. These boundary mixtures, which, if ignited, will just propagate flame, are known as the “lower and upper flammable or explosive limits” and are usually expressed as percent by volume of the material in air (or other oxidant). In popular terms, a mixture below the lower flammable limit (LFL) is too “lean” to burn, while a mixture above the upper flammable limit (UFL) is too “rich” to burn.

The values for the flammable limits given in this manual are based on atmospheric temperatures and pressures, unless otherwise indicated. There will be considerable variation in flammable limits at temperatures and pressures above or below ambient. The general effect of an increase in temperature or pressure is to decrease the lower limit and to increase the upper limit, i.e., broaden the range between the two limits. A decrease in the temperature or pressure has the opposite effect. In most cases, the values given in this manual represent the concentration limits over which hot-flame ignitions have been observed. If cool-flame ignitions are considered, wider flammable ranges are observed.

Research has shown that flammability limits are not a fundamental combustion property, but depend on many variables, including the surface-to-volume ratio of the test vessel, the direction of air flow, and the velocity of air flow. In some experiments conducted at laminar flow velocities, the upper limit increased with increasing flow velocity, reached a maximum that was independent of the diameter of the test vessel, then decreased as flow became turbulent. The lower limit has been unaffected by air flow rate.

ASTM E681 is the current test method for determining flammable limits. However, much of the data were obtained in small diameter tubes with ignition at the bottom so that flame propagation was upward. For most hydrocarbons, this method is appropriate. However, for highly oxygenated, aminated, or halogenated materials, larger diameter equipment is required to avoid quenching of the flame. Larger diameter test equipment or more energetic ignition sources may better reflect real world burning conditions.

The terms “flammable limits” and “explosive limits” are interchangeable.

The range of concentration between the lower flammable limit and the upper flammable limit is known as the “flammable range,” also referred to and synonymous with “explosive range.” All concentrations of a gas or vapor in air that lie between the flammable limits are ignitible.

1-3.6 Specific Gravity (Relative Density).

The specific gravity of a substance is the ratio of the weight of that substance to the weight of an equal volume of another substance. In this manual, the other substance is water. The values given in this manual for specific gravity are rounded to the nearest tenth. For materials whose specific gravity is from 0.95 to 1.0, the value is shown as 1.0-. For materials whose specific gravity is from 1.0 to 1.05, the value is given as 1.0+. In a few cases, such as fuel oils, where the percentage composition of the substance varies, specific gravity is given as less than (<) or greater than (>) 1.

1-3.7 Vapor Density.

The vapor density of a substance is the ratio of the weight of a volume of pure vapor or gas (no air present) to an equal volume of dry air at the same temperature and pressure. It is calculated as the ratio of the molecular weight of the substance to the molecular weight of air, 29. A vapor density of less than 1 indicates that the substance is lighter than air and will tend to rise in a relatively calm atmosphere. A vapor density of greater than 1 indicates that the substance is heavier than air and may travel along grade level for a considerable distance to a source of ignition and flash back, assuming the gas or vapor is flammable.

1-3.8 Boiling Point.

The boiling point of each liquid is given at a pressure of 14.7 psia (760 mm Hg). Where an accurate boiling point is not available for a specific entry or where a specific entry is actually a mixture of components and does not have a constant boiling point, the boiling point given is the 10 percent distillation point as determined by ASTM D86, *Standard Method of Test for Distillation of Petroleum Products*.

1-3.9 Melting Point.

Melting points are reported in this manual for most materials that melt at 70°F (21°C) or higher. However, the melting point is not available for some of these materials.

1-3.10 Water Solubility.

Water solubility data are reported only for those materials for which reliable information is available, because of the lack of uniformity with which water solubility data are reported in the literature and because of the conflicting statements that sometimes accompany these data. Where such data is reported in this manual, “No” indicates that the material’s solubility is less than 10 grams per 100 milliliters (ml) of water; “Slight” indicates solubility is between 10 and 24 grams per 100 ml of water; “Yes” indicates solubility of 25 or more grams per 100 ml of water.

“No,” “Very Slight,” “Slight,” and “Yes” are sometimes used without definition in the literature to describe water solubility. In those cases where doubt exists as to a material’s solubility in water, tests should be conducted.

Information on the degree to which a material is soluble in water is useful in determining effective extinguishing methods and agents. For example, alcohol-resistant fire fighting foams are usually recommended for water-soluble flammable and combustible liquids. Also, fires involving water-soluble liquids can be extinguished by dilution with water, although this method is not commonly used because of the amount of water needed to dilute most flammable liquids to the point of noncombustibility and because of the danger of frothing if the liquid is heated to the boiling point of water, 212°F (100°C).

1-4 Extinguishing Methods.

1-4.1 General.

The extinguishing methods commonly used for fires involving flammable liquids are suitable for use on fires involving most of the materials listed in this manual. Carbon dioxide, dry chemical, foam, and vaporizing liquid extinguishing agents have all been found to be suitable for use on flammable liquid fires of moderate size, such as in dip tanks or small spills of no appreciable depth. The following comments apply to other extinguishing methods that have been found effective for the control or extinguishment of some flammable liquids fires.

Water spray or fog can be particularly effective on fires involving flammable liquids and volatile solids whose flash points exceed 100°F (37.8°C). However, with liquids whose flash points exceed 212°F (100°C), frothing may occur. For information on the installation of water spray protection for flammable and combustible liquids, see NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*.

Automatic sprinklers are similar to water spray systems in extinguishing effectiveness. Their principal value is in absorbing the heat from the fire and keeping the surroundings cool until the flammable liquids fire either burns out or is extinguished by other means. Automatic sprinklers have a good record of fire control in garages, in paint and oil rooms, and in storage areas where liquids are kept in closed containers. In some industries that use water-soluble liquids, such as the distilled spirits industry, sprinkler systems have been used to achieve protection and extinguishment with excellent results. Where automatic sprinklers are used to protect open tanks, overflow drains are necessary to prevent sprinkler discharge from overflowing the tank and spreading burning liquid to others parts of the property. For further information on automatic sprinklers, see NFPA 13, *Standard for the Installation of Sprinkler Systems*.

Hose streams, both solid and straight streams, are frequently used to cool tanks, containers, and equipment from the heat of an exposing fire. They are also used for washing burning spills away from areas where the burning liquid could ignite other material. However, hose streams may also spread and extend the spill fire, if improperly used. Also, hose streams applied to open containers of burning liquid will only serve to spread the fire, either by splashing the burning liquid out of the container or by causing frothing of the liquid.

Use of automatic-closing covers on open tanks or equipment containing flammable or combustible liquid is also effective in fire control and extinguishment. The covers should be operated by a fusible link, with a manual override. Such covers are suitable for any size tank except where objects being dipped or conveyor systems may prevent tight closing of the cover.

1-4.2 Selecting an Extinguishing Method.

The selection of the extinguishing method used should be made with some degree of caution. Flowing fires, such as may be caused by a leaking overhead pipe, with burning liquid on the ground, are always difficult to extinguish. The amount of extinguishing agent and its rate and method of application must be carefully chosen in relation to the size and type of fire anticipated and may call for special engineering judgment. The use of approved extinguishing equipment is also a major consideration.

The chemical and physical properties of the material involved will also affect the choice of extinguishing method and agent. Standard fire fighting foam cannot be used on fires involving water-soluble flammable liquids; the liquid destroys the foam blanket. Those properties that affect extinguishment were taken into consideration when selecting the methods given for each material in the column headed “Extinguishing Methods.” The following information describes the properties of the material that dictate the numerically designated entries in this column.

1. *Water May Be Ineffective.* This precaution applies to materials that have a flash point below 100°F (37.8°C). Obviously, the lower the flash point, the less effective the water will be. However, water can be used on low-flash point liquids when applied as a spray to absorb heat and to protect exposed material of structures. Much of the effectiveness of using water spray, particularly from hose lines, will depend on the method of application. With proper selection of nozzles, even gasoline spill fires can be extinguished when several coordinated hose streams are used to sweep the flames from the surface of the burning liquid. Water has also been used to extinguish fires involving water-soluble flammable liquids by cooling and diluting the liquid. The distilled spirits industry has been especially successful in using water to control and extinguish fires of this type.

Thus, the phrase “water may be ineffective” indicates that, although water can be used to cool and protect exposed material, water may not be capable of extinguishing the fire unless used under favorable conditions by experienced fire fighters trained in fighting all types of flammable liquids fires.

2. *Water or Foam May Cause Frothing.* This statement applies to liquids having flash points above 212°F (100°C) and is included only as a precaution. It does not indicate that water or fire fighting foam should not be used. The frothing may be violent and could endanger any fire fighters located too close to the burning liquid, particularly when solid streams of water are directed onto the hot, burning liquid. On the other hand, a carefully applied water spray has frequently been used to achieve extinguishment by deliberately causing frothing only on the surface of the liquid; the foaming action blankets the surface of the liquid and extinguishes the fire by excluding oxygen. This tactic is especially successful with high viscosity liquids. For example, certain asphalts have a low-flash point solvent added for fluidity, but because of the relatively high viscosity, frothing action is able to achieve fire control and extinguishment.

3. *Water May Be Used to Blanket Fire.* This statement is applicable to those liquids that have a specific gravity of 1.1 or greater and are not water-soluble. However, the water must be gently

applied to the surface of the liquid, preferably with a fine spray or fog nozzle.

4. *Water May Be Ineffective, Except as a Blanket.* This statement is used as a warning for liquids whose flash points are below 100°F (37.8°C) and applies only to those liquids that have a specific gravity of 1.1 or greater and are not water-soluble. Here again, the water must be gently applied to the surface of the liquid.

5. *Alcohol Foam.* Alcohol-resistant fire fighting foam is recommended for use on all water-soluble liquids or polar solvent-type liquids, except for those that are only “very slightly” soluble. Certain judgment factors are introduced, however, since ordinary fire fighting foam may be used on some liquids that are only “slightly” soluble, particularly if the foam is applied at higher-than-normal applica- tion rates. Conversely, some flammable liquids, such as the higher molecular weight alcohols and amines, will destroy alcohol-resistant foams, even when applied at very high rates. Foams should not be used on water-reactive materials.

Some recently developed alcohol-resistant foams have been listed for use on both polar and nonpolar liquids. These “multipurpose” foams are suitable for use on nearly all flammable liquids except those that are water-reactive and are preferred for flammable liquid fires because they greatly minimize the problems of foam selection. Fire fighting foam suppliers should be consulted for recommendations regarding types of foam and application rates.

6. *Stop Flow of Gas.* For fires involving flammable gases, the best procedure is to stop the flow of the gas before attempting extinguishment of the fire. To extinguish the fire while allowing continued flow of the gas is extremely dangerous; an explosive cloud of gas/air mixture may be created that, if ignited, may cause far more damage than the original fire. Extinguishing the flame using carbon dioxide or dry chemical may be desirable to allow immediate access to valves to shut off the flow of gas, but this must be done carefully. In many cases, it will be preferable to allow continued burning, while protecting exposures with water spray, until the flow of gas can be stopped.

1-5 Suggested Hazard Identification.

1-5.1

The increased use of chemicals, many of which introduced hazards other than flammability, led to the need for a simple hazard identification system that could be immediately recognized by emergency response personnel. This need led to the development of the NFPA 704 Hazard Identification System, otherwise known as the NFPA 704 diamond. This system is completely described in NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials*. The system provides simple, readily recognized, and easily understood markings that give, at a glance, a general idea of the inherent hazards of the material and the order of severity of these hazards, as they relate to fire protection, exposure, and control. The system’s objectives are to provide an appropriate alert signal and on-the-spot information to safeguard the lives of both public and private emergency response personnel. The system also assists in planning for effective fire fighting operations and may be used by plant design engineers and plant protection and safety personnel.

The system identifies the hazards of a material in terms of three categories: “Health,” “Flammability,” and “Reactivity.” It indicates the order of severity of these hazards by means of a numerical rating of 0, indicating no special hazard, to 4, indicating extreme hazard. The three hazard categories were selected after studying about 35 inherent and environmental hazards of materials that could affect fire fighting operations. The five degrees of hazard were decided upon as necessary to give the required information. Finally, the system had to be relatively simple and readily understood.

While the system is basically simple in application, the hazard evaluation required for the use of the system in a specific location must be made by experienced, technically competent persons. Their judgment must be based on factors that encompass a knowledge of the inherent hazards of different materials, including the extent of change in behavior to be anticipated under conditions of fire exposure and control.

1-5.2 Degrees of Hazard.

The columns under "Suggested Hazard Identification" in this manual give the NFPA 704 severity ratings for each of the hazard categories for which information was available. Blank spaces indicate that sufficient information was not available for a severity rating to be assigned. It should be understood that the assignment of the ratings is based on judgment and that extenuating circumstances in plants and processes may dictate a change in any individual rating.

The following commentary on the degrees of hazard are an interpretation of the information contained in NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials,* and are specifically related to fire fighting. See NFPA 704 for more detailed information.

Note: The hazard identification rating definitions below and the actual ratings in the text are based on definitions from the 1985 edition of NFPA 704. All materials contained in this guide have not yet been rated using the new definitions appearing in the 1990 edition of NFPA 704.

1-5.3 Health Hazard Rating.

In general, the health hazard in fire fighting is that of a single exposure that may vary from a few seconds to as much as an hour. The physical exertion demanded in fire fighting operations or other emergencies may be expected to intensify the effects of any exposure. Only hazards arising out of the inherent properties of the material are considered. The following information on the five degrees of hazard are based on the information in NFPA 704 and relate to the protective equipment normally available to fire fighters.

4 Materials that, on very short exposure, could cause death or major residual injury, including those that are too dangerous to be approached without specialized protective equipment. A few whiffs of the vapor or gas can cause death, or contact with the vapor or liquid may be fatal, if it penetrates the fire fighter's normal protective gear. The normal full protective clothing and breathing apparatus available to the typical fire fighter will not provide adequate protection against inhalation or skin contact with these materials.

3 Materials that, on short exposure, could cause serious temporary or residual injury, including those requiring protection from all bodily contact. Fire fighters may enter the area only if they are protected from all contact with the material. Full protective clothing, including self-contained breathing apparatus, coat, pants, gloves, boots, and bands around legs, arms, and waist, should be provided. No skin surface should be exposed.

2 Materials that, on intense or continued (but not chronic) exposure, could cause temporary incapacitation or possible residual injury, including those requiring the use of respiratory protective equipment that has an independent air supply. These materials are hazardous to health, but areas may be entered freely if personnel are provided with full-face mask

self-contained breathing apparatus that provides complete eye protection.

1 Materials that, on exposure, would cause irritation, but only minor residual injury, including those requiring the use of an approved air-purifying respirator. These materials are only slightly hazardous to health and only breathing protection is needed.

0 Materials that, on exposure under fire conditions, offer no hazard beyond that of ordinary combustible material.

1-5.4 Flammability Hazard Rating.

Susceptibility to ignition and burning is the basis for assigning the degree of hazard within this category. The method of attacking the fire is influenced by this susceptibility factor. For further information, refer to Section 1-4, Extinguishing Methods. The following information is based on the definitions of Flammability Hazard Rating contained in NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials*.

4 This degree includes flammable gases, pyrophoric liquids, and Class IA flammable liquids. The preferred method of fire attack is to stop the flow of material or to protect exposures while allowing the fire to burn itself out.

3 This degree includes Class IB and IC flammable liquids and materials that can be easily ignited under almost all normal temperature conditions. Water may be ineffective in controlling or extinguishing fires in such materials.

2 This degree includes materials that must be moderately heated before ignition will occur and includes Class II and IIIA combustible liquids and solids and semi-solids that readily give off ignitible vapors. Water spray may be used to extinguish fires in these materials because the materials can be cooled below their flash points.

1 This degree includes materials that must be preheated before ignition will occur, such as Class IIIB combustible liquids and solids and semi-solids whose flash point exceeds 200°F (93.4°C), as well as most ordinary combustible materials. Water may cause frothing if it sinks below the surface of the burning liquid and turns to steam. However, a water fog that is gently applied to the surface of the liquid will cause frothing that will extinguish the fire.

0 This degree includes any material that will not burn.

1-5.5 Reactivity Hazard Rating.

The assignment of the degree of reactivity hazard is based on the potential of the material to release energy either by itself or when in contact with water. In assigning this rating, fire exposure was considered, along with exposure to shock and pressure. The following information is based on the definitions of Reactivity Hazard Rating contained in NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials*.

4 This degree includes those materials that, in themselves, are readily capable of detonation, explosive decomposition, or explosive reaction at normal temperatures and pressures. This includes materials that are sensitive to localized mechanical or thermal shock. If a material having this Reactivity Hazard Rating is involved in an advanced or massive fire, the area should be immediately evacuated.

3 This degree includes materials that, in themselves, are capable of detonation, explosive decomposition, or explosive reaction, but require a strong initiating source or heating under confinement. This includes materials that are sensitive to thermal and mechanical shock at elevated temperatures and pressures and materials that react explosively with water. Fires involving these materials should be fought from a protected location.

2 This degree includes materials that are normally unstable and readily undergo violent chemical change, but are not capable of detonation. This includes materials that can undergo chemical change with rapid release of energy at normal temperatures and pressures and materials that can undergo violent chemical changes at elevated temperatures and pressures. This also includes materials that may react violently with water or that may form potentially explosive mixtures with water. In advanced or massive fires involving these materials, fire fighting should be done from a safe distance or from a protected location.

1 This degree includes materials that are normally stable, but that may become unstable at elevated temperatures and pressures and materials that will react with water with some release of energy, but not violently. Fires involving these materials should be approached with caution.

0 This degree includes materials that are normally stable, even under fire exposure conditions, and that do not react with water. Normal fire fighting procedures may be used.

1-5.6 Additional Markings.

The fourth space in the NFPA 704 rating is reserved for the use of two special symbols: OX, to denote materials that are oxidizing agents, and ~~W~~, to denote materials that are water-reactive.

1-6 Additional Information.

1-6.1 Mixtures with Oxygen.

Unless otherwise indicated, all values in this manual are based on tests conducted in normal air. For mixtures involving enriched oxygen atmospheres, the values may differ and an increase in hazard is probable.

1-6.2 Mixtures of Materials.

Mixtures of two or more materials may have different fire hazard properties than any of the components. Although it is common practice to base the fire hazard of a mixture on that of the most hazardous component, consideration should be given to testing the mixture itself.

1-6.3 Mists and Froths.

In finely divided form, such as a mist or spray, liquids can be ignited at temperatures considerably below their flash points. As in the case of vapors, the droplets of mist or spray must be present at a minimum concentration. Similarly, froths may be ignited at temperatures below the flash point.

1-7 Indexing.

1-7.1

The materials in this manual are listed alphabetically by the name considered to be the most common. Other names and synonyms are indexed to this common name.

1-7.2

The following prefixes are considered to be a part of the name of the material. As such, they are generally not hyphenated and are used to alphabetically index the material when they appear at the beginning of the name.

Bis	Iso	Tetra
Di	Mono	Tri
Hexa	Penta	Tris

1-7.3

The prefix “mono” is often omitted. Thus, monochlorobenzene is frequently referred to as chlorobenzene. This manual uses the more common form. The alternate form is not given, unless it is also frequently used.

1-7.4

The following prefixes are not considered to be part of the name of the material. As such, they are hyphenated, but they are not used to alphabetically index the material.

o- (ortho)	d- (dextro)
m- (meta)	l- (levulo)
p- (para)	N- (nitro)
n- (normal)	α- (alpha)
sec- (secondary)	β- (beta)
tert- (tertiary)	γ- (gamma)

These prefixes may be written out in full, as in paradichlorobenzene. In this manual, they are usually abbreviated. Thus, paradichlorobenzene appears in this manual as p-dichlorobenzene and is indexed under D. In accordance with custom, the prefix n-, for “normal,” is omitted, unless it appears in the middle of a name.

1-7.5

The prefixes “cis” and “trans” may be placed either at the beginning or the end of a name. In this manual, they are always listed at the end.

Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids Table

	FLASH POINT °F (°C)	IGNITION TEMP. °F (°C)	FLAMMABLE LIMITS Percent by Vol. Lower	Upper	Sp. Gr. (Water = 1)	Vapor Density (Air = 1)	BOILING POINT °F (°C)	Water Soluble	SEE INTRODUCTION FOR SUGGESTED EXTINGUISHING METHODS	HAZARD IDENTIFICATION Health	Flamma-bility	Reac-tivity
Abalyn	See Methyl Abietate.											
Acetal $CH_3CH(OC_2H_5)_2$ (Acetaldehydediethylacetal)	−5 (−21)	446 (230)	1.6	10.4	0.8	4.1	215 (102)	Slight	1 5	2	3	0
Acetaldehyde CH_3CHO (Acetic Aldehyde) (Ethanal)	−38 (−39) Note: Polymerizes. See Hazardous Chemicals Data.	347 (175)	4.0	60	0.8	1.5	70 (21)	Yes	1 5	3	4	2
Acetaldehydediethyl-acetal	See Acetal.											
Acetaldol	See Aldol.											
Acetanilide $CH_3CONHC_6H_5$	337 (169) (oc) Note: Melting point 237 (114).	985 ± 10 (530)			1.21	4.65	582 (306)			3	1	0
Acetic Acid, Glacial CH_3COOH	103 (39) Note: See Hazardous Chemicals Data.	867 (463)	4.0 200	19.9 @ (93, 4)	1.0+	2.1	245 (118)	Yes	5	3	2	0
Acetic Acid, Water Solutions (Ethanoic Acid)	Note: Ordinary acetic acid is the same as glacial acetic acid with water. The properties of ordinary acetic acid depend upon the strength of the solution. In concentrated form its properties approach those of glacial acetic acid. In dilute solution it is nonhazardous.							Yes				
Acetic Acid, Isopropyl Ester	See Isopropyl Acetate.											
Acetic Acid, Methyl Ester	See Methyl Acetate.											
Acetic Acid, n-Propyl Ester	See Propyl Acetate.											
Acetic Aldehyde	See Acetaldehyde.											
Acetic Anhydride $(CH_3CO)_2O$ (Ethanoic Anhydride)	120 (49) Note: See Hazardous Chemicals Data.	600 (316)	2.7	10.3	1.1	3.5	284 (140)	Yes	5	3	2	1
Acetic Ester	See Ethyl Acetate.											
Acetic Ether	See Ethyl Acetate.											
Acetoacetanilide $CH_3COCH_2CONHC_6H_5$	365 (185) (oc) Note: Melting point 185 (85).				1.1 @ melting point			Slight	5 2	2	1	0
o-Acetoacet Anisidide $CH_3COCH_2CONHC_6H_4OCH_3$	325 (168) (oc) Note: Melting point 187.9 (87).				1.1 @ melting point	7.0		No	2	2	1	0
Acetoacet-para-Phenetide $CH_3COCH_2CONHC_6H_4OCH_2CH_3$	325 (163) Note: Melting point 210–219 (99–104).				1.0+		Decomposes		2	2	1	1
Acetoacet-ortho-Toluidide $CH_3COCH_2CONHC_6H_4CH_3$	320 (160) Note: Melting point 214 (101).						Decomposes		2	2	1	1
m-Acetoacet Xylidide $CH_3COCH_2CONHC_6H_3(CH_3)_2$	340 (171) (oc) Note: Melting point 197 (92).				1.2			Slight	5 2	2	1	0
Acetoacetic Acid, Ethyl Ester	See Ethyl Acetoacetate.											
Acetoethylamide	See N-Ethylacetamide.											
												0
Acetone Cyanohydrin $(CH_3)_2C(OH)CN$ (2-Hydroxy-2-Methyl Propionitrile)	165 (74) Note: See Hazardous Chemicals Data.	1270 (688)	2.2	12.0	0.9	2.9	248 (120) Decomposes	Yes	5	4	2	2

	FLASH POINT °F (°C)	IGNITION TEMP. °F (°C)	FLAMMABLE LIMITS Percent by Vol. Lower	Upper	Sp. Gr. (Water = 1)	Vapor Density (Air = 1)	BOILING POINT °F (°C)	Water Soluble	SEE INTRODUCTION FOR SUGGESTED EXTINGUISHING METHODS	HAZARD IDENTIFICATION Health	Flamma-bility	Reac-tivity
Acetonitrile CH_3CN (Methyl Cyanide)	42 (6) (oc)	975 (524)	3.0	16.0	0.8	1.4	179 (82)	Yes	1 5	2	3	0
	Note: See Hazardous Chemicals Data.											
Acetonyl Acetone $(CH_2COCH_3)_2$ (2,5-Hexanedione)	174 (79)	920 (499)			1.0–	3.9	378 (192)	Yes	5	1	1	0
Acetophenone $C_6H_5COCH_3$ (Phenyl Methyl Ketone)	170 (77)	1058 (570)			1.0+	4.1	396 (202)	No		1	2	0
p-Acetotoluidide $CH_3CONHC_6H_4CH_3$	334 (168)				1.2	5.4	583 (306)	No		2	1	
Acetyl Acetone	See 2,4-Pentanedione.											
Acetyl Chloride CH_3COCl (Ethanoyl Chloride)	40 (4)	734 (390)			1.1	2.7	124 (51)	Violent decompo-sition.	Do not use water or foam.	3	3	2W
	Note: See Hazardous Chemicals Data.											
Acetylene $CH{:}CH$ (Ethine) (Ethyne)	Gas	581 (305)	2.5	100		0.9	–118 (–83)	No	6	0	4	3
	Note: Low pressure. Acetylene dissolved in acetone in closed cylinders can carry a 2 reactivity. See Hazardous Chemicals Data.											
Acetylene Dichloride—cis	See Dichloroethylene—cis.											
Acetylene Dichloride—trans	See Dichloroethylene—trans.											
N-Acetyl Ethanolamine $CH_3C{:}ONHCH_2CH_2OH$ (N-(2-Hydroxyethyl) acetamide)	355 (179) (oc)	860 (460)			1.1		304–308 (151–153) @ 10 mm Decom-poses	Yes	5 2	1	1	1
N-Acetyl Morpholine $CH_3CONCH_2CH_2OCH_2CH_2$	235 (113)				1.1		Decom-poses	Yes	5 2	2	1	1
Acetyl Oxide	See Acetic Anhydride.											
Acetyl Peroxide 25% solution in Dimethyl Phthalate $(CH_3CO)_2O_2$					1.2	4.1	Explodes on heating	Slight		1	2	4
	Note: See Hazardous Chemicals Data.											
Acetylphenol	See Phenyl Acetate.											
Acrolein $CH_2{:}CHCHO$ (Acrylic Aldehyde)	–15 (–26)	428 (220) Unstable	2.8	31	0.8	1.9	125 (52)	Yes	1 5	4	3	3
	Note: See Hazardous Chemicals Data.											
Acrolein Dimer $(CH_2{:}CHCHO)_2$	118 (48) (oc)				1.1		304 (151)	Yes	5	1	2	1
	Note: See Hazardous Chemicals Data.											
Acrylic Acid (Glacial) $CH_2CHCOOH$	122 (50) (oc)	820 (438)	2.4	8.0	1.1	2.5	287 (142)	Yes	5	3	2	2
	Note: Polymerizes. See Hazardous Chemicals Data.											
Acrylic Aldehyde	See Acrolein.											
Acrylonitrile $CH_2{:}CHCN$ (Vinyl Cyanide) (Propenenitrile)	32 (0) (oc)	898 (481)	3.0	17	0.8	1.8	171 (77)	Yes	1 5	4	3	2
	Note: Polymerizes. See Hazardous Chemicals Data.											
Adipic Acid $HOOC(CH_2)_4COOH$	385 (196)	788 (420)			1.37	5.04	509 (265) @ 100 mm	No			1	0
Adipic Ketone	See Cyclopentanone.											
												1
	Note: See Hazardous Chemicals Data.											

	FLASH POINT °F (°C)	IGNITION TEMP. °F (°C)	FLAMMABLE LIMITS Percent by Vol. Lower	Upper	Sp. Gr. (Water = 1)	Vapor Density (Air = 1)	BOILING POINT °F (°C)	Water Soluble	SEE INTRODUCTION FOR SUGGESTED EXTINGUISHING METHODS	HAZARD IDENTIFICATION Health	Flamma-bility	Reac-tivity
Adipoyl Chloride $(-CH_2CH_2COCl)_2$ (Adipyl Chloride)	162 (72)						257–262 (125–128) @ 11 mm		5	2	2	0
Adipyldinitrile $CN(CH_2)_4CN$ (Adiponitrile) (Tetramethylene Dicyanide)	199 (93) (oc)				0.96	3.73	563 (295)	No		4	2	
Alcohol	See Ethyl Alcohol, Methyl Alcohol, Denatured Alcohol, etc.											
Aldol $CH_3CH(OH)CH_2CHO$ (3-Hydroxybutanal) (β-Hydroxybuteraldehyde)	150 (66) (oc)	482 (250)			1.1	3.0	174–176 (79–80) @ 12 mm Decom-poses @ 176 (80)	Yes	5	3	2	2
Allyl Acetate $CH_3COCH_2CH{:}CH_2$	72 (22) (oc)	705 (374)			0.9	3.45	219 (104)	No	5 1	1	3	0
Allyl Alcohol $CH_2{:}CHCH_2OH$	70 (21) Note: See Hazardous Chemicals Data.	713 (378)	2.5	18.0	0.9	2.0	206 (97)	Yes	1 5	4	3	1
Allylamine $CH_2{:}CHCH_2NH_2$ (2-Propenylamine)	−20 (−29) Note: See Hazardous Chemicals Data.	705 (374)	2.2	22	0.8	2.0	128 (53)	Yes	1 5	4	3	1
Allyl Bromide $CH_2{:}CHCH_2Br$ (3-Bromopropene)	30 (−1)	563 (295)	4.4	7.3	1.4	4.2	160 (71)	No	5 4	3	3	1
Allyl Caproate $CH_3(CH_2)_4COOCH_2CH{:}CH_2$ (Allyl Hexanoate) (2-Propenyl Hexanoate)	150 (66)				0.9		367–370 (186–188)	No	5	1	2	0
Allyl Chloride $CH_2{:}CHCH_2Cl$ (3-Chloropropene)	−25 (−32)	737 (485)	2.9	11.1	0.9	2.6	113 (45)	No	5	3	3	1
Allyl Chlorocarbonate	See Allyl Chloroformate.											
Allyl Chloroformate $CH_2{:}CHCH_2OCOCl$ (Allyl Chlorocarbonate)	88 (31) See Hazardous Chemicals Data.				1.1	4.2	223–237 (106–114)	No	5 4	3	3	1
Allyl Diglycol Carbonate	See Diethylene Glycol Bis (Allylcarbonate).											
Allylene	See Propyne.											
Allyl Ether $(CH_2{:}CHCH_2)_2O$ (Diallyl Ether)	20 (−7) (oc)				0.8	3.4	203 (95)	Slight	5 1	3	3	2
Allylidene Diacetate $CH_2{:}CHCH(OCOCH_3)_2$	180 (82) (oc)				1.1		225 (107) @ 50 mm	No	3	2	2	1
Allyl Isothiocyanate	See Mustard Oil.											
Allylpropenyl	See 1,4-Hexadiene.											
Allyl Trichloride	See 1,2,3-Trichloropropane.											
Allyl Trichlorosilane $CH_2{:}CHCH_2SiCl_3$	95 (35) (oc)				1.2	6.05	243 (117.5)		1	3	3	2W
Allyl Vinyl Ether	See Vinyl Allyl Ether.											
Alpha Methyl Pyridine	See Picoline-alpha.											
Aminobenzene	See Aniline.											
2-Aminobiphenyl	See 2-Biphenylamine.											
[illegible] $CH_3CH_2CHNH_2CH_2OH$	(74) (oc)						(170)					0
Aminocyclohexane	See Cyclohexylamine.											

	FLASH POINT °F (°C)	IGNITION TEMP. °F (°C)	FLAMMABLE LIMITS Percent by Vol. Lower	Upper	Sp. Gr. (Water = 1)	Vapor Density (Air = 1)	BOILING POINT °F (°C)	Water Soluble	SEE INTRODUCTION FOR SUGGESTED EXTINGUISHING METHODS	HAZARD IDENTIFICATION Health	Flamma-bility	Reac-tivity
1-Aminodecane	See Decylamine.											
Amino Ethane	See Ethylamine.											
2-Aminoethanol	See Ethanolamine.											
1-Amino-4-Ethoxybenzene	See p-Phenetidine.											
β-Aminoethyl Alcohol	See Ethanolamine.											
(2-Aminoethyl) Ethanolamine $NH_2C_2H_4NHC_2H_4OH$	270 (132)	695 (368)			1.0+		470 (243)	Yes	5 2	2	1	0
4-(2-Aminoethyl)-Morpholine $C_2H_4OC_2H_4NC_2H_4NH_2$					1.0	4.5	395.6 (202.8)	Yes	5	2	2	0
1-(2-Aminoethyl)-Piperazine $H_2NC_2H_4NCH_2CH_2NHCH_2CH_2$	200 (93) (oc)				1.0−	4.4	432 (222)	Yes	5	2	2	0
1-Aminoheptane	See Heptylamine.											
α-Aminoisopropyl Alcohol	See 1-Amino-2-Propanol.											
2-Amino-4-Methyl-pentane	See 1,3-Dimethylbutylamine.											
2-Amino-2-Methyl-1-Propanol $(CH_3)_2C(NH_2)CH_2OH$	153 (67)				0.9	3.0	329 (165)	Yes	5	2	2	0
1-Aminooctane	See Octylamine.											
2-Aminopentane	See sec-Amylamine.											
p-Aminophenetole	See p-Phenetidine.											
(m-Aminophenyl) Methyl Carbinol $NH_2C_6H_4(CH(OH)CH_3)$ (m-Amino-α-Methyl-benzyl Alcohol)	315 (157) (oc)				1.1		423 (217) @ 100 mm	Yes	5 2	2	1	0
3-Aminopropanol $H_2N(CH_2)_3OH$	175 (80) (oc)				<1.0		363–367 (184–186)	Yes	5	3	2	0
1-Amino-2-Propanol $NH_2CH_2CHOHCH_3$ (α-Aminoisopropyl Alcohol) (Isopropanolamine)	171 (77)	705 (374)			1.0−	2.6	320 (160)	Yes	5	2	2	0
N-(3-Aminopropyl) Cyclohexylamine $C_6H_{11}NHC_3H_6NH_2$	175 (79) (oc)				0.9	5.4		Yes	5	2	2	0
N-(3-Aminopropyl) Morpholine $C_2H_4OC_2H_4N(CH_2)_3NH_2$	220 (104) (oc)				1.0−		438 (226)	Yes	5 2	2	1	0
Ammonia, Anhydrous NH_3	Gas	1204 (651)	15	28	0.7@ −33°C	0.6	−28 (−33)	Yes	6	3	1*	0
Note: See Hazardous Chemicals Data. *This gas is "1" instead of "4" because it is hard to burn.												
Amoxybenzene	See Amyl Phenyl Ether.											
Amyl Acetate $CH_3COOC_5H_{11}$ (1-Pentanol Acetate) Comm.	60 (16) 70 (21)	680 (360)	1.1	7.5	0.9	4.5	300 (149)	Slight	1 5	1	3	0
sec-Amyl Acetate $CH_3COOCH(CH_3)$-$(CH_2)_2CH_3$ (2-Pentanol Acetate)	89 (32)				0.9	4.5	249 (121)	Slight	1 5	1	3	0
												0
sec-Amyl Alcohol $CH_3CH_2CH_2CH(OH)CH_3$ (Diethyl Carbinol)	94 (34)	650 (343)	1.2	9.0	0.8	3.0	245 (118)	Slight	1 5	1	3	0

	FLASH POINT °F (°C)	IGNITION TEMP. °F (°C)	FLAMMABLE LIMITS Percent by Vol. Lower	Upper	Sp. Gr. (Water = 1)	Vapor Density (Air = 1)	BOILING POINT °F (°C)	Water Soluble	SEE INTRODUCTION FOR SUGGESTED EXTINGUISHING METHODS	HAZARD IDENTIFICATION Health	Flamma-bility	Reac-tivity
Amylamine $C_5H_{11}NH_2$ (Pentylamine)	30 (−1)		2.2	22	0.8	3.0	210 (99)	Yes	1 5	2	3	0
sec-Amylamine $CH_3(CH_2)_2CH(CH_3)NH_2$ (2-Aminopentane) (Methylpropylcarbinylamine)	20 (−7)				0.7	3.0	198 (92)	Yes	5 1	2	3	0
p-tert-Amylaniline $(C_2H_5)(CH_3)_2CC_6H_4NH_2$	215 (102)				0.9		498–504 (259–262)	No	2	3	1	0
Amylbenzene $C_6H_5C_5H_{11}$ (Phenylpentane)	150 (66) (oc)				0.8–0.9	5.1	365 (185)	No		1	2	0
Amyl Bromide $CH_3CH_2CH_2CH_2CH_2Br$ (1-Bromopentane)	90 (32)				1.2		128–9 (53–54) @ 746 mm	No	4	1	3	0
Amyl Butyrate $C_5H_{11}OOCC_3H_7$	135 (57)				0.9	5.46	365 (185)	No	5	1	2	0
Amyl Carbinol	See Hexyl Alcohol.											
Amyl Chloride $CH_3(CH_2)_3CH_2Cl$ (1-Chloropentane)	55 (13) (oc)	500 (260)	1.6	8.6	0.9	3.7	223 (106)	No	1	1	3	0
tert-Amyl Chloride $CH_3CH_2CCl(CH_3)CH_3$		653 (345)	1.5	7.4	1.4	3.7	187 (86)	No	3	1	3	0
Amyl Chlorides (Mixed) $C_5H_{11}Cl$	38 (3) (oc)				0.9		185–228 (85–109)	No	1	1	3	0
Amylcyclohexane $C_5H_{11}C_6H_{11}$		462 (239)			0.8		395 (202)			1		0
Amylene	See 1-Pentene.											
β-Amylene-cis $C_2H_5CH{:}CHCH_3$ (2-Pentene-cis)	< −4 (< −20)				0.66	2.42	99 (37)			0	4	
β-Amylene-trans $C_2H_5CH{:}CHCH_3$ (2-Pentene-trans)	< −4 (< −20)				0.67	2.42	97 (36)			0	4	
Amylene Chloride	See 1,5-Dichloropentane.											
Amyl Ether $C_5H_{11}OC_5H_{11}$ (Diamyl Ether) (Pentyloxypentane)	135 (57) (oc)	338 (170)			0.8–0.9	5.5	374 (190)	No	5	1	2	0
Amyl Formate $HCOOC_5H_{11}$	79 (26)				0.9	4.0	267 (131)	No	1	1	3	0
Amyl Lactate $C_2H_5OCOOCH_2$-$CH(CH_3)C_2H_5$	175 (79)				1.0−	5.5	237–239 (114–115) @ 36 mm	Very slight		1	2	0
Amyl Laurate $C_{11}H_{23}COOC_5H_{11}$	300 (149)				0.9		554–626 (290–330)	No	2	0	1	0
Amyl Maleate $(CHCOOC_5H_{11})_2$	270 (132)				1.0−		518–599 (270–315)	No	2	0	1	0
Amyl Mercaptan (n) $C_5H_{11}SH$ (1-Pentanethiol)	65 (18) (oc)				0.8	3.59	260 (127)			2	3	
Amyl Mercaptans (Mixed) $CH_3(CH_2)_4SH$	65 (18) (oc) Note: See Hazardous Chemicals Data.				0.8		176–257 (80–125)	No	1	2	3	0
												0
Amyl Nitrate $CH_3(CH_2)_4NO_3$	118 (48) (oc)				1.0−		306–315 (153–157)	No		2	2	0 OX

	Flash Point °F (°C)	Ignition Temp. °F (°C)	Flammable Limits Percent by Vol. Lower	Upper	Sp. Gr. (Water = 1)	Vapor Density (Air = 1)	Boiling Point °F (°C)	Water Soluble	See Introduction for Suggested Extinguishing Methods	Hazard Identification Health	Flamma-bility	Reac-tivity
Amyl Nitrite $CH_3(CH_2)_4NO_2$		410 (210)			0.9	4.0	220 (104)	Slight	5	1		2
Amyl Oleate $C_{17}H_{33}COOC_5H_{11}$	366 (186)				0.9		392–464 (200–240) @ 20 mm	No	2	0	1	0
Amyl Oxalate $(COOC_5H_{11})_2$ (Diamyl Oxalate)	245 (118)				1.0–		464–523 (240–273)	No	2	0	1	0
o-Amyl Phenol $C_5H_{11}C_6H_4OH$	219 (104) (oc)				1.0–		455–482 (235–250)	Slight	5 2	2	1	0
p-tert-Amyl Phenol	See Pentaphen.											
p-sec-Amylphenol $C_5H_{11}C_6H_4OH$	270 (132)				1.0–		482–516 (250–269)	No	2	1	1	0
2-(p-tert-Amylphenoxy) ethanol $C_5H_{11}C_6H_4OCH_2CH_2OH$	280 (138)				1.0+		567–590 (297–310)	No	2	1	1	0
2-(p-tert-Amylphenoxy) ethyl Laurate $C_{11}H_{23}COO(CH_2)_2O$-$C_6H_4C_5H_{11}$	410 (210)				0.9		464–500 (240–260) @ 6 mm		2	0	1	0
p-tert-Amylphenyl Acetate $CH_3COOC_6H_4C_5H_{11}$	240 (116)				1.0–		507–511 (264–266)		2	0	1	0
p-tert-Amylphenyl Butyl Ether $C_5H_{11}C_6H_4OC_4H_9$	275 (135)				0.9		540–550 (282–288)	No	2	0	1	0
Amyl Phenyl Ether $CH_3(CH_2)_4OC_6H_5$ (Amoxybenzene)	185 (85)				0.9	5.7	421–444 (216–229)	No		0	2	0
p-tert-Amylphenyl Methyl Ether $C_5H_{11}C_6H_4OCH_3$	210 (99)				0.9		462–469 (239–243)			0	1	0
Amyl Phthalate	See Diamyl Phthalate.											
Amyl Propionate $C_2H_5COO(CH_2)_4CH_3$ (Pentyl Propionate)	106 (41) (oc)	712 (378)			0.9		275–347 (135–175)	No		0	2	0
Amyl Salicylate $HOC_6H_4COOC_5H_{11}$	270 (132)				1.1		512 (267)	No	2	0	1	0
Amyl Stearate $CH_3(CH_2)_{16}COOC_5H_{11}$	365 (185) (oc)				0.9		680 (360)	No	2	0	1	0
Amyl Sulfides, Mixed $C_5H_{11}S$	185 (85) (oc)				0.9		338–356 (170–180)	No		2	2	0
Amyl Toluene $C_5H_{11}C_6H_4CH_3$	180 (82) (oc)				0.9		400–415 (204–213)	No		2	2	0
Amyl Trichlorosilane $C_5H_{11}SiCl_3$	145 (63) (oc)				1.1		334 (168)			3	2	2W
Amyl Xylyl Ether $C_5H_{11}OC_6H_3(CH_3)_2$	205 (96) (oc)				0.9		480–500 (249–260)	No		2	1	0
Aniline $C_6H_5NH_2$ (Aminobenzene) (Phenylamine)	158 (70) Note: See Hazardous Chemicals Data.	1139 (615)	1.3	1.1	1.0+	3.2	364 (184)	Slight	5	3	2	0

	FLASH POINT °F (°C)	IGNITION TEMP. °F (°C)	FLAMMABLE LIMITS Percent by Vol. Lower	Upper	Sp. Gr. (Water = 1)	Vapor Density (Air = 1)	BOILING POINT °F (°C)	Water Soluble	SEE INTRODUCTION FOR SUGGESTED EXTINGUISHING METHODS	HAZARD IDENTIFICATION Health	Flamma-bility	Reac-tivity
2-Anilinoethanol $C_6H_5NHCH_2CH_2OH$ (β-Anilinoethanol Ethoxyaniline) (β-Hydroxyethylaniline)	305 (152) (oc)				1.1		547 (286)	Very slight	2	2	1	0
β-Anilinoethanol Ethoxyaniline	See 2-Anilinoethanol.											
o-Anisaldehyde	See o-Methoxy Benzaldehyde.											
o-Anisidine $H_2NC_6H_4OCH_3$ (2-Methoxyaniline)	244 (118) (oc)				1.1		435 (224)	No	5 2	2	1	0
Anisole $C_6H_5OCH_3$ (Methoxybenzene) (Methyl Phenyl Ether)	125 (52) (oc)	887 (475)			1.0 –	3.7	309 (154)	No		1	2	0
Anol	See Cyclohexanol.											
Anthracene $(C_6H_4CH)_2$	250 (121) Note: Melting point 423 (217).	1004 (540)	0.6		1.24	6.15	644 (340)			0	1	
Anthraquinone $C_6H_4(CO)_2C_6H_4$	365 (185) Note: Melting point 354 (179).				1.44	7.16	716 (380)	No		0	1	
Artificial Almond Oil	See Benzaldehyde.											
Asphalt (Cutback)	< 50 (< 10)							No	2	0	3	0
Asphalt, Liquid-Medium Curing	100 (38) (oc) 150 (66) (oc)	(min) (min)	Grades MC-30 and MC-70 Grades MC-250; MC-800; and MC-3000					No	2	0	2	0
Asphalt, Liquid-Rapid Curing	80 (27) (oc)	(min)	Grades RC-250, RC-800; and RC-3000					No	2	0	3	0
Asphalt, Liquid-Slow Curing	150 + (66) (oc) 175 + (79) (oc) 200 + (93) (oc) 225 + (107) (oc)	Grade SC-70 Grade SC-250 Grade SC-800 Grade SC-3000						No	2	0 0 0 0	2 2 1 1	0 0 0 0
Asphalt (Typical) (Petroleum Pitch)	400 + (204 +)	905 (485)			1.0–1.1		> 700 (> 371)	No	2	0	1	0
Aziridine	See Ethyleneimine.											
Azobisisobutyronitrile $N{:}CC(CH_3)_2N{:}NC(CH_3)_2C{:}N$	Note: Melting point 221 (105).	147 (64)					Decom-poses	No		3		2
Azole	See Pyrrole.											
Banana Oil	See Isoamyl Acetate.											
Benzaldehyde C_6H_5CHO (Artificial Almond Oil) (Benzenecarbonal)	145 (63)	377 (192)			1.1	3.7	355 (179)	No	3	2	2	0
Benzedrine	< 212				0.93	4.67	392			0	1	

C_6H_6 (Benzol)	Note: See Hazardous Chemicals Data.											0
Benzenecarbonal	See Benzaldehyde.											
Benzene Carbonyl Chloride	See Benzoyl Chloride.											

	FLASH POINT °F (°C)	IGNITION TEMP. °F (°C)	FLAMMABLE LIMITS Percent by Vol. Lower	Upper	Sp. Gr. (Water = 1)	Vapor Density (Air = 1)	BOILING POINT °F (°C)	Water Soluble	SEE INTRODUCTION FOR SUGGESTED EXTINGUISHING METHODS	HAZARD IDENTIFICATION Health	Flamma-bility	Reac-tivity
Benzine	See Petroleum Ether.											
Benzocyclobutene	95 (35)	477 (247)			0.96		306 (152)					
Benzoic Acid C_6H_5COOH	250 (121) Note: Melting point 252 (122).	1058 (570)			1.27	4.21	482 (250)	Slight		2	1	
Benzol	See Benzene.											
Benzol Diluent	−25 (−32) Note: Flash point and ignition temperature will vary depending on the manufacturer.	450 (232)	1.0	7.0	<1		140–210 (60–99)	No	1	2	3	0
p-Benzoquinone $C_6H_4O_2$ (Quinone)	100–200 (38–93) Note: Melting point 234–237 (112–114).	1040 (560)			1.3	3.7	Sublimes	No		1	2	1
Benzotrichloride $C_6H_5CCl_3$ (Toluene, α, α, α-Trichloro) (Phenyl Chloroform)	260 (127)	412 (211)			1.4		429 (221)	No	2	3	1	0
Benzotrifluoride $C_6H_5CF_3$	54 (12) Note: See Hazardous Chemicals Data.				1.2	5.0	216 (102)	No	4	3	3	1
Benzoyl Chloride C_6H_5COCl (Benzene Carbonyl Chloride)	162 (72) Note: See Hazardous Chemicals Data.				1.2	4.9	387 (197)	Decomposes		3	2 Decomposes in water.	2W
Benzyl Acetate $CH_3COOCH_2C_6H_5$	195 (90)	860 (460)			1.1		417 (214)	Slight	5 2	1	1	0
Benzyl Alcohol $C_6H_5CH_2OH$ (Phenyl Carbinol)	200 (93)	817 (436)			1.0+		403 (206)	Slight	5 2	2	1	0
Benzyl Benzoate $C_6H_5COOCH_2C_6H_5$	298 (148)	896 (480)			1.1		614 (323)	No	2	1	1	0
Benzyl Butyl Phthalate $C_4H_9COOC_6H_4COOCH_2$-C_6H_5 (Butyl Benzyl Phthalate)	390 (199)				1.1		698 (370)	No	2	1	1	0
Benzyl Carbinol	See Phenethyl Alcohol.											
Benzyl Chloride $C_6H_5CH_2Cl$ (α-Chlorotoluene)	153 (67) Note: See Hazardous Chemicals Data.	1085 (585)	1.1		1.1	4.4	354 (179)	No	3	3	2	1
Benzyl Cyanide $C_6H_5CH_2CN$ (Phenyl Acetonitrile) (α-Tolunitrile)	235 (113) (oc)				1.0+		452 (233.5)	No	5 2	2	1	0
N-Benzyldiethylamine $C_6H_5CH_2N(C_2H_5)_2$	170 (77) (oc)				0.9		405–420 (207–216)			2	2	0
Benzyl Ether	See Dibenzyl Ether.											
Benzyl Mercaptan $C_6H_5CH_2SH$ (α-Toluenethiol)	158 (70)				1.06	4.28	383 (195)			2	2	
Benzyl Salicilate $OHC_6H_4COOCH_2C_6H_5$ (Salycilic Acid Benzyl Ester)	>212 (>100)				1.2		406 (208)	No	5	1	1	0
Bicyclohexyl $[CH_2(CH_2)_4CH]_2$ (Dicyclohexyl)	165 (74)	473 (245)	0.7 @ 212 (100)	5.1 @ 302 (150)	0.9	5.7	462 (239)	Slight	5	1	2	0
Biphenyl	235	1004	0.6	5.8	1.2		489	No	2	2	1	0

2-Biphenylamine $NH_2C_6H_4C_6H_5$ (2-Aminobiphenyl)	Note: Melting point 121 (49).	842 (450)				5.8	570 (299)	No	2	2	1	0

	FLASH POINT °F (°C)	IGNITION TEMP. °F (°C)	FLAMMABLE LIMITS Percent by Vol. Lower	Upper	Sp. Gr. (Water = 1)	Vapor Density (Air = 1)	BOILING POINT °F (°C)	Water Soluble	SEE INTRODUCTION FOR SUGGESTED EXTINGUISHING METHODS	HAZARD IDENTIFICATION Health	Flamma-bility	Reac-tivity
Bis (p-tert-Butylphenyl) phenyl Phosphate $(C_4H_9C_6H_4O)_2POOC_6H_5$	482 (250)				1.1		500–527 (260–275) @ 5 mm	No	2		1	0
Bis [2-(2-Chloroethoxy) ethyl] Ether $(CH_2ClCH_2OCH_2CH_2)_2O$ (Tetraglycol Dichloride)	> 250 (> 121)				1.2		237 (114)	Slight	5 2	2	1	0
Bis (2-Chloroethyl) Ether $(CH_2ClCH_2)_2O$ (Chlorex)	131 (55)				1.2	4.9	353 (178)	Very slight		2	2	0
Bis (2-Chloroethyl) Formal $CH_2(OCH_2CH_2Cl)_2$ (Di-(2-Chloroethyl) Formal) (2,2-Dichloroethyl Formal)	230 (110) (oc)				1.2		425 (218)	Very slight	5 2	2	1	0
Bis (β-Chloroisopropyl) Ether	See Dichloroisopropyl Ether.											
Bis-Diethylene Glycol Monoethyl Ether Phthalate $C_6H_4(COOC_2H_4OC_2H_4$-$OC_2H_5)_2$	405 (207)				1.1		500 (260)		5 2	1	1	0
Bis (2,4-Dimethylbutyl) Maleate $[(CH_3)_2CHCH_2CH(CH_3)$-$OCOCH{:}]_2$ (Di(Methylamyl) Maleate)	290 (143) (oc)				0.9		394 (201) @ 50 mm	No	2	1	1	0
N,N[1]-Bis-(1,4-Dimethyl-pentyl)p-Phenylenediamine $C_6H_4[NHCH(CH_3)CH_2CH_2$-$CH(CH_3)_2]_2$	347 (175) (oc)	770 (410)			0.9				5 2	2	1	0
1,3-Bis (Ethylamino) Butane	See N,N-Diethyl-1,3-Butanediamine.											
Bis (2-Ethylhexyl) Amine $[C_4H_9CH(C_2H_5)CH_2]_2NH$ (Diethylhexylamine) (Dioctylamine)	270 (132) (oc)				0.8		537 (281)	Slight	5 2	3	1	0
Bis (2-Ethylhexyl)-Ethanolamine $[C_4H_9CH(C_2H_5)CH_2]_2$-NC_2H_4OH (Diethylhexylethanolamine)	280 (138)				0.9		421 (216) @ 50 mm	Slight	5 2	1	1	0
Bis (2-Ethylhexyl) Maleate $C_8H_{17}OCOCH{:}CHCOOC_8H_{17}$ (Di(2-Ethylhexyl) Maleate)	365 (185)				0.9		408 (209) @ 10 mm	No	5 2	0	1	0
Bis (2-Ethylhexyl) Phosphoric Acid $[C_4H_9CH(C_2H_5)CH]_2HPO_4$ (Di(2-Ethylhexyl) Phosphoric Acid)	385 (196) (oc)				1.0–			No	5 2			
Bis (2-Ethylhexyl) Succinate $(C_{10}H_{19}O_2)_2$ (Di(2-Ethylhexyl) Succinate)	315 (157)				0.9		495 (257) @ 50 mm	Slight	5 2	0	1	0
N,N-Bis (1-Methylheptyl) Ethylenediamine $HC(CH_3)(C_6H_{13})NHCH_2$-$CH_2NHCH(CH_3)(C_6H_{13})$	> 400 (> 204)				0.8		424 (218) @ 43 mm	No	2	0	1	0
Bis (β-Methylpropyl) Amine	See Diisobutylamine.											
Bis (2,2,4-Trimethyl-pentanediolisobutyrate) Diglycolate	383 (195) (oc)				1.1		639 (337)		2	0	1	0

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Borneol $C_{10}H_{17}OH$ (Borneo Camphor)	150 (66)				1.0+		413 (212) Sublimes	No		2	2	0
Boron Trifluoride Etherate $CH_3CH_2O(BF_3)CH_2CH_3$	147 (64) (oc)				1.1		259 (126)	Decomposes		3	2 Decomposes in water.	1W
Brandy	See Ethyl Alcohol and Water.											
Brazil Wax	See Carnauba Wax.											
Bromobenzene C_6H_5Br (Phenyl Bromide)	124 (51)	1049 (565)			1.5	5.4	313 (156)	No	3	2	2	0
1-Bromo Butane	See Butyl Bromide.											
4-Bromodiphenyl $C_6H_5C_6H_4Br$	291 (144)						592 (311)	No	2	2	1	0
Bromoethane	See Ethyl Bromide.											
Bromomethane	See Methyl Bromide.											
1-Bromopentane	See Amyl Bromide.											
3-Bromopropene	See Allyl Bromide.											
o-Bromotoluene $BrC_6H_4CH_3$	174 (79)				1.4	5.9	359 (182)	No	3	2	2	0
p-Bromotoluene $BrC_6H_4CH_3$	185 (85)				1.4	5.9	363 (184)	No	3	2	2	0
Bronzing Liquid	May be below 80 (27).							No				
1,3-Butadiene $CH_2{:}CHCH{:}CH_2$ (Erythrene)	Gas Note: Polymerizes. See Hazardous Chemicals Data.	788 (420)	2.0	12.0		1.9	24 (−4)	No	6	2	4	2
Butadiene Monoxide $CH_2{:}CHCHOCH_2$ (Vinylethylene Oxide)	< −58 (< −50)				0.9	2.4	151 (66)		1	2	3	2
Butanal	See Butyraldehyde.											
Butanal Oxime	See Butyraldoxime.											
Butane $CH_3CH_2CH_2CH_3$	−76 (−60)	550 (287)	1.9	8.5		2.0	31 (−1)	No	6	1	4	0
1,3-Butanediamine $NH_2CH_2CH_2CHNH_2CH_3$ (1,3-Diaminobutane)	125 (52) (oc)				0.9	3.0	289–302 (143–150)	Yes	5	3	2	0
1,2-Butanediol $CH_3CH_2CHOHCH_2OH$ (1,2-Dihydroxybutane) (Ethylethylene Glycol)	104 (40)				1.0	3.1	381 (194)	Slight	5	1	2	0
1,3-Butanediol	See β-Butylene Glycol.											
1,4-Butanediol $HOCH_2CH_2CH_2CH_2OH$	250 (121) (oc) Note: Melting point 64–66 (18–19).				1.0+	3.1	442 (228)	Yes	2 5	1	1	0
2,3-Butanediol $CH_3CHOHCHOHCH_3$		756 (402)			1.0+		363 (184)	Yes	5	1	1	0
2,3-Butanedione $CH_3COCOCH_3$ (Diacetyl)	80 (27)				1.0−	3.0	190 (88)	Yes	5	1	3	0
1-Butanethiol $CH_3CH_2CH_2CH_2SH$ (Butyl Mercaptan)	35 (2)				0.8	3.1	208 (98)	Slight	5 1	2	3	0
2-Butanethiol	−10				0.8	3.11	185	No	5	2	3	0

2-Butanol	See sec-Butyl Alcohol.											
2-Butanone	See Methyl Ethyl Ketone.											
2-Butenal	See Crotonaldehyde.											

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1-Butene $CH_3CH_2CH:CH_2$ (α-Butylene)	Gas	725 (385)	1.6	10.0		1.9	21 (−6)	No	6	1	4	0
2-Butene-cis $CH_3CH:CHCH_3$	Gas	617 (325)	1.7	9.0	0.6	1.9	38.7 (4)		6	1	4	0
2-Butene-trans $CH_3CH:CHCH_3$ (β-Butylene)	Gas	615 (324)	1.8	9.7		1.9	−34 (1)	No	6	1	4	0
Butenediol $HOCH_2CH:CHCH_2OH$ (2-Butene-1,4-Diol)	263 (128) (oc) Note: Melting point 45 (7).				1.1	3.0	286–300 (141–149) @ 20 mm	Yes	2 5	1	1	0
2-Butene-1,4-Diol	See Butenediol.											
2-Butene Nitrile	See Crotononitrile.											
Butoxybenzene	See Butyl Phenyl Ether.											
1-Butoxybutane	See Dibutyl Ether.											
2,β-Butoxyethoxyethyl Chloride $C_4H_9CH_2CH_2OCH_2CH_2Cl$	190 (88)				1.0	6.1	392–437 (200–225)			2	2	0
1-(Butoxyethoxy)-2-Propanol $CH_3CH(OH)CH_2OC_2H_4$- $OC_2H_4C_2H_5$	250 (121) (oc)	509 (265)			0.9		445 (229)	Yes	5 2	2	1	0
Butoxyethyl Diglycol Carbonate	See Diethylene Glycol Bis (2-Butoxyethyl Carbonate).											
β-Butoxyethyl Salicylate $OCH_6H_4COOCH_2CH_2OC_4H_9$	315 (157)				1.0+		367–378 (186–192)	No	2	0	1	0
Butoxyl	See 3-Methoxybutyl Acetate.											
N-Butyl Acetamide $CH_3CONHC_4H_9$	240 (116)				0.9		455–464 (235–240)		2	2	1	0
N-Butylacetanilide $CH_3(CH_2)_3N(C_6H_5)COCH_3$	286 (141)				1.0−		531–538 (277–281)	No	2	2	1	0
Butyl Acetate $CH_3COOC_4H_9$ (Butylethanoate)	72 (22)	797 (425)	1.7	7.6	0.9	4.0	260 (127)	Slight	1 5	1	3	0
sec-Butyl Acetate $CH_3COOCH(CH_3)C_2H_5$	88 (31) (oc)		1.7	9.8	0.9	4.0	234 (112)	Slight	1 5	1	3	0
Butyl Acetoacetate $CH_3COCH_2COO(CH_2)_3CH_3$	185 (85) (oc)				1.0−	5.5	417 (214)	Slight	5	1	2	0
Butyl Acetyl Ricinoleate $C_{17}H_{32}(OCOCH_3)$- $(COOC_4H_9)$	230 (110)	725 (385)			0.9		428 (220)	No	2	2	1	0
Butyl Acrylate $CH_2:CHCOOC_4H_9$	84 (29)	559 (292)	1.7	9.9	0.9	4.4	260 (127) Polymerizes	No		2	2	2
Butyl Alcohol $CH_3(CH_2)_2CH_2OH$ (1-Butanol) (Propylcarbinol) (Propyl Methanol)	98 (37)	650 (343)	1.4	11.2	0.8	2.6	243 (117)	No	1 5	1	3	0
sec-Butyl Alcohol $CH_3CH_2CHOHCH_3$ (2-Butanol) (Methyl Ethyl Carbinol)	75 (24)	761 (405)	1.7 @ 212 (100)	9.8 @ 212 (100)	0.8	2.6	201 (94)	Slight	1 5	1	3	0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0

Butylamine $C_4H_9NH_2$ (1-Amino Butane)	10 (−12)	594 (312)	1.7	9.8	0.8	2.5	172 (78)	Yes	1 5	3	3	0

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sec-Butylamine $CH_3CH_2CH(NH_2)CH_3$	16 (−9)				0.72	2.52	145 (63)			3	3	
tert-Butylamine $(CH_3)_3C{:}NH_2$		716 (380)	1.7 @ 212 (100)	8.9 @ 212 (100)	0.7	2.5	113 (45)	Yes	5	2	4	0
Butylamine Oleate $C_{17}H_{33}COONH_3C_4H_9$	150 (66) (oc)				0.9			Yes	5	3	2	0
tert-Butylaminoethyl Methacrylate $(CH_3)_3CNHC_2H_4$- $OOCC(CH_3){:}CH_2$	205 (96) (oc)				0.9	5.5	200–221 (93–105)	No		2	1	0
N-Butylaniline $C_6H_5NHC_4H_9$	225 (107) (oc)				0.9		465 (241)	Slight	5 2	3	1	0
Butylbenzene $C_6H_5C_4H_9$	160 (71) (oc)	770 (410)	0.8	5.8	0.9	4.6	356 (180)	No		2	2	0
sec-Butylbenzene $C_6H_5CH(CH_3)C_2H_5$	126 (52)	784 (418)	0.8	6.9	0.9	4.6	344 (173)	No		2	2	0
tert-Butylbenzene $C_6H_5C(CH_3)_3$	140 (60) (oc)	842 (450)	0.7 @ 212 (100)	5.7 @ 212 (100)	0.9	4.6	336 (169)	No		2	2	0
Butyl Benzoate $C_6H_5COOC_4H_9$	225 (107) (oc)				1.0		482 (250)	No	2	1	1	0
Butyl Benzyl Phthalate	See Benzyl Butyl Phthalate.											
2-Butylbiphenyl $C_6H_5.C_6H_4.C_4H_9$	> 212 (> 100)	806 (430)				7.26	~554 (~290)			0	1	
Butyl Bromide $CH_3(CH_2)_2CH_2Br$ (1-Bromo Butane)	65 (18)	509 (265)	2.6 @ 212 (100)	6.6 @ 212 (100)	1.3	4.7	215 (102)	No	4	2	3	0
Butyl Butyrate $CH_3(CH_2)_2COOC_4H_9$	128 (53) (oc)				0.9	5.0	305 (152)	Slight	5	2	2	0
Butylcarbamic Acid, Ethyl Ester	See N-Butylurethane.											
tert-Butyl Carbinol $(CH_3)_3CCH_2OH$ (2,2-Dimethyl-1-Propanol)	98 (37)				0.8	3.0	237 (114)	Slight	1 5	2	3	0
Butyl Carbitol	See Diethylene Glycol Monobutyl Ether.											
4-tert-Butyl Catechol $(OH)_2C_6H_3C(CH_3)_3$	266 (130)				1.0+		545 (285)	No	2	2	1	0
Butyl Chloride C_4H_9Cl (1-Chlorobutane)	15 (−9)	464 (240)	1.8	10.1	0.9	3.2	170 (77)	No	1	2	3	0
sec-Butyl Chloride $CH_3CHClC_2H_5$ (2-Chlorobutane)	<32 (<0)				0.87	3.20	155 (68)			2	3	
tert-Butyl Chloride $(CH_3)_3CCl$ (2-Chloro-2-Methyl-Propane)	<32 (<0)				0.87	3.20	124 (51)			2	3	
4-tert-Butyl-2-Chlorophenol	225 (107)				1.1		453–484 (234–251)	No	2	2	1	0
											2	0
p-tert-Butyl-o-Cresol $(OH)C_6H_3CH_3C(CH_3)_3$	244 (118)				1.0−		278–280 (137–138)	No	2	2	1	0

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Butylcyclohexane $C_4H_9C_6H_{11}$ (1-Cyclohexylbutane)		475 (246)			0.8		352–356 (178–180)			0		0
sec-Butylcyclohexane $CH_3CH_2CH(CH_3)C_6H_{11}$ (2-Cyclohexylbutane)		531 (277)			0.8		351 (177)			0		0
tert-Butylcyclohexane $(CH_3)_3CC_6H_{11}$		648 (342)			0.8		333–336 (167–169)			0		0
N-Butylcyclohexylamine $C_6H_{11}NH(C_4H_9)$	200 (93) (oc)				0.8		409 (209)	Slight	5	2	1	0
Butylcyclopentane $C_4H_9C_5H_9$		480 (250)			0.8		314 (157)			0		0
Butyldecalin $C_4H_9C_{10}H_{17}$	500 (260)								2	1	1	0
tert-Butyldecalin $C_4H_9C_{10}H_{17}$	640 (338)								2	1	1	0
N-Butyldiethanolamine $C_4H_9N(C_2H_4OH)_2$	245 (118) (oc)				1.0 –		504 (262)	Yes	5 2	2	1	0
tert-Butyldiethanolamine $C_8H_{19}NO_2$ [2,2-(tert-Butylimino) Diethanol]	285 (141) (oc) Note: Melting point 117 (47).				1.0 –		329–338 (165–170) @ 33 mm	Yes	2 5	2	1	0
Butyl Diglycol Carbonate	See Diethylene Glycol Bis (Butyl Carbonate).											
α-Butylene	See 1-Butene.											
β-Butylene	See 2-Butene-trans.											
γ-Butylene	See 2-Methylpropene.											
α-Butylene Glycol $C_2H_5CHOHCH_2OH$ (1,2-Butanediol)	194 (90)				1.01	3.10	377 (192)			0	2	
β-Butylene Glycol $CH_3CH(OH)CH_2CH_2OH$ (1,3-Butanediol)	250 (121)	743 (395)			1.0		399 (204)	Yes	5 2	1	1	0
Butylene Glycol (pseudo) $CH_3(CHOH)_2CH_3$ (2,3-Butanediol) (Dihydroxy Butane 2,3)	185 (85) (oc)				1.01	3.10	356 (180)			0	2	
2,3-Butylene Oxide $CH_3HCOCHCH_3$	5 (–15)	822 (439)	1.5	18.3	0.83	2.49	149 (65)	Slight		2	3	2
1,2-Butylene Oxide $H_2COCHCH_2CH_3$	–7 (–22) Note: See Hazardous Chemicals Data.	822 (439)	1.7	19	0.8	2.2	145 (63)	Yes	5 1	2	3	2
Butyl Ethanedioate	See Butyl Oxalate.											
N-Butyl Ethanolamine $CH_3(CH_2)_3NHCH_2CH_2OH$	170 (77) (oc)				0.9	4.0	377 (192)	Yes	5	1	2	0
Butyl Ether	See Dibutyl Ether.											
Butylethylacetaldehyde	See 2-Ethylhexanal.											
Butyl Ethylene	See 1-Hexene.											
Butyl Ethyl Ether	See Ethyl Butyl Ether.											
Butyl Formate $HCOOC_4H_9$ (Butyl Methanoate) (Formic Acid, Butyl Ester)	64 (18)	612 (322)	1.7	8.2	0.9	3.5	225 (107)	Yes	1 5	2	3	0

$(CH_3)_3COOH$	(< 27) Note: May explode. See Hazardous Chemicals Data.	4 OX
2,2-(Butylimino) Diethanol	See tert-Butyldiethanolamine.	

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n-Butyl Isocyanate $CH_3(CH_2)_3NCO$ (Butyl Isocyanate)	66 (19)				0.9	3.00	235 (113)	Reacts	5	3	2	2
Butyl Isovalerate $C_4H_9OOCCH_2CH(CH_3)_2$	127 (53)				0.87	5.45	302 (150)			0		
Butyl Lactate $CH_3CH(OH)COOC_4H_9$	160 (71) (oc)	720 (382)			1.0–	5.0	320 (160)	Slight	5	1	2	0
Butyl Mercaptan	See 1-Butanethiol.											
tert-Butyl Mercaptan	See 2-Methyl-2-Propanethiol.											
Butyl Methacrylate $CH_2{:}C(CH_3)$-$COO(CH_2)_3CH_3$	126 (52) (oc)				0.9	4.9	325 (163)	No		2	2	0
Butyl Methanoate	See Butyl Formate.											
N-Butyl Monoethanolamine $C_4H_9NHC_2H_4OH$	170 (77) (oc)				0.9	4.0	378 (192)	Yes	5	1	2	0
Butyl Naphthalene $C_4H_9C_{10}H_7$	680 (360)							No	2	1	1	0
Butyl Nitrate $CH_3(CH_2)_3ONO_2$	97 (36)				1.0+	4.1	277 (136)	No	1	1	3	3
2-Butyloctanol $C_6H_{13}CH(C_4H_9)CH_2OH$	230 (110)				0.8		486 (252)	No	2	1	1	0
Butyl Oleate $C_{17}H_{33}COOC_4H_9$	356 (180) (oc)				0.9		440.6–442.4 (227–228) @ 15 mm	No	2	0	1	0
Butyl Oxalate $(COOC_4H_9)_2$ (Butyl Ethanedioate)	265 (129) (oc)				1.0–		472 (244)	No	2	0	1	0
tert-Butyl Peracetate diluted with 25% of benzene $CH_3CO(O_2)C(CH_3)_3$	<80 (<27) Note: Rapid decomposition at 200 (93). See Hazardous Chemicals Data.						Explodes on heating.	No	1	2	3	4
tert-Butyl Perbenzoate $C_6H_5COOOC(CH_3)_3$	>190 (>88) (oc) See Hazardous Chemicals Data.				1.0+		Explodes on heating.	No		1	3	4 OX
tert-Butyl Peroxypivalate diluted with 25% of mineral spirits $(CH_3)_3COOCOC(CH_3)_3$	>155 (>68) (oc) Note: Rapid decomposition at 90 (32). See Hazardous Chemicals Data.						Explodes on heating.	No		0	3	4 OX
β-(p-tert-Butyl Phenoxy) Ethanol $(CH_3)_3CC_6H_4OCH_2CH_2OH$	248 (120) (oc)				1.0+		293–313 (145–156)	No	2	0	1	0
β-(p-tert-Butylphenoxy) Ethyl Acetate $(CH_3)_3CC_6H_4OCH_2$-CH_2OCOCH_3	324 (162) (oc)				1.0+		579–585 (304–307)	No	2	0	1	0
Butyl Phenyl Ether $CH_3(CH_2)_3OC_6H_5$ (Butoxybenzene)	180 (82) (oc)				0.9	5.2	410 (210)	No		1	2	0
4-tert-Butyl-2-Phenylphenol $C_6H_5C_6H_3OHC(CH_3)_3$	320 (160)				1.0+		385–388 (196–198)	No	2	1	1	0
Butyl Phosphate $PO_4(C_4H_9)_3$ (Tributyl Phosphate)	295 (146) (oc)				0.98	9.12	559 (293)			3	1	
												0
Butyl Propionate $C_2H_5COOC_4H_9$	90 (32)	799 (426)			0.9	4.5	295 (146)	No	1	2	3	0

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Butyl Ricinoleate $C_{18}H_{33}O_3C_4H_9$	230 (110)				0.9		790 (421)	No	2	1	1	0
Butyl Sebacate $[(CH_2)_4COOC_4H_9]_2$	353 (178) (oc)				0.9		653 (345)	No	2	1	1	0
Butyl Stearate $C_{17}H_{35}COOC_4H_9$	320 (160)	671 (355)			0.9		650 (343)	No	2	1	1	0
tert-Butylstyrene	177 (81) TCC		1	2.7	0.9		426 (219)	No		2	2	2
tert-Butyl Tetralin $C_4H_9C_{10}H_{11}$	680 (360)								2	2	1	0
Butyl Trichlorosilane $CH_3(CH_2)_3SiCl_3$	130 (54) (oc)				1.2	6.5	300 (149)	No	3	2	2	0
N-Butylurethane $CH_3(CH_2)_3NHCOOC_2H_5$ (Butylcarbamic Acid, Ethyl Ester) (Ethyl Butylcarbamate)	197 (92)				0.9	5.0	396–397 (202–203)	No			2	0
Butyl Vinyl Ether	See Vinyl Butyl Ether.											
2-Butyne $CH_3C:CCH_3$ (Crotonylene)	< –4 (< –20)		1.4		0.69	1.86	81 (27)				4	
Butyraldehyde $CH_3(CH_2)_2CHO$ (Butanal) (Butyric Aldehyde)	–8 (–22) Note: See Hazardous Chemicals Data.	425 (218)	1.9	12.5	0.8	2.5	169 (76)	No	1	3	3	0
Butyraldol $C_8H_{16}O_2$	165 (74) (oc)				0.9		280 (138) @ 50 mm	Slight	5	2	2	0
Butyraldoxime C_4H_8NOH (Butanal Oxime)	136 (58)				0.9	3.0	306 (152)	Slight	5	2	2	0
Butyric Acid $CH_3(CH_2)_2COOH$	161 (72) Note: See Hazardous Chemicals Data.	830 (443)	2.0	10.0	1.0–	3.0	327 (164)	Yes	5	3	2	0
Butyric Acid, Ethyl Ester	See Ethyl Butyrate.											
Butyric Aldehyde	See Butyraldehyde.											
Butyric Anhydride $[CH_3(CH_2)_2CO]_2O$	180 (54)	535 (279)	0.9	5.8	1.0–	5.4	388 (196)	Decomposes	5	1	2	1W
Butyric Ester	See Ethyl Butyrate.											
Butyrolactone $CH_2CH_2CH_2COO$ (ring)	209 (98) (oc)				1.1		399 (204)	Yes	5	0	1	0
Butyrone	See 4-Heptanone.											
Butyronitrile $CH_3CH_2CH_2CN$	76 (24) (oc)	935 (501)	1.65		0.8	2.4	243 (117)	Slight	5	3	3	0
Camphor $C_{10}H_{16}O$ (Gum Camphor)	150 (66)	871 (466)	0.6	3.5	1.0–	5.24	399 (204)	No		0	2	0
Camphor Oil (light) (Liquid Camphor)	117 (47)				0.9		347–392 (175–200)	No		2	2	0
Caproaldehyde	See Hexanal.											
Caproic Acid	215	716			0.9		400	No	2	2	1	0
(Caprylic Aldehyde) (Octanal)								Slight				0
Caprylic Aldehyde	See Caprylaldehyde.											

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Caprylyl Chloride $CH_3(CH_2)_6COCl$	180 (82)				1.0–	5.6	384 (196)	Decomposes	5	3	2	1
Carbitol	See Diethylene Glycol Monoethyl Ether.											
Carbolic Acid	See Phenol.											
Carbon Bisulfide	See Carbon Disulfide.											
Carbon Disulfide CS_2 (Carbon Bisulfide)	–22 (–30) Note: See Hazardous Chemicals Data.	194 (90)	1.3	50.0	1.3	2.6	115 (46)	No	4	3	3	0
Carbon Monoxide CO	Gas	1128 (609)	12.5	74		1.0	–314 (–192)	Slight or very slight, 2, 3ml per 100 ml	6	3	4	0
Carbon Oxysulfide COS (Carbonyl Sulfide)	Gas		12	29		2.1	–58 (–50)		6	3	4	1
Carbonyl Sulfide	See Carbon Oxysulfide.											
Carnauba Wax (Brazil Wax)	540 (282) Note: Melting point 185 (85).				1.0–			No	2	0	1	0
Castor Oil (Ricinus Oil)	445 (229)	840 (449)			1.0–		595 (313)	No	2	0	1	0
Castor Oil (Hydrogenated) $(C_{18}H_{35}O_3)_3C_3H_5$	401 (205)							No	2	0	1	0
Cellulose Nitrate Wet with Alcohol (Nitrocellulose)	55 (13)							No	1 5	2	3	3
Cetane	See Hexadecane.											
China Wood Oil	See Tung Oil.											
Chlorex	See Bis (2-chloroethyl) Ether.											
Chlorine Monoxide Cl_2O	Gas		23.5	100			Explodes @ 39 (4)	Yes		3 Explodes on heating.	4	3
Chloroacetic Acid $CH_2ClCOOH$	259 (126)	>932 (>500)			1.58	3.26	372 (189)	Yes		3	1	0
Chloroaceto Phenone $C_6H_5COCH_2Cl$ (Phenacyl Chloride)	244 (118)				1.32	5.32	477 (247)	No		2	1	0
2-Chloro-4,6-di-tert-Amylphenol $(C_5H_{11})_2C_6H_2ClOH$	250 (121)				1.0+		320–354 (160–179) @ 22 mm		2	2	1	0
Chloro-4-tert-Amylphenol $C_5H_{11}C_6H_3ClOH$	225 (107)				1.1		487–509 (253–265)		2	2	1	0
2-Chloro-4-tert-Amyl-phenyl Methyl Ether $C_5H_{11}C_6H_3ClOCH_3$	230 (110)				1.1	7.3	518–529 (270–276)		2	1	1	0
p-Chlorobenzaldehyde ClC_6H_4CHO	190 (88) Note: Melting point 114 (46).				1.2		417 (214)	Slight	5	2	2	0
Chlorobenzene C_6H_5Cl (Chlorobenzol) (Monochlorobenzene) (Phenyl Chloride)	82 (28) Note: See Hazardous Chemicals Data.	1099 (593)	1.3	9.6	1.1	3.9	270 (132)	No	4	2	3	0
Chlorobenzol	See Chlorobenzene.											
Chlorobenzotrifluoride (o-Chloro-α,α,α-trifluorotoluene)	117				1.35	6.24	282 (139)				2	0 1
Chlorobutadiene	See 2-Chloro-1,3-Butadiene.											

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2-Chloro-1,3-Butadiene CH_2:CCl:CH:CH_2 (Chlorobutadiene) (Chloroprene)	−4 (−20)		4.0	20.0	1.0	3.0	138 (59)	Slight	1 5	2	3	0
1-Chlorobutane	See Butyl Chloride.											
2-Chlorobutene-2 CH_3CCl:$CHCH_3$	−3 (−19)		2.3	9.3	0.9	3.1	143–159 (62–71)	Very slight	1	2	3	0
Chlorodiethylaluminum	See Diethylaluminum Chloride.											
Chlorodinitrobenzene	See Dinitrochlorobenzene.											
Chloroethane	See Ethyl Chloride.											
2-Chloroethanol CH_2ClCH_2OH (2-Chloroethyl Alcohol) (Ethylene Chlorohydrin)	140 (60)	797 (425)	4.9	15.9	1.2	2.8	264-266 (129–130)	Yes	5	4	2	0
Chloroethyl Acetate $C_2H_4ClOOCCH_3$	129 (54)				1.2	4.2	293 (145)	No	3	2	2	0
2-Chloroethyl Acetate $CH_3COOCH_2CH_2Cl$	151 (66)				1.2	4.2	291 (144)	No	3	2	2	0
2-Chloroethyl Alcohol	See 2-Chloroethanol.											
Chloro-4-Ethylbenzene $C_2H_5C_6H_4Cl$	147 (64)				1.0+	4.9	364 (184)	No		1	2	0
Chloroethylene	See Vinyl Chloride.											
2-Chloroethyl Vinyl Ether	See Vinyl 2-Chloroethyl Ether.											
2-Chloroethyl-2-Xenyl Ether $C_6H_5C_6H_4OCH_2CH_2Cl$	320 (160)				1.1		613 (323)	Slight	2 5		1	0
1-Chlorohexane $CH_3(CH_2)_4CH_2Cl$ (Hexyl Chloride)	95 (35)				0.9	4.2	270 (132)	No	1		3	0
Chloroisopropyl Alcohol	See 1-Chloro-2-Propanol.											
Chloromethane	See Methyl Chloride.											
1-Chloro-2-Methyl Propane	See Isobutyl Chloride.											
1-Chloronaphthalene $C_{10}H_7Cl$	250 (121)	>1036 (>558)			1.2	5.6	505 (263)	No	2	1	1	0
2-Chloro-5-Nitrobenzotrifluoride $C_6H_3CF_3$(2-Cl, 5-NO_2) (2-Chloro-α,α,α-Trifluoro-5-Nitrotoluene)	275 (135)				1.6		446 (230)		2		1	3
1-Chloro-1-Nitroethane $C_2H_4NO_2Cl$	133 (56) (oc)				1.3	3.8	344 (173)	Slight	5		2	3
1-Chloro-1-Nitropropane $CHNO_2ClC_2H_5$	144 (62) (oc)				1.2	4.3	285 (141)	Slight	5		2	3
2-Chloro-2-Nitropropane $CH_3CNO_2ClCH_3$	135 (57) (oc)				1.2	4.3	273 (134) Explodes upon rapid heating	Slight			2 Explodes on heating.	3
1-Chloropentane	See Amyl Chloride.											
β-Chlorophenetole $C_6H_5OCH_2CH_2C$ (β-Phenoxyethyl Chloride)	225 (107)				1.1		306–311 (152–155)	Slight	5 2		1	0
o-Chlorophenol	147				1.3		347	Slight	5	3	2	0
												0
2-Chloro-4-Phenylphenol $C_6H_5C_6H_3ClOH$	345 (174) Note: Melting point 172–176 (78–80).				<1		613 (323)	Slight	2 5	2	1	0
Chloroprene	See 2-Chloro-1,3-Butadiene.											

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1-Chloropropane	See Propyl Chloride.											
2-Chloropropane	See Isopropyl Chloride.											
2-Chloro-1-Propanol $CH_3CHClCH_2OH$ (β-Chloropropyl Alcohol) (Propylene Chlorohydrin)	125 (52)				1.1	3.3	271–273 (133–134)	Yes	5	2	2	0
1-Chloro-2-Propanol $CH_2ClCHOHCH_3$ (Chloroisopropyl Alcohol) (sec-Propylene Chlorohydrin)	125 (52) (oc)				1.1	3.3	261 (127)	Yes	5	2	2	0
1-Chloro-1-Propene	See 1-Chloropropylene.											
3-Chloropropene	See Allyl Chloride.											
α-Chloropropionic Acid $CH_3CHClCOOH$	225 (107)	932 (500)			1.3		352–374 (178–190)	Yes	5 2		1	0
3-Chloropropionitrile $ClCH_2CH_2CN$	168 (76)				1.1	3.0	348.8 (176) Decom-poses	Yes	5		2	1
2-Chloropropionyl Chloride	88 (31)				1.3	0.12	230 (110)	Reacts				
β-Chloropropyl Alcohol	See 2-Chloro-1-Propanol.											
1-Chloropropylene $CH_3CH:CHCl$ (1-Chloro-1-Propene)	<21 (<−6)		4.5	16	0.9		95–97 (35–36)		1	2	4	2
2-Chloro Propylene $CH_3CCl:CH_2$ (β-Chloropropylene) (2-Chloropropene)	<−4 (<−20)		4.5	16	0.93	2.63	73 (23)			2	4	0
2-Chloropropylene Oxide	See Epichlorohydrin.											
γ-Chloropropylene Oxide	See Epichlorohydrin.											
Chlorotoluene $C_6H_4ClCH_3$ (Tolyl Chloride)	126 (52) (oc)				1.08	4.37	320 (160)			2	2	0
α-Chlorotoluene	See Benzyl Chloride.											
Chlorotrifluoroethylene	See Trifluorochloroethylene.											
2-Chloro-α,α,α-Trifluoro-5-Nitrotoluene	See 2-Chloro-5-Nitrobenzotrifluoride.											
o-Chloro-α,α,α-Trifluorotoluene	See o-Chlorobenzotrifluoride.											
Cimene	See Dipentene.											
Cinnamene	See Styrene											
Citral $(CH_3)_2C:CH(CH_2)_2C(CH_3):CHCHO$ (3,7-Dimethyl-2,6-Octadienal) (Geranial)	195 (91)				0.9		197–199 (92–93)	No	5	0	2	0
Citronellal $(CH_3)_2C:CH(CH_2)_2CH(CH_3)CH_2CHO$ (3,7-Dimethyl-6-Octenal) (Rhodinal)	165 (74)				0.9		117 (47)	No	5	0	2	0
Citronellol $(CH_3)_2C:CH(CH_2)_2CH(CH_3)(CH_2)_2OH$	205 (96)				0.85		227 (108.4)	No	5	0	1	0
											2	0

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Cleaning Solvents, 140 (60) Class	138.2 (59) or higher	453.2 (234) or higher	0.8 @ 302 (150)	0.8		Ini- tial 357.8 (181) or higher		No		0	2	0
Coal Gas	See Gas.											
Coal Oil	See Fuel Oil No. 1.											
Coal Tar Light Oil	<80 (<27)				<1			No		2	3	0
Coal Tar Pitch	405 (207)				>1			No	2	0	1	0
Cobalt Naphtha (Cobalt Naphthenate)	121 (49)	529 (276)			0.9			No		1	2	0
Cobalt Naphthenate	See Cobalt Naphtha.											
Cocoanut Oil Refined Crude	420 (216) 548 (287) 420 (216) Note: Melting point 72 (22).				0.9			No	2	0	1	0
Cod Liver Oil	412 (211)				0.9			No	2	0	1	0
Collodion $C_{12}H_{16}O_6(NO_3)_4$- $C_{13}H_{17}O_7(NO_3)_3$ Solution of Nitrated Cellulose in Ether-Alcohol	<0 (< −18)								1 5	1	4	0
Cologne Spirits	See Ethyl Alcohol.											
Columbian Spirits	See Methyl Alcohol.											
Colza Oil	See Rape Seed Oil.											
Corn Oil Cooking	490 (254) 610 (321) (oc)	740 (393)			0.9 <1			No	2 2	0	1	0
Cottonseed Oil Refined Cooking	486 (252) 610 (321) (oc)	650 (343)			0.9 <1			No No	2 2	0	1	0
Creosote Oil	165 (74)	637 (336)			>1		382–752 (194–400)	No	3	2	2	0
o-Cresol $CH_3C_6H_4OH$ (Cresylic Acid) (o-Hydroxytoluene) (o-Methyl Phenol)	178 (81) Note: Melting point 88 (31). See Hazardous Chemicals Data.	1110 (599)	1.4 @ 300 (149)		1.1	3.7	376 (191)	No	3	3	2	0
m- or p-Cresol $CH_3C_6H_4OH$	187 (86) Note: Melting point of meta: 53.6 (12); of para: 94.6 (35). See Hazardous Chemicals Data.	1038 (558)	1.1 @ 302 (150)		1.0		395 (201)	No		3	2	0
p-Cresyl Acetate $CH_3C_6H_4OCOCH_3$ (p-Tolyl Acetate)	195 (91)				1.1				5	1	2	0
Cresyl Diphenyl Phosphate	450				1.2		734		2	0	1	0

Crotonaldehyde $CH_3CH{:}CHCHO$ (2-Butenal) (Crotonic Aldehyde) (Propylene Aldehyde)	55 (13) Note: See Hazardous Chemicals Data.	450 (232)	2.1	15.5	0.9	2.4	216 (102)	Slight	1 5	4	3	2

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Crotonic Acid $CH_3CH{:}CHCOOH$	190 (88) (oc) Note: Melting point 162 (72).	745 (396)			1.0– @ 176 (80)	3.0	372 (189)	Yes	5	3	2	0
Crotonic Aldehyde	See Crotonaldehyde.											
Crotononitrile $CH_3CH{:}CHCN$ (2-Butenenitrile)	<212 (<100)				0.8	2.3	230–240.8 (110–116)	No			1	0
Crotonyl Alcohol $CH_3CH{:}CHCH_2OH$ (2-Buten-1-ol) (Crotyl Alcohol)	81 (27)	660 (349)	4.2	35.3	0.85	2.49	250 (121)	To 16%			3	2
1-Crotyl Bromide $CH_3CH{:}CHCH_2Br$ (1-Bromo-2-Butene)			4.6	12.0		4.66				2	3	2
1-Crotyl Chloride $CH_3CH{:}CHCH_2Cl$ (1-Chloro-2-Butene)			4.2	19.0		3.13				2	3	2
Cumene $C_6H_5CH(CH_3)_2$ (Cumol) (2-Phenyl Propane) (Isopropyl Benzene)	96 (36)	795 (424)	0.9	6.5	0.9	4.1	306 (152)	No		2	3	1
Cumene Hydroperoxide $C_6H_5C(CH_3)_2OOH$	175 (79) Note: See Hazardous Chemicals Data.						Explodes on heating.	Slight		1	2	4 OX
Cumol	See Cumene.											
Cyanamide NH_2CN	286 (141) Note: Melting point 111 (44).				1.07	1.45	500 (260) Decom-poses			4	1	3
2-Cyanoethyl Acrylate $CH_2CHCOOCH_2CH_2CN$	255 (124) (oc)				1.1	4.3	Polymer-izes	No	2	2	1	1
N-(2-Cyanoethyl) Cyclohexylamine $C_6H_{11}NHC_2H_4CN$	255 (124) (oc)				0.9	5.2		No	2	2	1	0
Cyanogen $(CN)_2$	Gas Note: See Hazardous Chemicals Data.		6.6	32		1.8	−6 (−21)		6	4	4	2
Cyclamen Aldehyde $(CH_3)_2CHC_6H_4CH(CH_3)CH_2CHO$ (Methyl Para-Isopropyl Phenyl Propyl Aldehyde)	190 (88)				1.0–				5		2	0
Cyclobutane C_4H_8 (Tetramethylene)	Gas		1.8			1.9	55 (13)	No	6	1	4	0
1,5,9-Cyclododecatriene $C_{12}H_{18}$	160 (71)				0.9		448 (231)	No			2	0
Cycloheptane $CH_2(CH_2)_5CH_2$	<70 (<21)		1.1	6 7	0.81	3.39	246 (119)			0	3	0
Cyclohexane C_6H_{12} (Hexahydrobenzene) (Hexamethylene)	−4 (−20)	473 (245)	1.3	8	0.8	29	179 (82)	No	1	1	3	0
1,4-Cyclohexane Dimethanol $C_8H_{16}O_2$ (CHDM)	332 (167)	600 (316)			1.0–		525 (274)	Yes	5 2		1	0
												0
Cyclohexanol $C_6H_{11}OH$ (Anol) (Hexalin) (Hydralin)	154 (68) Note: Melting point 75 (24).	572 (300)			1.0–	3.5	322 (161)	Slight	5	1	2	0

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Cyclohexanone $C_6H_{10}O$ (Pimelic Ketone)	111 (44)	788 (420)	1.1 @ 212 (100)	9.4	0.9	3.4	313 (156)	Slight	5	1	2	0
Cyclohexene $CH_2CH_2CH_2CH_2CH{:}CH$	<20 (< −7)	471 (244)			0.8	2.8	181 (83)	No	1	1	3	0
3-Cyclohexene-1-Carboxaldehyde	See 1,2,3,6-Tetrahydrobenzaldehyde.											
Cyclohexenone△ C_6H_8O	93 (34)					3.3	313 (156)		1	1	3	0
Cyclohexyl Acetate $CH_3CO_2C_6H_{11}$ (Hexalin Acetate)	136 (58)	635 (335)			1.0−	4.9	350 (177)	No		1	2	0
Cyclohexylamine $C_6H_{11}NH_2$ (Amino Cyclohexane) (Hexahydroaniline)	88 (31) Note: See Hazardous Chemicals Data.	560 (293)			0.9	3.4	274 (134)	Yes	1 5	3	3	0
Cyclohexylbenzene $C_6H_5C_6H_{11}$ (Phenylcyclohexane)	210 (99) (oc)				0.9		459 (237)	No		2	1	0
Cyclohexyl Chloride $CH_2(CH_2)_4CHCl$ (Chlorocyclohexane)	90 (32)				0.99	4.08	288 (142)			2	3	0
Cyclohexylcyclohexanol $C_6H_{11}C_6H_{10}OH$	270 (132)				1.0−		304–313 (151–156)	No	2	0	1	0
Cyclohexyl Formate $CH_2(CH_2)_4HCOOCH$	124 (51)				1.01	4.42	324 (162)				2	0
Cyclohexylmethane	See Methylcyclohexane.											
o-Cyclohexylphenol $C_6H_{11}C_6H_4OH$	273 (134) Note: Melting point 116 (47).				1.0+		298 (148) @ 10 mm	Slight	5 2	2	1	0
Cyclohexyltrichlorosilane $C_6H_{11}SiCl_3$	196 (91) (oc)				1.2	7.5	406 (208)	No	3	2	2	1
1,5-Cyclooctadiene C_8H_{10}	95 (35)				0.9	3.66	304 (151)	No	1		3	0
Cyclopentane C_5H_{10}	<20 (< −7)	682 (361)	1.5		0.7	2.4	121 (49)	No	1	1	3	0
Cyclopentene $CH{:}CHCH_2CH_2CH_2$	−20 (−29)	743 (395)			0.8	2.35	111 (44)		1	1	3	1
Cyclopentanol $CH_2(CH_2)_3CHOH$	124 (51)				0.95	2.97	286 (141)			0	2	0
Cyclopentanone $OCCH_2CH_2CH_2CH_2$ (Adipic Ketone)	79 (26)				0.9	2.3	267 (131)	Slight	1 5	2	3	0
Cyclopropane $(CH_2)_3$ (Trimethylene)	Gas	928 (498)	2.4	10.4		1.5	−29 (−34)	No	6	1	4	0
p-Cymene $CH_3C_6H_4CH(CH_3)_2$ Tech. (4-Isopropyl-1-Methyl Benzene)	117 (47) 127 (53)	817 (436) 833 (445)	0.7 @ 212 (100)	5.6 5.6	0.9	4.6	349 (176)	No		2	2	0
	Note: Melting point 211.5 (100).						Note: See Hazardous Chemicals Data.					1
Decahydronaphthalene $C_{10}H_{18}$ (Decalin)	136 (58)	482 (250)	0.7 @ 212 (100)	4.9 @ 212 (100)	0.9	4.8	382 (194)	No		2	2	0

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Decahydronaphthalene-trans $C_{10}H_{18}$	129 (54)	491 (255)	0.7	5.4	0.87	4.77	369 (187)			0	2	0
Decalin	See Decahydronaphthalene.											
Decane $CH_3(CH_2)_8CH_3$	115 (46)	410 (210)	0.8	5.4	0.7	4.9	345 (174)	No		0	2	0
Decanol $CH_3(CH_2)_8CH_2OH$ (Decyl Alcohol)	180 (82) (oc)	550 (288)			0.8	5.5	444.2 (229)	No		0	2	0
1-Decene $CH_3(CH_2)_7CH{:}CH_2$	<131 (<55)	455 (235)			0.74	4.84	342 (172)			0	2	0
Decyl Acrylate $CH_3(CN_2)_9OCOCH{:}CH_2$	441 (227) (oc)				0.9		316 (158) @ 50 mm	Very slight	2	2	1	0
Decyl Alcohol	See Decanol.											
Decylamine $CH_3(CH_2)_9NH_2$ (1-Aminodecane)	210 (99)				0.8		429 (221)	Slight	5	2	1	0
Decylbenzene $C_{10}H_{21}C_6H_5$	225 (107)				0.9		491–536 (255–280)	No	2	2	1	0
tert-Decylmercaptan $C_{10}H_{21}SH$	190 (88)				0.9	6.0	410–424 (210–218)			2	2	0
Decylnaphthalene $C_{10}H_{21}C_{10}H_7$	350 (177)				0.9		635–680 (335–360)	No	2	1	1	0
Decyl Nitrate $CH_3(CH_2)_9ONO_2$	235 (113) (oc)				1.0–		261 (127) @ 11 mm	No	2		1	0
Dehydroacetic Acid $CH_3C{:}CHC(O)$- $CH(COCH_3)C(O)O$ (DHA) (Methylacetopyranone)	315 (157) (oc) Note: Melting point 228–232 (109–111).	690 (366)					518 (270)	No	2	1	1	0
Denatured Alcohol	60 (16)	750 (399)			0.8	1.6	175 (79)	Yes	1 5	0	3	0
Government Formula CD-5	60–62 (16–17)											
CD-5A	60–61 (15.5–16)											
CD-10	49–59 (9–15)											
SD-1	57 (14)											
SD-2B	56 (13)											
SD-3A	59 (15)											
SD-13A	<19 (<–7)											
SD-17	60 (16)											
SD-23A	35 (2)											
SD-30	59 (15)											
SD-39B	60 (16)											
SD-39C	59 (15)											
SD-40M	59 (15)											
												0
Diacetone	See Diacetone Alcohol.											

	FLASH POINT °F (°C)	IGNITION TEMP. °F (°C)	FLAMMABLE LIMITS Percent by Vol. Lower	Upper	Sp. Gr. (Water = 1)	Vapor Density (Air = 1)	BOILING POINT °F (°C)	Water Soluble	SEE INTRODUCTION FOR SUGGESTED EXTINGUISHING METHODS	HAZARD IDENTIFICATION Health	Flamma-bility	Reac-tivity
Diacetone Alcohol $CH_3COCH_2C(CH_3)_2OH$ Acetone-free Commercial (Diacetone) (4-Hydroxy-4-Methyl-2-Pentanone)	148 (64) 136 (58) 148 (64)	1118 (603) 1190 (643) 1118 (603)	1.8	6.9	0.9	4.0	328 (164)	Yes	5	1	2	0
Diacetyl	See 2,3-Butanedione.											
Diallyl Ether	See Allyl Ether.											
Diallyl Phthalate $C_6H_4(CO_2C_3H_5)_2$	330 (166)				1.1		554 (290)	No	2	2	1	0
1,3-Diaminobutane	See 1,3-Butanediamine.											
1,3-Diamino-2-Propanol $NH_2CH_2CHOHCH_2NH_2$	270 (132)				1.1		266 (130)	Yes	2 5	2	1	0
1,3-Diaminopropane	See 1,3-Propanediamine.											
Diamylamine $(C_5H_{11})_2NH$	124 (51) Note: See Hazardous Chemicals Data.				0.8	5.4	356 (180)	Slight	5	3	2	0
Diamylbenzene $(C_5H_{11})_2C_6H_4$	225 (107) (oc)				0.9		491–536 (255–280)	No	2	0	1	0
Diamylbiphenyl $C_5H_{11}(C_6H_4)_2C_5H_{11}$ (Diaminodiphenyl)	340 (171)				1.0–		687–759 (364–404)	No	2	0	1	0
Di-tert-Amylcyclohexanol $(C_5H_{11})_2C_6H_9OH$	270 (132)				0.9		554–572 (290–300)	No	2	0	1	0
Diamyldiphenyl	See Diamylbiphenyl.											
Diamylene $C_{10}H_{20}$	118 (48) (oc)				0.8		302 (150)			0	2	0
Diamyl Ether	See Amyl Ether.											
Diamyl Maleate $(CHCOOC_5H_{11})_2$	270 (132)				1.0–		505–572 (263–300)	No	2	0	1	0
Diamyl Naphthalene $C_{10}H_6(C_5H_{11})_2$	315 (159) (oc)				0.9		624 (329)	No	2	0	1	0
2,4-Diamylphenol $(C_5H_{11})_2C_6H_3OH$	260 (127) (oc)				0.9		527 (275)	No	2	2	1	0
Di-tert-Amylphenoxy Ethanol $C_6H_3(C_5H_{11})_2OC_2H_4OH$	300 (149) (oc)				1.0–		615 (324)	No	2	0	1	0
Diamyl Phthalate $C_6H_4(COOC_5H_{11})_2$ (Amyl Phthalate)	245 (118)				1.0		475–490 (246–254) @ 50 mm	No	2	0	1	0
Diamyl Sulfide $(C_5H_{11})_2S$	185 (85) (oc)				0.9		338–356 (170–180)	No		2	2	0
o-Dianisidine $[NH_2(OCH_3)C_6H_3]_2$ (o-Dimethoxybenzidine)	403 (206) Note: Melting point 297 (147).					8.43					1	0
Dibenzyl Ether $(C_6H_5CH_2)_2O$ (Benzyl Ether)	275 (135)				1.0		568 (298)	No	2	0	1	0
Diborane B_2H_6	Gas Note: Ignites spontaneously in moist air.	100– 125 (38–52)	0.8	88		1.0–			6	4 Reacts violently with halogenated extinguishing agents.	4	3W
	(oc)											0

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Dibutoxymethane $CH_2(OC_4H_9)_2$	140 (60) Note: Melting point 140 (60).				0.8		330–370 (166–188)	No		0	2	0
Dibutoxy Tetraglycol $(C_4H_9OC_2H_4OC_2H_4)_2O$ (Tetraethylene Glycol Dibutyl Ether)	305 (152) (oc)				0.9		635 (335)	Slight	2 5	2	1	0
N,N-Dibutylacetamide $CH_3CON(C_4H_9)_2$	225 (107)				0.9		469–482 (243–250)		2	0	1	0
Dibutylamine $(C_4H_9)_2NH$	117 (47)		1.1		0.8	4.5	322 (161)	Slight	5	3	2	0
Di-sec-Butylamine $[C_2H_5(CH_3)CH]_2NH$	75 (24) (oc)				0.8	4.5	270–275 (132–135)	Yes	5	3	3	0
Dibutylaminoethanol $(C_4H_9)_2NC_2H_4OH$	200 (93) (oc)				0.9		432 (222)	No		3	2	0
1-Dibutylamino-2-Propanol	See Dibutylisopropanolamine.											
N,N-Dibutylaniline $C_6H_5N(CH_2CH_2CH_2CH_3)_2$	230 (110)				0.9		505–527 (263–275)	No	2	3	1	0
Di-tert-Butyl-p-Cresol $C_6H_2(C_4H_9)_2(CH_3)OH$	261 (127) Note: Melting point 154.4 (68).						495–511 (257–266)	No	2	0	1	0
Dibutyl Ether $(C_4H_9)_2O$ (1-Butoxybutane) (Butyl Ether)	77 (25) Note: See Hazardous Chemicals Data.	382 (194)	1.5	7.6	0.8	4.5	286 (141)	No	1 5	2	3	1
2,5-Di-tert-Butylhydroquinone $[C(CH_3)_3]_2C_6H_2(OH)_2$ (DTBHQ)	420 (216) (oc) Note: Melting point 410 (210).	790 (421)						No	2	1	1	0
Dibutyl Isophthalate $C_6H_4(CO_2C_4H_9)_2$	322 (161)							No	2	0	1	0
N,N[1]-Di-sec-Butyl-p-Phenylenediamine $C_6H_4(-NHCH(CH_3)-CH_2CH_3)_2$	270 (132)	625 (329)	0.6 @ 329		0.9				5 2	2	1	0
Dibutylisopropanolamine $CH_3CHOHCH_2N(C_4H_9)_2$	205 (96) (oc)				0.8		444 (229)	Slight	5	2	1	0
Dibutyl Maleate $(=CHCO_2C_4H_9)_2$	285 (141) (oc)				1.0–		Decom-poses		2	1	1	0
Dibutyl Oxalate $C_4H_9OOCCOOC_4H_9$	220 (104)				1.0+		472 (244)	No	2	0	1	0
Di-tert-Butyl Peroxide $(CH_3)_3COOC(CH_3)_3$	65 (18) (oc) Note: See Hazardous Chemicals Data.				0.8		231 (111)	Slight	1	3	2	4 OX
Dibutyl Phosphite $(C_4H_9O)_2P(O)H$	120 (49)				1.0–		239 (115)	No		3	2	0
Dibutyl Phthalate $C_6H_4(CO_2C_4H_9)_2$ (Dibutyl-o-Phthalate)	315 (157)	757 (402)	0.5 @ 456 (235)		1.0+		644 (340)	No	2	0	1	0
Dibutyl Sebacate $[(CH_2)_4COOC_4H_9]_2$	353 (178)	690 (365)	0.44 @		1.0–		650 (343)	No	2	0	1	0
$C_{17}H_{35}CON(C_4H_9)_2$	(216)						[illegible] @ 0.4 mm					0

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n-Dibutyl Tartrate $(COOC_4H_9)_2(CHOH)_2$ (Dibutyl-d-2,3-Dihydroxybutanedioate)	195 (91)	544 (284)			1.1		650 (343)	No	5	0	2	0
N,N-Dibutyltoluene-sulfonamide $CH_3C_6H_4SO_3N(C_4H_9)_2$	330 (166)				1.1		392 (200) @ 10 mm		2	0	1	0
Dicaproate	See Triethylene Glycol.											
Dicapryl Phthalate $C_6H_4[COOCH(CH_3)C_6H_{13}]_2$	395 (202)				1.0–	9.8	441–453 (227–234) @ 4.5 mm	No	2	0	1	0
Dichloroacetyl Chloride $CHCl_2COCl$ (Dichloroethanoyl Chloride)	151 (66)					5.1	225–226 (107–108)	Decomposes	5	3	2	2W
3,4-Dichloroaniline $NH_2C_6H_3Cl_2$	331 (166) (oc) Note: Melting point 161 (72). See Hazardous Chemicals Data.						522 (272)	No	2	3	1	0
o-Dichlorobenzene $C_6H_4Cl_2$ (o-Dichlorobenzol)	151 (66) Note: See Hazardous Chemicals Data.	1198 (648)	2.2	9.2	1.3	5.1	356 (180)	No	3	2	2	0
p-Dichlorobenzene $C_6H_4Cl_2$	150 (66) Note: Melting point 127 (53).				1.5	5.1	345 (174)	No	3	2	2	0
o-Dichlorobenzol	See o-Dichlorobenzene.											
2,3-Dichlorobutadiene-1,3 $CH_2{:}C(Cl)C(Cl){:}CH_2$	50 (10)	694 (368)	1.0	12.0	1.2	4.24	212 (100)	No	1	3	3	2
1,2-Dichlorobutane $CH_3CH_2CHClCH_2Cl$		527 (275)				4.38				2	2	0
1,4-Dichlorobutane $CH_2ClCH_2CH_2CH_2Cl$	126 (52) Note: See Hazardous Chemicals Data.				1.1	4.4	311 (155)	No	3	3	2	0
2,3-Dichlorobutane $CH_3CHClCHClCH_3$	194 (90) (oc)				1.1	4.4	241–253 (116–123)			2	2	0
1,3-Dichloro-2-Butene $CH_2ClCH{:}CClCH_3$	80 (27)				1.2	4.31	262 (128)	No	1	3	3	2
3,4-Dichlorobutene-1 $CH_2ClCHClCHCH_2$	113 (45)				1.1	4.31	316 (158)			3	2	1
1,3-Dichlorobutene-2 $CH_2ClCH{:}CClCH_3$	80 (27)					4.3	258 (126)		1	2	3	0
Dichlorodimethylsilane	See Dimethyldichlorosilane.											
1,1-Dichloroethane	See Ethylidene Dichloride.											
1,2-Dichloroethane	See Ethylene Dichloride.											
Dichloroethanoyl Chloride	See Dichloroacetyl Chloride.											
1,1-Dichloroethylene	See Vinylidene Chloride.											
sym-Dichloroethylene **1,2-Dichloroethylene** $ClCH{:}CHCl$ Note: Exists as cis and trans isomers.	36 (2)	860 (460)	5.6	12.8	1.3	3.4	119 (48)	No	4	2	3	2
2,2[1]-Dichloroethyl Ether $ClCH_2CH_2OCH_2CH_2Cl$	131 (55) Note: See Hazardous Chemicals Data.	696 (369)	2.7		1.2	4.93	352 (178)	No	5	3	2	1
2,2-Dichloroethyl Formal	See Bis(2-Chloroethyl) Formal.											
Di-(2-Chloroethyl) Formal	See Bis(2-Chloroethyl) Formal.											

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Dichloroisopropyl Ether $ClCH_2CH(CH_3)OCH(CH_3)CH_2Cl$ [Bis (β-Chloroisopropyl) Ether]	185 (85) (oc)				1.1	6.0	369 (187)	No	3	2	2	0
2,2-Dichloro Isopropyl Ether $[ClCH_2CH(CH_3)]_2O$ [Bis (2-Chloro-1-Methylethyl Ether)]	185 (85) (oc)				1.11	5.90	369 (187)			2	2	0
Dichloromethane	See Methylene Chloride.											
1,1-Dichloro-1-Nitro Ethane $CH_3CCl_2NO_2$	168 (76) (oc)				1.4	5.0	255 (124)	No	3	2	2	3
1,1-Dichloro-1-Nitro Propane $C_2H_5CCl_2NO_2$	151 (66) (oc)				1.3	5.5	289 (143)	Slight	5	2	2	3
Dichloropentanes (Mixed) $C_5H_{10}Cl_2$	106 (41) (oc)				1.0+	4.8	266 (130)	No		2	2	0
1,5-Dichloropentane $CH_2Cl(CH_2)_3CH_2Cl$ (Amylene Chloride) (Pentamethylene Dichloride)	>80 (>27) (oc)				1.1	4.9	352–358 (178–181)	No	4	2	3	0
2,4-Dichlorophenol $Cl_2C_6H_3OH$	237 (114) (oc) Note: Melting point 113 (45).				1.4 @ 140 (60)	5.6	410 (210)	Slight	5 2		1	0
1,2-Dichloropropane	See Propylene Dichloride.											
1,3-Dichloro-2-Propanol $CH_2ClCHOHCH_2Cl$	165 (74) (oc)				1.4	4.4	346 (174)	Slight	5	2	2	0
1,3-Dichloropropene $CHCl{:}CHCH_2Cl$	95 (35)		5.3	14.5	1.2	3.8	219 (104)	No		2	3	0
2,3-Dichloropropene $CH_2{:}CClCH_2Cl$	59 (15) (TCC)		2.6	7.8	1.2	3.8	201 (94)	Slight		3	3	0
Dichlorosilane H_2SiCl_2	−35	136 (36)	4.1	99	1.2	3.5	47	Yes	Avoid water.	3	4	2W
α,β-Dichlorostyrene $C_6H_5CCl{:}CHCl$	225 (107) (oc)							No	2	2	1	2
Dicyclohexyl	See Bicyclohexyl.											
Dicyclohexylamine $(C_6H_{11})_2NH$	>210 (>99) (oc)				0.9		496 (258)	Slight	5	3	1	0
Dicyclopentadiene $C_{10}H_{12}$	90 (32) (oc) Note: Melting point 91 (33).	937 (503)			1.0−		342 (172)	No	1	1	3	1
Didecyl Ether $(C_{10}H_{21})_2O$ (Decyl Ether)		419 (215)				10.3				0	1	0
Diesel Fuel Oil No. 1-D	100 Min. (38) or Legal							No		0	2	0
Diesel Fuel Oil	125							No		0	2	0

Diesel Fuel Oil No. 4-D	130 Min. (54) or Legal							No		0	2	0

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Diethanolamine $(HOCH_2CH_2)_2NH$	342 (172) (oc) Note: Melting point 82 (28).	1224 (662)			1.1		514 (268)	Yes	5 2	1	1	0
1,2-Diethoxyethane	See Diethyl Glycol.											
Diethylacetaldehyde	See 2-Ethylbutyraldehyde.											
Diethylacetic Acid	See 2-Ethylbutyric Acid.											
N,N-Diethyl-acetoacetamide $CH_3COCH_2CON(C_2H_5)_2$	250 (121) (oc)				1.0 –	5.4	Decom-poses	Yes	2 5	0	1	0
Diethyl Acetoacetate $CH_3COC(C_2H_5)_2COOC_2H_5$	170 (77)				1.0 –	6.4	412–424 (211–218) Decom-poses	Very slight		2	2	0
Diethylaluminum Chloride $(C_2H_5)_2AlCl$ (Chlorodiethylaluminum)	Note: Ignites spontaneously in air. See Hazardous Chemicals Data.									3 Do not use water, foam or halogenated extinguishing agents.	4	3W
Diethylaluminum Hydride $(C_2H_5)_2AlH$	Note: Ignites spontaneously in air.									Do not use water, foam or halogenated extinguishing agents.	3	3W
Diethylamine $(C_2H_5)_2NH$	–9 (–23) Note: See Hazardous Chemicals Data.	594 (312)	1.8	10.1	0.7	2.5	134 (57)	Yes	5 1	3	3	0
2-Diethyl (Amino) Ethanol	See N,N-Diethylethanolamine.											
2-(Diethylamino) Ethyl Acrylate $CH_2{:}CHCOOCH_2CH_2$-$HN(CH_3CH_2)_2$	195 (91) (oc)				0.9	5.9	Decom-poses	Decomposes		2	2	1
3-(Diethylamino)-Propylamine $(C_2H_5)_2NCH_2CH_2CH_2NH_2$ (N,N-Diethyl-1,3-Propanediamine)	138 (59) (oc)				0.8	4.5	337 (169)	Yes	5	2	2	0
N,N-Diethylaniline $C_6H_5N(C_2H_5)_2$ (Phenyldiethylamine)	185 (85)	1166 (630)			1.0 –	5.0	421 (216)	Slight	5	3	2	0
o-Diethyl Benzene $C_6H_4(C_2H_5)_2$	135 (57)	743 (395)			0.9	4.6	362 (183)	No		2	2	0
m-Diethyl Benzene $C_6H_4(C_2H_5)_2$	133 (56)	842 (450)			0.9	4.6	358 (181)	No		2	2	0
p-Diethyl Benzene $C_6H_4(C_2H_5)_2$	132 (55)	806 (430)	0.7	6.0	0.9	4.6	358 (181)	No		2	2	0
N,N-Diethyl-1,3-Butanediamine $C_2H_5NHCH_2CH_2CH$-$N(C_2H_5)CH_3$ [1,3-Bis(ethylamino) Butane]	115 (46) (oc)				0.8	5.0	354–365 (179–185)	Yes	5	2	2	0
Di-2-Ethylbutyl Phthalate $C_6H_4[COOCH_2CH(C_2H_5)_2]_2$	381 (194) (oc)				1.0 +		662 (350)	No	5 2	0	1	0
Diethyl Carbamyl Chloride $(C_2H_5)_2NCOCl$	325–342 (163–172) (oc)						369–374 (187–190)	Yes	5 2	2	1	2W
Diethyl Carbinol	See sec-Amyl Alcohol.											
Diethyl Carbonate $(C_2H_5)_2CO_3$ (Ethyl Carbonate)	77 (25)				1.0 –	4.1	259 (126)	No	1	2	3	1
			(60)	(110)								0
1,3-Diethyl-1,3-Diphenyl Urea $[(C_2H_5)(C_6H_5)N]_2CO$	302 (150) Note: Melting point 160 (71).				1.1		620 (327)		2	1	1	0

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Diethylene Diamine	144 (62)						299 (150)	Yes				
Diethylene Dioxide	See p-Dioxane.											
Diethylene Glycol $O(CH_2CH_2OH)_2$ (2,2-Dihydroxyethyl Ether)	255 (124)	435 (224)			1.1		472 (244)	Yes	5 2	1	1	0
Diethylene Glycol Bis (Allylcarbonate) $(CH_2{:}CHCH_2OCOOCH_2\text{-}CH_2)_2O$ (Allyl Diglycol Carbonate)	378 (192) (oc)				1.1		320 (160) @ 2 mm	No	2	1	1	0
Diethylene Glycol Bis (2-Butyoxyethyl Carbonate) $[CH_3(CH_2)_3O(CH_2)_2OO\text{-}COCH_2CH_2]_2O$ (Butoxyethyl Diglycol Carbonate)	379 (193)				1.1		392–403 (200–206) @ 2 mm	Slight	5 2	1	1	1
Diethylene Glycol Bis (Butyl Carbonate) $[CH_3(CH_2)_3OOCOCH_2\text{-}CH_2]_2O$ (Butyl Diglycol Carbonate)	372 (189)				1.1		327 (164) @ 2 mm	Slight	5 2	1	1	1
Diethylene Glycol Bis (Phenylcarbonate) $(C_6H_5OOCOCH_2CH_2)_2O$ (Phenyl Diglycol Carbonate)	460 (238)				1.2		437–444 (225–229) @ 2 mm	No	2	0	1	1
Diethylene Glycol n-Butyl Ether $C_4H_9OC_2H_4OC_2H_4OH$ (Butoxy Diethylene Glycol)	230 (110) (oc)	442 (228)			1.0+		448 (231)	Yes	5 2	1	1	0
Diethylene Glycol Butyl Ether Acetate $CH_3COO(C_2H_4O)_2C_4H_9$	241 (116) (oc)	563 (295)			0.98	7.05	475 (246)				1	0
Diethylene Glycol Diacetate $(CH_3COOC_2H_4)_2O$	275 (135) (oc)				1.1		482 (250)	Yes	5 2	1	1	0
Diethylene Glycol Dibenzoate $(C_6H_5COOCH_2CH_2)_2O$	450 (232)				1.2 @ 68 (20)		457 (236) @ 5 mm	Yes	5 2	0	1	0
Diethylene Glycol Dibutyl Ether $C_4H_9O(C_2H_4O)_2C_4H_9$ (Dibutoxy Diethylene Glycol)	245 (118)	590 (310)			0.9		493 (256)	Slight	5 2	1	1	0
Diethylene Glycol Diethyl Ether $CH_3(CH_2OCH_2)_3CH_3$	180 (82) (oc)				0.9	5.6	372 (189)	Yes	5	1	2	0
Diethylene Glycol Diethyl Levulinate $(CH_3COC_2H_4COOC_2H_4)_2O$	340 (171)				1.14	10.4				0	1	0
Diethylene Glycol Dimethyl Ether $CH_3OCH_2CH_2OCH_2\text{-}CH_2OCH_3$	153 (67)				0.95		324 (162)	Yes	5	1	2	1
Diethylene Glycol Dipropionate	260 (127)				1.1		491–529 (255–276)	Slight	5 2	1	1	0
[illegible]											1	0
Diethylene Glycol Ethyl Ether Phthalate $C_6H_4[COO(C_2H_4O)_2C_2H_5]_2$ (Bis[2-(Ethoxyethoxy)-Ethyl] Phthalate) (Carbitol Phthalate)	406 (208)				1.12	13.7	>500 (>260)			0	1	0

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Diethylene Glycol Methyl Ether $CH_3OC_2H_4OC_2H_4OH$ (2-(2-Methoxyethoxy) Ethanol)	205 (96) (oc)	465 (240)	1.38	22.7	1.04	4.14	379 (193)			2	2	0
Diethylene Glycol Methyl Ether Acetate $CH_3COOC_2H_4OC_2H_4OCH_3$	180 (82) (oc)				1.04	5.59	410 (210)			0	2	0
Diethylene Glycol Monobutyl Ether $C_4H_9OCH_2CH_2OCH_2CH_2OH$	172 (78)	400 (204)	0.85	24.6	1.0–	5.6	448 (231)	Yes	5	1	2	0
Diethylene Glycol Monobutyl Ether Acetate $C_4H_9O(CH_2)_2O(CH_2)_2$- $OOCCH_3$	240 (116)	570 (298.9)	0.76	10.7	1.0–		476 (247)	Slight	5 2	1	1	0
Diethylene Glycol Monoethyl Ether $CH_2OHCH_2OCH_2$- $CH_2OC_2H_5$	201 (94)	400 (204)	1.2 @ 275 (135)	23.5 @ 360 (182)	1.0–		396 (202)	Yes	5	1	1	0
Diethylene Glycol Monoethyl Ether Acetate $C_2H_5O(CH_2)_2O(CH_2)_2$- $OOCCH_3$	225 (107) (oc)	680 (360)	1.0 @ 275 (135)	19.4 @ 365 (185)	1.0+		424 (218)	Yes	5 2	1	1	0
Diethylene Glycol Monoisobutyl Ether $(CH_3)_2CHCH_2O(CH_2)_2$- $O(CH_2)_2OH$	222 (106)	452–485 (233– 252)	0.98	10.7	1.0–		422–437 (217–225)	Yes	5 2	1	1	0
Diethylene Glycol Monomethyl Ether $CH_3O(CH_2)O(CH_2)_2OH$	205 (96) (oc)				1.0+		381 (194)	Yes	5	1	1	0
Diethylene Glycol Mono-Methyl Ether Formal $CH_2(CH_3OCH_2CH_2OCH_2$- $CH_2O)_2$	310 (154) (oc)				1.0+		581 (305)	Yes	5 2	1	1	0
Diethylene Glycol Phthalate $C_6H_4[COO(CH_2)_2OC_2H_5]_2$	343 (173)				1.1			Yes	5 2	0	1	0
Diethylene Oxide	See Tetrahydrofuran.											
Diethylene Triamine $NH_2CH_2CH_2NHCH_2CH_2NH_2$	208 (98) (oc) Note: See Hazardous Chemicals Data.	676 (358)	2	6.7	1.0–	3.56	404 (207)	Yes	5 2	3	1	0
N,N-Diethylethanolamine $(C_2H_5)_2NC_2H_4OH$ (2-(Diethylamino) Ethanol)	140 (60) (oc)	608 (320)			0.9	4.0	324 (162)	Yes	5	3	2	0
Diethyl Ether	See Ethyl Ether.											
N,N-Diethylethylene-diamine $(C_2H_5)_2NC_2H_4NH_2$	115 (46) (oc)				0.8	4.0	293 (145)	Yes	5	3	2	0
Diethyl Fumarate C_2H_5OCOCH:- $CHCOOC_2H_5$	220 (104)				1.0+ @ 68 (20)		442 (217)	Slight	5 2	1	1	0
Diethyl Glycol $(C_2H_5OCH_2)_2$ (1,2-Diethoxyethane)	95 (35)	401 (205)			0.84	4.07	252 (122)	Slight			3	0
Di-2-Ethylhexyl Adipate $C_4H_8[COOCH_2CH(C_2H_5)$- $C_4H_9]_2$ (Dioctyl Adipate)	385 (196)				0.9		783 (417)	No	5 2	0	1	0
Di(2-Ethylhexyl) Maleate	See Bis(2-Ethylhexyl) Maleate.											
Di(2-Ethylhexyl) Phosphoric Acid	See Bis(2-Ethylhexyl) Phosphoric Acid.											

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Di(2-Ethylhexyl) Succinate	See Bis(2-Ethylhexyl) Succinate.											
Diethyl Ketone $C_2H_5COC_2H_5$ (3-Pentanone)	55 (13) (oc)	842 (450)	1.6		0.8	3.0	217 (103)	Slight	1 5	1	3	0
N,N-Diethyllauramide $C_{11}H_{23}CON(C_2H_5)_2$	>150 (>66) (oc)				0.9	8.8	331–351 (166–177) @ 2 mm		No		2	0
Diethyl Maleate $(-CHCO_2C_2H_5)_2$	250 (121) (oc)	662 (350)			1.1		438 (226)	No	2	1	1	0
Diethyl Malonate $CH_2(COOC_2H_5)_2$ (Ethyl Malonate)	200 (93) (oc)				1.1		390 (199)	No	3	0	1	0
Diethyl Oxide	See Ethyl Ether.											
3,3-Diethylpentane $CH_3CH_2C(C_2H_5)_2CH_2CH_3$		554 (290)	0.7	5.7	0.8	4.4	295 (146)	No		0	3	0
Diethyl Peroxide $C_2H_5OOC_2H_5$		Explodes on heating.	2.3		0.8	7.7	Explodes on heating.				4	4
Diethyl Phthalate $C_6H_4(COOC_2H_5)_2$	322 (161) (oc)	855 (457)	0.7 @ 368 (186)		1.1		565 (296)	No	2	0	1	0
p-Diethyl Phthalate	See Diethyl Terephthalate.											
N,N-Diethyl-1,3-Propanediamine	See 3-(Diethylamino) Propylamine.											
2,2-Diethyl-1,3-Propanediol $HOCH_2C(C_2H_5)_2CH_2OH$	215 (102) (oc) Note: Melting point 142 (61).				0.9 @ 142 (61)		320 (160) @ 50 mm	Yes	5 2	2	1	0
Diethyl Selenide $(C_2H_5)_2Se$			2.5		1.2	4.7	226 (108)	No		2		0
N,N-Diethylstearamide $C_{17}H_{35}CON(C_2H_5)_2$	375 (191)				0.9		246–401 (119–205) @ 1 mm	No	2	0	1	0
Diethyl Succinate $(CH_2COOCH_2CH_3)_2$	195 (90)				1.0+		421 (216)	Slight	5 2	1	1	0
Diethyl Sulfate $(C_2H_5)_2SO_4$ (Ethyl Sulfate)	220 (104) Note: See Hazardous Chemicals Data.	817 (436)			1.2		Decomposes, giving Ethyl Ether	No, slight decom-position	5 2	3	1	1
Diethyl Tartrate $CHOHCOO(C_2H_5)_2$	200 (93)				1.2		536 (280)	Yes	5	0	1	0
Diethyl Terephthalate $C_6H_4(COOC_2H_5)_2$ (p-Diethyl Phthalate)	243 (117) Note: Melting point 112 (44).				1.1		576 (302)	No	2	0	1	0
3,9-Diethyl-6-tridecanol	See Heptadecanol.											
Diethylzinc $(C_2H_5)_2Zn$ (Zinc Diethyl)		Note: Ignites spontaneously in air. See Hazardous Chemicals Data								3	4	3W Do not use water, foam or halogenated extinguishing agents.
Difluoro-1-Chloroethane CF_2ClCH_3 (R-142B) (1-Chloro-1,1-Difluoroethane)	Gas		6.2	17.9			4 (−16)				4	0
Diglycol Chlorformate $O:(CH_2CH_2OCOCl)_2$	295 (146)						256–261 (124–127) @ 5 mm		2	0	1	0
	(oc)											0
Diglycol Diacetate $(CH_3COOCH_2CH_2)_2:O$	255 (124)				1.1	6.5	482 (250)	Yes	2 5	0	1	0

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Diglycol Dilevulinate $[CH_2CH_2OOC(CH_2)_2COCH_3]_2O$	340 (171)				1.1			Yes	2 5	0	1	
Diglycol Laurate $C_{16}H_{32}O_4$	290 (143)				1.0−		559–617 (293–325)		2	0	1	0
Dihexyl	See Dodecane.											
Dihexylamine $[CH_3(CH_2)_5]_2NH$	220 (104) (oc)				0.8		451–469 (233–243)	No	2	2	1	0
Dihexyl Ether	See Hexyl Ether.											
Dihydropyran $CH_2CH_2CH_2{:}CHCHO$	0 (−18)				0.9	2.9	186 (86)	Slight	5	2	3	0
o-Dihydroxybenzene $C_6H_4(OH)_2$ (Pyrocatechol)	260 (127)				1.34	3.79	473 (245)	Slight			1	0
p-Dihydroxybenzene $C_6H_4(OH)_2$ (Hydroquinone)	329 (165) Note: Melting point 338 (170).	959 (515)			1.36	3.81	547 (286)				1	0
1,2-Dihydroxybutane	See 1,2-Butanediol.											
2,2-Dihydroxyethyl Ether	See Diethylene Glycol.											
2,5-Dihydroxyhexane	See 2,5-Hexanediol.											
Diisobutylaluminum Hydride $[(CH_3)_2CHCH_2]_2AlH$	Note: Ignites spontaneously in air.									Do not use water, foam or halogenated extinguishing agents.	3	3W
Diisobutylamine $[(CH_3)_2CHCH_2]_2NH$ (Bis(β-Methylpropyl) Amine)	85 (29)				0.7		273–286 (134–141)	No	5 1	3	3	0
Diisobutyl Carbinol $[(CH_3)_2CHCH_2]_2CHOH$ (Nonyl Alcohol)	165 (74)		0.8 @ 212 (100)	6.1 @ 212 (100)	0.8	5.0	353 (178)	No	5	1	2	0
Diisobutylene	See 2,4,4-Trimethyl-1-Pentene.											
Diisobutylene $(CH_3)_3CCH_2C(CH_3){:}CH_2$ (2,4,4-Trimethyl-l[2]-Pentene)	23 (−5)	736 (391)	0.8	4.8	0.7	3.87	214 (101)		1	1	3	0
Diisobutyl Ketone $[(CH_3)_2CHCH_2]_2CO$ (2,6-Dimethyl-4-Heptanone) (Isovalerone)	120 (49)	745 (396)	0.8 @ 200 (93)	7.1 @ 200 (93)	0.8	4.9	335 (168)	No		1	2	0
Diisobutyl Phthalate $C_6H_4[COOCH_2CH(CH_3)_2]_2$	365 (185) (oc)	810 (432)	0.4 @ 448		1.0−		621 (327)	No	5 2	0	1	0
Diisodecyl Adipate $C_{10}H_{21}O_2C(CH_2)_4CO_2C_{10}H_{21}$	225 (107) (oc)				0.9		660 (349)		2	0	1	0
Diisodecyl Phthalate $C_6H_4(COOC_{10}H_{21})_2$	450 (232) (oc)	755 (402)	0.3 @ 508		1.0−		482 (250)	No	5 2	0	1	0
Diisooctyl Phthalate $(C_8H_{17}COO)_2C_6H_4$	450 (232)				1.0−		698 (370)	No	2	0	1	0
Diisopropanolamine $[CH_3CH(OH)CH_2]_2NH$	260 (127) (oc)	705 (374)			1.0−		480 (249)	Yes	5 2	2	1	0
Diisopropyl	See 2,3-Dimethylbutane.											
												0

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Diisopropyl Benzene $[(CH_3)_2CH]_2C_6H_4$	170 (77) (oc)	840 (449)			0.9	5.6	401 (205)	No		0	2	0
N,N-Diisopropyl-ethanolamine $[(CH_3)_2CH]_2NC_2H_4OH$	175 (79) (oc)				0.9	5.0	376 (191)	No		1	2	0
Diisopropyl Ether	See Isopropyl Ether.											
Diisopropyl Maleate $(CH_3)_2CHOCOCH:$ $CHCOOCH(CH_3)_2$	220 (104) (oc)				1.0+		444 (229)	Slight	5 2	1	1	0
Diisopropylmethanol	See 2,4-Dimethyl-3-Pentanol.											
Diisopropyl Peroxydicarbonate $(CH_3)_2CHOCOOOCO-$ $OCH(CH_3)_2$	Note: Rapid decomposition at 53 (12). Melting Point 46–50 (8–10). See Hazardous Chemicals Data.						Explodes on heating.	No		0	4	4 OX
Diketene $CH_2:CCH_2C(O)O$ (Vinylaceto-β-Lactone)	93 (34) Note: See Hazardous Chemicals Data.				1.1	2.9	261 (127)	Decomposes	5	4	2	2
2,5-Dimethoxyaniline $NH_2C_6H_3(OCH_3)_2$	302 (150) (oc) Note: Melting point 156–163 (69–73).	735 (391)					518 (270)	Yes	2	2	1	0
2,5-Dimethoxy-chlorobenzene $C_8H_9ClO_2$	243 (117)					5.9	460–467 (238–242)	Slight	2 5	2	1	0
1,2-Dimethoxyethane	See Ethylene Glycol Dimethyl Ether.											
Dimethoxyethyl Phthalate $C_6H_4(COOCH_2CH_2OCH_3)_2$ [Bis(2-methoxyethyl) Phthalate]	410 (210) (oc)	750 (399)	0.7 @ 440 (227)		1.2		644 (340)	No	5 2	0	1	0
Dimethoxymethane	See Methylal.											
Dimethoxy Tetraglycol $CH_3OCH_2(CH_2-$ $OCH_2)_3CH_2OCH_3$ (Tetraethylene Glycol Dimethyl Ether)	285 (141) (oc)				1.0+		528 (276)	Yes	2 5	1	1	0
Dimethylacetamide $(CH_3)_2NC:OCH_3$ (DMAC)	158 (70) (oc)	914 (490)	1.8 @ 212	11.5 @ 320	1.0		330 (165)	Yes	5	2	2	0
Dimethylamine $(CH_3)_2NH$	Gas Note: See Hazardous Chemicals Data.	752 (400)	2.8	14.4		1.6	45 (7)	Yes	6	3	4	0
2-(Dimethylamino) Ethanol $(CH_3)_2NCH_2CH_2OH$ (Dimethylethanolamine)	105 (41) (oc)	563 (295)			0.9	3:1	272 (133)	Yes	1 5	2	2	0
2-(Dimethylamino) Ethyl Methacrylate $C_8H_{15}NO_2$	165 (74) (oc) Note: Polymerizes.				0.9	5.4	207 (97) @ 40 mm	Yes	5	2	2	0
3-(Dimethylamino)-propionitrile $(CH_3)_2NC_2H_4CN$	149 (65) (oc)				0.86	3.35	338 (170)				2	1
3-(Dimethylamino)-propylamine $(CH_3)_2N(CH_2)_3NH_2$	100 (38) (oc)				0.8	3.5	278 (137)	Yes	5	3	2	0
Di(Methylamyl) Maleate	See Bis(2,4-Dimethylbutyl) Maleate.											
[illegible]	145	700			1.0–	4.2	379	Slight	5	3	2	0

o-Dimethylaniline	See o-Xylidine.											
Dimethyl Anthranilate $CH_3OOCC_6H_4NHCH_3$ (N-Methyl Methyl Anthranilate)	195 (91)				1.1					1	2	0
1,2-Dimethylbenzene	See o-Xylene.											
1,3-Dimethylbenzene	See m-Xylene.											

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1,4-Dimethylbenzene	See p-Xylene.											
Dimethylbenzylcarbinyl Acetate $C_6H_5CH_2C(CH_3)_2OOCCH_3$ (alpha, alpha-Dimethyl-phenethyl Acetate)	205 (96) Note: Melting point 84–86 (29–30).				1.0–					1	1	0
2,2-Dimethylbutane $(CH_3)_3CCH_2CH_3$ (Neohexane)	−54 (−48)	761 (405)	1.2	7.0	0.6	3.0	122 (50)	No	1	1	3	0
2,3-Dimethylbutane $(CH_3)_2CHCH(CH_3)_2$ (Diisopropyl)	−20 (−29)	761 (405)	1.2	7.0	0.7	3.0	136 (58)	No	1	1	3	0
1,3-Dimethylbutanol	See Methyl Isobutyl Carbinol.											
2,3-Dimethyl-1-Butene $CH_3CH(CH_3)C(CH_3){:}CH_2$	< −4 (< −20)	680 (360)			0.68	2.91	133 (56)			0	3	0
2,3-Dimethyl-2-Butene $CH_3C(CH_3){:}C(CH_3)_2$	< −4 (< −20)	753 (401)			0.71	2.91	163 (73)			0	3	0
1,3-Dimethylbutyl Acetate $CH_3COOCH(CH_3)CH_2$-$CH(CH_3)_2$	113 (45)				0.9	5.0	284–297 (140–147)	Slight	5	1	2	0
1,3-Dimethylbutylamine $CH_3CHNH_2(CH_2)CH(CH_3)_2$ (2-Amino-4-Methylpentane)	55 (13) (oc)				0.7	3.5	223–228 (106–109)	No	1	2	3	0
Dimethyl Carbinol	See Isopropyl Alcohol.											
Dimethyl Carbonate	See Methyl Carbonate.											
Dimethyl Chloracetal $ClCH_2CH(OCH_3)_2$	111 (44)	450 (232)			1.0+		259–270 (126–132)			2	2	0
Dimethylcyanamide $(CH_3)_2NCN$	160 (71)				0.88	2.42	320 (160)			4	2	1
1,2-Dimethylcyclohexane $(CH_3)_2C_6H_{10}$		579 (304)			0.8	3.87	260 (127)	No		0		0
1,3-Dimethylcyclohexane $(CH_3)_2C_6H_{10}$ (Hexahydroxylene)	~50 (10)	583 (306)			0.8	3.87	−256 (124)	No	1	0	3	0
1,4-Dimethylcyclohexane $(CH_3)_2C_6H_{10}$ (Hexahydroxylol)	52 (11)	579 (304)			0.8	3.9	248 (120)	No	1	1	3	0
1,4-Dimethylcyclohexane-cis $C_6H_{10}(CH_3)_2$	61 (16)						255 (124)			0	3	0
1,4-Dimethylcyclohexane-trans $C_6H_{10}(CH_3)_2$	51 (11)						246 (119)			0	3	0
Dimethyl Decalin $C_{10}H_{16}(CH_3)_2$	184 (84)	455 (235)	0.7 @ 200 (93)	5.3 @ 300 (149)	1.0		455 (235)			0	2	0
Dimethyldichlorosilane $(CH_3)_2SiCl_2$ (Dichlorodimethylsilane)	<70 (<21)		3.4	>9.5	1.1	4.4	158 (70)	Decomposes		3 Decomposes in water.	3	1
Dimethyl-o,o-Dichloro-vinyl-2,2-Phosphate (Technical) $(CH_3O)_2P(O)OCH{:}CCl_2$ (DDVP)	350 (177) (oc)						248 (120) @ 14 mm	Slight	5 2	3	1	
Dimethyldioxane $CH_3CHCH_2OCH_2(CH_3)CHO$	75 (24) (oc)				0.9	4.0	243 (117)	Slight	1 5	2	3	0
												0
Dimethylene Oxide	See Ethylene Oxide.											
N,N-Dimethyl-ethanolamine	See 2-(Dimethylamino) Ethanol.											

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Dimethyl Ether	See Methyl Ether.											
Dimethyl Ethyl Carbinol	See 2-Methyl-2-Butanol.											
2,4-Dimethyl-3-Ethylpentane $CH_3CH(CH_3)CH(CH_2H_5)CH(CH_3)_2$ (3-Ethyl-2,4-Dimethylpentane)	734 (390)				0.74	4.43	279 (137)			0	3	0
N,N-Dimethylformamide $HCON(CH_3)_2$	136 (58)	833 (445)	2.2 @ 212 (100)	15.2	0.9	2.5	307 (153)	Yes	5	1	2	0
2,5-Dimethylfuran $OC(CH_3):CHCH:C(CH_3)$	45 (7) (oc)				0.9	3.3	200 (93)	Slight	1 5	2	3	0
Dimethyl Glycol Phthalate $C_6H_4[COO(CH_2)_2OCH_3]_2$	369 (187)				1.8		446 (230)		2	0	1	0
3,3-Dimethylheptane $CH_3(CH_2)_3C(CH_3)_2CH_2CH_3$		617 (325)			0.73	4.43	279 (137)			0	3	0
2,6-Dimethyl-4-Heptanone	See Diisobutyl Ketone.											
2,3-Dimethylhexane $CH_3CH(CH_3)CH(CH_3)$-$C_2H_5CH_3$	45 (7) (oc)	820 (438)			0.7	3.9	237 (114)	No	1	0	3	0
2,4-Dimethylhexane $CH_3CH(CH_3)CH(CH_3)$-$C_2H_5CH_3$	50 (10) (oc)				0.7	3.9	229 (109)	No	1	0	3	0
Dimethyl Hexynol $C_4H_9CCH_3(OH)C{:}CH$ (3,5-Dimethyl-1-Hexyn-3-ol)	135 (57) (oc)				0.85	4.35	302 (150)			0	2	0
1,1-Dimethylhydrazine $(CH_3)_2NNH_2$ (Dimethylhydrazine, Unsymmetrical)	5 (−15)	480 (249)	2	95	0.8	2.0	145 (63)	Yes	5 1	4	3	1
Dimethylhydrazine-Unsymmetrical	See 1,1-Dimethylhydrazine.											
Dimethylisophthalate $CH_3OOCC_6H_4COOCH_3$	280 (138) Note: Melting point 153–154 (67–68).							No	2	0	1	0
N,N-Dimethyliso-propanolamine $(CH_3)_2NCH_2CH(OH)CH_3$	95 (35) (oc)				0.9	3.6	257 (125)	Yes	1 5	2	3	0
Dimethyl Ketone	See Acetone.											
Dimethyl Maleate $(-CHCOOCH_3)_2$	235 (113) (oc)				1.2		393 (201)	No	2	1	1	0
2,6-Dimethylmorpholine $CH(CH_3)CH_2OCH_2CH(CH_3)NH$	112 (44) (oc)				0.9	4.0	296 (147)	Yes	5	2	2	0
2,3-Dimethyloctane $CH_3(CH_2)_4CH(CH_3)$-$CH(CH_3)CH_3$	<131 (<55)	437 (225)			0.74	4.91	327 (164)			0	2	0
3,4-Dimethyloctane $C_3H_7CH(CH_3)CH(CH_3)C_3H_7$	<131 (<55)				0.75	4.91	324 (162)			0	2	0
2,3-Dimethylpentaldehyde $CH_3CH_2CH(CH_3)CH$-$(CH_3)CHO$	94 (34) (oc)				0.8	3.9	293 (145)		1	2	3	0
2,3-Dimethylpentane $CH_3CH(CH_3)CH$-$(CH_3)CH_2CH_3$	<20 (<−7)	635 (335)	1.1	6.7	0.7	3.5	194 (90)	No	1	0	3	0
												0
2,4-Dimethyl-3-Pentanol $(CH_3)_2CHCHOHCH(CH_3)_2$ (Diisopropylmethanol)	120 (49)				0.8	4.0	284 (140)	Very slight		0	2	0

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Dimethyl Phthalate $C_6H_4(COOCH_3)_2$	295 (146)	915 (490)	0.9 @ 358 (180)		1.2		540 (282)	No	2	0	1	0
Dimethylpiperazine-cis $C_6H_{14}N_2$	155 (68) (oc)				0.92	3.94	329 (165)			2	2	0
2,2-Dimethylpropane $(CH_3)_4C$ (Neopentane)	Gas	842 (450)	1.4	7.5		2.5	49 (9)	No	6	0	4	0
2,2-Dimethyl-1-Propanol	See tert-Butyl Carbinol.											
2,5-Dimethylpyrazine $CH_3C{:}CHN{:}C(CH_3)CH{:}N$	147 (64) (oc)				0.99	3.72	311 (155)	Yes			2	0
Dimethyl Sebacate $[-(CH_2)_4COOCH_3]_2$ (Methyl Sebacate)	293 (145) (oc) Note: Melting point 76 (24).				1.0–		565 (296)		2	0	1	0
Dimethyl Sulfate $(CH_3)_2SO_4$ (Methyl Sulfate)	182 (83) (oc) Note: See Hazardous Chemicals Data.	370 (188)			1.3	4.4	370 (188)	Very slight	3	4	2	0
Dimethyl Sulfide $(CH_3)_2S$	<0 (< –18) Note: See Hazardous Chemicals Data.	403 (206)	2.2	19.7	0.8	2.1	99 (37)	Slight	1	1	4	0
Dimethyl Sulfoxide $(CH_3)_2SO$	203 (95) (oc) Note: Melting point 65 (18).	419 (215)	2.6	42	1.1		372 (189)	Yes	5	1	1	0
Dimethyl Terephthalate $C_6H_4(COOCH_3)_2$ (Dimethyl-1,4-Benzene-Dicarboxylate) (DMT)	308 (153) (oc)	965 (518)					543 (284)	No	5 2	1	1	0
2,4-Dinitroaniline $(NO_2)_2C_6H_3NH_2$	435 (224) Note: Melting point 370 (188).				1.6			No	2	3	1	3
1,2-Dinitro Benzol $C_6H_4(NO_2)_2$ (o-Dinitrobenzene)	302 (150) Note: Melting point 244 (118).				1.57	5.79	604 (318)			3	1	4
Dinitrochlorobenzene $C_6H_3Cl(NO_2)_2$ (Chlorodinitrobenzene)	382 (194) Note: Melting point 109 (43). See Hazardous Chemicals Data.		2.0	22	1.7		599 (315)	No	2	3	1	4
2,4-Dinitrotoluene $(NO_2)_2C_6H_3CH_3$	404 (207) Note: Melting point 158 (70).				1.52	6.27	572 (300)			3	1	3
Dioctyl Adipate $[-(CH_2)_2COOCH_2$-$CH(C_2H_5)C_4H_9]_2$ [Bis(2-Ethylhexyl) Adipate] [Di(2-Ethylhexyl) Adipate]	402 (206) (oc)	710 (377)	0.4 @ 467 (242)		0.9		680 (360)	No	5 2	0	1	0
Dioctylamine	See Bis(2-Ethylhexyl) Amine.											
Dioctyl Azelate $(CH_2)_7[COOCH_2CH(C_2H_5)$-$C_4H_9]_2$ [Bis(2-Ethylhexyl) Azelate] [Di(2-Ethylhexyl) Azelate]	440 (227) (oc)	705 (374)	0.3 @ 510 (266)		0.9		709 (376)	No	5 2	0	1	0
Dioctyl Ether $(C_8H_{17})_2O$ (Octyl Ether)	>212 (>100)	401 (205)			0.82	8.36	558 (292)			0	1	0
[Di(2-Ethylhexyl) Phthalate] [Bis(2-Ethylhexyl) Phthalate]			(245)									0

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p-Dioxane $OCH_2CH_2OCH_2CH_2$ (Diethylene Dioxide)	54 (12) Note: See Hazardous Chemicals Data.	356 (180)	2.0	22	1.0+	3.0	214 (101)	Yes	1 5	2	3	1
Dioxolane $OCH_2CH_2OCH_2$	35 (2) (oc)				1.1	2.6	165 (74)	Yes	1 5	2	3	2
Dipentene $C_{10}H_{16}$ (Cinene) (Limonene)	113 (45)	458 (237)	0.7 @ 302 (150)	6.1 @ 302 (150)	0.9	4.7	339 (170)	No		0	2	0
Diphenyl	See Biphenyl.											
Diphenylamine $(C_6H_5)_2NH$ (Phenylaniline)	307 (153) Note: Melting point 127 (53).	1173 (634)			1.2		575 (302)	No	2	3	1	0
1,1-Diphenylbutane $(C_6H_5)_2CHC_3H_7$	>212 (>100)	851 (455)			0.98	7.26	561 (294)			0	1	0
1,3-Diphenyl-2-buten-1-one	See Dypnone.											
Diphenyldichlorosilane $(C_6H_5)_2SiCl_2$	288 (142)				1.2		581 (305)	Yes	2	3	1	0
Diphenyldodecyl Phosphite $(C_6H_5O)_2POC_{10}H_{21}$	425 (218) (oc) Melting point 64 (18).				1.0+			No	2	0	1	0
1,1-Diphenylethane (uns) $(C_6H_5)_2CHCH_3$	>212 (>100)	824 (440)			1.0	6.29	546 (286)			0	1	0
1,2-Diphenylethane (sym) $C_6H_5CH_2CH_2C_6H_5$	264 (129)	896 (480)			1.0	6.29	544 (284)			0	1	0
Diphenyl Ether	See Diphenyl Oxide.											
Diphenylmethane $(C_6H_5)_2CH_2$ (Ditane)	266 (130) Note: Melting point 79 (26).	905 (485)			1.0		508 (264)	No	2	1	1	0
Diphenyl (o-Xenyl) Phosphate $(C_6H_5O)_2PO(OC_6H_4C_6H_5)$	437 (225)				1.2		482–545 (250–285) @ 5 mm		2	0	1	0
Diphenyl Oxide $(C_6H_5)_2O$ (Diphenyl Ether)	239 (115) Note: Melting point 81 (27).	1144 (618)	0.7	6.0	1.1		496 (258)	No	2	1	1	0
1,1-Diphenylpentane $(C_6H_5)_2CHC_4H_9$	>212 (>100)	824 (440)			0.97	7.74	586 (308)			0	1	0
1,1-Diphenylpropane $CH_3CH_2CH(C_6H_5)_2$	>212 (>100)	860 (460)			0.97	6.77	541 (283)			0	1	0
Diphenyl Phthalate $C_6H_4(COOC_6H_5)_2$	435 (224) Note: Melting point 158 (70).				1.3		761 (405)	No	2	0	1	0
Dipropylaluminum Hydride $(C_3H_7)_2AlH$	Note: Ignites spontaneously in air.									Do not use water, foam or halogenated extinguishing agents.	3	3W
Dipropylamine $(C_3H_7)_2NH$	63 (17) (oc)	570 (299)			0.7	3.5	229 (109)	No	1	3	3	0
Dipropylene Glycol $(CH_3CHOHCH_2)_2O$	250 (121) (oc)				1.0+	4.63	449 (232)	Yes	2 5	0	1	0
Dipropylene Glycol Methyl	186		1.1	3.0	1.0	5.11	408	Partly		0	2	0

Dipropyl Ketone	See 4-Heptanone.											
Ditane	See Diphenylmethane.											
Ditridecyl Phthalate $C_6H_4(COOC_{13}H_{27})_2$	470 (243) (oc)				1.0–		547 (286) @ 5 mm		2	0	1	0

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Divinyl Acetylene $(:CCH:CH_2)_2$ (1,5-Hexadien-3-yne)	< −4 (< −20)					2.69	183 (84)				3	3
Divinylbenzene $C_6H_4(CH:CH_2)_2$	169 (76) (oc)		0.7	6.2	0.9		392 (200)	No		1	2	2
Divinyl Ether $(CH_2:CH)_2O$ (Ethenyloxyethene) (Vinyl Ether)	< −22 (< −30)	680 (360)	1.7	27	0.8	2.4	83 (28)	No	1	2	4	2
	Note: See Hazardous Chemicals Data.											
Di(o-Xenyl) Phenyl Phosphate $(C_6H_5C_6H_4)_2PO(OC_6H_5)$	482 (250)				1.2		545–626 (285–330) @ 5 mm		2	0	1	0
Dodecane $CH_3(CH_2)_{10}CH_3$ (Dihexyl)	165 (74)	397 (203)	0.6		0.8	5.9	421 (216)	No		0	2	0
1-Dodecanethiol $CH_3(CH_2)_{11}SH$ (Dodecyl Mercaptan) (Lauryl Mercaptan)	262 (128) (oc)				0.8		289 (143) @ 15 mm	No	5 2	2	1	0
1-Dodecanol $CH_3(CH_2)_{11}OH$ (Lauryl Alcohol)	260 (127)	527 (275)			0.8		491 (255)	No	2	0	1	0
Dodecyl Benzene (Crude) $C_6H_5C_{12}H_{25}$ (Alkane) (Detergent Alkylate)	285				0.9		554–770 (290–410)	No	2	1	1	0
Dodecyl Bromide	See Lauryl Bromide.											
Dodecylene (α) $C_{16}H_{21}CH:CH_2$ (1-Dodecane)	< 212 (< 100)	491 (255)			0.76	5.81	406 (208)			0	1	0
Dodecyl Mercaptan	See 1-Dodecanethiol.											
tert-Dodecyl Mercaptan $C_{12}H_{25}SH$	205 (96) (oc)				0.9		428–451 (220–233)	No		2	1	0
4-Dodecyloxy-2-Hydroxy-Benzophenone $C_{25}H_{34}O_3$	498 (254)	715 (379)						No	2		1	0
	Note: Melting point 109 (43)											
Dodecyl Phenol $C_{12}H_{25}C_6H_4OH$	325 (163) (oc)				0.9	9.0	597–633 (314–334)	No	2	0	1	0
Dypnone $C_6H_5COCH:C(CH_3)C_6H_5$ (1,3-Diphenyl-2-Buten-1-one)	350 (177) (oc)				1.1		475 (246) @ 50 mm	Slight	2 5	1	1	0
Eicosane $C_{20}H_{42}$	> 212 (> 100)	450 (232)			0.79	9.75	651 (344)				1	0
Epichlorohydrin CH_2CHOCH_2Cl (2-Chloropropylene Oxide) (γ-Chloropropylene Oxide)	88 (31)	772 (411)	3.8	21.0	1.2	3.2	239 (115)	Yes	5	3	3	2
	Note: See Hazardous Chemicals Data.											
1,2-Epoxyethane	See Ethylene Oxide.											
Erythrene	See 1,3-Butadiene.											
Ethanal	See Acetaldehyde.											
[illegible]	Gas	882	3.0	12.5		1.0	−128	No	6	1	4	0
1,2-Ethanediol Diformate $HCOOCH_2CH_2OOCH$ (Ethylene Formate) (Ethylene Glycol Diformate) (Glycol Diformate)	200 (93) (oc)				1.2		345 (174)	Decomposes		[illegible]	[illegible]	0
										Decomposes in water.		

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Ethanethiol	See Ethyl Mercaptan.											
Ethanoic Acid	See Acetic Acid.											
Ethanoic Anhydride	See Acetic Anhydride.											
Ethanol	See Ethyl Alcohol.											
Ethanolamine $NH_2CH_2CH_2OH$ (2-Amino Ethanol) (β-Aminoethyl Alcohol)	186 (86)	770 (410)	3.0	23.5 @ 140°C	1.0+	2.1	342 (172)	Yes	5	3	2	0
Ethanoyl Chloride	See Acetyl Chloride.											
Ethene	See Ethylene.											
Ethenyl Ethanoate	See Vinyl Acetate.											
Ethenyloxyethene	See Divinyl Ether.											
Ether	See Ethyl Ether.											
Ethine	See Acetylene.											
Ethoxyacetylene $C_2H_5OC{:}CH$	< 20 (< −7)				0.8	2.4	124 (51)	No	1	2	3	1
Ethoxybenzene $C_6H_5OC_2H_5$ (Ethyl Phenyl Ether) (Phenetole)	145 (63)				1.0−	4.2	342 (172)	No		0	2	0
2-Ethoxy-3,4-Dihydro-2-Pyran $C_7H_{12}O_2$	111 (44) (oc)				1.0−		289 (143)	Very slight		2	2	1
2-Ethoxy Ethanol	See Ethylene Glycol Monoethyl Ether.											
2-Ethoxyethyl Acetate $CH_3COOCH_2CH_2OC_2H_5$ (Ethyl Glycol Acetate)	117 (47)	716 (380)	1.7		1.0−	4.6	313 (156)	Yes	5	2	2	0
3-Ethoxypropanal $C_2H_5OC_2H_4CHO$ (3-Ethoxypropionaldehyde)	100 (38)				0.98	3.52	275 (135)			2	2	0
1-Ethoxypropane	See Ethyl Propyl Ether.											
3-Ethoxypropionaldehyde $C_2H_5OCH_2CH_2CHO$	100 (38)				0.9	3.5	275 (135)	Yes	5	2	3	0
3-Ethoxypropionic Acid $C_2H_5OCH_2CH_2COOH$	225 (107)				1.0+		426 (219)	Yes	5 2	2	1	0
Ethoxytriglycol $C_2H_5O(C_2H_4O)_3H$ (Triethylene Glycol, Ethyl Ether)	275 (135) (oc)				1.0+		492 (256)	Yes	2 5	0	1	0
Ethyl Abietate $C_{19}H_{29}COOC_2H_5$	352 (178) (oc)				1.0+		662 (350)	No	2	0	1	0
N-Ethylacetamide $CH_3CONHC_2H_5$ (Acetoethylamide)	230 (110)				0.9		401 (205)	Yes	5 2	1	1	0
N-Ethyl Acetanilide $CH_3CON(C_2H_5)(C_6H_5)$	126 (52)				0.9	5.6	400 (204)	No		0	2	0
Ethyl Acetate $CH_3COOC_2H_5$ (Acetic Ester) (Acetic Ether) (Ethyl Ethanoate)	24 (−4)	800 (426)	2.0	11.5	0.9	3.0	171 (77)	Slight	1 5	1	3	0
Ethyl Acetoacetate $C_2H_5CO_2CH_2COCH_3$	135 (57)	563 (295)	1.4 @ 200	95 @ 350	1.0+	4.5	356 (180)	Slight	5	2	2	0
(Ethyl Glycolate Acetate)												0
Ethyl Acrylate $CH_2{:}CHCOOC_2H_5$	50 (10) (oc) Note: Polymerizes. See Hazardous Chemicals Data.	702 (372)	1.4	14	0.9	3.5	211 (99)	Slight	1 5	2	3	2

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Ethyl Alcohol C_2H_5OH (Grain Alcohol, Cologne Spirits, Ethanol)	55 (13)	685 (363)	3.3	19	0.8	1.6	173 (78)	Yes	1 5	0	3	0
Ethyl Alcohol and Water 96%	62 (17)											
95%	63 (17)											
80%	68 (20)											
70%	70 (21)											
60%	72 (22)											
50%	75 (24)											
40%	79 (26)											
30%	85 (29)											
20%	97 (36)											
10%	120 (49)											
5%	144 (62)											
Ethylaluminum Dichloride $C_2H_5AlCl_2$ (Dichloroethylaluminum)	Notes: Fumes vigorously in air. May ignite spontaneously.									3 Do not use water, foam or halogenated extinguishing agents.	3	3W
Ethylaluminum Sesquichloride $(C_2H_5)_3Al_2Cl_3$	−4 (−20) Note: Ignites spontaneously in air.				1.1		297 (147)			Do not use water, foam or halogenated extinguishing agents.	3	3W
Ethylamine $C_2H_5NH_2$ 70% aqueous solution (Aminoethane)	<0 (<−18) Note: See Hazardous Chemicals Data.	725 (385)	3.5	14.0	0.8	1.6	62 (17)	Yes	1 5	3	4	0
Ethyl Amino Ethanol $C_2H_5NHC_2H_4OH$ (2-(Ethylamino)ethanol)	160 (71) (oc)				0.92	3.06	322 (161)				2	0
Ethylaniline $C_2H_5NH(C_6H_5)$	185 (85) (oc) Note: See Hazardous Chemicals Data.				1.0−	4.2	401 (205)	No		3	2	0
Ethylbenzene $C_2H_5C_6H_5$ (Ethylbenzol) (Phenylethane)	70 (21) Note: See Hazardous Chemicals Data.	810 (432)	0.8	6.7	0.9	3.7	277 (136)	No	1	2	3	0
Ethyl Benzoate $C_6H_5COOC_2H_5$	190 (88)	914 (490)			1.0+		414 (212)	No		1	1	0
Ethylbenzol	See Ethylbenzene.											
Ethyl Benzoylacetate $C_6H_5COCH_2COOC_2H_5$	285 (141) (oc)				1.1		291–298 (144–148)	No	2	0	1	0
Ethylbenzylaniline $C_6H_5N(C_2H_5)CH_2C_6H_5$	284 (140) (oc)	<932 (500)			1.0+		594 (312) Slight decomp.	No	5 2	2	1	0
Ethyl Borate $(C_2H_5)_3BO_3$	52 (11)				0.9	5.0	233 (112)	Decomposes		2	3	0
Ethyl Bromide C_2H_5Br	None	952 (511)	6.8	8.0	1.4	3.8	100 (38)	Slight	1	2	1	0
												0
2-Ethylbutanal	See 2-Ethylbutyraldehyde.											
Ethyl Butanoate	See Ethyl Butyrate.											
2-Ethyl-1-Butanol	See 2-Ethylbutyl Alcohol.											
2-Ethyl-1-Butene $(C_2H_5)_2C:CH_2$	<−4 (<−20)	599 (315)			0.69	2.90	144 (62)			0	3	0

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3-(2-Ethylbutoxy) Propionic Acid $CH_3CH_2CH(C_2H_5)CH_2$-OCH_2CH_2COOH	280 (138) (oc)				1.0 –		392 (200) @ 100 mm	No	2	2	1	0
2-Ethylbutyl Acetate $CH_3COOCH_2CH(C_2H_5)_2$	130 (54) (oc)				0.9	5.0	324 (162)	No		1	2	0
2-Ethylbutyl Acrylate CH_2:$CHCOOCH_2CH$-$(C_2H_5)C_2H_5$	125 (52) (oc)				0.9		180 (82) @ 10 mm	No		2	2	0
2-Ethylbutyl Alcohol $(C_2H_5)_2CHCH_2OH$ (2-Ethyl-1-Butanol)	135 (57) (oc)				0.8	3.5	301 (149)	No		1	2	0
Ethylbutylamine $CH_3CH_2CH_2CH_2$-$NHCH_3CH_2$	64 (18) (oc)				0.7	3.5	232 (111)	No	1	3	3	0
Ethyl Butylcarbamate	See N-Butylurethane.											
Ethyl Butyl Carbonate $(C_2H_5)(C_4H_9)CO_3$	122 (50)				0.9	5.0	275 (135)			2	2	1
Ethyl Butyl Ether $C_2H_5OC_4H_9$ (Butyl Ethyl Ether)	40 (4)				0.8	3.7	198 (92)	Slight	1 5	2	3	0
2-Ethyl Butyl Glycol $(C_2H_5)_2CHCH_2OC_2H_4OH$ [2-(2-Ethylbutoxy)ethanol]	180 (82) (oc)				0.90	5.05	386 (197)			0	2	0
Ethyl Butyl Ketone $C_2H_5CO(CH_2)_3CH_3$ (3-Heptanone)	115 (46) (oc)				0.8	4.0	299 (148)	No		1	2	0
2-Ethyl-2-Butyl-1,3-Propanediol $HOCH_2C(C_2H_5)(C_4H_9)$-CH_2OH	280 (138) (oc) Note: Melting point 107 (42).				0.9 @ 122°F (50°C)		352 (178) @ 50 mm	Yes	2 5	2	1	0
2-Ethylbutyraldehyde $(C_2H_5)_2CHCHO$ (Diethyl Acetaldehyde) (2-Ethylbutanal)	70 (21) (oc)		1.2	7.7	0.8	3.5	242 (117)	No	1 5	2	3	1
Ethyl Butyrate $CH_3CH_2CH_2COOC_2H_5$ (Butyric Acid, Ethyl Ester) (Butyric Ester) (Ethyl Butanoate)	75 (24)	865 (463)			0.9	4.0	248 (120)	No	1 5	0	3	0
2-Ethylbutyric Acid $(C_2H_5)_2CHCOOH$ (Diethyl Acetic Acid)	210 (99) (oc)	752 (400)			0.9		380 (193)	Slight	5	2	1	0
2-Ethylcaproaldehyde	See 2-Ethylhexanal.											
Ethyl Caproate $C_5H_{11}COOC_2H_5$ (Ethyl Hexoate) (Ethyl Hexanoate)	120 (49)				0.9	4.97	333 (167)	No	5	2	2	0
Ethyl Caprylate $CH_3(CH_2)_6COOC_2H_5$ (Ethyl Octoate) (Ethyl Octanoate)	175 (79)				0.9		405–408 (207–209)	No	5	2	2	0
Ethyl Carbonate	See Diethyl Carbonate.											
Ethyl Chloride C_2H_5Cl (Chloroethane) (Hydrochloric Ether) (Muriatic Ether)	−58 (−50) Note: See Hazardous Chemicals Data.	966 (519)	3.8	15.4	0.9	2.2	54 (12)	Slight	1	1	4	0
[illegible]	[illegible]				[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	0
Ethyl Chlorocarbonate	See Ethyl Chloroformate.											
Ethyl Chloroformate $ClCOOC_2H_5$ (Ethyl Chlorocarbonate) (Ethyl Chloromethanoate)	61 (16)	932 (500)			1.1	3.7	201 (94)	Decomposes		4	3	1

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Ethyl Chloromethanoate	See Ethyl Chloroformate.											
Ethyl Crotonate $CH_3CH:CHCOOC_2H_5$	36 (2)				0.9	3.9	282 (139)	No	1	2	3	0
Ethyl Cyanoacetate $CH_2CNCOOC_2H_5$	230 (110)				1.1		401–408 (205–209)		2	2	1	0
Ethylcyclobutane $C_2H_5C_4H_7$	<4 (< −16)	410 (210)	1.2	7.7		2.9	160 (71)	No		1	3	0
Ethylcyclohexane $C_2H_5C_6H_{11}$	95 (35)	460 (238)	0.9	6.6	0.8	3.9	269 (132)	No		1	3	0
N-Ethylcyclohexylamine $C_6H_{11}NHC_2H_5$	86 (30) (oc)				0.8	4.4		Slight	1 5	3	3	0
Ethylcyclopentane $C_2H_5C_5H_9$	<70 (<21)	500 (260)	1.1	6.7	0.8	3.4	218 (103)			1	3	0
Ethyl Decanoate $C_9H_{19}COOC_2H_5$ (Ethyl Caprate)	>212 (>100)				0.9		469 (243)	No	5	0	1	0
Ethyl Dichlorosilane $C_2H_5SiHCl_2$	30 (−1)				1.1	4.45	168 (75.5)	Yes	1	3	3	0
N-Ethyldiethanolamine $C_2H_5N(C_2H_4OH)_2$	280 (138) (oc)				1.0+		487 (253)	Yes	2 5	2	1	0
Ethyl Dimethyl Methane	See Isopentane.											
Ethylene $H_2C:CH_2$ (Ethene)	Gas Note: See Hazardous Chemicals Data.	842 (450)	2.7	36.0		1.0	−155 (−104)	Yes	6	1	4	2
Ethylene Acetate	See Glycol Diacetate.											
Ethylene Carbonate OCH_2CH_2OCO	290 (143) (oc) Note: Melting point 96 (36).						351 (177) @ 100 mm	Yes	2 5	2	1	1
Ethylene Chlorohydrin	See 2-Chloroethanol.											
Ethylene Cyanohydrin $CH_2(OH)CH_2CN$ (Hydracrylonitrile)	265 (129) (oc) Note: See Hazardous Chemicals Data.				1.1		445 (229) Decom- poses	Yes	2 5	1	1	2
Ethylenediamine $H_2NCH_2CH_2NH_2$ Anydrous 76%	104 (40) 150 (66) (oc)	725 (385)	2.5 @ 100°C	12.0	0.9 1.0−	2.1	241 (116) 239–252 (115–122)	Yes Yes	5 5	3	2	0
Ethylene Dichloride CH_2ClCH_2Cl (1,2-Dichloroethane) (Glycol Dichloride)	56 (13) Note: See Hazardous Chemicals Data.	775 (413)	6.2	16	1.3	3.4	183 (84)	No	4	2	3	0
Ethylene Dicyanide	See Succinonitrile.											
2,2-Ethylenedioxydiethanol	See Triethylene Glycol.											
Ethylene Formate	See 1,2-Ethanediol Diformate.											
Ethylene Glycol HOC_2H_4OH (1,2-Ethanediol) (Glycol)	232 (111)	748 (398)	3.2		1.1		387 (197)	Yes	5 2	1	1	0
Ethylene Glycol N-Butyl Ether $HOCH_2CH_2OC_4H_9$	150 (66)		1.1	10.6	0.897	4.10	340 (171)	Yes	5	1	2	0
Ethylene Glycol Diacetate	See Glycol Diacetate.											
												0

Ethylene Glycol Diethyl Ether $C_2H_5OCH_2CH_2OC_2H_5$	95 (35) (oc)	406			0.8	4.07	251 (122)	Slight	5 1	1	3	0
Ethylene Glycol Diformate	See 1,2-Ethanediol Diformate.											

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Ethylene Glycol Dimethyl Ether $CH_3O(CH_2)_2OCH_3$ (1,2-Dimethoxyethane)	29 (−2)	395 (202)			0.9		174 (79) @ 630 mm	Slight	5	2	2	0
Ethylene Glycol Ethylbutyl Ether $(C_2H_5)_2CHCH_2OCH_2CH_2OH$	180 (85) (oc)				0.9		386 (197)	No	5	1	2	0
Ethylene Glycol Ethylhexyl Ether $C_4H_9CH(C_2H_5)CH_2OCH_2$- CH_2OH	230 (110) (oc)				0.9		442 (228)	No	5 2	0	1	0
Ethylene Glycol Isopropyl Ether $(CH_3)_2CHOCH_2CH_2OH$	92 (33) (oc)				0.9	3.58	289 (143)	Yes	5 1	1	3	0
Ethylene Glycol Monoacetate $CH_2OHCH_2OOCCH_3$ (Glycol Monoacetate)	215 (102) (oc)				1.1		357 (181)	Yes	5 2	0	1	0
Ethylene Glycol Monoacrylate $CH_2{:}CHCOOC_2H_4OH$ (2-Hydroxyethylacrylate)	220 (104) (oc)				1.1		410 (210)	Yes	5 2	2	1	1
Ethylene Glycol Monobenzyl Ether $C_6H_5CH_2OCH_2CH_2OH$	265 (129) (oc)	665 (352)			1.1		493 (256)	No	5 2	2	1	0
Ethylene Glycol Monobutyl Ether $C_4H_9O(CH_2)_2OH$ (2-Butoxyethanol)	143 (62)	460 (238)	1.1 @ 200 (93)	12.7 @ 275 (135)	0.9	4.1	340 (171)	Yes	5	2	2	0
Ethylene Glycol Monobutyl Ether Acetate $C_4H_9O(CH_2)_2OOCCH_3$	160 (71)	645 (340)	0.88 @ 200 (93)	8.54 @ 275 (135)	0.9		377 (192)	No	5	1	2	0
Ethylene Glycol Monoethyl Ether $HOCH_2CH_2OC_2H_5$ (2-Ethoxyethanol)	110 (43)	455 (235)	1.7 @ 200 (93)	15.6 @ 200 (93)	0.9	3.0	275 (135)	Yes	5	2	2	0
Ethylene Glycol Monoethyl Ether Acetate $CH_3COOCH_2CH_2OC_2H_5$ (Cellosolve Acetate)	124 (52)	715 (379)	1.7		1.0−	4.72	313 (156)	Yes	5	1	2	
Ethylene Glycol Mono-isobutyl Ether $(CH_3)_2CHCH_2OCH_2CH_2OH$	136 (58)	540 (282)	1.2 @ 200 (93)	9.4 @ 275 (135)	0.9	4.1	316–323 (158–162)	Yes	5	2	2	
Ethylene Glycol Monomethyl Ether $CH_3OCH_2CH_2OH$ (2-Methoxyethanol)	102 (39)	545 (285)	1.8 @ STP	14 @ STP	1.0−	2.6	255 (124)	Yes	5	2	2	0
Ethylene Glycol Mono-methyl Ether Acetal $CH_3CH(OCH_2CH_2OCH_3)_2$	200 (93) (oc)				1.0−		405 (207)	Yes	5	1	2	
Ethylene Glycol Mono-methyl Ether Acetate $CH_3O(CH_2)_2OOCCH_3$	120 (49)	740 (392)	1.5 @ 200 (93)	12.3 @ 200 (93)	1.0+	4.1	293 (145)	Yes	5	1	2	
Ethylene Glycol Mono-methyl Ether Formal $CH_2(OCH_2CH_2OCH_3)_2$	155 (68) (oc)				1.0−	5.65	394 (201)	Yes	5	1	2	
Ethylene Glycol Phenyl Ether	260 (127)				1.1	4.8	473 (245)	No	2	0	1	0

Air

(Dimethylene Oxide)
(1,2-Epoxyethane)
(Oxirane)

Note: See Hazardous Chemicals Data.

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Ethylenimine $NHCH_2CH_2$ (Aziridine)	12 (−11)	608 (320)	3.3	54.8	0.8	1.5	132 (56)	Yes	5	4	3	3
	Note: See Hazardous Chemicals Data.											
Ethyl Ethanoate	See Ethyl Acetate.											
N-Ethylethanolamine $C_2H_5NHC_2H_4OH$	160 (71) (oc)				0.9	3.0	322 (161)	Yes	5	1	2	0
Ethyl Ether $C_2H_5OC_2H_5$ (Diethyl Ether) (Diethyl Oxide) (Ether) (Ethyl Oxide)	−49 (−45)	356 (180)	1.9	36.0	0.7	2.6	95 (35)	Slight	1 5	1	4	1
	Note: See Hazardous Chemicals Data.											
Ethylethylene Glycol	See 1,2-Butanediol.											
Ethyl Fluoride C_2H_5F (1-Fluoroethane)					0.72 @ 7.2 atm	1.66	−36 (−38)				4	0
Ethyl Formate $HCO_2C_2H_5$ (Ethyl Methanoate) (Formic Acid, Ethyl Ester)	−4 (−20)	851 (455)	2.8	16.0	0.9	2.6	130 (54)	No	1 5	2	3	0
Ethyl Formate (ortho) $(C_2H_5O)_3CH$ (Triethyl Orthoformate)	86 (30)				0.90	5.11	291 (144)			0	3	0
Ethyl Glycol Acetate	See 2-Ethoxyethyl Acetate.											
2-Ethylhexaldehyde	See 2-Ethylhexanal.											
2-Ethylhexanal $C_4H_9CH(C_2H_5)CHO$ (Butylethylacetaldehyde) (2-Ethylcaproaldehyde) (2-Ethylhexaldehyde)	112 (44)	375 (190)	0.85 @ 200 (93)	7.2 @ 275 (135)	0.8	4.4	325 (163)	Very slight		2	2	1
2-Ethyl-1,3-Hexanediol $C_3H_7CH(OH)CH(C_2H_5)CH_2OH$	260 (127) (oc)	680 (360)			0.9		472 (244)	Slight	2 5	1	1	0
2-Ethylhexanoic Acid $C_4H_9CH(C_2H_5)COOH$ (2-Ethyl Hexoic Acid)	245 (118) (oc)	700 (371)	0.8	6.0	0.9	5.0	440 (227)	No	2	1	1	0
2-Ethylhexanol $C_4H_9CH(C_2H_5)CH_2OH$ (2-Ethylhexyl Alcohol) (Octyl Alcohol)	164 (73)	448 (231)	0.88	9.7	0.8	4.5	359 (182)	Slight	5	2	2	0
2-Ethylhexenyl	See 2-Ethyl-3-Propylacrolein.											
2-Ethylhexoic Acid	See 2-Ethylhexanoic Acid.											
2-Ethylhexyl Acetate $CH_3COOCH_2CH(C_2H_5)C_4H_9$ (Octyl Acetate)	160 (71)	515 (268)	0.76	8.14	0.9	5.9	390 (199)	No		2	2	0
2-Ethylhexyl Acrylate $CH_2{:}CHCOOCH_2CH(C_2H_5)C_4H_9$	180 (82) (oc)	485 (252)			0.9		266 (130) @ 50 mm	No		2	2	2
2-Ethylhexylamine $C_4H_9CH(C_2H_5)CH_2NH_2$	140 (60) (oc)				0.8	4.5	337 (169)	Yes	5	2	2	0
N-2-(Ethylhexyl) Aniline $C_6H_5NHCH_2CH(C_2H_5)C_4H_9$	325 (163) (oc)				0.9		379 (193) @ 50 mm	No	2	3	1	0
2-Ethylhexyl Chloride $C_4H_9CH(C_2H_5)CH_2Cl$	140 (60)				0.9	5.1	343 (173)	No		2	2	0
$C_6H_{11}NH(CH_2CH(C_2H_5)C_4H_9)$	(oc)						@ 50 mm					0
2-Ethylhexyl Ether $[C_4H_9CH(C_2H_5)CH_2]_2O$	235 (113)				0.8		517 (269)	No	2	1	1	0

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2-Ethylhexyl Vinyl Ether	See Vinyl-2-Ethylhexyl Ether.											
1,1-Ethylidene Dichloride CH_3CHCl_2 (1,1-Dichloroethane)	2 (−17)		5.4	11.4	1.2		135–138 (57–59)	Slight	4 5	2	3	0
1,2-Ethylidene Dichloride $ClCH_2CH_2Cl$	55 (13)	824 (440)	6.2	16	1.25	3.42	183 (84)			2	3	0
Ethyl Isobutyrate $(CH_3)_2CHCOOC_2H_5$	<70 (<21)				0.87	4.0	230 (110)			0	3	0
2-Ethylisohexanol $(CH_3)_2CHCH_2CH(C_2H_5)$-CH_2OH (2-Ethyl Isohexyl Alcohol) (2-Ethyl-4-Methyl Pentanol)	158 (70)	600 (316)			0.8		343–358 (173–181)			1	2	
Ethyl Lactate $CH_3CHOHCOOC_2H_5$ Tech.	115 (46) 131 (55)	752 (400)	1.5 @ 212 (100)		1.0+	4.1	309 (154)	Yes	5	2	2	0
Ethyl Malonate	See Diethyl Malonate.											
Ethyl Mercaptan C_2H_5SH (Ethanethiol) (Ethyl Sulfhydrate)	<0 (<−18)	572 (300)	2.8	18.0	0.8	2.1	95 (35)	No	1	2	4	0
Ethyl Methacrylate CH_2:$C(CH_3)COOC_2H_5$ (Ethyl Methyl Acrylate)	68 (20) (oc)				0.9	3.9	239–248 (115–120)	No	1	2	3	0
Ethyl Methanoate	See Ethyl Formate.											
Ethyl Methyl Acrylate	See Ethyl Methacrylate.											
Ethyl Methyl Ether	See Methyl Ethyl Ether.											
7-Ethyl-2-Methyl-4-Hendecanol $C_4H_9CH(C_2H_5)C_2H_4$-$CHOHCH_2CH(CH_3)_2$	285 (141) (oc)				0.8		507 (264)	Very slight	2	0	1	0
Ethyl Methyl Ketone	See Methyl Ethyl Ketone.											
4-Ethylmorpholine $CH_2CH_2OC_2H_4NCH_2CH_3$	90 (32) (oc)				0.9	4.0	280 (138)	Yes	1 5	2	3	0
1-Ethylnaphthalene $C_{10}H_7C_2H_5$		896 (480)			1.02	5.39	496 (258)			0	1	0
Ethyl Nitrate $CH_3CH_2ONO_2$ (Nitric Ether)	50 (10)		4.0		1.1	3.1	190 (88)	No	4	2	3	4
Ethyl Nitrite C_2H_5ONO (Nitrous Ether)	−31 (−35) Decomposes Note: See Hazardous Chemicals Data.	194 (90)	4.0	50.	0.9	2.6	63 (17)	No		3	4	4
3-Ethyloctane $C_5H_{11}CH(C_2H_5)C_2H_5$		446 (230)			0.74	4.91	333 (167)			0	2	0
4-Ethyloctane $C_4H_9CH(C_2H_5)C_3H_7$		445 (229)			0.74	4.91	328 (164)			0	2	0
Ethyl Orthosilicate	See Ethyl Silicate.											
Ethyl Oxalate $(COOC_2H_5)_2$ (Oxalic Ether) (Diethyl Oxalate)	168 (76)				1.1	5.0	367 (186)	Slight gradual decomposition		0	2	0
Ethyl Oxide	See Ethyl Ether.											
Ethyl 3-Oxobutanoate	See Ethyl Acetoacetate.											
												0
Ethyl Phenylacetate $C_6H_5CH_2COOC_2H_5$	210 (99)				1.0+		529 (276)	No		0	1	
Ethyl Phenyl Ether	See Ethoxybenzene.											

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Ethyl Phenyl Ketone $C_2H_5COC_6H_5$ (Propiophenone)	210 (99) (oc) Note: Melting point 70 (21).				1.01	4.63	425 (218)				1	0
Ethyl Phosphate	See Triethyl Phosphate.											
Ethyl Phthalyl Ethyl Glycolate $C_2H_5OCOC_6H_4OCO$-$CH_2OCOC_2H_5$	365 (185)				1.2		608 (320)	Yes	2 5	0	1	0
Ethyl Propenyl Ether $CH_3CH{:}CHOCH_2CH_3$	>19 (> −7) (oc)				0.8		158 (70)		1	2	3	1
Ethyl Propionate $C_2H_5COOC_2H_5$	54 (12)	824 (440)	1.9	11	0.9	3.5	210 (99)	No	1		3	0
2-Ethyl-3-Propylacrolein $C_3H_7CH{:}C(C_2H_5)CHO$ (2-Ethylhexenal)	155 (68) (oc)				0.9	4.4	347 (175)	No	5	2	2	1
2-Ethyl-3-Propylacrylic Acid $C_3H_7CH{:}C(C_2H_5)COOH$	330 (166) (oc)				0.9		450 (232)	Slight	2 5	2	1	1
Ethyl Propyl Ether $C_2H_5OC_3H_7$ (1-Ethoxypropane)	< −4 (< −20)		1.7	9.0	0.8		147 (64)	Yes	5	1	3	0
Ethyl Silicate $(C_2H_5)_4SiO_4$ (Ethyl Orthosilicate) (Tetraethyl Orthosilicate)	125 (52) (oc)				0.9	7.2	334 (168)	Decomposes		2	2	0
Ethyl Sulfate	See Diethyl Sulfate.											
Ethyl Sulfhydrate	See Ethyl Mercaptan.											
m-Ethyltoluene $CH_3C_6H_4C_2H_5$ (1-Methyl-3-Ethylbenzene)		896 (480)			0.88	4.15	322 (161)				2	0
o-Ethyltoluene $CH_3C_6H_4C_2H_5$ (1-Methyl-2-Ethylbenzene)		824 (440)			0.88	4.15	329 (165)				2	0
p-Ethyltoluene $CH_3C_6H_4C_2H_5$ (1-Methyl-4-Ethylbenzene)		887 (475)			0.88	4.15	324 (162)				2	0
Ethyl p-Toluene Sulfonamide $C_7H_7SO_2NHC_2H_5$	260 (127)				1.3		208 (98) @ 745 mm		2		1	0
Ethyl p-Toluene Sulfonate $C_7H_7SO_3C_2H_5$	316 (158)				1.2		345 (174)	No	2		1	0
Ethyltrichloro Silane $CH_3CH_2SiCl_3$	72 (22) (oc)				1.2		208 (98) @ 745 mm		1	3	3	2W
Ethyl Vinyl Ether	See Vinyl Ethyl Ether.											
Ethyne	See Acetylene.											
Fish Oil	420 (216)							No	2	0	1	0
Fluorobenzene C_6H_5F	5 (−15)				1.03	3.31	185 (85)				3	0
Formal	See Methylal.											
Formalin	See Formaldehyde.											
[illegible] **37%, 15% Methanol** (Formalin) (Methylene Oxide)	[illegible] 122 (50) Note: See Hazardous Chemicals Data.	[illegible]	[illegible]	[illegible]	[illegible]					3	2	0 0 0

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Formamide $HCONH_2$	310 (154) (oc)				1.1		410 (210) Decom-poses	Yes	2	2	1	
Formic Acid HCOOH **90% Solution**	156 (69) 122 (50)	1004 (539) 813 (434)	 18	 57	1.2	1.6	213 (101)	Yes	5	3	2	0
	Note: See Hazardous Chemicals Data.											
Formic Acid, Butyl Ester	See Butyl Formate.											
Formic Acid, Ethyl Ester	See Ethyl Formate.											
Formic Acid, Methyl Ester	See Methyl Formate.											
Fuel Oil No. 1 (Kerosene) (Range Oil) (Coal Oil)	100–162 (38–72)	410 (210)	0.7	5	<1		304–574 (151–301)	No		0	2	0
Fuel Oil No. 2	126–204 (52–96)	494 (257)			<1			No		0	2	0
Fuel Oil No. 4	142–240 (61–116)	505 (263)			<1			No		0	2	0
Fuel Oil No. 5 Light Heavy	 156–336 (69–169) 160–250 (71–121)				<1			No		0	2	0
Fuel Oil No. 6	150–270 (66–132)	765 (407)			1±			No		0	2	0
2-Furaldehyde	See Furfural.											
Furan CH:CHCH:CHO (Furfuran)	<32 (<0)		2.3	14.3	0.9	2.3	88 (31)	No	1	1	4	1
Furfural OCH:CHCH:CHCHO (2-Furaldehyde) (Furfuraldehyde) (Furol)	140 (60)	600 (316)	2.1	19.3	1.2	3.3	322 (161)	Slight	5	3	2	0
	Note: See Hazardous Chemicals Data.											
Furfuraldehyde	See Furfural.											
Furfuran	See Furan.											
Furfuryl Acetate $OCH:CHCH:CCH_2OOCCH_3$	185 (85)				1.1	4.8	356–367 (180–186)	No	3	1	2	1
Furfuryl Alcohol $OCH:CHCH:CCH_2OH$	167 (75) (oc)	915 (491)	1.8	16.3	1.1	3.4	340 (171)	Yes	5	1	2	1
Furfurylamine $C_4H_3OCH_2NH_2$	99 (37) (oc)				1.05	3.35	295 (146)				3	0
Furol	See Furfural.											
Fusel Oil	See Isoamyl Alcohol.											
Gas, Blast Furnace			35	74					6	2	4	0
Gas, Coal Gas			5.3	32					6	2	4	0
Gas, Coke-Oven			4.4	34					6	2	4	0
Gas, Natural (Natural Gas)		900– 1170	3.8– 6.5	13– 17					6	1	4	0
												0
Gas, Producer			20–30	70–80					6	2	4	0
Gas, Water			7.0	72					6	2	4	0
Gas, Water (Carbureted)			5.6	46.2					6	2	4	0
Gas Oil	150+ (66+)	640 (338)	0.5	5.0	<1		500–700 (260–371)	No		0	2	0

	FLASH POINT °F (°C)	IGNITION TEMP. °F (°C)	FLAMMABLE LIMITS Percent by Vol. Lower	Upper	Sp. Gr. (Water = 1)	Vapor Density (Air = 1)	BOILING POINT °F (°C)	Water Soluble	SEE INTRODUCTION FOR SUGGESTED EXTINGUISHING METHODS	HAZARD IDENTIFICATION Health	Flamma-bility	Reac-tivity
Gasoline C_5H_{12} to C_9H_{20} 56–60 Octane 73 Octane 92 Octane 100 Octane	−45 (−43) −45 (−43) −36 (−38)	 536 (280) 853 (456)	1.4 1.4 1.4 1.5 1.4	7.6 7.6 7.6 7.6 7.4	0.8	3–4	100–400 (38–204)	No	1	1	3	0
	Note: Values may vary considerably for different grades of gasoline.											
Gasoline 100–130 (Aviation Grade)	−50 (−46) (approx.)	824 (440)	1.3	7.1						1	3	0
Gasoline 115–145 (Aviation Grade)	−50 (−46) (approx.)	880 (471)	1.2	7.1						1	3	0
Gasoline (Casinghead)	0 (−18) or less							No	1	1	4	0
Geraniol $(CH_3)_2C{:}CH(CH_2)_2$-$C(CH_3){:}CHCH_2OH$ (trans-3,7-Dimethyl-2,6-Octadien-1-ol)	>212 (>100)				0.9		446 (230)	No	5	0	1	0
Geranyl Acetate $CH_3COOC_{10}H_{17}$ (Geraniol Acetate)	>212 (>100)				0.9		468–473 (242–245)	No	5	0	1	0
Geranyl Butyrate $C_3H_7COOC_{10}H_{17}$ (Geraniol Butyrate)	>212 (>100)				0.9		304 (151)	No	5	0	1	0
Geranyl Formate $HCOOC_{10}H_{17}$ (Geraniol Formate)	185 (85)				0.9		235 (113)	No	5	0	2	0
Geranyl Propionate $C_2H_5COOC_{10}H_{17}$ (Geraniol Propionate)	>212 (>100)				0.9				5	0	1	0
Gin	See Ethyl Alcohol and Water.											
Glucose Pentapropionate $C_6H_7O_6(COC_2H_5)_5$ (Pentapropionyl Glucose) (Tetrapropionyl Glucosyl Propionate)	509 (265)				1.2		401 (205) @ 2 mm	No	2	1	1	0
Glycerine $HOCH_2CHOHCH_2OH$ (Glycerol)	390 (199)	698 (370)			1.3	3.1	340 (171)	Yes	2 5	1	1	0
α,β-Glycerin Dichlorohydrin $CH_2ClCHClCH_2OH$	200 (93)				1.4		360 (182)	Yes	5	2	1	0
Glycerol	See Glycerine.											
Glyceryl Triacetate $(C_3H_5)(OOCCH_3)_3$ (Triacetin)	280 (138)	812 (433)	1.0 @ 373 (189)		1.2		496 (258)	Slight	2 5	1	1	0
Glyceryl Tributyrate $C_3H_5(OOCC_3H_7)_3$ (Tributyrin) (Butyrin) (Glycerol Tributyrate)	356 (180) (oc)	765 (407)	0.5 @ 406 (208)		1.0+		597 (314)	No	5 2	0	1	0
Glyceryl Trichlorohydrin	See 1,2,3-Trichloropropane.											
Glyceryl Trinitrate	See Nitroglycerine.											
Glyceryl Tripropionate	332	790	0.8		1.1		540	No	5	0	1	0
	(oc)						@ 2 mm					0
Glycol	See Ethylene Glycol.											
Glycol Benzyl Ether $C_6H_5CH_2OCH_2CH_2OH$ (2-Benzyloxyethanol)	264 (129) (oc)	662 (350)			1.07	5.20	493 (256)	No		0	1	0

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Glycol Diacetate $(CH_2OOCCH_3)_2$ (Ethylene Acetate) (Ethylene Glycol Diaceate)	191 (88)	900 (482)	1.6	8.4	1.1		375 (191)	Slight	5	1	1	0
Glycol Dichloride	See Ethylene Dichloride.											
Glycol Diformate	See 1,2-Ethanediol Diformate.											
Glycol Dimercaptoacetate $(HSCH_2C{:}OOCH_2-)_2$ (GDMA)	396 (202)				1.3		280 (138) 1.2 mm	No	5 2	2	1	0
Glycol Monoacetate	See Ethylene Glycol Monoacetate.											
Grain Alcohol	See Ethyl Alcohol.											
Heavy Hydrogen	See Deuterium.											
Hendecane $CH_3(CH_2)_9CH_3$ (Undecane)	149 (65) (oc)				0.7	5.4	384 (196)	No	1	0	2	0
Heptadecanol $C_4H_9CH(C_2H_5)C_2H_4$- $CH(OH)C_2H_4CH(C_2H_5)_2$ (3,9-Diethyl-6-Tridecanol)	310 (154) (oc) Note: Melting point 130 (54).				0.8		588 (309)	No	2	0	1	0
Heptane $CH_3(CH_2)_5CH_3$	25 (−4)	399 (204)	1.05	6.7	0.7	3.5	209 (98)	No	1	1	3	0
2-Heptanol $CH_3(CH_2)_4CH(OH)CH_3$	160 (71)				0.8	4.0	320 (160)	No		0	2	0
3-Heptanol $CH_3CH_2CH(OH)C_4H_9$	140 (60)				0.8	4.0	313 (156)	Slight	5	0	2	0
3-Heptanone	See Ethyl Butyl Ketone.											
4-Heptanone $(C_3H_7)_2CO$ (Butyrone) (Dipropyl Ketone)	120 (49)				0.8	3.9	290 (143)	No		2	2	0
1-Heptene	See Heptylene.											
3-Heptene (mixed cis and trans) $C_3H_7CH{:}CHC_2C_5$ (3-Heptylene)	21 (−6)				0.7	3.39	203 (95)	No	1	0	3	0
Heptylamine $CH_3(CH_2)_6NH_2$ (1-Aminoheptane)	130 (54) (oc)				0.8	4.0	311 (155)	Slight	5	2	2	0
Heptylene $C_5H_{11}CH{:}CH_2$ (1-Heptene)	<32 (<0)	500 (260)			0.7	3.39	201 (94)	No		0	3	0
Heptylene-2-trans $C_4H_9CH{:}CHCH_3$ (2-Heptene-trans)	<32 (<0)				0.7	3.34	208 (98)			0	3	0
Hexachlorobutadiene $CCl_2{:}CClCCl{:}CCl_2$		1130 (610)				8.99				2	1	1
Hexachloro Diphenyl Oxide $(C_6H_2Cl_3)_2O$ (Bis(Trichlorophenyl) Ether)		1148 (620)				13.0				2	1	1
Hexadecane $CH_3(CH_2)_{14}CH_3$ (Cetane)	>212 (>100) Note: Melting point 68 (20).	396 (202)			0.8 @ 68 (20)	7.8	549 (287)	No		0	1	0
tert-Hexadecanethiol $C_{16}H_{33}SH$	265 (129)				0.9		298–307 (148–153) @ 11 mm	No	2	0	1	0
												0
Hexadecyl-tert-Mercaptan	See tert-Hexadecanethiol.											
Hexadecyltrichlorosilane $C_{16}H_{33}SiCl_3$	295 (146)				1.0−		516 (269)	Yes	2	3	1	0

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2,4-Hexadienal $CH_3CH{:}CHCH{:}CHC(O)H$	154 (68) (oc)		1.3	8.1	0.9		339 (171)	Very slight		2	2	0
1,4-Hexadiene $CH_3CH{:}CHCH_2CH{:}CH_2$ (Allylpropenyl)	−6 (−21)		2.0	6.1	0.7	2.8	151 (66)	No	1	0	3	0
Hexahydroaniline	See Cyclohexylamine.											
Hexahydrobenzene	See Cyclohexane.											
Hexahydropyridine	See Piperidine.											
Hexahydrotoluene	See Methylcyclohexane.											
Hexahydroxylol	See 1,4-Dimethylcyclohexane.											
Hexaldehyde	See Hexanal.											
Hexalin	See Cyclohexanol.											
Hexalin Acetate	See Cyclohexyl Acetate.											
Hexamethylene	See Cyclohexane.											
Hexanal $CH_3(CH_2)_4CHO$ (Caproaldehyde) (Hexaldehyde)	90 (32) (oc)				0.8	3.6	268 (131)	No	1	2	3	1
Hexane $CH_3(CH_2)_4CH_3$ (Hexyl Hydride)	−7 (−22)	437 (225)	1.1	7.5	0.7	3.0	156 (69)	No	1	1	3	0
1,2-Hexanediol	See Hexylene Glycol.											
2,5-Hexanediol $CH_3CH(OH)CH_2$-$CH_2CH(OH)CH_3$ (2,5-Dihydroxyhexane)	230 (110)				1.0 −		429 (221)	Yes	2 5	2	1	0
2,5-Hexanedione	See Acetonyl Acetone.											
1,2,6-Hexanetriol $HOCH_2CH(OH)$-$(CH_2)_3CH_2OH$	375 (191) (oc)				1.1		352 (178) @ 5 mm	Yes	2 5	1	1	0
Hexanoic Acid	See Caproic Acid.											
1-Hexanol	See Hexyl Alcohol.											
2-Hexanone	See Methyl Butyl Ketone.											
3-Hexanone $C_2H_5COC_3H_7$ (Ethyl n-Propyl Ketone)	95 (35) (oc)		~1	~8	0.82	3.46	253 (123)			1	3	0
1-Hexene $CH_2{:}CH(CH_2)_3CH_3$ (Butyl Ethylene)	< 20 (< −7)	487 (253)			0.7	3.0	146 (63)	No	1	1	3	0
2-Hexene (Mixed cis and trans isomers) $CH_3CH{:}CH(CH_2)_2CH_3$	< 20 (< −7)	473 (245)			0.7	3.0	155 (68)	No	1	1	3	0
2-Hexene-cis $C_3H_7CH{:}CHCH_3$	< −4 (< −20)				0.69	2.90	156 (69)			0	3	0
3-Hexenol-cis $CH_3CH_2CH{:}CHCH_2CH_2OH$ (3-Hexen-l-ol) (Leaf Alcohol)	130 (54)				0.85	3.45	313 (156)	Slight	5	1	2	0
Hexone	See Methyl Isobutyl Ketone.											
Hexyl Acetate $(CH_3)_2CH(CH_2)_3OOCCH_3$ (Methylamyl Acetate)	113 (45)				0.9	5.0	285 (141)	No	5	1	2	0
												0
sec-Hexyl Alcohol $C_4H_9CH(OH)CH_3$ (2-Hexanol)	136 (58)				0.81	3.53	284 (140)			0	2	0
Hexylamine $CH_3(CH_2)_5NH_2$	85 (29) (oc)				0.8	3.5	269 (132)	Slight	1 5	2	3	0

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Hexyl Chloride	See 1-Chlorohexane.											
Hexyl Cinnamic Aldehyde $C_6H_{13}C(CHO):CHC_6H_5$ (Hexyl Cinnamaldehyde)	>212 (>100)				1.0−		486 (252)		5		1	0
Hexylene Glycol $CH_2OHCHOH(CH_2)_3CH_3$ (1,2-Hexanediol)	215 (102) (oc)				0.9		385 (196)		2	1	1	0
Hexyl Ether $C_6H_{13}OC_6H_{13}$ (Dihexyl Ether)	170 (77) (oc)	365 (185)			0.8	6.4	440 (227)	No		2	2	0
Hexyl Hydride	See Hexane.											
Hexyl Methacrylate $C_6H_{13}OOCC(CH_3):CH_2$	180 (82) (oc)				0.9	5.9	388–464 (198–240)			0	2	0
Hexyl Methyl Ketone	See 2-Octanone.											
Hydracrylonitrile	See Ethylene Cyanohydrin.											
Hydralin	See Cyclohexanol.											
Hydrazine (Anhydrous) H_2NNH_2	100 (38) Ignition temperatures vary widely in contact with iron rust 74 (23); black iron 270 (132); stainless steel 313 (156); glass 518 (270). Note: See Hazardous Chemicals Data.		2.9	98	1.0+	1.1	236 (113)	Yes		3 Vapors explosive.	3	3
Hydrindane C_9H_{16} (Hexahydroindane) (Octahydroindene)		565 (296)			0.9		318 (159)		5			0
Hydrochloric Ether	See Ethyl Chloride.											
Hydrocyanic Acid—96% HCN (Prussic Acid) (Hydrogen Cyanide)	0 (−18) Note: See Hazardous Chemicals Data.	1000 (538)	5.6	40.0	0.7	0.9	79 (26)	Yes		4 Vapors extremely toxic.	4	2
Hydrogen H_2	Gas Note: See Hazardous Chemicals Data.	932 (500)	4.0	75		0.1	−422 (−252)	Slight	6	0	4	0
Hydrogen Cyanide	See Hydrocyanic Acid.											
Hydrogen Sulfide H_2S	Gas Note: See Hazardous Chemicals Data.	500 (260)	4.0	44.0		1.2	−76 (−60)	Yes	6	4	4	0
Hydroquinone $C_6H_4(OH)_2$ (HQ) (Quinol) (Hydroquinol)	329 (165)	960 (516)			1.3		547 (286)	No	5 2	2	1	0
Hydroquinone Di-(β-Hydroxyethyl) Ether $C_6H_4(\text{-}OCH_2CH_2OH)_2$	435 (224) Note: Melting point 201–205 (94–96).	875 (468)					365–392 @ 0.3 mm (185–200)	Slight	2		1	0
Hydroquinone Monomethyl Ether $CH_3OC_6H_4OH$ (HQMME) (4-Methoxy Phenol) (Para-Hydroxyanisole)	270 (132) (oc) Note: Melting point 126 (52).	790 (421)			1.5		475 (246)	No	2		1	0
o-Hydroxybenzaldehyde	See Salicylaldehyde.											
3-Hydroxybutanal	See Aldol.											
β-Hydroxybutyraldehyde	See Aldol.											
Hydroxycitronellal Hydroxyoctanal)	>212				0.9		201–205	Slight	5		1	0
N-(2-Hydroxyethyl)-acetamide	See N-Acetyl Ethanolamine.											
2-Hydroxyethyl Acrylate (HEA)	214 (101)		1.8 @ 100°C		1.1		410 (210)	Yes		2	1	2

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β-Hydroxyethylaniline	See 2-Anilinoethanol.											
N-(2-Hydroxyethyl) Cyclohexylamine $C_6H_{11}NHC_2H_4OH$	249 (121) (oc) Note: Melting point 97–102 (36–39).							Yes	2 5	3	1	0
(2-Hydroxyethyl)-Ethylenediamine $CH_2OHCH_2NHCH_2CH_2NH_2$	275 (135)				1.0+		460–464 (238–240)	Yes	2 5	1	1	0
4-(2-Hydroxyethyl) Morpholine $C_2H_4OC_2H_4NC_2H_4OH$	210 (99) (oc)				1.1		437 (225)	Yes	5	2	1	0
1-(2-Hydroxyethyl) Piperazine $HOCH_2CH_2$-$NCH_2CH_2NHCH_2CH_2$	255 (124) (oc)				1.1	4.5	475 (246)	Yes	2 5	0	1	0
n-(2-Hydroxyethyl) Propylenediamine $CH_3CH(NHC_2H_4OH)CH_2NH_2$	260 (127) (oc)				1.0–		465 (241)	Yes	2 5	2	1	0
Hydroxylamine NH_2OH (Oxammonium)	Explodes @ 265 (129) Note: Melting point 92 (33). See Hazardous Chemicals Data.				1.2		158 (70)	Yes		2	0	3
4-Hydroxy-4-Methyl-2-Pentanone	See Diacetone Alcohol.											
2-Hydroxy-2-methyl-propionitrile	See Acetone Cyanohydrin.											
Hydroxypropyl Acrylate	See Propylene Glycol Monoacrylate.											
o-Hydroxytoluene	See o-Cresol.											
Ionone Alpha (α-Ionone) $C(CH_3)_2CH_2CH_2CH{:}C(CH_3)$-$CHCH{:}CHC(CH_3){:}O$ (α-Cyclocitrylideneacetone) [4-(2,6,6-Trimethyl-2-Cyclohexen-1-yl)-3-Buten-2-one]	>212 (>100)				0.9		259–262 (126–128) @ 12 mm	Slight	5		1	0
Ionone Beta (β-Ionone) $C(CH_3)_2CH_2CH_2CH_2$-$C(CH_3){:}CCHCHC(CH_3){:}O$ (β-Cyclocitrylidene-acetone) [4-(2,6,6-Trimethyl-1-Cyclohexen-1-yl)-3-Buten-2-one]	>212 (>100)				0.9		284 (140) @ 18 mm	No	5		1	0
Iron Carbonyl $Fe(CO)_5$	5 (−15)				1.45	6.74	221 (105)			2	3	1W
Isano Oil	Exothermic reaction above 502 (261) may become explosive.				1.0–						1 May explode above 502 (261).	3
Isoamyl Acetate $CH_3COOCH_2CH_2CH(CH_3)_2$ (Banana Oil) (3-Methyl-1-Butanol Acetate) (2-Methyl Butyl Ethanoate)	77 (25)	680 (360)	1.0 @ 212 (100)	7.5	0.9	4.5	290 (143)	Slight	5 1	1	3	0
Isoamyl Alcohol $(CH_3)_2CHCH_2CH_2OH$ (Isobutyl Carbinol)	109 (43)	662 (350)	1.2	9.0 @ 212	0.8	3.0	270 (132)	Slight	5	1	2	0

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Isoamyl Butyrate $C_3H_7CO_2(CH_2)_2CH(CH_3)_2$ (Isopentyl Butyrate)	138 (59)				0.88	5.45	352 (178)				2	
Isoamyl Chloride $(CH_3)_2CHCH_2CH_2Cl$ (1-Chloro-3-Methylbutane)	<70 (<21)		1.5	7.4	0.89	3.67	212 (100)				3	

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Isobornyl Acetate $C_{10}H_{17}OOCCH_3$	190 (88)				1.0 –		428–435 (220–224)	No	5	1	2	0
Isobutane $(CH_3)_3CH$ (2-Methylpropane)	Gas	860 (460)	1.8	8.4		2.0	11 (–12)	No	6	1	4	0
Isobutyl Acetate $CH_3COOCH_2CH(CH_3)_2$ (β-Methyl Propyl Ethanoate)	64 (18)	790 (421)	1.3	10.5	0.9	4.0	244 (118)	No	5 1	1	3	0
Isobutyl Acrylate $(CH_3)_2CHCH_2OOCCH{:}CH_2$	86 (30) (oc)	800 (427)			0.9	4.42	142–145 (61–63) @ 15 mm		5 1	1	3	1
Isobutyl Alcohol $(CH_3)_2CHCH_2OH$ (Isopropyl Carbinol) (2-Methyl-1-Propanol)	82 (28)	780 (415)	1.7 @ 123 (51)	10.6 @ 202 (94)	0.8	2.6	225 (107)	Yes	5 1	1	3	0
Isobutylamine $(CH_3)_2CHCH_2NH_2$	15 (–9)	712 (378)			0.7	2.5	150 (66)	Yes	5 1	2	3	0
Isobutylbenzene $(CH_3)_2CHCH_2C_6H_5$	131 (55)	802 (427)	0.8	6.0	0.9	4.6	343 (173)	No		2	2	0
Isobutyl Butyrate $C_3H_7CO_2CH_2CH(CH_3)_2$	122 (50)				0.87	5.0	315 (157)			0	2	
Isobutyl Carbinol	See Isoamyl Alcohol.											
Isobutyl Chloride $(CH_3)_2CHCH_2Cl$ (1-Chloro-3-Methyl-propane)	<70 (<21)		2.0	8.8	0.9	3.2	156 (69)			2	3	0
Isobutylcyclohexane $(CH_3)_2CHCH_2C_6H_{11}$		525 (274)			0.8		336 (169)			0		0
Isobutylene	See 2-Methylpropene.											
Isobutyl Formate $HCOOCH_2CH(CH_3)_2$	<70 (<21)	608 (320)	~1.7	~8	0.88	3.52	208 (98)				3	
Isobutyl Heptyl Ketone $(CH_3)_2CHCH_2COCH_2$-$CH(CH_3)CH_2CH(CH_3)_2$ (2,6,8-Trimethyl-4-Non- anone)	195 (91) (oc)	770 (410)			0.8		412–426 (211–219)	No	5	2	2	0
Isobutyl Isobutyrate $(CH_3)_2CHCOOCH_2$-$CH(CH_3)_2$	101 (38)	810 (432)	0.96	7.59	0.9	4.97	291–304 (144–151)	No	5	0	2	0
Isobutyl Phenylacetate $(CH_3)_2CHCH_2OOCCH_2C_6H_5$	>212 (>100)				1.0		477 (247)		5	0	1	0
Isobutyl Phosphate $PO_4(CH_2CH(CH_3)_2)_3$ (Triisobutyl Phosphate)	275 (135) (oc)				0.98	9.12	302 (150) @ 20 mm				1	
Isobutyl Vinyl Ether	See Vinyl Isobutyl Ether.											
Isobutyraldehyde $(CH_3)_2CHCHO$ (2-Methylpropanal)	–1 (–18)	385 (196)	1.6	10.6	0.8	2.5	142 (61)	Slight	5 1	2	3	1
Isobutyric Acid $(CH_3)_2CHCOOH$	132 (56)	900 (481)	2.0	9.2	1.0 –	3.0	306 (152)	Yes	5	1	2	0
Isobutyric Anhydride $[(CH_3)_2CHCO]_2O$	139 (59)	625 (329)	1.0	6.2	1.0 –	5.5	360 (182)	Decomposes	5	1	2	1W
Isobutyronitrile $(CH_3)_2CHCN$ (2-Methylpropanenitrile) (Isopropylcyanide)	47 (8)	900 (482)			0.8	2.38	214–216 (101–102)	Slight	5 1	3	3	0
Isodecaldehyde	185				0.8	5.4	387	No		0	2	0
$C_7H_{15}CH(CH_3)_2$ (2-Methylnonane)		(210)					(167)					0
Isodecanoic Acid $C_9H_{19}COOH$	300 (149) (oc)				0.9	5.9	489 (254)	No	2	0	1	0

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Isodecanol, Mixed Isomers $C_{10}H_{21}OH$	220 (104) (oc)				0.8	5.5	428 (220)	No	2	0	1	0
Isoevgenol $(CH_3CHCH)C_6H_3OHOCH_3$ (1-Hydroxy-2-Methoxy-4-Propenylbenzene)	>212 (>100)				1.1		514 (268)	No	5	0	1	0
Isoheptane $(CH_3)_2CHC_4H_9$ (2-Methylhexane) (Ethyl-isobutylmethane)	<0 (−18)		1.0	6.0	0.7	3.45	194 (90)	No	1	0	3	0
Isoheptane, Mixed Isomers	<0 (< −18)	428 (220)	1.0	6.0	0.7		176–195 (80–91)	No	1	1	3	0
Isohexane (Mixture of Hexane Isomers)	< −20 (< −29)	507 (264)	1.0	7.0	0.7		134–142 (57–61)	No	1	1	3	0
tert-Isohexyl Alcohol $C_2H_5(CH_3)C(OH)C_2H_5$ (3-Methyl-3-Pentanol)	115 (46)				0.77	3.53	252 (122)				2	0
Isooctane $(CH_3)_2CHCH_2C(CH_3)_3$ (2,2,4-Trimethylpentane)	40 (4.5) (oc)	784 (418)			0.7	3.94	210 (99)	No	1	0	3	0
Isooctanoic Acid (Mixed isomers) $C_6H_{15}COOH$	270 (132) (oc)	738 (392)			0.9	5.0	428 (220) Decomposes	No	2	0	1	0
Isooctenes C_8H_{16}	<20 (−7)				0.7	3.87	190–200 (88–93)		1	0	3	0
Isooctyl Alcohol $C_7H_{15}CH_2OH$ (Isooctanol)	180 (82) (oc)				0.8		83–91 (182–195)	No	5	0	2	0
Isooctyl Nitrate $C_8H_{17}NO_3$	205 (96) (oc)				1.0 –		106–109 (41–43) @ 1 mm	No			1	
Isooctyl Vinyl Ether	See Vinyl Isooctyl Ether.											
Isopentaldehyde $(CH_3)_2CHCH_2CHO$	48 (9) (oc)				0.8	2.97	250 (121)	Slight	5 1	2	3	0
Isopentane $(CH_3)_2CHCH_2CH_3$ (2-Methylbutane) (Ethyl Dimethyl Methane)	< −60 (< −51)	788 (420)	1.4	7.6	0.6		82 (28)	No	1	1	4	0
Isopentanoic Acid $(CH_3)_2CHCH_2COOH$ (Isovaleric Acid)		781 (416)			0.9		361 (183)	No		1		0
Isophorone $COCHC(CH_3)CH_2C(CH_3)_2CH_2$	184 (84)	860 (460)	0.8	3.8	0.9		419 (215)	Slight		2	2	0
Isophthaloyl Chloride $C_6H_4(COCl)_2$ (m-Phthalyl Dichloride)	356 (180) (oc) Note: Melting point 109.9 (43).				1.4	6.9	529 (276)	No	2		1	0
Isoprene $CH_2:C(CH_3)CH:CH_2$ (2-Methyl-1,3-Butadiene)	−65 (−54)	743 (395)	1.5	8.9	0.7	2.4	93 (34)	No	1	1	4	2
Isopropanol	See Isopropyl Alcohol.											
Isopropanolamine	See 1-Amino-2-Propanol.											
Isopropenyl Acetate $CH_3COOC(CH_3):CH_2$ (1-Methylvinyl Acetate)	60 (16)	808 (431)			0.9	3.5	207 (97)	Slight	5 1	2	3	0
2-Isopropoxypropane	See Isopropyl Ether.											
3-Isopropoxypropionitrile $(CH_3)_2CHOCH_2CH_2CN$	155 (68)				0.9	3.9	149 (65) @ 10 mm	Slight	5	1	2	1

2

	FLASH POINT °F (°C)	IGNITION TEMP. °F (°C)	FLAMMABLE LIMITS Percent by Vol. Lower	Upper	Sp. Gr. (Water = 1)	Vapor Density (Air = 1)	BOILING POINT °F (°C)	Water Soluble	SEE INTRODUCTION FOR SUGGESTED EXTINGUISHING METHODS	HAZARD IDENTIFICATION Health	Flamma-bility	Reac-tivity
Isopropyl Acetate $(CH_3)_2CHOOCCH_3$	35 (2)	860 (460)	1.8 @ 100 (38)	8	0.9	3.5	194 (90)	Slight	5 1	1	3	0
Isopropyl Alcohol $(CH_3)_2CHOH$ (Isopropanol) (Dimethyl Carbinol) (2-Propanol) 87.9% iso	53 (12) 57 (14)	750 (399)	2.0	12.7 @ 200 (93)	0.8	2.1	181 (83)	Yes	5 1	1	3	0
Isopropylamine $(CH_3)_2CHNH_2$	−35 (−37) (oc)	756 (402)			0.7	2.0	89 (32)	Yes	5 1	3	4	0
Isopropylbenzene	See Cumene.											
Isopropyl Benzoate $C_6H_5COOCH(CH_3)_2$	210 (99)				1.0+		426 (219)	No		1	1	
Isopropyl Bicyclohexyl $C_{15}H_{28}$	255 (124)	446 (230)	0.5 @ 302 (150)	4.1 @ 400 (204)	0.9		530–541 (277–283)		2	0	1	0
2-Isopropylbiphenyl $C_{15}H_{16}$	285 (141)	815 (435)	0.5 @ 347 (175)	3.2 @ 392 (200)	1.0−		518 (270)		2	0	1	0
Isopropyl Carbinol	See Isobutyl Alcohol.											
Isopropyl Chloride $(CH_3)_2CHCl$ (2-Chloropropane)	−26 (−32)	1100 (593)	2.8	10.7	0.9	2.7	95 (35)	Very slight	1	2	4	0
Isopropylcyclohexane $(CH_3)_2CHC_6H_{11}$ (Hexahydrocumene) (Normanthane)		541 (283)			0.8		310 (154.5)			1		0
Isopropylcyclohexylamine $C_6H_{11}NHCHC_2H_6$	93 (34) (oc)				0.8	4.9		No	1	3	3	0
Isopropyl Ether $(CH_3)_2CHOCH(CH_3)_2$ (2-Isopropoxypropane) (Diisopropyl Ether)	−18 (−28) Note: See Hazardous Chemicals Data.	830 (443)	1.4	7.9	0.7	3.5	156 (69)	Very slight	5 1	1	3	1
Isopropylethylene	See 3-Methyl-1-Butene.											
Isopropyl Formate $HCOOCH(CH_3)_2$ (Isopropyl Methanoate)	22 (−6)	905 (485)			0.9	3.0	153 (67)	Slight		2	3	0
4-Isopropylheptane $C_3H_7CH(C_3H_7)C_3H_7$ (m-Dihydroxybenzene)		491 (255)			0.87	3.04	155 (68)			0	2	0
Isopropyl-2-Hydroxypropanoate	See Isopropyl Lactate.											
Isopropyl Lactate $CH_3CHOHCCOCH(CH_3)_2$ (Isopropyl-2-Hydroxypropionate)	130 (54) (oc)				1.0−	4.2	331–334 (166–168)	Yes	5	2	2	0
Isopropyl Methanoate	See Isopropyl Formate.											
4-Isopropyl-1-Methyl Benzene	See p-Cymene.											
Isopropyl Vinyl Ether	See Vinyl Isopropyl Ether.											
Isovalerone	See Diisobutyl Ketone.											
Jet Fuels	110–150						400–550			0	2	0
												0
Jet Fuels JP-4	−10 to +30 (−23 to −1)	464 (240)	1.3	8.0						1	3	0
Jet Fuels JP-5	95–145 (35–63)	475 (246) (approx.)								0	2	0

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Jet Fuels JP-6	100 (38) (oc)	446 (230)	0.6	3.7	0.8	<1	250 (121)	No				
Katchung Oil	See Peanut Oil (cooking).											
Kerosene	See Fuel Oil No. 1.											
Kerosene, Deodorized	See Ultrasene.											
Lactonitrile $CH_3CH(OH)CN$	171 (77)				0.98	2.45	361 (183)	Yes		4	2	1
Lanolin (Wool Grease)	460 (238)	833 (445)			<1			No	2	0	1	0
Lard Oil (Commercial or Animal)	395 (202)	833 (445)			<1			No	2	0	1	0
No. 1	440 (227)											
Lard Oil (Pure)	500 (260)				0.9			No	2	0	1	0
No. 2	419 (215)											
Mineral	404 (207)											
Lauryl Alcohol	See 1-Dodecanol.											
Lauryl Bromide $CH_3(CH_2)_{10}CH_2Br$ (Dodecyl Bromide)	291 (144)				1.0+		356 (180) @ 45 mm	No	2	1	1	0
Lauryl Mercaptan	See 1-Dodecanethiol.											
Linalool (Ex Bois de Rose; Synthetic) $(CH_3)_2C{:}CHCH_2CH_2C(CH_3)$- $OHCA{:}CH_2$ (3,7-Dimethyl-1,6-Octadiene-3-01)	160 (71)				0.9		383–390 (195–199)	No	5		2	0
Linseed Oil, Raw	432 (222)	650 (343)			0.9		600+ (316+)	No	2	0	1	0
Boiled	403 (206)											
Liquid Camphor	See Camphor Oil (light).											
Lubricating Oil, Mineral (Paraffin Oil, includes Motor Oil)	300–450 (149–232)	500–700 (260–371)			<1		680 (360)	No	2	0	1	0
Lubricating Oil, Spindle (Spindle Oil)	169 (76)	478 (248)			<1			No		0	2	0
Lubricating Oil, Turbine (Turbine Oil)	400 (204) (oc)	700 (371)			<1			No	2	0	1	0
Lynalyl Acetate (Ex Bois de Rose; Synthetic) $(CH_3)_2C{:}CHCH_2CH_2$- $C(\text{-}OOCCH_3)CH{:}CH_2$ (Bergamol)	185 (85)				0.9		226–230 (108–110)	No	5		2	0
Maleic Anhydride $(COCH)_2O$	215 (102) Note: Melting point 127 (53). See Hazardous Chemicals Data.	890 (477)	1.4	7.1	0.9		396 (202)	Slight	5 2	3	1	1
Marsh Gas	See Methane.											
Menhaden Oil (Pogy Oil)	435 (224)	828 (442)			0.9			No	2	0	1	0
2-Mercaptoethanol	165				1.1	2.7	315	Yes	5	2	2	

Mesityl Oxide $(CH_3)_2CCHCOCH_3$	87 (31) Note: See Hazardous Chemicals Data.	652 (344)	1.4	7.2	0.9	3.4	266 (130)	Slight	1 5	2	3	1

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Metaldehyde $(C_2H_4O)_4$	97 (36)						subl. 233–240 (112–116)	No	1	1	3	1
α-Methacrolein	See 2-Methylpropenal.											
Methacrylic Acid $CH_2{:}C(CH_3)COOH$	171 (77) (oc) Note: Polymerizes. See Hazardous Chemicals Data.	154 (68)	1.6	8.8	1.0+	2.97	316 (158)	Yes	5	3	2	2
Methacrylonitrile C_4H_5N	34 (1.1) (TCC)		2	6.8	0.8	2.3	194 (90)	Slight		2	3	2
Methallyl Alcohol $CH_2C(CH_3)CH_2OH$	92 (33)				0.9	2.5	237 (114)	Slight	1 5	2	3	0
Methallyl Chloride $CH_2C(CH_3)CH_2Cl$	11 (−12)		3.2	8.1	0.9	3.1	162 (72)	No	1 5	2	3	1
Methane CH_4 (Marsh Gas)	Gas	999 (537)	5.0	15.0		0.6	−259 (−162)	No	6	1	4	0
Methanol	See Methyl Alcohol.											
Methanethiol	See Methyl Mercaptan.											
Methox	See Methoxy Ethyl Phthalate.											
o-Methoxybenzaldehyde $CH_3OC_6H_4CHO$ (o-Anisaldehyde)	104 (40) (oc)				1.1		275 (135)	No	2	2	1	0
Methoxybenzene	See Anisole.											
3-Methoxybutanol $CH_3CH(OCH_3)CH_2CH_2OH$	165 (74) (oc)				0.9	3.6	322 (161)	Yes	5	1	2	0
3-Methoxybutyl Acetate $CH_3OCH(CH_3)CH_2CH_2$- $OOCCH_3$ (Butoxyl)	170 (77)				1.0−	5.0	275–343 (135–173)	Slight	5	1	2	0
3-Methoxybutyraldehyde $CH_3CH(OCH_3)CH_2CHO$ (Aldol Ether)	140 (60)				0.94	3.52	262 (128)			0	2	0
2-Methoxyethanol	See Ethylene Glycol Monomethyl Ether.											
2-Methoxyethyl Acrylate $C_2H_3COOC_2H_4OCH_3$	180 (82) (oc)				1.01	4.49	142 (61) @ 17 mm			0	2	0
Methoxy Ethyl Phthalate (Methox)	275 (135)				1.2		376–412 (191–211)		2	0	1	0
3-Methoxypropionitrile $CH_3OC_2H_4CN$	149 (65) (oc)				0.92	2.94	320 (160)			4	2	1
3-Methoxypropylamine $CH_3OC_3H_6NH_2$	90 (32)				0.86	3.07	241 (116)			2	3	0
Methoxy Triglycol $CH_3O(C_2H_4O)_3H$ (Triethylene Glycol, Methyl Ether)	245 (118) (oc)				1.0+		480 (249)	Yes	5 2	0	1	0
Methoxytriglycol Acetate $CH_3COO(C_2H_4O)_3CH_3$	260 (127) (oc)				1.1		266 (130)	Yes	2 5	0	1	0
Methyl Abietate $C_{19}H_{29}COOCH_3$ (Abalyn)	356 (180) (oc)				1.0+		680–689 (360–365) Decomposes	No	2	0	1	0
(Methyl Acetic Ester)												0
Methyl Acetic Ester	See Methyl Acetate.											

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Methyl Acetoacetate $CH_3CO_2CH_2COCH_3$	170 (77)	536 (280)			1.1	4.0	338 (170)	Yes	5	2	2	0
p-Methyl Acetophenone $CH_3C_6H_4COCH_3$ (Methyl para-Tolyl Ketone) (p-Acetotoluene)	205 (96)				1.0–		439 (226)	No	5	0	1	0
Methylacetylene	See Propyne.											
α-Methylacrolein	See 2-Methylpropenal.											
Methyl Acrylate CH_2:CHCOOCH$_3$	27 (–3) (oc) Note: Polymerizes. See Hazardous Chemicals Data.	875 (468)	2.8	25	1.0–	3.0	176 (80)	Very slight	1	3	3	2
Methylal $CH_3OCH_2OCH_3$ (Dimethoxymethane) (Formal)	–26 (–32) (oc)	459 (237)	2.2	13.8	0.9	2.6	111 (44)	Yes	1 5	2	3	2
Methyl Alcohol CH_3OH (Methanol) (Wood Alcohol) (Columbian Spirits)	52 (11)	867 (464)	6.0	36	0.8	1.1	147 (64)	Yes	1 5	1	3	0
Methylaluminum Sesqui-bromide $(CH_3)_3Al_2Br_3$	Note: Ignites spontaneously in air.									Do not use water, foam or halogenated extinguishing agents.	3	3W
Methylaluminum Sesqui-chloride $(CH_3)_3Al_2Cl_3$	Note: Ignites spontaneously in air.									Do not use water, foam or halogenated extinguishing agents.	3	3W
Methylamine CH_3NH_2	Gas Note: See Hazardous Chemicals Data.	806 (430)	4.9	20.7		1.0	21 (–6)	Yes	6	3	4	0
2-(Methylamino) Ethanol	See N-Methylethanolamine.											
Methylamyl Acetate	See Hexyl Acetate.											
Methylamyl Alcohol	See Methyl Isobutyl Carbinol.											
Methyl Amyl Ketone $CH_3CO(CH_2)_4CH_3$ 2-Heptanone	102 (39)	740 (393)	1.1 @ 151 (66)	7.9 @ 250 (121)	0.8	3.9	302 (150)	Slight	5	1	2	0
2-Methylaniline	See o-Toluidine.											
4-Methylaniline	See p-Toluidine.											
Methyl Anthranilate $H_2NC_6H_4CO_2CH_3$ (Methyl-ortho-Amino Benzoate) (Neroli Oil, Artificial)	>212 (>100)				1.2		275 @ 15 mm (135)	Slight	5	0	1	0
Methylbenzene	See Toluol.											
Methyl Benzoate $C_6H_5COOCH_3$ (Niobe Oil)	181 (83)				1.1	4.7	302 (150)	No	3	0	2	0
α-Methylbenzyl Alcohol	See Phenyl Methyl Carbinol.											
α-Methylbenzylamine $C_6H_5CH(CH_3)NH_2$	175 (79) (oc)				1.0–	4.2	371 (188)	Slight	5	2	2	0
α-Methylbenzyl Dimethyl Amine $C_6H_5CH(CH_3)N(CH_3)_2$	175 (79) (oc)				0.9	5.2	384 (196)	Slight	5	2	2	0
												0

2-Methylbiphenyl $C_6H_5C_6H_4CH_3$	280 (137) (oc)	936 (502)			1.0+		492 (255)			2		0

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Methyl Borate $B(OCH_3)_3$ (Trimethyl Borate)	<80 (<27)				0.9	3.6	156 (69)	Decomposes		2	3	1
Methyl Bromide CH_3Br (Bromomethane)	Practi-cally non-flam-mable Note: See Hazardous Chemicals Data.	999 (537)	10	16.0	1.7	3.3	38.4 (4)	No		3	1	0
2-Methyl-1,3-Butadiene	See Isoprene.											
2-Methylbutane	See Isopentane.											
3-Methyl-2-Butanethiol $C_5H_{11}SH$ (sec-Isoamyl Mercaptan)	37 (3) (oc)				0.85	3.59	230 (110)	No	5 1	2	3	0
2-Methyl-1-Butanol $CH_3CH_2CH(CH_3)CH_2OH$	122 (50) (oc)	725 (385)			0.8	3.0	262 (128)	Slight	5	2	2	0
2-Methyl-2-Butanol $CH_3CH_2(CH_3)_2COH$ (tert-Isoamyl Alcohol) (Dimethyl Ethyl Carbinol)	67 (19)	819 (437)	1.2	9.0	0.8	3.0	215 (102)	Slight	5 1	1	3	0
3-Methyl-1-Butanol	See Isoamyl Alcohol.											
3-Methyl-1-Butanol Acetate	See Isoamyl Acetate.											
2-Methyl-1-Butene (Technical Grade) $CH_2:C(CH_3)CH_2CH_3$	<20 (< −7)				0.7	2.4	88 (31)	No	1	2	4	0
2-Methyl-2-Butene $(CH_3)_2C:CCHCH_3$ (Trimethylethylene)	<20 (< −7)				0.7	2.4	101 (38)	Slight	1 5	2	3	0
3-Methyl-1-Butene $(CH_3)_2CHCH:CH_2$ (Isopropylethylene)	<20 (< −7)	689 (365)	1.5	9.1	0.6	2.4	68 (20)	No	1	2	4	0
N-Methylbutylamine $CH_3CH_2CH_2CH_2NHCH_3$	55 (13) (oc)				0.7	3.0	196 (91)	Yes	1 5	3	3	0
2-Methyl Butyl Ethanoate	See Isoamyl Acetate.											
Methyl Butyl Ketone $CH_3CO(CH_2)_3CH_3$ (2-Hexanone)	77 (25)	795 (423)		8	0.8	3.5	262 (128)	Slight	1 5	2	3	0
3-Methyl Butynol $(CH_3)_2C(OH)C:CH$	77 (25) (oc)				0.9	2.9	218 (103)	Yes	1 5	2	3	0
2-Methylbutyraldehyde $CH_3CH_2CH(CH_3)CHO$	49 (9) (oc) Note: See Hazardous Chemicals Data.				0.8	2.97	198–199 (92–93)	No	5 1	2	3	0
Methyl Butyrate $CH_3OOCCH_2CH_2CH_3$	57 (14)				0.9	3.5	215 (102)	Slight	1 5	2	3	0
Methyl Carbonate $CO(OCH_3)_2$ (Dimethyl Carbonate)	66 (19) (oc)				1.1	3.1	192 (89)	Slight	1 5	3	3	0
Methyl Cellosolve Acetate $CH_3COOC_2H_4OCH_3$ (2-Methoxyethyl Acetate)	~111 (−44)		1.7	8.2	1.0	4.07	292 (144)	Yes		0	2	0
Methyl Chloride CH_3Cl (Chloromethane)	−50 Note: See Hazardous Chemicals Data.	1170 (632)	8.1	17.4		1.8	−11 (−24)	Slight	6	1	4	0

1

Methyl Chloroethanoate	See Methyl Chloroacetate.											
Methyl para-Cresol $CH_3C_6H_4OCH_3$ (p-Methylanisole) (p-Cresyl Methyl Ether, p-Methoxy Toluene)	140 (60)				1.0–	4.21			5		2	0

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Methyl Cyanide	See Acetonitrile.											
Methylcyclohexane $CH_2(CH_2)_4CHCH_3$ (Cyclohexylmethane) (Hexahydrotoluene)	25 (−4)	482 (250)	1.2	6.7	0.8	3.4	214 (101)	No	1	2	3	0
2-Methylcyclohexanol $C_7H_{13}OH$	149 (65)	565 (296)			0.9	3.9	329 (165)	Slight	5		2	0
3-Methylcyclohexanol $CH_3C_6H_{10}OH$	−158 (−70)	563 (295)								0	2	0
4-Methylcyclohexanol $C_7H_{13}OH$	158 (70)	563 (295)			0.9	3.9	343 (173)	Slight	5		2	0
Methylcyclohexanone $C_7H_{12}O$	118 (48)				0.9	3.9	325 (163)	No			2	0
4-Methylcyclohexene $CH{:}CHCH_2CH(CH_3)CH_2CH_2$	30 (−1) (oc)				0.8	3.3	217 (103)	No	1	1	3	0
Methylcyclohexyl Acetate $C_9H_{16}O_2$	147 (64)				0.9		351–381 (177–194)			1	2	0
Methyl Cyclopentadiene C_6H_8	120 (49)	833 (445)	1.3 @ 212 (100)	7.6 @ 212 (100)	0.9		163 (73)			1	2	1
Methylcyclopentane C_6H_{12}	<20 (<−7)	496 (258)	1.0	8.35	0.8	2.9	161 (72)	No	1	2	3	0
2-Methyldecane $CH_3(CH_2)_7CH(CH_3)_2$		437 (225)			0.74	5.39	374 (190)			0	2	0
Methyldichlorosilane CH_3HSiCl_2	15 (−9)	>600 (316)	6.0	55	1.1	3.97	106 (41)	Yes	1	3	3	2W
	Note: See Hazardous Chemicals Data.											
N-Methyldiethanolamine $CH_3N(C_2H_4OH)_2$	260 (127) (oc)				1.0+		464 (240)	Yes	2 5	1	1	0
1-Methyl-3,5-Diethyl-benzene $(CH_3)C_6H_3(C_2H_5)_2$ (3,5-Diethyltoluene)		851 (455)			0.86	5.12	394 (201)			0	2	0
Methyl Dihydroabietate $C_{19}H_{31}COOCH_3$	361 (183)				1.0+		689–698 (365–370)		2	1	1	0
Methylene Chloride CH_2Cl_2 (Dichloromethane)	None	1033 (556)	13	23	1.3	2.9	104 (40)	Slight		2	1	0
	Note: See Hazardous Chemicals Data.											
Methylenedianiline $H_2NC_6H_4CH_2C_6H_4NH_2$ (MDA) (p,p′-Diaminodi-Phenylmethane)	428 (220)				1.1		748–750 (398–399) @ 78 mm	Slight	2	3	1	0
	Note: Melting point 198–199 (92–93).											
Methylene Diisocyanate $CH_2(NCO)_2$	185 (85) (oc)									1	2	1W
Methylene Oxide	See Formaldehyde.											
N-Methylethanolamine $CH_3NHCH_2CH_2OH$ (2-(Methylamino) Ethanol)	165 (74) (oc)				0.9	2.6	319 (159)	Yes	5	2	2	0
Methyl Ether $(CH_3)_2O$ (Dimethyl Ether) (Methyl Oxide)	Gas	662 (350)	3.4	27.0		1.6	−11 (−24)	Yes	6	1	4	1
$(CH_3)(C_2H_5)COCH_2CH_2O$	(oc)											0
Methyl Ethylene Glycol	See Propylene Glycol.											

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Methyl Ethyl Ether $CH_3OC_2H_5$ (Ethyl Methyl Ether) Note: See Hazardous Chemicals Data.	−35 (−37)	374 (190)	2.0	10.1	0.7	2.1	51 (11)	Yes	1 5	1	4	1
2-Methyl-4-Ethylhexane $(CH_3)_2CHCH_2CH(C_2H_5)_2$ (4-Ethyl-2-Methylhexane)	<70 (<21)	536 (280)	−0.7		0.72	4.43	273 (134)			0	3	0
3-Methyl-4-Ethylhexane $C_2H_5CH(CH_3)CH(C_2H_5)_2$ (3-Ethyl-4-Methylhexane)	75 (24)				0.72	4.43	284 (140)			0	3	0
Methyl Ethyl Ketone $C_2H_5COCH_3$ (2-Butanone) (Ethyl Methyl Ketone)	16 (−9)	759 (404)	1.4 @ 200 (93)	11.4 @ 200 (93)	0.8	2.5	176 (80)	Yes	1 5	1	3	0
Methyl Ethyl Ketoxime $CH_3C(C_2H_5):NOH$	156–170 (69–77)				0.9	3.0	306–307 (152–153)	Slight	5		2	0
2-Methyl-3-Ethylpentane $(CH_3)_2CHCH(C_2H_5)_2$ (3-Ethyl-2-Methylpentane)	<70 (<21)	860 (460)			0.72	3.94	241 (116)			0	3	0
2-Methyl-5-Ethyl-piperidine $NHCH(CH_3)CH_2CH_2CH$- $(C_2H_5)CH_2$	126 (52) (oc)				0.8	4.4	326 (163)	Slight	5	2	2	0
2-Methyl-5-Ethylpyridine $N:C(CH_3)CH:CHC(C_2H_5):CH$	155 (68) (oc)		1.1	6.6	0.9	4.2	353 (178)	Slight	5	3	2	0
Methyl Eugenol $(CH_3O)_2C_6H_3CH_2CH:CH_2$ (4-Allyl-1,2-Dimethoxy-benzene) (4-Allyl Veratrole) (1,2-Dimethoxy-4-Allyl-benzene) (Eugenyl Methyl Ether)	210 (99)				1.0+		196–203 (91–95)	No	5	0	1	0
Methyl Formate CH_3OOCH (Formic Acid, Methyl Ester) (Methyl Methanoate) Note: See Hazardous Chemicals Data.	−2 (−19)	840 (449)	4.5	23	1.0−	2.1	90 (32)	Yes	1 5	2	4	0
2-Methylfuran $C_4H_3OCH_3$ (Sylvan)	−22 (−30)				0.9		144–147 (62–64)	No	1	2	3	1
Methyl Glycol Acetate $CH_2OHCHOHCH_2CO_2CH_3$ (Propylene Glycol Acetate)	111 (44)					4.6				1	2	0
Methyl Heptadecyl Ketone $C_{17}H_{35}COCH_3$ Note: Melting point 127 (53)	255 (124)						329 (165) @ 3 mm	No	2	0	1	0
Methylheptenone $(CH_3)_2C:CH(CH_2)_2COCH_3$ (6-Methyl-5-Hepten-2-one)	135 (57)				0.9	4.35	343–345 (173–174)	No	5	1	2	0
Methyl Heptine Carbonate $CH_3(CH_2)_4C:CCOOCH_3$ (Methyl 2-Octynoate)	190 (88)				0.9				5		2	0
Methyl Heptyl Ketone $C_7H_{15}COCH_3$ (5-Methyl-2-Octanone)	140 (60)	680 (360)	0.9 @ 180 (82)	5.9 @ 313 (156)	0.8 @ 86 (30)	4.9	361–383 (183–195)	No		0	2	0
2-Methylhexane	<0	536			0.68	3.46	194 (90)			0	3	0
												0
Methyl Hexyl Ketone $CH_3COC_6H_{13}$ (2-Octanone) (Octanone)	125 (52)				0.8	4.41	344 (173.5)	No				0
Methylhydrazine CH_3NHNH_2	17 (−8)	382 (194)	2.5	92	0.9	1.6	190 (88)	Slight	1 5	4	3	2

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Methyl-3-Hydroxybutyrate $CH_3CHOHCH_2COOCH_3$	180 (82) (oc)				1.1	4.1	347 (175)	Yes	5	1	2	0
Methyl Ionone $C_{14}H_{22}O$ (Irone)	>212 (>100)				0.9		291 (144) @ 16 mm	No	5	0	1	0
Methyl Isoamyl Ketone $CH_3COCH_2CH_2CH(CH_3)_2$	96 (36)	375 (191)	1.0 @ 200 (93)	8.2 @ 200 (93)	0.8	3.9	294 (146)	No		1	2	0
Methyl Isobutyl Carbinol $CH_3CHOHCH_2CHCH_3CH_3$ (1,3-Dimethylbutanol) (4-Methyl-2-Pentanol) (Methylamyl Alcohol)	106 (41)		1.0	5.5	0.8		266–271 (130–133)	Slight	5	2	2	0
Methylisobutylcarbinol Acetate	See 4-Methyl-2-Pentanol Acetate.											
Methyl Isobutyl Ketone $CH_3COCH_2CH(CH_3)_2$ (Hexone) (4-Methyl-2-Pentanone)	64 (18)	840 (448)	1.2 @ 200 (93)	8.0 @ 200 (93)	0.8	3.5	244 (118)	Slight	5 1	2	3	1
Methyl Isopropenyl Ketone $CH_2COC:CH_2(CH_3)$			1.8	9.0		2.9	208 (98)			2		0
Methyl Isocyanate CH_3NCO (Methyl Carbonimide)	19 (−7)	994 (534)	5.3	26	1.0−	1.97	102 (39)	Yes	5	4	3	2W
Methyl Iso Eugenol $CH_3CH:CHC_6H_3(OCH_3)_2$ (Propenyl Guaiacol)	>212 (>100)				1.1		504–507 (262–264)	No	5	0	1	0
Methyl Lactate $CH_3CHOHCOOCH_3$	121 (49)	725 (385)	2.2 @ 212 (100)		1.1	3.6	293 (145)	Yes Decomposes		1	2	0
Methyl Mercaptan CH_3SH (Methanethiol)			3.9	21.8	0.9	1.7	42.4 (6)	Yes	5	4	4	0
β-Methyl Mercapto-propionaldehyde $CH_3SC_2H_4CHO$ (3-(Methylthio) Propionalde-hyde)	142 (61)	491 (255)			1.03	3.60	~329 (~165)				2	0
Methyl Methacrylate $CH_2:C(CH_3)COOCH_3$	50 (10) (oc) Note: Polymerizes. See Hazardous Chemicals Data.		1.7	8.2	0.9	3.6	212 (100)	Very slight	1	2	3	2
Methyl Methanoate	See Methyl Formate.											
4-Methylmorpholine $C_2H_4OC_2H_4NCH_3$	75 (24)				0.9	3.5	239 (115)	Yes	1 5	2	3	0
1-Methylnaphthalene $C_{10}H_7CH_3$		984 (529)			1.0+		472 (244)	No		2	2	0
Methyl Nonyl Ketone $C_9H_{19}COCH_3$	192 (89)				0.8 @ 86 (30)	5.9	433 (223)	No		0	2	0
Methyl Oxide	See Methyl Ether.											
Methyl Pentadecyl Ketone $C_{15}H_{31}COCH_3$	248 (120)						313 (156) @ 3 mm	No	2	0	1	0
												0
4-Methyl-1,3-Pentadiene $CH_2:CHCH_2:C(CH_3)_2$	−30 (−34)				0.7		168 (76)	No	1	0	3	1
Methylpentaldehyde $CH_3CH_2CH_2C(CH_3)HCHO$ (Methyl Pentanal)	68 (20) (oc)				0.8	3.5	243 (117)	Very slight	1	2	3	1
Methyl Pentanal	See Methylpentaldehyde.											

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2-Methylpentane $(CH_3)_2CH(CH_2)_2CH_3$ (Isohexane)	< 20 (< −7)	583 (306)	1.2	7.0	0.7	3.0	140 (60)	No	1	1	3	0
3-Methylpentane $CH_3CH_2CH(CH_3)CH_2CH_3$	< 20 (< −7)	532 (278)	1.2	7.0	0.7	3.0	146 (63)	No	1	1	3	0
2-Methyl-1,3-Pentanediol $CH_3CH_2CH(OH)$-$CH(CH_3)CH_2OH$	230 (110)				1.0−		419 (215)		2	2	1	0
2-Methyl-2,4-Pentanediol $(CH_3)_2C(OH)CH_2CH$-$(OH)CH_3$	205 (96) (oc)				0.92	4.07	385 (196)	Yes		0	1	0
2-Methylpentanoic Acid $C_3H_7CH(CH_3)COOH$	225 (107) (oc)	712 (378)			0.9	4.0	381 (194)	No	2	0	1	0
2-Methyl-1-Pentanol $CH_3(CH_2)_2CH(CH_3)CH_2OH$	129 (54)	590 (310)	1.1	9.65	0.8	3.5	298 (148)	No		0	2	0
4-Methyl-2-Pentanol	See Methyl Isobutyl Carbinol.											
4-Methyl-2-Pentanol Acetate $CH_3COOCH(CH_3)CH_2$-$CH(CH_3)_2$ (Methylisobutylcarbinol Acetate)	110 (43) (oc)	660 (349)	0.9 @ 212 (100)	5.83 @ 212 (100)	0.9	5.0	295 (146)	Very slight		1	2	0
4-Methyl-2-Pentanone	See Methyl Isobutyl Ketone.											
2-Methyl-1-Pentene $CH_2{:}C(CH_3)CH_2CH_2CH_3$	< 20 (< −7)	572 (300)			0.7	2.9	143 (62)		1	1	3	0
4-Methyl-1-Pentene $CH_2{:}CHCH_2CH(CH_3)_2$	< 20 (< −7)	572 (300)			0.7	2.9	129 (54)		1	1	3	0
2-Methyl-2-Pentene $(CH_3)_2C{:}CHCH_2CH_3$	< 20 (< −7)				0.7	2.9	153 (67)		1	1	3	0
4-Methyl-2-Pentene $CH_3CH{:}CHCH(CH_3)_2$	< 20 (< −7)				0.7		133–137 (56–58)		1	1	3	0
3-Methyl-1-Pentynol $(C_2H_5)(CH_3)C(OH)C{:}CH$	101 (38) (oc)				0.9	3.4	250 (121)	Yes	5	1	2	0
o-Methyl Phenol	See o-Cresol.											
Methyl Phenylacetate $C_6H_5CH_2COOCH_3$	195 (91)				1.1		424 (218)	No	5	0	2	0
Methylphenyl carbinol $C_6H_5CH(CH_3)OH$ (α-Methylbenzyl Alcohol) (Styralyl Alcohol) (sec-Phenethyl Alcohol)	200 (93)				1.0+		399 (204)	Slight	5	0	2	0
Methyl Phenyl Carbinyl Acetate $C_6H_5CH(CH_3)OOCH_3$ (α-Methyl-Benzyl Acetate) (Styralyl Acetate) (sec-Phenylethyl Acetate) (Phenyl Methylcarbinyl Acetate)	195 (91)				1.0+			No	5	0	2	0
Methyl Phenyl Ether	See Anisole.											
Methyl Phthalyl Ethyl Glycolate $CH_3COOC_6H_4COO$-$CH_2COOC_2H_5$	380 (193) (oc)				1.2		590 (310)	No	2	2	1	0
1-Methyl Piperazine $CH_3NCH_2CH_2NHCH_2CH_2$	108 (42)				0.9	3.5	280 (138)	Yes	5	2	2	0
2-Methylpropane	See Isobutane.											
2-Methyl-2-Propanethiol $(CH_3)_3CSH$ (tert-Butyl Mercaptan)	< −20 (< −29)				0.8	3.1	149–153 (65–67)	No	1	2	3	0

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2-Methyl Propanol-1	See Isobutyl Alcohol.											
2-Methyl-2-Propanol	See tert-Butyl Alcohol.											
2-Methylpropenal $CH_2:C(CH_3)CHO$ (Methacrolein) (α-Methyl Acrolein)	35 (2) (oc)				0.8	2.4	154 (68)	Yes	1 5	3	3	2
2-Methylpropene $CH_2:C(CH_3)CH_3$ (γ-Butylene) (Isobutylene)	Gas	869 (465)	1.8	9.6		1.9	20 (−7)	No	6	1	4	0
Methyl Propionate $CH_3COOCH_2CH_3$	28 (−2)	876 (469)	2.5	13	0.9	3.0	176 (80)	No	1	1	3	0
Methyl Propyl Acetylene $CH_3C_2H_4C:CCH_3$ (2-Hexyne)	<14 (<−10)				0.73	2.83	185 (85)				3	
Methyl Propyl Carbinol $CH_3CHOHC_3H_7$ (2-Pentanol)	105 (41)				0.8	3.0	247 (119)	No		0	2	0
Methylpropylcarbinylamine	See sec-Amylamine.											
Methyl n-Propyl Ether $CH_3OC_3H_7$	<−4 (<−20)				0.91	2.56	102 (39)			0	3	0
Methyl Propyl Ketone $CH_3COC_3H_7$ (2-Pentanone)	45 (7)	846 (452)	1.5	8.2	0.8	3.0	216 (102)	Slight	1 5	2	3	0
2-Methylpyrazine N:C(CH$_3$)CH:NCH:CH	122 (50) (oc)				1.02	3.25				2	2	0
2-Methyl Pyridine	See 2-Picoline.											
Methylpyrrole N(CH$_3$)CH:CHCH:CH	61 (16)				0.9	2.8	234 (112)	No	1	2	3	1
Methylpyrrolidine $CH_3NC_4H_8$	7 (−14)				0.8	2.9	180 (82)	Slight	5 1	2	3	1
1-Methyl-2-Pyrrolidone $CH_3NCOCH_2CH_2CH_2$ (n-Methyl-2-Pyrrolidone)	204 (96) (oc)	655 (346)			1.0+	3.4	396 (202)	Yes	5	2	1	0
Methyl Salicylate $HOC_6H_4COOCH_3$ (Oil of Wintergreen) (Gaultheria Oil) (Betula Oil) (Sweet-Birch Oil)	205 (96)	850 (454)			1.2		432 (222)	No	2	1	1	0
Methyl Stearate $C_{17}H_{35}COOCH_3$	307 (153)				0.9		421 (216)	No	2	0	1	0
α-Methylstyrene **1-Methylethenyl Benzine** **1-Methyl-1-phenylethene**	129 (54)	1066 (574)	1.9	6.1	0.9		329–331 (165–166)	No		1	2	1
Methylstyrene $CH_2CHC_6H_4CH_3$ (Vinyl Toluene)	See Vinyl Toluene.											
Methyl Sulfate	See Dimethyl Sulfate.											
2-Methyltetrahydrofuran $C_4H_7OCH_3$	12 (−11)				0.9	3.0	176 (80)	Slight	1 5	2	3	0
Methyl Toluene Sulfonate $CH_3C_6H_4SO_3CH_3$	306 (152) (oc) Note: Melting point 75 (24).						315 (157) @ 8 mm	No	2	2	1	0

2W

Methyl Undecyl Ketone $C_{11}H_{23}COCH_3$ (2-Tridecanone)	225 (107)				0.8		248 (120)	No	2	1	1	0
2-Methylvaleraldehyde $C_6H_{12}O$	62 (17)	390 (199)			0.8	3.45	240 (116)		5 1	1	3	0

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1-Methylvinyl Acetate	See Isopropenyl Acetate.											
Methyl Vinyl Ether	See Vinyl Methyl Ether.											
Methyl Vinyl Ketone $CH_3COCH{:}CH_2$	20 (−7)	915 (491)	2.1	15.6		2.4	177 (81)		1	4	3	2
Mineral Oil	380 (193) (oc)				0.8–0.9		680 (360)	No	2	0	1	0
Mineral Seal Oil Typical (Signal Oil)	275 (135) (oc)				0.8		480–680 (249–360)	No		0	2	0
Mineral Spirits Mineral Spirits, 360° End Point (182)	104 (40)	473 (245)	0.8 @ 212 (100)		0.8	3.9	300 (149)	No		0	2	0
Mineral Wax	See Wax, Ozocerite.											
Monochlorobenzene	See Chlorobenzene.											
Morpholine $OC_2H_4NHCH_2CH_2$	98 (37) (oc) Note: Decomposes at 489 (250). Note: See Hazardous Chemicals Data.	555 (290)	1.4	11.2	1.0	3.0	262 (128)	Yes	5	3	3	0
Muriatic Ether	See Ethyl Chloride.											
Mustard Oil $C_3H_5N{:}C{:}S$ (Allyl Isothiocyanate)	115 (46)				1.0+	3.4	304 (151)	No		3	2	0
Naphtha 49° Be-Coal Tar Type	107 (42)	531 (277)						No		2	2	0
Naphtha, Petroleum	See Petroleum Ether.											
Naphtha, Safety Solvent	See Cleaning Solvent.											
Naphtha V.M. & P., 50° Flash (10)	50 (10) Note: Flash point and ignition temperature will vary depending on the manufacturer.	450 (232)	0.9	6.7	<1	4.1	240–290 (116–143)	No	1	1	3	0
Naphtha V.M. & P., High Flash	85 (29) Note: Flash point and ignition temperature will vary depending on the manufacturer.	450 (232)	1.0	6.0	<1	4.3	280–350 (138–177)	No	1	1	3	0
Naphtha V.M. & P., Regular	28 (−2) Note: Flash point and ignition temperature will vary depending on the manufacturer.	450 (232)	0.9	6.0	<1		212–320 (100–160)	No	1	1	3	0
Naphthalene $C_{10}H_8$ (White Tar)	174 (79) Note: Melting point 176 (80). See Hazardous Chemicals Data.	979 (526)	0.9	5.9	1.1	4.4	424 (218)	No		2	2	0
β-Naphthol $C_{10}H_7OH$ (β-Hydroxy Naphthalene) (2-Naphthol)	307 (153) Note: Melting point 253 (123).				1.22	4.98	545 (285)				1	0
1-Naphthylamine $C_{10}H_7NH_2$	315 (157) Note: Melting point 122 (50).				1.2		572 (300)	No	2	2	1	0
Natural Gas	See Gas.											
Neatsfoot Oil	470 (243) Note: Melting point 84–106 (29–41).	828 (442)			0.9			No	2	0	1	0
[illegible] $HOCH_2C(CH_3)_2CH_2OH$ (2,2-Dimethyl 1,3 Propanediol)	[illegible] (129) (oc) Note: Melting point 255–266 (124–130).	[illegible] (399)			[illegible]		[illegible] (210)					0
Nickel Carbonyl $Ni(CO)_4$	< −4 (< −24)		2		1.32	5.89	110 (43)			4	3	3

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Nicotine $C_{10}H_{14}N_2$		471 (244)	0.7	4.0	1.0	5.6	475 (246)	Yes	2 5	4	1	0
Niobe Oil	See Methyl Benzoate.											
Nitric Ether	See Ethyl Nitrate.											
2,2′,2″-Nitrilotriethanol	See Triethanolamine.											
1,1′,1″-Nitrilotri-2-propanol	See Triisopropanolamine.											
p-Nitroaniline $NO_2C_6H_4NH_2$	390 (199) Note: Melting point 298 (148).				1.44	4.77	637 (336)			3	1	2
Nitrobenzene $C_6H_5NO_2$ (Nitrobenzol) (Oil of Mirbane)	190 (88) Note: See Hazardous Chemicals Data.	900 (482)	1.8 @ 200 (93)		1.2	4.3	412 (211)	No	3	3	2	1
1,3-Nitrobenzotrifluoride $C_6H_4NO_2CF_3$ (α,α,α-Trifluoronitro-toluene)	217 (103) (oc)				1.44	6.59	397 (203)				1	
Nitrobenzol	See Nitrobenzene.											
Nitrobiphenyl $C_6H_5C_6H_4NO_2$	290 (143)				1.2		626 (330)	No	2	2	1	0
Nitrocellulose	See Cellulose Nitrate.											
Nitrochlorobenzene $C_6H_4ClNO_2$	261 (127) Note: Melting point 111 (44). Note: See Hazardous Chemicals Data.				1.5		457 (236)	No	2	3	1	1
p-Nitrochlorobenzene $C_6H_4ClNO_2$ (1-Chloro-4-Nitro-benzene)	261 (127) Note: Melting point 181 (83).				1.37	5.44	468 (242)			2	1	3
Nitrocyclohexane $CH_2(CH_2)_4CHNO_2$	190 (88) (oc)				1.07	4.46	403 (206) Decomposes			2	2	3
Nitroethane $C_2H_5NO_2$	82 (28) Note: See Hazardous Chemicals Data.	778 (414)	3.4		1.1	2.6	237 (114)	Slight	4 5	1	3 Explodes on heating.	3
Nitroglycerine $C_3H_5(NO_3)_3$ (Glyceryl Trinitrate)	Explodes	518 (270)			1.6		502 (261) Explodes	No		2	2	4
Nitromethane CH_3NO_2	95 (35) Note: May detonate under high temperature and pressure conditions. See Hazardous Chemicals Data.	785 (418)	7.3		1.1	2.1	214 (101)	Slight	1 5	1	3	4
1-Nitronaphthalene $C_{10}H_7NO_2$	327 (164) Note: Melting point 140 (60).				1.3		579 (304)	No	2	1	1	0
1-Nitropropane $CH_3CH_2CH_2NO_2$	96 (36) Note: See Hazardous Chemicals Data.	789 (421)	2.2		1.0	3.1	268 (131)	Slight	5	1	3 May explode on heating.	2
2-Nitropropane $CH_3CH(NO_2)CH_3$ (sec-Nitropropane)	75 (24) Note: See Hazardous Chemicals Data.	802 (428)	2.6	11.0	1.0−	3.1	248 (120)	Slight	5	1	3 May explode on heating.	2
sec-Nitropropane	See 2-Nitropropane.											
Nitrotoluene	See p-Nitrotoluol.											
m-Nitrotoluene [illegible]	223 (106)				1.16	4.73	450 (232)			3	1	1
	Note: Melting point 25 (−4).											1
p-Nitrotoluene $NO_2C_6H_4CH_3$	223 (106) Note: Melting point 125 (52). Note: See Hazardous Chemicals Data.				1.3		461 (238)	No	2	3	1	1

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2-Nitro-p-toluidine $CH_3C_6H_3(NH_2)NO_2$	315 (157) Note: Melting point 259 (126).				1.31	5.25				2	1	4
Nitrous Ether	See Ethyl Nitrite.											
Nonadecane $CH_3(CH_2)_{17}CH_3$	>212 (>100) Note: Melting point 90 (32).	446 (230)			0.79	9.27	628 (331)			0	1	0
Nonane C_9H_{20}	88 (31)	401 (205)	0.8	2.9	0.7	4.4	303 (151)	No	1	0	3	0
Nonane (iso) $C_6H_{13}CH(CH_3)_2$ (2-Methyloctane)		428 (220)			0.71	4.43	290 (143)			0	3	0
Nonane (iso) $C_5H_{11}CH(CH_3)C_2H_5$ (3-Methyloctane)		428 (220)			0.72	4.43	291 (144)			0	3	0
Nonane (iso) $C_4H_9CH(CH_3)C_3H_7$ (4-Methyloctane)		437 (225)			0.72	4.43	288 (142)			0	3	0
Nonene C_9H_{18} (Nonylene)	78 (26) (oc)				0.7	4.35	270–290 (132–143)	No	1	0	3	0
Nonyl Acetate $CH_3COOC_9H_{19}$	155 (68)				0.9	6.4	378 (192)	Very slight	5	1	2	0
Nonyl Alcohol	See Diisobutyl Carbinol.											
Nonylbenzene $C_9H_{19}C_6H_5$	210 (99)				0.9		468–486 (242–252)	No		0	1	0
tert-Nonyl Mercaptan $C_9H_{19}SH$	154 (68) (oc)				0.9	5.53	370–385 (188–196)	No	5	2	2	0
Nonylnaphthalene $C_9H_{19}C_{10}H_7$	<200 (<93)				0.9	8.8	626–653 (330–345)	No		0	2	0
Nonylphenol $C_6H_4(C_9H_{19})OH$	285 (141)				1.0–		559–567 (293–297)	Very slight	2 5	2	1	0
2,5-Norbornadiene C_7H_8 (NBD)	−6 (−21)				0.9	3.17	193 (89)	No	1		3	1
Octadecane $C_{18}H_{38}$	>212 (>100) Note: Melting point 82 (28).	441 (227)			0.78	8.73	603 (317)			0	1	0
Octadecylene α $CH_3(CH_2)_{15}CH{:}CH_2$ (1-Octadecene)	>212 (>100) Note: Melting point 64 (18).	482 (250)			0.79	8.71	599 (315)			0	1	0
Octadecyltrichlorosilane $C_{18}H_{37}SiCl_3$ (Trichlorooctadecylsilane)	193 (89)				1.0		716 (380)	Yes		3	2	2
Octadecyl Vinyl Ether	See Vinyl Octadecyl Ether.											
Octanal	See Caprylaldehyde.											
Octane $CH_3(CH_2)_6CH_3$	56 (13)	403 (206)	1.0	6.5	0.7	3.9	258 (126)	No	1	0	3	0
1-Octanethiol $C_8H_{17}SH$ (n-Octyl Mercaptan)	156 (69) (oc)				0.85	5.04	390 (199)	No	5	2	2	0
1-Octanol	See Octyl Alcohol.											
2-Octanol $CH_3CHOH(CH_2)_5CH_3$	190 (88)				0.8	4.5	363 (184)	No		1	2	0
												0
2-Octene (Mixed cis and trans isomers) $CH_3CH{:}CHC_5H_{11}$	70 (21) (oc)				0.7	3.9	257 (125)	No	1	1	3	0
Octyl Acetate	See 2-Ethylhexyl Acetate.											

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Octyl Alcohol $CH_3(CH_2)_6CH_2OH$ (1-Octanol)	178 (81)				0.8	4.5	381 (194)	No		1	2	0
Octylamine $CH_3(CH_2)_6CH_2NH_2$ (1-Aminooctane)	140 (60)				0.8	4.5	338 (170)	Slight	5	2	2	0
tert-Octylamine $(CH_3)_3CCH_2C(CH_3)_2NH_2$ (1,1,3,3-Tetramethyl-butylamine)	91 (33) (oc)				1.41	4.46	284 (140)				3	0
Octyl Chloride $CH_3(CH_2)_7Cl$	158 (70)				0.9	5.1	359 (182)	No		1	2	0
Octylene Glycol $[CH_3(CH_2)_2CHOH]_2$	230 (110)	635 (335)			0.9		475 (246)	No	2	1	1	0
tert-Octyl Mercaptan $C_8H_{17}SH$	115 (46) (oc)				0.8	5.0	318–329 (159–165)	No		2	2	0
p-Octylphenyl Salicylate $C_{21}H_{26}O_3$	420 (216) (oc) Note: Melting point 162–165 (72–74).	780 (416)							2	1	1	0
Oil of Mirbane	See Nitrobenzene.											
Oil of Wintergreen	See Methyl Salicylate.											
Oleic Acid $C_8H_{17}CH{:}CH(CH_2)_7COOH$ (Red Oil) Distilled	372 (189) 364 (184)	685 (363)			0.9		547 (286)	No	2	0	1	0
Oleo Oil	450 (232)				0.9		464 (240)	No	2	0	1	0
Olive Oil (Sweet Oil)	437 (225)	650 (343)			0.9			No	2	0	1	0
Oxalic Ether	See Ethyl Oxalate.											
Oxammonium	See Hydroxylamine.											
Oxirane	See Ethylene Oxide.											
Palm Butter	See Palm Oil.											
Palm Kernel Oil (Palm Nut Oil)	398 (203) Note: Melting point 78–86 (26–30).				0.9			No	2	0	1	0
Palm Nut Oil	See Palm Kernel Oil.											
Palm Oil (Palm Butter)	323 (162) Note: Melting point 80–110 (27–43).	600 (316)			0.9			No	2	0	1	0
Paraffin Oil (See also Lubricating Oil)	444 (229)								2	0	1	0
Paraformaldehyde $HO(CH_2O)_nH$	158 (70) Note: Melting point 248–356 (120–180). See Hazardous Chemicals Data.	572 (300)	7.0	73				Slight	5	3	1	0
Paraldehyde $(CH_3CHO)_3$	96 (36) (oc) Note: Melting point 54 (12). See Hazardous Chemicals Data.	460 (238)	1.3		1.0–	4.5	255 (124)	Slight	1 5	2	3	1
Peanut Oil Cooking (Katchung Oil)	540 (282)	833 (445)			0.9			No	2	0	1	0
									ith - guishing agents.	2		
	Note: Ignites spontaneously in air. See Hazardous Chemicals Data.											
Pent-Acetate Mixture of Isomeric Amyl Acetates and Amyl Alcohols	98 (37)				0.9		260 (127)	No	1	2	3	0

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1,3-Pentadiene (cis and trans mix) $CH_2{:}CHCH{:}CHCH_3$ (Piperylene)	−20 (−29)				0.7	2.35	−45 (−43)	No	1	0	4	2
1,2,3,4,5-Pentamethyl Benzene 95% $C_6H(CH_3)_5$ (Pentamethylbenzene)	200 (93)	800 est (427)			0.9		449 (232)	No			2	0
Pentamethylene Dichloride	See 1,5-Dichloropentane.											
Pentamethylene Glycol	See 1,5-Pentanediol.											
Pentamethylene Oxide $O(CH_2)_4CH_2$ (Tetrahydropyran)	−4 (−20)				0.9	3.0	178 (81)	Yes	1 5	2	3	1
Pentanal	See Valeraldehyde.											
Pentane $CH_3(CH_2)_3CH_3$	< −40 (< −40)	500 (260)	1.5	7.8	0.6	2.5	97 (36)	No	1	1	4	0
1,5-Pentanediol $HO(CH_2)_5OH$ (Pentamethylene Glycol)	265 (129) (oc)	635 (335)			1.0 −		468 (242)	Yes	2 5	1	1	0
2,4-Pentanedione $CH_3COCH_2COCH_3$ (Acetyl Acetone)	93 (34)	644 (340)			1.0 −	3.5	284 (140)	Yes	5	2	2	0
Pentanoic Acid C_4H_9COOH (Valeric Acid)	205 (96) (oc)	752 (400)			0.9	3.5	366 (186)	Very slight		2	1	0
1-Pentanol	See Amyl Alcohol.											
2-Pentanol	See Methyl Propyl Carbinol.											
3-Pentanol $CH_3CH_2CH(OH)CH_2CH_3$ (tert-n-Amyl Alcohol)	105 (41)	815 (435)	1.2	9.0	0.8	3.0	241 (116)	Slight	5	1	2	0
1-Pentanol Acetate	See Amyl Acetate.											
2-Pentanol Acetate	See sec-Amyl Acetate.											
2-Pentanone	See Methyl Propyl Ketone.											
3-Pentanone	See Diethyl Ketone.											
Pentaphen $C_5H_{11}C_6H_4OH$ (p-tert-Amyl Phenol)	232 (111) (oc) Note: Melting point 195 (91).				0.9		482 (250)	No	2	2	1	0
Pentapropionyl Glucose	See Glucose Pentapropionate.											
1-Pentene $CH_3(CH_2)_2CH{:}CH_2$ (Amylene)	0 (−18) (oc)	527 (275)	1.5	8.7	0.7	2.4	86 (30)		1	1	4	0
1-Pentene-cis	See β-Amylene-cis.											
2-Pentene-trans	See β-Amylene-trans.											
Pentylamine	See Amylamine.											
Pentyloxypentane	See Amyl Ether.											
Pentyl Propionate	See Amyl Propionate.											
1-Pentyne $HC{:}CC_3H_7$ (n-Propyl Acetylene)	< −4 (< −20)				0.69	2.35	104 (40)				3	3
Peracetic Acid Diluted with 60% acetic acid	105 (41) Note: Decomposes violently at 230 (110).						221 (105)	Yes		3	2 Explodes on heating.	4 OX
$Cl_2C=CCl_2$												0
Perhydrophenanthrene $C_{14}H_{24}$ (Tetradecahydro Phenanthrene)		475 (246)			0.9		187–192 (86–89)					0
Perilla Oil	522 (272)				0.9			No	2	0	1	0

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Petroleum, Crude, Sour	20–90 (−7 to 32)				<1			No	1	2	3	0
Petroleum, Crude, Sweet	20–90 (−7 to 32)				<1			No	1	1	3	0
Petroleum Ether (Benzine) (Naphtha, Petroleum)	<0 (< −18)	550 (288)	1.1	5.9	0.6	2.5	95–140 (35–60)	No	1	1	4	0
Petroleum Pitch	See Asphalt (Typical).											
Petroleum Sulfonate	400 (204) (oc)							No	2	0	1	0
β-Phellandrene $CH_2:CCH:CHCH[CH(CH_3)_2]-CH_2CH_2$ (p-Mentha-1(7), 2-Diene)	120 (49)				~0.9	4.68	340 (171)	No		0	2	0
Phenanthrene $(C_6H_4CH)_2$ (Phenanthrin)	340 (171) (oc) Note: Melting point 212 (100).				1.1		644 (340)	No	2		1	0
Phenethyl Alcohol $C_6H_5CH_2CH_2OH$ (Benzyl Carbinol) (Phenylethyl Alcohol)	205 (96)				1.0+		430 (221)	No	2	1	1	0
o-Phenetidine $H_2NC_6H_4OC_2H_5$ (2-Ethoxyaniline) (o-Amino-Phenetole)	239 (115) (oc)						442–446 (228–230)	No	5 2	2	1	0
p-Phenetidine $C_2H_5OC_6H_4NH_2$ (1-Amino-4-Ethoxy-benzene) (p-Aminophenetole)	241 (116)				1.1		378–484 (192–251)	Very slight	2	2	1	0
Phenetole	See Ethoxybenzene.											
Phenol C_6H_5OH (Carbolic Acid)	175 (79) Note: See Hazardous Chemicals Data. Melting point 108 (42).	1319 (715)	1.8	8.6	1.1	3.2	358 (181)	Yes	5	4	2	0
2-Phenoxyethanol	See Ethylene Glycol, Phenyl Ether.											
Phenoxy Ethyl Alcohol $C_6H_5O(CH_2)_2OH$ (2-Phenoxyethanol) (Phenyl Cellosolve)	250 (121) (oc) Note: Melting point 58 (14).				1.11	4.77	468 (242)			0	1	0
N-(2-Phenoxyethyl) Aniline $C_6H_5O(CH_2)_2NHC_6H_5$	338 (170)				1.1		396 (202)	No	2	1	1	0
β-Phenoxyethyl Chloride	See β-Chlorophenetole.											
Phenylacetaldehyde $C_6H_5CH_2CHO$ (α-Toluic Aldehyde)	160 (71)				1.0+		383 (195)	No	5	1	2	0
Phenyl Acetate $CH_3COOC_6H_5$ (Acetylphenol)	176 (80)				1.1	4.7	384 (196)	Slight	5	1	2	0
Phenylacetic Acid $C_6H_5CH_2COOH$ (α-Toluic Acid)	>212 (>100) Note: Melting point 169–171 (76–77)				1.1		504 (262)	Yes	5	1	1	0

Phenylbenzene	See Biphenyl.											
Phenyl Bromide	See Bromobenzene.											
1-Phenyl-2-Butene $C_6H_5CH_2CH:CHCH_3$	160 (71) (oc)				0.9	4.6	346 (174)				2	0

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Phenyl Carbinol	See Benzyl Alcohol.											
Phenyl Chloride	See Chlorobenzene.											
Phenylcyclohexane	See Cyclohexylbenzene.											
Phenyl Didecyl Phosphite $(C_6H_5O)P(OC_{10}H_{21})_2$	425 (218) (oc)				0.9				2	0	1	0
N-Phenyldiethanolamine $C_6H_5N(C_2H_4OH)_2$	385 (196) (oc) Note: Melting point 136 (58).	730 (387)	0.7		1.1		376 (191)	No	2	1	1	0
Phenyldiethylamine	See N,N-Diethylaniline.											
Phenyl Diglycol Carbonate	See Diethylene Glycol Bis (Phenylcarbonate).											
Phenyl Di-o-Xenyl Phosphate $(C_{12}H_9O)_2POOC_6H_5$	482 (250)				1.2		545–626 (285–330)	No	2	0	1	1
o-Phenylenediamine $NH_2C_6H_4NH_2$ (1,2-Diaminobenzene)	313 (156) Note: Melting point 284 (140).		1.5			3.73	513 (267)				1	0
Phenylethane	See Ethylbenzene.											
N-Phenylethanolamine $C_6H_5NHC_2H_4OH$	305 (152) (oc) Note: See Hazardous Chemicals Data.				1.1		545 (285)	Slight	2 5	1	1	0
Phenylethyl Acetate (β) $C_6H_5CH_2CH_2OOCCH_3$	230 (110) (oc)				1.03	5.67	435 (224)			0	1	0
Phenylethyl Alcohol	See Phenethyl Alcohol.											
Phenylethylene	See Styrene.											
N-Phenyl-N-Ethyl-ethanolamine $C_6H_5N(C_2H_5)C_2H_4OH$	270 (132) (oc)	685 (362)	0.8		1.0+		514 (268) @ 740 mm	Slight	2 5	2	1	0
Phenylhydrazine $C_6H_5NHNH_2$	190 (88)				1.1		Decom- poses	Slight	5	3	2	0
Phenylmethane	See Toluol.											
Phenylmethyl Ethanol Amine $C_6H_5N(CH_3)C_2H_4OH$ (2-(N-Methylaniline)-Ethanol)	280 (138) (oc)				1.07	5.22	378 (192) @ 100 mm			2	1	0
Phenyl Methyl Ketone	See Acetophenone.											
4-Phenylmorpholine $C_6H_5NC_2H_4OCH_2CH_2$	220 (104) (oc)				1.1		518 (270)	Slight	5 2	2	1	0
Phenylpentane	See Amylbenzene.											
o-Phenylphenol $C_6H_5C_6H_4OH$	255 (124) Note: Melting point 134 (57).	986 (530)			1.2		547 (286)	Slight	5 2	1	1	0
Phenylpropane	See Propylbenzene.											
2-Phenylpropane	See Cumene.											
Phenylpropyl Alcohol $C_6H_5(CH_2)_3OH$ (Hydrocinnamic Alcohol) (3-Phenyl-l-propanol) (Phenylethyl Carbinol)	212 (100)				1.0+		426 (219)	No	5	0	1	0
(Hydrocinnamic Aldehyde)												0
Phenyl Toluene o $C_6H_5C_6H_4CH_3$ (2-Methylbiphenyl)	>212 (>100)	923 (495)			1.01	5.82	500 (260)				1	0
Phenyl Trichloro Silane $C_6H_5SiCl_3$ (Trichloro(phenyl)silane)	196 (91) (oc)				1.32	7.36	394 (201)			3	2	0

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Phorone $(CH_3)_2CCHCOCHC(CH_3)_2$	185 (85) (oc) Note: Melting point 82 (28).				0.9	4.8	388 (198)	No		2	2	0
Phosphine PH_3	Gas	212 (100)			0.57 @ 20 atm	1.17	−126 (−88)			4	4	2
Phthalic Acid $C_6H_4(COOH)_2$	334 (168) Note: Melting point 376 (191).				1.59	5.73	552 (289)			0 Forms anhydride (Dust explosion hazard.)	1	1
Phthalic Anhydride $C_6H_4(CO)_2O$	305 (152) Note: Melting point 262 (128).	1058 (570)	1.7	10.5	1.5		543 (284)	No	2	3	1	0
m-Phthalyl Dichloride	See Isophthaloyl Chloride.											
2-Picoline $CH_3C_5H_4N$ (2-Methylpyridine)	102 (39) (oc)	1000 (538)			1.0−	3.2	262 (128)	No		2	2	0
4-Picoline $CH_3C_5H_4N$	134 (57) (oc)				1.0−	3.2	292 (144)	Yes	5	2	2	0
Pimelic Ketone	See Cyclohexanone.											
Pinane $C_{10}H_{18}$		523 (273)	0.7 @ 320 (160)	7.2 @ 320 (160)	0.8		336 (151)			0		0
α-Pinene $C_{10}H_{16}$	91 (33)	491 (255)			0.9	4.7	312 (156)	No	1	1	3	0
Pine Oil Steam Distilled	172 (78) 138 (59)				0.9		367–439 (186–226)	No		0	2	0
Pine Pitch	285 (141) Note: Melting point 148 (64).				1.1		490 (254)	No	2	0	1	0
Pine Tar	130 (54)	671 (355)					208 (98)	No		0	2	0
Pine Tar Oil (Wood Tar Oil)	144 (62)				0.9			No		0	2	0
Piperazine $HNCH_2CH_2NHCH_2CH_2$	178 (81) (oc)				1.1	3.0	294 (146)	Slight	5	2	2	0
Piperidine $(CH_2)_5NH$ (Hexahydropyridine)	61 (16)				0.9	3.0	223 (106)	Yes	1 5	3	3	0
Pogy Oil	See Menhaden Oil.											
Polyamyl Naphthalene Mixture of Polymers	360 (182) (oc)				0.9		667–747 (353–397)	No	2	0	1	0
Polyethylene Glycols $OH(C_2H_5O)_nC_2H_4OH$	360–550 (182–287) (oc)							Yes	5 2	0	1	0
Polyoxyethylene Lauryl Ether $C_{12}H_{25}O(OCH_2CH_2)_nOH$	>200 (>93)				0.95					0	1	0
Polypropylene Glycols $OH(C_3H_6O)_nC_3H_6OH$	365 (185) (oc)				1.0+		Decom-poses		5 2	0	1	0
Polyvinyl Alcohol **Mixture of Polymers**	175 (79)							Yes	5	0	2	0
[illegible]	[illegible]											0
Potassium Xanthate $KS_2C\text{-}OC_2H_5$	205 (96)			9.6	1.56	5.53	392 (200) Decom-poses	Yes		2	1	0

	FLASH POINT °F (°C)	IGNITION TEMP. °F (°C)	FLAMMABLE LIMITS Percent by Vol. Lower	Upper	Sp. Gr. (Water = 1)	Vapor Density (Air = 1)	BOILING POINT °F (°C)	Water Soluble	SEE INTRODUCTION FOR SUGGESTED EXTINGUISHING METHODS	HAZARD IDENTIFICATION Health	Flammability	Reactivity
Propanal CH_3CH_2CHO (Propionaldehyde)	−22 (−30) Note: See Hazardous Chemicals Data.	405 (207)	2.6	17	0.8	2.0	120 (49)	Slight	1 5	2	3	2
Propane $CH_3CH_2CH_3$	Gas	842 (450)	2.1	9.5		1.6	−44 (−42)	No	6	1	4	0
1,3-Propanediamine $NH_2CH_2CH_2CH_2NH_2$ (1,3-Diaminopropane) (Trimethylenediamine)	75 (24) (oc)				0.9	2.6	276 (136)	Yes	1 5	2	3	0
1,2-Propanediol	See Propylene Glycol.											
1,3-Propanediol	See Trimethylene Glycol.											
1-Propanol	See Propyl Alcohol.											
2-Propanol	See Isopropyl Alcohol.											
2-Propanone	See Acetone.											
Propanoyl Chloride	See Propionyl Chloride.											
Propargyl Alcohol $HC{:}CCH_2OH$ (2-Propyn-1-ol)	97 (36) (oc)				0.97	1.93	239 (115)			4	3	3
Propargyl Bromide $HC{:}CCH_2Br$ (3-Bromopropyne)	50 (10) Note: See Hazardous Chemicals Data.	615 (324)	3.0		1.57	4.10	192 (89)			3	3	4
Propene	See Propylene.											
2-Propenylamine	See Allylamine.											
Propenyl Ethyl Ether $CH_3CH{:}CHOCH_2CH_3$	<20 (<−7) (oc)				0.8	1.3	158 (70)		1	2	3	0
β-Propiolactone $C_3H_4O_2$	165 (74)		2.9		1.1	2.5	311 (155)	Yes	5	0	2	0
Propionaldehyde	See Propanal.											
Propionic Acid CH_3CH_2COOH	126 (52) Note: See Hazardous Chemicals Data.	870 (465)	2.9	12.1	1.0−	2.5	297 (147)	Yes	5	3	2	0
Propionic Anhydride $(CH_3CH_2CO)_2O$	145 (63)	545 (285)	1.3	9.5	1.0+	4.5	336 (169)	Decomposes		3 Decomposes in water.	2	1
Propionic Nitrile CH_3CH_2CN (Propionitrile)	36 (2)		3.1		0.78	1.90	207 (97)	Yes		4	3	1
Propionyl Chloride CH_3CH_2COCl (Propanoyl Chloride)	54 (12)				1.1	3.2	176 (80)	Decomposes	1	3 Decomposes in water.	3	1
Propyl Acetate $C_3H_7OOCCH_3$ (Acetic Acid, n-Propyl Ester)	55 (13)	842 (450)	1.7 @ 100 (38)	8	0.9	3.5	215 (102)	Slight	1 5	1	3	0
Propyl Alcohol $CH_3CH_2CH_2OH$ (1-Propanol)	74 (23)	775 (412)	2.2	13.7	0.8	2.1	207 (97)	Yes	1 5	1	3	0
Propylamine $CH_3(CH_2)_2NH_2$	−35 (−37) Note: See Hazardous Chemicals Data.	604 (318)	2.0	10.4	0.7	2.0	120 (49)	Yes	1 5	3	3	0
Propylbenzene $C_3H_7C_6H_5$ (Phenylpropane)	86 (30)	842 (450)	0.8	6.0	0.9	4.1	319 (159)	No	1	2	3	0
2-Propybiphenyl	>212 (>100)	833 (445)				6.77	−536 (−280)			0	1	0
												0
n-Propyl Butyrate $C_3H_7COOC_3H_7$	99 (37)				0.87	4.49	290 (143)			0	3	0
Propyl Carbinol	See Butyl Alcohol.											
Propyl Chloride C_3H_7Cl (1-Chloropropane)	<0 (<−18)	968 (520)	2.6	11.1	0.9	2.7	115 (46)	Very slight	1	2	3	0

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Propyl Chlorothiolformate C_3H_7SCOCl	145 (63)				1.1	4.8	311 (155)	No		2	2	0
Propylcyclohexane $H_7C_3C_6H_{11}$		478 (248)			0.8		313–315 (156–157)			0		0
Propylcyclopentane $C_3H_7C_5H_9$ (1-Cyclopentylpropane)		516 (269)			0.8		269 (131)			0		0
Propylene $CH_2{:}CHCH_3$ (Propene)	Gas	851 (455)	2.0	11.1		1.5	−53 (−47)	No	6	1	4	1
	Note: See Hazardous Chemicals Data.											
Propylene Aldehyde	See Crotonaldehyde.											
Propylene Carbonate $OCH_2CH_2CH_2OCO$	275 (135) (oc)				1.2		468 (242)	Yes	2 5	1	1	0
Propylene Chlorohydrin	See 2-Chloro-1-Propanol.											
sec-Propylene Chlorohydrin	See 1-Chloro-2-Propanol.											
Propylenediamine $CH_3CH(NH_2)CH_2NH_2$	92 (33) (oc)	780 (416)			0.9	2.6	246 (119)	Yes	1 5	2	3	0
Propylene Dichloride $CH_3CHClCH_2Cl$ (1,2-Dichloropropane)	60 (16)	1035 (557)	3.4	14.5	1.2	3.9	205 (96)	No	4	2	3	0
Propylene Glycol $CH_3CHOHCH_2OH$ (Methyl Ethylene Glycol) (1,2-Propanediol)	210 (99)	700 (371)	2.6	12.5	1.0+	2.62	370 (188)	Yes	5	0	1	0
Propylene Glycol Acetate	See Methyl Glycol Acetate.											
Propylene Glycol Isopropyl Ether	110 (43)				0.86		283 (140)	Yes				
Propylene Glycol Methyl Ether $CH_3OCH_2CHOHCH_3$ (1-Methoxy-2-propanol)	90 (32)		1.6	13.8	0.92	3.11	248 (120)	Yes		0	3	0
Propylene Glycol Methyl Ether Acetate (99% Pure)	108 (42)		1.5 @200°C	7.0	0.966	4.6	295 (146)	Slight	5	0	2	0
Propylene Glycol Mono-acrylate $CH_2{:}CHCOO(C_3H_6)OH$ (Hydroxypropyl Acrylate)	207 (97)		1.4 @100°C		1.05	4.5	410 (210)	Yes	5	3	1	2
Propylene Oxide OCH_2CHCH_3	−35 (−37)	840 (449)	2.3	36	0.83	2.0	94 (35)	Yes	1 5	3	4	2
	Note: See Hazardous Chemicals Data.											
n-Propyl Ether $(C_3H_7)_2O$ (Dipropyl Ether)	70 (21)	370 (188)	1.3	7.0	0.75	3.53	194 (90)				3	0
Propyl Formate $HCOOC_3H_7$	27 (−3)	851 (455)			0.9	3.0	178 (81)	Slight	1 5	2	3	0
Propyl Methanol	See Butyl Alcohol.											
Propyl Nitrate $CH_3CH_2CH_2NO_3$	68 (20)	347 (175)	2	100	1.1		231 (111)	Slight	1 5	2 May explode on heating.	3	3 OX
Propyl Propionate $CH_3CH_2COOCH_2CH_2CH_3$	175 (79) (oc)				0.9	4.0	245 (118)	No		1	3	0
Propyltrichlorosilane $(C_3H_7)SiCl_3$	98 (37)				1.2	6.12	254 (123.5)	Yes	1	3	3	1
	Note: See Hazardous Chemicals Data.											
(Allylene) (Methylacetylene)												2
Prussic Acid	See Hydrocyanic Acid.											
Pseudocumene	See 1,2,4-Trimethylbenzene.											

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Pyridine CH < (CHCH)$_2$ > N	68 (20)	900 (482)	1.8	12.4	1.0−	2.7	239 (115)	Yes	1 5	3	3	0
	Note: See Hazardous Chemicals Data.											
Pyroxylin Solution	80 (27) May be below.							No	1	1	3	0
Pyrrole (CHCH)$_2$NH (Azole)	102 (39)				1.0−	2.3	268 (131)	No		2	2	0
Pyrrolidine NHCH$_2$CH$_2$CH$_2$CH$_2$ (Tetrahydropyrrole)	37 (3)				0.9	2.5	186–189 (86–87)	Yes	5 1	2	3	1
2-Pyrrolidone NHCOCH$_2$CH$_2$CH$_2$	265 (129) (oc)				1.1	2.9	473 (245)	Yes	2 5	2	1	0
	Note: Melting point 77 (25).											
Quenching Oil	365 (185)				0.9			No	2	0	1	0
Quinoline C$_6$H$_4$N:CHCH:CH		896 (480)			1.1	4.5	460 (238)	No		2	1	0
Range Oil	See Fuel Oil No. 1.											
Rape Seed Oil (Colza Oil)	325 (163)	836 (447)			0.9			No	2	0	1	0
Red Oil	See Oleic Acid.											
Resorcinol C$_6$H$_4$(OH)$_2$ (Dihydroxybenzol)	261 (127)	1126 (608)	1.4 @ 392 (200)		1.28	3.80	531 (277)				1	0
	Note: Melting point 232 (111).											
Rhodinol CH$_2$:C(CH$_3$)(CH$_2$)$_3$CH-(CH$_3$)(CH$_2$)$_2$OH	> 212 (> 100)				0.9		237–239 (114–115) @ 12 mm	No		0	1	0
Ricinus Oil	See Castor Oil.											
Rosin Oil	266 (130)	648 (342)			1.0−		> 680 (> 360)	No	2	0	1	0
Rum	See Ethyl Alcohol and Water.											
Salicylaldehyde HOC$_6$H$_4$CHO (o-Hydroxybenzaldehyde)	172 (78)				1.2		384 (196)	Slight	5	0	2	0
Salicylic Acid HOC$_6$H$_4$COOH	315 (157)	1004 (540)	1.1 @ 392 (200)		1.5	4.8	Sublimes @ 169 (76)	No	2	0	1	0
	Note: Melting point 316–322 (158–161).											
Safrole C$_3$H$_5$C$_6$H$_3$O$_2$CH$_2$ (4-allyl-1,2-Methylene-dioxy-benzene)	212 (100)				1.1		451 (233)	No			1	0
Santalol C$_{15}$H$_{24}$O (Arheol)	> 212 (> 100)				1.0−		~572 (~300)	No			1	0
Sesame Oil	491 (255)				0.9			No	2	0	1	0
Signal Oil	See Mineral Seal Oil, Typical.											
Silane SiH$_4$ (Silicon Hydride)	Gas	Pyrophoric				1.3	−169	Slight	Avoid halon	1	4	3
[illegible]	540	833			0.9			No	2	0	1	0
[illegible]	[illegible] 460 (238)	[illegible]										0
Spindle Oil	See Lubricating Oil, Spindle.											
Stearic Acid CH$_3$(CH$_2$)$_{16}$COOH	385 (196)	743 (395)			0.8		726 (386)	No	2	1	1	0
	Note: Melting point 157 (69).											

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Stearyl Alcohol $CH_3(CH_2)_{17}OH$ (1-Octadecanol)	Note: Melting point 131 (55).	842 (450)			0.8		410 (210) @ 15 mm	No		0		0
Straw Oil	315–361 (157–183)							No	2	0	1	0
Styrene $C_6H_5CH{:}CH_2$ (Cinnamene) (Phenylethylene) (Vinyl Benzene)	88 (31) Note: Polymerizes. See Hazardous Chemicals Data.	914 (490)	0.9	6.8	0.9	3.6	295 (146)	No	1	2	3	2
Styrene Oxide $C_6H_5CHOCH_2$	165 (74) (oc)	929 (498)			1.1					2	2	0
Succinonitrile $NCCH_2CH_2CN$ (Ethylene Dicyanide)	270 (132) Note: Melting point 130 (54).				1.0 –	2.1	509–513 (265–267)	Yes	2 5		1	0
Sulfolane $CH_2(CH_2)_3SO_2$ (Tetrahydrothiophene-1,1-Dioxide) (Tetramethylene Sulfone)	350 (177) (oc) Note: Melting point 81 (27).				1.3		545 (285)	Yes	2	2	1	0
Sulfur	405 (207)	450 (232)			1.8		832 (445)	No		2	1	0
Sulfur Chloride S_2Cl_2	245 (118) Note: See Hazardous Chemicals Data.	453 (234)			1.7		280 (138)	Decomposes		3 Decomposes in water.	1	1
Sweet Oil	See Olive Oil.											
Sylvan	See 2-Methylfuran.											
Tallow	509 (265) Note: Melting point 88–100 (31–38).				0.9			No	2	0	1	0
Tallow Oil	492 (256) Note: Melting point 109 (43).				0.9			No	2	0	1	0
Tannic Acid $(HO)_3C_6H_2CO_2C_6H_2(OH)_2$-COOH (Tannin) (Digallic Acid)	390 (199) (oc)	980 (527)					Decom-poses 392 (200)	Yes	2	0	1	0
Tartaric Acid (d, l) $(CHOHCO_2H)_2$	410 (210) (oc) Note: Melting point 338 (170).	797 (425)			1.76	5.18				0	1	0
Terephthalic Acid $C_6H_4(COOH)_2$ (para-Phthalic Acid) (TPA) (Benzene-para-Dicarboxylic Acid)	500 (260) (oc)	925 (496)			1.5		Sublimes above 572 (300)	No	2	0	1	0
Terephthaloyl Chloride $C_6H_4(COCl)_2$ (Terephthalyl Dichloride) (p-Phthalyl Dichloride) (1,4-Benzenedicarbonyl Chloride)	356 (180) Note: Melting point 175 (79).						498 (259)	Yes	2	3	1	0
o-Terphenyl $(C_6H_5)_2C_6H_4$	325 (163) (oc)				1.1		630 (332)	No	2	0	1	0
[illegible]	Note: Melting point [illegible]											0
Terpineol $C_{10}H_{17}OH$ (Terpilenol)	195 (91)				0.9		417–435 (214–224)	No		0	2	0
Terpinyl Acetate $C_{10}H_{17}OOCCH_3$	200 (93)				1.0 –		428 (220)	Slight	5 2	0	2	0

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Tetraamylbenzene $(C_5H_{11})_4C_6H_2$	295 (146)				0.9		608–662 (320–350)	No	2	0	1	0
1,1,2,2-Tetrabromoethane $CHBr_2CHBr_2$ (Acetylene Tetrabromide)		635 (335)			2.97	11.9	275 (135)			3	0	1
Tetrachlorobenzene $C_6H_2Cl_4$	311 (155)				1.7		475 (246)	No	2	0	1	0
1,2,4,5-Tetrachlorobenzene $C_6H_{12}Cl_4$	311 (155)				1.86		472 (245)	No		1	1	0
Tetradecane $CH_3(CH_2)_{12}CH_3$	212 (100)	392 (200)	0.5		0.8		487 (253)	No		0	1	0
Tetradecanol $C_{14}H_{29}OH$	285 (141) (oc)				0.8		507 (264)	No	2	0	1	0
1-Tetradecene $CH_2{:}CH(CH_2)_{11}CH_3$	230 (110)	455 (235)			0.8	6.8	493 (256)	No	2	0	1	0
tert-Tetradecyl Mercaptan $C_{14}H_{29}SH$	250 (121)				0.9		496–532 (258–278)		5 2	2	1	0
Tetraethoxypropane $(C_2H_5O)_4C_3H_4$	190 (88) (oc)				1.12	6.70	621 (327)			0	2	0
Tetra (2-Ethylbutyl) Silicate $[C_2H_5CH(C_2H_5)CH_2O]_4Si$	335 (168) (oc)				0.9		460 (238) @ 50 mm	No	2	1	1	0
Tetraethylene Glycol $HOCH_2(CH_2OCH_2)_3CH_2OH$	360 (182) (oc)				1.1	6.7	Decom-poses	Yes	2 5	1	1	0
Tetraethylene Glycol, Dibutyl Ether	See Dibutoxy Tetraglycol.											
Tetraethylene Glycol, Dimethyl Ether	See Dimethoxy Tetraglycol.											
Tetraethylene Pentamine $H_2N(C_2H_4NH)_3C_2H_4NH_2$	325 (163) (oc)	610 (321)			1.0–		631 (333)	Yes	2 5	2	1	0
Tetra (2-Ethylhexyl) Silicate $[C_4H_9CH(C_2H_5)CH_2O]_4Si$	390 (199) (oc)				0.9			No	2	1	1	0
Tetraethyl Lead, Compounds $Pb(C_2H_5)_4$	200 (93) Note: See Hazardous Chemicals Data.		1.8		1.6	8.6	Decom-poses above 230 (110)	No		3	2	3
Tetraethyl Orthosilicate	See Ethyl Silicate.											
Tetrafluoroethylene $F_2C{:}CF_2$ (TFE) (Perfluoroethylene)	Gas Note: See Hazardous Chemicals Data.	392 (200)	10.0	50.0	1.5	3.87	–105 (–76)	No		2	4	3
Tetraglycol Dichloride	See Bis[2-(2-Chloroethoxy) Ethyl] Ether.											
1,2,3,6-Tetrahydro-benzaldehyde $CH_2CH{:}CHCH_2CH_2CHCHO$ (3-Cyclohexene-1-Carboxaldehyde)	135 (57) (oc)				1.0–	3.8	328 (164)	Slight	5	2	2	0
endo-Tetrahydrodicyclo-pentadiene $C_{10}H_{16}$ (Tricyclodecane)		523 (273)			0.9		379 (193)					0
(Diethylene Oxide) (Tetramethylene Oxide)	Note: See Hazardous Chemicals Data.											1

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Tetrahydrofurfuryl Alcohol $C_4H_7OCH_2OH$	167 (75) (oc)	540 (282)	1.5	9.7	1.1		352 (178) @ 743 mm	Yes	5	2	2	0
Tetrahydrofurfuryl Oleate $C_4H_7OCH_2OOCC_{17}H_{33}$	390 (199)				0.9		392–545 (200–285) @ 16 mm	No	2	1	1	0
Tetrahydronaphthalene $C_6H_2(CH_2)_2C_2H_4$ (Tetralin)	160 (71)	725 (385)	0.8 @ 212 (100)	5.0 @ 302 (150)	1.0–	4.6	405 (207)	No		1	2	0
Tetrahydropyran	See Pentamethylene Oxide.											
Tetrahydropyran-2-Methanol $OCH_2CH_2CH_2CH_2CHCH_2OH$	200 (93) (oc)				1.0+	4.0	368 (187)	Yes	5	1	2	0
Tetrahydropyrrole	See Pyrrolidine.											
Tetralin	See Tetrahydronaphthalene.											
1,1,3,3-Tetramethoxy-propane $[(CH_3O)_2CH]_2CH_2$	170 (77)				1.0–		361 (183)	Yes	5	0	2	0
1,2,3,4-Tetramethyl-benzene 95% $C_6H_2(CH_3)_4$ (Prehnitene)	166 (74)	800 est. (427)			0.9		399–401 (204–205)	No		0	2	0
1,2,3,5-Tetramethyl-benzene 85.5% $C_6H_2(CH_3)_4$ (Isodurene)	160 (71)	800 est. (427)			0.9		387–389 (197–198)	No		0	2	0
1,2,4,5-Tetramethyl-benzene 95% $C_6H_2(CH_3)_4$ (Durene)	130 (54) Note: Melting point 174 (79).				0.8 @ 178 (81)	4.6	385 (196)	No		0	2	0
Tetramethylene	See Cyclobutane.											
Tetramethyleneglycol $CH_2OH(CH_2)_2CH_2OH$		734 (390)			1.0+		230 (110)	Yes	5	0	1	0
Tetramethylene Oxide	See Tetrahydrofuran.											
Tetramethyl Lead, Compounds $Pb(CH_3)_4$	100 (38) Note: See Hazardous Chemicals Data.				1.6	6.5		Decom-poses above 212 (100)	No	3	3	3
2,2,3,3-Tetramethyl Pentane $(CH_3)_3CC(CH_3)_2CH_2CH_3$	<70 (<21)	806 (430)	0.8	4.9	0.7	4.4	273 (134)			0	3	0
2,2,3,4-Tetramethyl-pentane $(CH_3)_3CCH(CH_3)CH(CH_3)_2$	<70 (<21)				0.74	4.43	270 (132)			0	3	0
Tetramethyl Tin $Sn(CH_3)_4$	<70 (<21)		1.9		1.3	6.2	172 (78)	No	3	2		0
Tetraphenyl Tin $(C_6H_5)_4Sn$	450 (232) Note: Melting point 439 (226).				1.5	14.7	795 (424)	No	2	3	1	0
Tetrapropionyl Glucosyl Propionate	See Glucose Pentapropionate.											
Thialdine $SCH(CH_3)SCH(CH_3)NHCHCH_3$	200 (93)				1.1		Decom-poses	Slight	5	2	2	1
2,2-Thiodiethanol $(HOCH_2CH_2)_2S$ (Thiodiethylene Glycol)	320 (160) (oc)				1.2		540 (282)	Yes	5 2	[illegible]	[illegible]	0
Thiodiethylene Glycol	See 2,2-Thiodiethanol.											

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Thiodiglycol $(CH_2CH_2OH)_2S$ (Thiodiethylene Glycol) (Beta-bis-Hydroxyethyl Sulfide) (Dihydroxyethyl Sulfide)	320 (160)	568 (298)			1.2		541 (283)	Yes	2	2	1	0
Thiophene SCH:CHCH:CH	30 (−1)				1.1	2.9	184 (84)	No	1	2	3	0
1,4-Thioxane $O(CH_2CH_2)_2S$ (1,4-Oxathiane)	108 (42)				1.12	3.59	300 (149)			2	2	0
Toluene $C_6H_5CH_3$ (Methylbenzene) (Phenylmethane) (Toluol)	40 (4) Note: See Hazardous Chemicals Data.	896 (480)	1.1	7.1	0.9	3.1	231 (111)	No	1	2	3	0
Toluene-2,4-Diisocyanate $CH_3C_6H_3(NCO)_2$	260 (127) Note: See Hazardous Chemicals Data.		0.9	9.5	1.2	6.0	484 (251)	No		3 Reacts exothermically with water.	1	3 W
p-Toluenesulfonic Acid $C_6H_4(SO_3H)(CH_3)$	363 (184) Note: Melting point 220 (104.5).						295 (140) @ 20 mm	Yes	2	3	1	1
Toluhydroquinone $C_6H_3(OH)_2CH_3$ (Methylhydroquinone)	342 (172) (oc) Note: Melting point 259 (126).	875 (468)					545 (285)	Yes	2		1	0
o-Toluidine $CH_3C_6H_4NH_2$ (2-Methylaniline)	185 (85) Note: See Hazardous Chemicals Data.	900 (482)			1.0−	3.7	392 (200)	No		3	2	0
p-Toluidine $CH_3C_6H_4NH_2$ (4-Methylaniline)	188 (87) Note: Melting point 111 (44). See Hazardous Chemicals Data.	900 (482)			1.0−	3.9	392 (200)	No		3	2	0
Toluol	See Toluene.											
m-Tolydiethanolamine $(HOC_2H_4)_2NC_6H_4CH_3$ (MTDEA)	400 (204) (oc) Note: Melting point 144 (62).	740 (393)	0.6					No	2	2	1	0
2,4-Tolylene Diisocyanate	See Toluene-2,4-Diisocyanate.											
o-Tolyl Phosphate	See Tri-o-Cresyl Phosphate.											
o-Tolyl p-Toluene Sulfonate $C_{14}H_{14}O_3S$	363 (184)				1.2				2	1	1	0
Transformer Oil (Transil Oil)	295 (146) (oc)				0.9			No	2	0	1	0
Transil Oil	See Transformer Oil.											
Triacetin	See Glyceryl Triacetate.											
Triamylamine $(C_5H_{11})_3N$	215 (102) (oc) Note: See Hazardous Chemicals Data.				0.8		453 (234)	No	2	2	1	0
Triamylbenzene $(C_5H_{11})_3C_6H_3$	270 (132) (oc)				0.9		575 (302)	No	2	0	1	0
Triamyl Borate	180 (82)				0.8	9.4	430 (221)			1	2	0
	(oc) Note: See Hazardous Chemicals Data.											0
Tri-n-Butyl Borate $B(OC_4H_9)_3$	200 (93) (oc)				0.85	7.94	446 (230)			3	2	1

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Tributyl Citrate $C_3H_4(OH)(COOC_4H_9)_3$	315 (157)	695 (368)			1.0+		450 (232)	No	2	0	1	0
Tributyl Phosphate $(C_4H_9)_3PO_4$	295 (146) (oc)				1.0−		560 (293)	No	2	2	1	0
Tributylphosphine $(C_4H_9)_3P$		392 (200)					473 (245)	No		0	1	0
Tributyl Phosphite $(C_4H_9)_3PO_3$	248 (120) (oc)				0.9		244–250 (118–121) @ 7 mm	Decomposes		2	1	1
1,2,4-Trichlorobenzene $C_6H_3Cl_3$	222 (105)	1060 (571)	2.5 @ 302 (150)	6.6	1.5		415 (213)	No	3	2	1	0
1,1,1-Trichloroethane CH_3CCl_3 (Methyl Chloroform)	None		7.5	12.5	1.32	4.55	165 (74)	No		2	1	0
Trichloroethylene $ClHC:CCl_2$	None Note: See NFPA 49, Hazardous Chemicals Data.	788 (420)	8 @ 25°C 7.8 @ 100°C	10.5 52	1.5	4.5	188 (87)	No		2	1	0
1,2,3-Trichloropropane $CH_2ClCHClCH_2Cl$ (Allyl Trichloride) (Glyceryl Trichlorohydrin)	160 (71)		3.2 @120°C	12.6 @150°C	1.4	5.1	313 (156)	No	3	3	2	0
Trichlorosilane $HSiCl_3$	7 (−14) (oc)				1.3	4.7	89 (32)	Decomposes		3	4	2W
Tri-o-Cresyl Phosphate $(CH_3C_6H_4)_3PO_4$ (o-Tolyl Phosphate)	437 (225)	725 (385)			1.2		770 (410) Decom-poses	No	2	2	1	0
Tridecanol $CH_3(CH_2)_{17}OH$	250 (121) (oc) Note: Melting point 86 (30).				0.8	6.9	525 (274)	No	2	0	1	0
2-Tridecanone	See Methyl Undecyl Ketone.											
Tridecyl Acrylate $CH_2:CHCOOC_{13}H_{27}$	270 (132) (oc)				0.9		302 (150) @ 10 mm	No	2	1	1	0
Tridecyl Alcohol $C_{12}H_{25}CH_2OH$ (Tridecanol)	180 (82) (oc) Note: Melting point 88 (31).				0.8		485–503 (252–262)		5	0	2	0
Tridecyl Phosphite $(C_{10}H_{21}O)_3P$	455 (235) (oc)				0.9		356 (180) @ 0.1 mm	No	2	0	1	0
Triethanolamine $(CH_2OHCH_2)_3N$ (2,2',2''-Nitrilotriethanol)	354 (179)				1.1	5.1	650 (343)	Yes	2 5	2	1	1
1,1,3-Triethoxyhexane $CH(OC_2H_5)_2CH_2CH\text{-}(OC_2H_5)C_3H_7$	210 (99) (oc)				0.9	7.5	271 (133) @ 50 mm Decom-poses @ 760 mm	No		1	1	0
Triethylaluminum $(C_2H_5)_3Al$	Note: Ignites spontaneously in air.									3 Do not use water,	4 ...ated	3W ...ts.
$(C_2H_5)_3N$	(−7) (oc)	(249)					(89)		5			0
1,2,4-Triethylbenzene $(C_2H_5)_3C_6H_3$	181 (83) (oc)			56 @115°C	0.9	5.6	423 (217)	No			2	0

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Triethylborane $(C_2H_5)_3B$	Note: Ignites spontaneously in air.									1 Do not use halogenated extinguishing agents.	3	3W
Triethyl Citrate $HOC(CH_2CO_2C_2H_5)_2$-$CO_2C_2H_5$	303 (151)				1.1		561 (294)	Very slight	2	0	1	0
Triethylene Glycol $HOCH_2(CH_2OCH_2)_2CH_2OH$ (Dicaproate) (2,2-Ethylenedioxydiethanol)	350 (177) (oc)	700 (371)	0.9	9.2	1.1	5.2	546 (286)	Yes	2 5	1	1	0
Triethylene Glycol Diacetate $CH_3COO(CH_2CH_2O)_3$-$COCH_3$ (TDAC)	345 (174) (oc)				1.1		572 (300)	Yes	5 2	0	1	0
Triethylene Glycol, Dimethyl Ether $CH_3(OCH_2)_3OCH_3$	232 (111) (oc)				1.0−	4.7	421 (216)		2	1	1	0
Triethylene Glycol, Ethyl Ether	See Ethoxytriglycol.											
Triethylene Glycol, Methyl Ether	See Methoxy Triglycol.											
Triethyleneglycol Monobutyl Ether $C_4H_9O(C_2H_4O)_3H$	290 (143)				1.0+		270 (132)	Yes	5 2	0	1	0
Triethylenetetramine $H_2NCH_2(CH_2NHCH_2)_2$-CH_2NH_2	275 (135)	640 (338)			1.0−		532 (278)	Yes	2 5	3	1	0
Triethyl Phosphate $(C_2H_5)_3PO_4$ (Ethyl Phosphate)	240 (115) (oc)	850 (454)			1.1		408–424 (209–218)	Yes	5 2	0	1	1
Trifluorochloroethylene CF_2:CFCl (R-1113) (Chlorotrifluoroethylene)	Gas		8.4	16.0	1.31 @5.7 atm	4.02	−18 (−28)		6		4	0
Triglycol Dichloride $ClCH_2(CH_3OCH_2)_2CH_2Cl$	250 (121) (oc)				1.2		466 (241)	No	2	2	1	0
Trihexyl Phosphite $(C_6H_{13})_3PO_3$	320 (160) (oc)				0.9		275–286 (135–141) @ 2 mm	Decomposes		Decomposes in water.	1	0
Triisobutylaluminum $[(CH_3)_2CHCH_2]_3Al$	Note: May ignite spontaneously in air.									3 Do not use water, foam or halogenated extinguishing agents.	4	3W
Triisobutyl Borate $B(OC_4H_9)_3$	185 (85) (oc)				0.84	7.94	413 (212)			3	2	1
Triisopropanolamine $[(CH_3)_2COH]_3N$ (1,1′,1″-Nitrolotri-2-propanol)	320 (160) (oc)	608 (320)			1.0−		584 (307)	Yes	2 5	2	1	0
Triisopropylbenzene $C_6H_3(CH_3CHCH_3)_3$	207 (97) (oc)				0.9		495 (237)	No		0	1	0
Triisopropyl Borate $(C_3H_7O)_3B$	82 (28)				0.82	6.49	288 (142)			3	3	1
[illegible]					[illegible]				2	0	1	0
Trimethylaluminum $(CH_3)_3Al$	Note: Ignites spontaneously in air.									Do not use water, foam or halogenated extinguishing agents.		3W
Trimethylamine $(CH_3)_3N$	Gas Note: See Hazardous Chemicals Data.	374 (190)	2.0	11.6		2.0	38 (3)	Yes	6	3	4	0

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1,2,3-Trimethylbenzene $C_6H_3(CH_3)_3$ (Hemellitol)	111 (44)	878 (470)	0.8	6.6	0.89	4.15	349 (176)			0	2	0
1,2,3-Trimethylbenzene 90.5% $C_6H_3(CH_3)_3$ (Hemimellitine 90.5%)	128 (53)	895 (479)			0.9	4.1	347–351 (175–177)	No		0	2	0
1,2,4-Trimethylbenzene $C_6H_3(CH_3)_3$ (Pseudocumene)	112 (44)	932 (500)	0.9	6.4	0.87	4.15	329 (165)	No		0	2	0
1,3,5-Trimethylbenzene $C_6H_3(CH_3)_3$ (Mesitylene)	122 (50)	1039 (559)			0.9	4.1	328 (164)	No		0	2	0
Trimethyl Borate	See Methyl Borate.											
2,2,3-Trimethylbutane $(CH_3)_2C(CH_3)CHCH_3$ (Triptane—an isomer of Heptane)	<32 (<0)	774 (412)			0.69	3.46	178 (81)			0	3	0
2,3,3-Trimethyl-1-Butene $(CH_3)_2CC(CH_3):CH_2$ (Heptylene)	<32 (<0)	707 (375)			0.71	3.39	172 (78)			0	3	0
Trimethyl Carbinol	See tert-Butyl Alcohol.											
Trimethylchlorosilane $(CH_3)_3SiCl$	−18 (−28)				0.9	3.75	135 (57)	Yes	1	3	3	2W
1,3,5-Trimethylcyclohexane $(CH_3)_3C_6H_9$ (Hexahydromesitylene)		597 (314)			0.8		283 (139)			0		0
Trimethylcyclohexanol $CH(OH)CH_2C(CH_3)_2$- $CH_2CH(CH_3)CH_2$	165 (74) (oc)				0.9	4.9	388 (198)	No		2	2	0
3,3,5-Trimethyl-1-Cyclohexanol $CH_2CH(CH_3)CH_2C(CH_3)_2$- CH_2CHOH	190 (88) (oc)				0.9	4.9	388 (198)	Slight	5	2	2	0
Trimethylene	See Cyclopropane.											
Trimethylenediamine	See 1,3-Propanediamine.											
Trimethylene Glycol $HO(CH_2)_3OH$ (1,3-Propanediol)		752 (400)			1.1	2.6	417 (214)	Yes	5	1		0
Trimethylethylene	See 2-Methyl-2-Butene.											
2,5,5-Trimethylheptane $C_2H_5C(CH_3)_2(CH_2)_2$- $CH(CH_3)_2$	<131 (<55)	527 (275)			0.73	4.91	304 (151)			0	2	0
2,2,5-Trimethylhexane $(CH_3)_3C(CH_2)_2CH(CH_3)_2$	55 (13) (oc)				0.7	4.4	255 (124)	No	1	2	3	0
3,5,5-Trimethylhexanol $CH_3C(CH_3)_2CH_2CH$- $(CH_3)CH_2CH_2OH$	200 (93) (oc)				0.8		381 (194)	No		2	2	0
2,4,8-Trimethyl-6-Nonanol $C_4H_9CH(OH)C_7H_{15}$ (2,6,8-Trimethyl-4-nonanol)	199 (93) (oc)				0.82	6.43	491 (255)			0	2	0
2,6,8-Trimethyl-4-Nonanol	200				0.8		438	No		2	2	0
Nonanone $(CH_3)_2CHCH_2CH(CH_3)CH_2$- $COCH_2CH(CH_3)_2$	(91) (oc)						(218)					0
Trimethylolpropane Triacrylate $C_2H_5C(CH_2OCOCHCH_2)_3$	300 (149) (oc)				1.5		392 (200)		2	0	1	0
2,2,3-Trimethylpentane $CH_3CH_2CH(CH_3)C(CH_3)_3$	<70 (<21)	745 (346)			0.72	3.94	230 (110)			0	3	0

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2,2,4-Trimethylpentane $(CH_3)_3CCH_2CH(CH_3)_2$	10 (−12)	779 (415)	1.1	6.0	0.7	3.9	211 (99)	No	1		3	0
2,3,3-Trimethylpentane $CH_3CH_2C(CH_3)_2CH(CH_3)_2$	<70 (<21)	797 (425)			0.73	3.94	239 (115)			0	3	0
2,2,4-Trimethyl-1,3-Pentanediol $(CH_3)_2CHCH(OH)C(CH_3)_2$-$CH_2OH$	235 (113) (oc)	655 (346)			0.9		419–455 (215–235)	No	2	0	1	0
	Note: Melting point 115–131 (46–55).											
2,2,4-Trimethyl pentanediol Diisobutyrate $C_{16}H_{30}O_4$	250 (121) (oc)	795 (424)	0.5 @ 342 (172)		0.9	9.9	536 (280)		2	0	1	0
2,2,4-Trimethyl-1,3-Pentanediol Isobutyrate $(CH_3)_2CHCH(OH)C(CH_3)_2$-$CH_2OOCCH(CH_3)_2$	248 (120) (oc)	740 (393)	0.6 @ 300 (149)	4.2 @ 393 (201)	1.0−		356–360 125 mm (180–182)	No	2	0	1	0
2,2,4-Trimethylpentanediol Isobutyrate Benzoate $C_{19}H_{28}O_4$	325 (163) (oc)				1.0		167 (75) @ 10 mm		2	0	1	0
2,3,4-Trimethyl-1-pentene $H_2C{:}C(CH_3)CH(CH_3)$-$CH(CH_3)_2$	<70 (<21)	495 (257)			7.2	3.87	214 (101)			0	3	0
2,4,4-Trimethyl-1-pentene $CH_2{:}C(CH_3)CH_2C(CH_3)_3$ (Diisobutylene)	23 (−5)	736 (391)	0.8	4.8	0.7	3.8	214 (101)	No	1	2	3	0
2,4,4-Trimethyl-2-pentene $CH_3CH{:}C(CH_3)C(CH_3)_3$	35 (2) (oc)	581 (305)			0.7	3.8	221 (105)	No	1	2	3	0
3,4,4-Trimethyl-2-pentene $(CH_3)_3CC(CH_3){:}CHCH_3$	<70 (<21)	617 (325)			0.74	3.87	234 (112)			0	3	0
Trimethyl Phosphite $(CH_3O)_3P$	130 (54) (oc)				1.0+	4.3	232–234 (111–112)	No		0	2	0
Trioctyl Phosphite $(C_8H_{17}O)_3P$ [Tris (2-Ethylhexyl) Phosphite]	340 (171) (oc)				0.9		212 (100) @ 0.01 mm	No	2	0	1	0
Trioxane $OCH_2OCH_2OCH_2$	113 (45) (oc)	777 (414)	3.6	29			239 (115) Sublimes	Slight	5	2	2	0
	Note: Melting point 147 (64).											
Triphenylmethane $(C_6H_5)_3CH$	>212 (>100)				1.01	8.43	678 (359)			0	1	0
	Note: Melting point 200 (93).											
Triphenyl Phosphate $(C_6H_5)_3PO_4$	428 (220)				1.3		750 (399)	No	2	2	1	0
	Note: Melting point 122 (50).											
Triphenylphosphine	See Triphenylphosphorus.											
Triphenyl Phosphite $(C_6H_5O)_3PO_3$	425 (218) (oc)				1.2		311–320 (155–160) @ 0.1 mm	No	2	0	1	0
Triphenylphosphorus $(C_6H_5)_3P$ (Triphenylphosphine)	356 (180) (oc)					9.0	711 (377)	No	2	0	1	0
	Note: Melting point 176 (80)											

3W

ated extinguishing agents.

Tripropylamine $(CH_3CH_2CH_2)_3N$	105 (41) (oc)				0.8	4.9	313 (156)	Very slight		2	2	0

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Tripropylene C_9H_{18} (Propylene Trimer)	75 (24) (oc)				0.7	4.35	271–288 (133–142)		1	0	3	0
Tripropylene Glycol $H(OC_3H_6)_3OH$	285 (141)				1.0+		514 (268)	Yes	2	0	1	0
Tripropylene Glycol Methyl Ether $HO(C_3H_6O)_2C_3H_6OCH_3$	250 (121)				0.97	7.12	470 (243)			0	1	0
Tris (2-Ethylhexyl) Phosphite	See Trioctyl Phosphite.											
Tung Oil (China Wood Oil)	552 (289) Note: Melting point 88 (31).	855 (457)			0.9			No	2	0	1	0
Turbine Oil	See Lubricating Oil, Turbine.											
Turbo Fuels	See Jet Fuels.											
Turkey Red Oil	476 (247)	833 (445)			1.0−			Yes	2 5	0	1	0
Turpentine	95 (35)	488 (253)	0.8		<1		300 (149)	No	1	1	3	0
Ultrasene (Kerosene, Deodorized)	175 (79)							No		1	2	0
Undecane	See Hendecane.											
2-Undecanol $C_4H_9CH(C_2H_5)C_2H_4$- $CH(OH)CH_3$	235 (113) (oc)				0.8		437 (225)	No	2	1	1	0
Unsymmetrical Dimethyl-hydrazine	See 1,1-Dimethylhydrazine.											
Valeraldehyde $CH_3(CH_2)_3CHO$ (Pentanal)	54 (12) (oc)	432 (222)			0.8	3.0	217 (103)	No	1	1	3	0
Valeric Acid	See Pentanoic Acid.											
Vinyl Acetate CH_2:$CHOOCCH_3$ (Ethenyl Ethanoate)	18 (−8) Note: Polymerizes. See Hazardous Chemicals Data.	756 (402)	2.6	13.4	0.9	3.0	161 (72)	Slight	1 5	2	3	2
Vinylaceto-β-Lactone	See Diketene.											
Vinyl Acetylene CH_2:CHC:CH (1-Buten-3-yne)			21	100 Spont. decomposition	0.68 @1.7 atm	1.80	41 (5)			2	4	3
Vinyl Allyl Ether CH_2:$CHOCH_2CH_2O$- $(CH_2)_3CH_3$ (Allyl Vinyl Ether)	<68 (<20) (oc)				0.8		153 (67)	Very slight	1	2	3	2
Vinylbenzene	See Styrene.											
Vinylbenzylchloride $ClCH_2C_6H_4CH$:CH_2	220 (104) (oc)				1.1		444 (229)	No	2	2	1	
Vinyl Bromide	None	986 (530)	9	15	1.5	3.7	60 (15.8)	No		2	0	1
Vinyl Butyl Ether CH_2:$CHOC_4H_9$ (Butyl Vinyl Ether)	15 (−9) (oc)	437 (255)			0.8	3.5	202 (94)	Slight	1 5	2	3	2
Vinyl Butyrate CH_2:$CHOCOC_3H_7$	68 (20)		1.4	8.8	0.9	4.0	242 (117)	Slight	1 5	2	3	2
(2-Chloroethyl Vinyl Ether)	(oc)											2
Vinyl Chloride CH_2CHCl (Chloroethylene)	−108.4 (−78) (oc) Note: Polymerizes. See Hazardous Chemicals Data.	882 (472)	3.6	33.0	.91	2.2	7 (−14)	No	6	2	4	2

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Vinyl Crotonate $CH_2{:}CHOCOCH{:}CHCH_3$	78 (26) (oc)				0.9	4.0	273 (134)	Slight	1 5	2	3	2
Vinyl Cyanide	See Acrylonitrile.											
4-Vinyl Cyclohexene C_8H_{12}	61 (16)	517 (269)			0.8	3.7	266 (130)		1	0	3	2
Vinyl Ether	See Divinyl Ether.											
Vinyl Ethyl Alcohol $CH_2{:}CH(CH_2)_2OH$ (3-Buten-1-ol)	100 (38)		4.7	34	0.84	2.49	233 (112)	Yes		0	2	0
Vinylethylene Oxide	See Butadiene Monoxide.											
Vinyl Ethyl Ether $CH_2{:}CHOC_2H_5$ (Ethyl Vinyl Ether)	< −50 (< −46)	395 (202)	1.7	28	0.8	2.5	96 (36)	No	1 5	2	4	2
Vinyl 2-Ethylhexoate $CH_2{:}CHOCOCH(C_2H_5)C_4H_9$	165 (74) (oc)				0.9	6.0	365 (185)	No		2	2	2
Vinyl 2-Ethylhexyl Ether $C_{10}H_{20}O$ (2-Ethylhexyl Vinyl Ether)	135 (57) (oc)	395 (202)			0.8	5.4	352 (178)	Slight	5	2	2	2
2-Vinyl-5-Ethylpyridine $N{:}C(CH{:}CH_2)CH{:}CH$- $C(C_2H_5){:}CH$	200 (93) (oc)				0.9		248 (120) @ 50 mm	No		2	2	2
Vinyl Fluoride $CH_2{:}CHF$	Gas		2.6	21.7			−97.5 (−72)	Slight	6	1	4	2
Vinylidene Chloride $CH_2{:}CCl_2$ (1,1-Dichloroethylene)	−19 (−28) Note: Polymerizes. See Hazardous Chemicals Data.	1058 (570)	6.5	15.5	1.2	3.4	89 (32)	No	4	2	4	2
Vinylidene Fluoride $CH_2{:}CF_2$	Gas		5.5	21.3			−122.3 (−86)	Slight	6	1	4	2
Vinyl Isobutyl Ether $CH_2{:}CHOCH_2CH(CH_3)CH_3$ (Isobutyl Vinyl Ether)	15 (−9)				0.8	3.5	182 (83)	Slight	1 5	2	3	2
Vinyl Isooctyl Ether $CH_2{:}CHO(CH_2)_5CH(CH_3)_2$ (Isooctyl Vinyl Ether)	140 (60)				0.8	5.4	347 (175)	No		1	2	0
Vinyl Isopropyl Ether $CH_2{:}CHOCH(CH_3)_2$ (Isopropyl Vinyl Ether)	−26 (−32)	522 (272)				3.0	133 (56)		1 5	2	4	2
Vinyl 2-Methoxyethyl Ether $CH_2{:}CHOC_2H_4OCH_3$ (1-Methoxy-2-Vinyloxy-ethane)	64 (18) (oc)				0.90	3.52	228 (109)			0	3	0
Vinyl Methyl Ether $CH_2{:}CHOCH_3$ (Methyl Vinyl Ether)	Gas	549 (287)				2.0	43 (6)	Slight	6	2	4	2
Vinyl Octadecyl Ether $CH_2{:}CHO(CH_2)_{17}CH_3$ (Octadecyl Vinyl Ether)	350 (177) Note: Melting point 82.4 (28).				0.8		297–369 (147–187) @ 5 mm	No	2	0	1	0
Vinyl Propionate $CH_2{:}CHOCOC_2H_5$	34 (1) (oc)				0.9	3.3	203 (95)	Slight	1 5	2	3	2
1-Vinylpyrrolidone $CH_2{:}CHNCOCH_2CH_2CH_2$	209 (98) (oc)				1.0+	3.8	205 (96) @ 14 mm	Yes	5	0	1	0

Vinyl Toluene $CH_3C_6H_4CH{:}CH_2$	127 (53) Note: See Hazardous Chemicals Data.	1000 (538)	0.8	11.0	0.9	4.08	334 (168)	No	[illegible]	[illegible]	[illegible]	2
Vinyl Trichlorosilane $CH_2{:}CHSiCl_3$	70 (21) (oc)				1.3	5.61	195 (91)		1	3	3	2W

	FLASH POINT °F (°C)	IGNITION TEMP. °F (°C)	FLAMMABLE LIMITS Percent by Vol. Lower	Upper	Sp. Gr. (Water = 1)	Vapor Density (Air = 1)	BOILING POINT °F (°C)	Water Soluble	SEE INTRODUCTION FOR SUGGESTED EXTINGUISHING METHODS	HAZARD IDENTIFICATION Health	Flamma-bility	Reac-tivity
Water Gas	See Gas.											
Wax, Microcrystalline	>400 (>204)				0.9				2	0	1	0
Wax, Ozocerite (Mineral Wax)	236 (113)				0.9			No	2	0	1	0
Wax, Paraffin	390 (199) Note: Melting point 120–167 (49–75).	473 (245)			0.9		>700 (>371)	No	2	0	1	0
Whale Oil	446 (230)	800 (427)			0.9			No	2	0	1	0
Whiskey	See Ethyl Alcohol and Water.											
White Tar	See Naphthalene.											
Wines Sherry and Port High	See Ethyl Alcohol and Water.											
Wood Alcohol	See Methyl Alcohol.											
Wood Tar Oil	See Pine Tar Oil.											
Wool Grease	See Lanolin.											
m-Xylene $C_6H_4(CH_3)_2$ (1,3-Dimethylbenzene)	81 (27) Note: See Hazardous Chemicals Data.	982 (527)	1.1	7.0	0.9	3.7	282 (139)	No	1	2	3	0
o-Xylene $C_6H_4(CH_3)_2$ (1,2-Dimethylbenzene) (o-Xylol)	90 (32) Note: See Hazardous Chemicals Data.	867 (463)	0.9	6.7	0.9	3.7	292 (144)	No	1	2	3	0
p-Xylene $C_6H_4(CH_3)_2$ (1,4-Dimethylbenzene)	81 (27) Note: See Hazardous Chemicals Data.	984 (528)	1.1	7.0	0.9	3.7	281 (138)	No	1	2	3	0
o-Xylidine $C_6H_3(CH_3)_2NH_2$ (o-Dimethylaniline)	206 (97) Note: See Hazardous Chemicals Data.		1.0		1.0–		435 (224)	No		3	1	0
o-Xylol	See o-Xylene.											
Zinc Diethyl	See Diethylzinc.											
Zinc Stearate $Zn_{18}H_{35}O_2$	530 (277) (oc)	788 (420)			1.1					0	1	0

1993 Edition

This edition of NFPA 326, *Standard Procedures for the Safe Entry of Underground Storage Tanks*, was prepared by the Technical Committee on Tank Leakage and Repair Safeguards, released by the Correlating Committee on Flammable Liquids, 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.

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

Origin and Development of NFPA 326

The text of this standard was originally intended as amendments to NFPA 327, *Standard Procedures for Cleaning or Safeguarding Small Tanks and Containers Without Entry*, and would have expanded the scope of NFPA 327 to those situations in which tank cleaning or repair required that personnel gain entry to the tank. Recognizing the likely conflict that would result, the Committee decided that a separate standard would be desirable. An initial draft of NFPA 326, based on the existing text of NFPA 327, was developed by a Task Group of the Committee in January of 1990. This draft was revised several times over the following two years, during which time appropriate changes were also made to the text of NFPA 327.

The text of this first edition of NFPA 326 was adopted in 1993.

Committee on Flammable Liquids

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Committee Scope: To direct the activities of the Technical Committees assigned to it which have primary responsibility for the development and revision of NFPA codes, standards, recommended practices and manuals pertaining to the storage, transportation, handling, and use of flammable and combustible liquids.

Technical Committee on Tank Leakage and Repair Safeguards

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Committee Scope: This Committee shall have primary responsibility for documents on the criteria for safeguarding against the fire and explosion hazards associated with cleaning and repair of tanks and containers that contained flammable or combustible liquids; safe entry into tanks and similar enclosures that contain or have contained flammable or combustible liquids; methods for detecting, controlling, and removing underground leakage; methods for controlling flammable and combustible liquids and gases found in manholes, sewers, vaults and similar underground structures.

NFPA 326
Standard Procedures for the
Safe Entry of Underground Storage Tanks

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 Provisions

1-1 Scope.

1-1.1

These standard procedures shall apply to the entry of underground storage tanks, operating at nominal atmospheric pressure, that have contained flammable or combustible liquids, and that might contain flammable or combustible vapors or residues.

1-1.2

These procedures shall not apply to aboveground tanks that are entered; underground tanks that have been removed from the ground; tank vehicles or tank cars; tanks, bunkers, or compartments on ships or barges; gas plant equipment or gas distribution systems for natural or manufactured gas; or compressed and liquefied gas cylinders. Procedures for making some of these vessels safe are covered separately in the following publications:

(a) AGA, *Purging Principles and Practices*

(b) ANSI Z117.1, *American National Standard Safety Requirements for Confined Spaces*

(c) API 1631, *Interior Lining of Underground Storage Tanks*

(d) API 2013, *Cleaning Mobile Tanks in Flammable or Combustible Liquid Service*

(e) API 2015, *Safe Entry and Cleaning of Petroleum Storage Tanks*

(f) NFPA 306, *Standard for the Control of Gas Hazards on Vessels*

(g) NLPA 631, *Entry, Cleaning, Interior Inspection, Repair, and Lining of Underground Storage Tanks*

(h) OSHA, *Code of Federal Regulations*, Title 29, Part 1910.146, "Permit-Required Confined Spaces."

1-1.3*

These procedures shall not apply to tanks that are protected with an inert atmosphere. Providing and working in an inert atmosphere requires special safety procedures that shall not be covered by this standard. (*See API 2217A, Guidelines for Work in Inert Confined Spaces in the Petroleum Industry*.)

1-1.4

This standard shall not apply to the procedures that might be required to safely work on or repair an underground tank.

1-2 Purpose.

The purpose of this standard is to provide procedures for the safe excavation, opening, entry, cleaning, and closure of an underground storage tank that contained flammable or combustible vapors, gases, liquids, or solids.

1-3 Definitions.

For the purpose of this standard, the following terms shall have the meanings given below.

Bonding. The electrical interconnection (metallic bond wire or metal-to-metal contact) between two conductors that would otherwise be electrically isolated from each other.

Combustible Gas Indicator. A device capable of detecting, measuring, and monitoring the concentration in the atmosphere of the gas or vapor for which the indicator is calibrated.

Flammable Gas. Any substance that exists in the gaseous state at normal atmospheric temperature and pressure and that is capable of being ignited and burned when mixed with the proper proportions of air, oxygen, or other oxidizer.

Hazardous Work. Any work that involves any source of ignition, including open flames, cutting and welding, sparking of electrical equipment, grinding, buffing, drilling, chipping, sawing, or other similar operations that might create hot metal sparks or surfaces from friction or impact.

Inert Gas. Any gas that is nonflammable, nonreactive, and noncontaminating for the use intended.

Inerting. A technique by which a combustible mixture is rendered nonignitible by the addition of an inert gas.

Liquid. Any material that has a fluidity greater than that of 300 penetration asphalt when tested in accordance with ASTM D5, *Standard Test Method for Penetration of Bituminous Materials*. Where not otherwise identified, the term “liquid” shall mean both flammable and combustible liquids.

(a) *Combustible Liquid.* A liquid having a closed-cup flash point at or above 100°F (37.8°C). Combustible liquids shall be subdivided as follows:

1. Class II liquids shall include those liquids having closed-cup flash points at or above 100°F (37.8°C) and below 140°F (60°C).

2. Class IIIA liquids shall include those liquids having closed-cup flash points at or above 140°F (60°C) and below 200°F (93.4°C).

3. Class IIIB liquids shall include those liquids having flash points above 200°F (93.4°C).

(b) *Flammable Liquid.* A liquid having a closed-cup flash point below 100°F (37.8°C) and having a Reid vapor pressure not exceeding 40 psia (2068.8 mm Hg) at 100°F (37.8°C), as determined by ASTM D323, *Standard Test Method for Vapor Pressure of Petroleum Products (Reid Method)*. Flammable liquids shall be subdivided as follows:

1. Class IA liquids shall include those liquids having closed-cup flash points below 73°F (22.8°C) and boiling points below 100°F (37.8°C).

2. Class IB liquids shall include those liquids having closed-cup flash points below 73°F (22.8°C) and boiling points at or above 100°F (37.8°C).

3. Class IC liquids shall include those liquids having closed-cup flash points at or above 73°F (22.8°C).

Lower Flammable Limit. The minimum concentration of vapor in air at which propagation of a flame does not occur on contact with a source of ignition.

Oxygen Monitor. A device capable of detecting, measuring, and monitoring concentrations of oxygen in the atmosphere.

Purging. The process of displacing the flammable vapors from an enclosure or confined space.

Qualified Person. A person designated in writing as being capable, by education or specialized training, of performing specified tasks; of recognizing the potential hazards of those tasks; of recognizing any other unsafe conditions in a confined space; of specifying the necessary control and protective action to ensure worker safety; and who is knowledgeable of the procedures described in this standard.

Self-Contained Breathing Apparatus. A portable respiratory device designed to protect the wearer from an oxygen-deficient or other hazardous atmosphere. It supplies a respirable atmosphere that is either carried on, in, or generated by the apparatus and is independent of the ambient environment. It is equipped with a full-face mask and is approved by the U.S. Mine Safety and Health Administration and the National Institute for Occupational Safety and Health.

Standby Person. A person trained in emergency rescue procedures and who is assigned to remain on the outside of the confined space and to be in communication with those working inside.

Static Electricity. The electrification of materials through physical contact and separation and the various effects that result from the positive and negative charges so formed, particularly where they constitute a fire or explosion hazard.

Unstable (Reactive) Liquid. A liquid that, in the pure state or as commercially produced or transported, will vigorously polymerize, decompose, condense; or will become self-reactive under conditions of shock, pressure, or temperature.

Chapter 2 Basic Precautions

2-1 General.

Work on tanks that have held liquids shall be performed only by personnel who understand the fire and explosion potential of the liquids and their residues. All personnel shall be sufficiently skilled to safely carry out the necessary operations. The characteristics of the previous contents of the tank shall be determined.

2-1.1

The contractor or the person or persons responsible for the tank entry procedure shall implement a confined space entry plan. (*See 3-6*.)

2-2 Ignition Concerns.

2-2.1

Prior to any work being performed, the site shall be safeguarded from all sources of ignition for a minimum distance of 25 ft (7.6 m) in all directions. Barricades and warning signs reading “FLAMMABLE - NO SMOKING” shall be provided and placed in accordance with the requirements of the authority having jurisdiction. The area shall then be tested for the presence of flammable or combustible gases, liquids, or vapors. The confirmed presence of flammable or combustible gases, liquids, or vapors shall require an extension of the 25-ft (7.6-m) minimum distance.

2-2.2

The characteristics of the previously contained material shall be determined. Tanks shall not be worked on until information concerning the specific hazards of that material has been obtained and safe procedures have been established. All compartments of a multicompartment tank and the annular (interstitial) space of a secondary containment-type tank shall be considered when these procedures are established.

2-2.3

Tank contents shall be vented to a safe location. Before work is started on tanks that might be under pressure, the pressure shall be reduced to atmospheric pressure.

2-2.4

Two portable fire extinguishers, each having a rating not less than 80 B:C, shall be provided on the site in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*.

2-2.5

A dependable method shall be available for notifying the fire department in the event of a fire or other emergency.

2-2.6

Adequate precautions shall be taken to prevent the accumulation and discharge of static electricity. (*See API 2003, Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents, and NFPA 77, Recommended Practice on Static Electricity*.)

2-2.7

Any electrical equipment used in the area described in Section 2-1 shall be suitable for Class I, Group D, Division 1 hazardous (classified) locations, as defined in NFPA 70, *National Electrical Code®*.

2-2.8

Any equipment capable of providing a source of ignition shall not be permitted within the vicinity of the tank until the tank and the area around the tank have been tested and found to be safe.

2-3 Safe Atmosphere.

To ensure a safe atmosphere within the tank, tests for flammable vapors shall be made with an appropriate combustible gas detector as follows:

(a) Immediately before entry or re-entry, and

(b) Immediately before beginning alterations or repairs, and

(c) Immediately before and during any welding, cutting, or heating operations, and

(d) Periodically during the course of the work.

All work shall be stopped immediately when the presence of flammable vapors exceeding 10 percent of the lower flammable limit is indicated. The source of the vapor release shall be located and removed.

Chapter 3 Tank Entry

3-1 Excavation.

If excavation is necessary to gain access to the top of the tank, the access pit shall be at least 4 ft × 4 ft (0.6 m × 0.6 m). Personnel shall be familiar with all applicable procedures such as those established by the U.S. Occupational Safety and Health Administration in 29 CFR 1926, Subpart P, "Excavations."

3-2 Preparation for Opening the Tank.

3-2.1

Before any work on the exterior surface of the tank begins, the tank shall be isolated. If the tank on which work is to be performed is equipped with a manifold vent, fill line, or siphon assembly, necessary measures shall be taken to isolate that tank from all other tanks. All product and vapor recovery piping shall be disconnected and blanked off. The vent for the tank being entered shall be isolated from vents of other tanks that might still be in service. A separate temporary vent for the tank being entered shall be provided, if necessary.

3-2.2

All electrical circuits supplying power to submerged pumps or other equipment connected to the tank shall be disconnected and locked out.

3-2.3

As much product, water, and sediment as possible shall be removed using explosion-proof or air-driven pumps. Pump motors and suction hoses shall be bonded to the tank to prevent static electricity ignition hazards. (*See API 2003, Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents, and NFPA 77, Recommended Practice on Static Electricity*.) A small quantity of water shall be permitted to be pumped into the tank through the tank gauge stick access line to float any remaining product from a low spot so that it can be pumped from the tank.

3-3 Displacement with Air.

3-3.1

The tank shall be thoroughly purged with air to remove flammable vapors. The concentration of flammable vapors in a tank might go through the flammable range before a safe atmosphere is obtained. Precautions shall be taken to eliminate the possibility of static electric discharge during gas-freeing procedures. (*See API 2003, Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents, and NFPA 77, Recommended Practice on Static Electricity. See also, NFPA 69, Standard on Explosion Prevention Systems*.)

3-3.2

Where purging the tank with air, the air pressure in the tank shall not exceed 5 psig (34.5 kPa). To prevent excess air pressure, the vent line shall be checked to make certain it is free of blockages, obstructions, or traps.

3-3.3

Displacement of the tank atmosphere with air shall be accomplished by one of the following methods:

3-3.3.1 An eductor air mover, preferably driven by compressed air. The eductor shall be air-tight and attached to the fill connection. Where using this method on tanks with fill (drop) tubes, the tube shall remain in place to ensure that vapors are drawn from the bottom of the tank. An extension shall be used to discharge vapors a minimum of 12 ft (3.7 m) above grade and away from any areas that might contain sources of ignition. The eductor shall be properly bonded to prevent the generation of static electric charges.

3-3.3.2 A diffused airblower. Fill (drop) tubes shall be removed to enhance diffusion of air into the tank. The air shall be supplied from a compressor that has been checked to ensure delivery of clean air that is free of volatile vapors. The air pressure in the tank shall not exceed 5 psig (34.5 kPa). The air-diffusing pipe shall be properly bonded to prevent the generation of static electric charges.

3-3.4

Where access must be gained to a tank that is located indoors or in a confined area, such as under a building, ventilation shall be sufficient to prevent the accumulation of flammable vapors.

3-4 Testing for Flammable Vapors.

3-4.1

During tank excavation, tank opening, and tank entry, tests shall be conducted to determine the concentration of flammable vapors in the excavated area and in the tank. Vapor concentrations shall not exceed 10 percent of the lower flammable limit. Tests shall be made with a combustible gas indicator that has been properly calibrated using hexane in air and thoroughly checked and maintained in accordance with the manufacturer’s instructions.

3-4.2

Persons responsible for testing shall be trained in the use of the instrument, interpretations of its readings, and its limitations.

3-4.3

Where purging is being performed by an eductor air mover, the eductor shall create a vacuum that draws air through at least one tank opening and discharges through another opening. Testing for flammable vapors shall be conducted with a combustible gas indicator with its probe inserted into the probe hole provided in the side of the eductor. Testing for flammable vapor concentrations shall be performed with the eductor on and tightly secured to the tank’s fill tube. Readings of 10 percent or less of the lower flammable limit shall be obtained before the tank shall be considered safe for opening.

3-4.4

Where purging is being performed by an air blower, the blower shall force air into the tank through at least one tank opening and discharge through the vent line opening. Testing for flammable vapor concentrations shall be performed with a combustible gas indicator whose probe is placed in the tank’s vent line. When readings of 10 percent or less of the lower flammable limit are obtained, the air blower shall be shut off. Readings shall be taken at the bottom, middle, and upper portions of the tank. The instrument shall be purged with fresh air after each reading. If readings in the tank are taken through the fill line, the fill tube shall be removed. The air blower shall be immediately turned on after the last test in the tank, and the tank's vent line shall be tested thereafter. Readings of 10 percent or less of the lower flammable limit shall be obtained in the bottom, middle, and upper portion of the tank and in the vent line before the tank shall be considered safe for opening.

3-5 Opening the Tank.

3-5.1

Purging, displacement with air, and testing shall continue while personnel are working on or in the tank. Personnel shall never enter a tank without first testing for adequate ventilation. Ventilation shall be continuous while personnel are in the tank. No cutting torch or other flame-producing equipment shall be used for cutting into a tank.

3-5.2 Steel Tanks.

If a manway exists, the bolts and lid shall be removed. If no manway exists, an opening having a minimum dimension of either 18 in. × 18 in. (46 cm × 46 cm) or 24 in. (61 cm) in diameter shall be cut in the top of the tank. The section to be removed shall be marked with chalk, and a hole shall be drilled with an air-driven drill at one corner of the section using lubricated cutting oil to reduce friction, heat, and possible sparks. After the hole is drilled, the tank vapors shall again be tested by inserting the meter probe at least 24 in. (61 cm) into the drilled hole to verify that the vapor concentration in the tank does not exceed 10 percent of the lower flammable limit before cutting the access opening.

3-5.3 Fiberglass Tanks.

If no manway exists, an opening having a minimum dimension of 18 in. × 18 in. (46 cm × 46 cm) and maximum dimension of 24 in. × 24 in. (61 cm × 61 cm) shall be cut through the end cap. The first cut shall be made at least 5 in. (14.5 cm) and no more than 12 in. (30.5 cm) from any rib. The opening shall be bevel cut to prevent it from falling through when it is replaced.

3-5.4

The tank shall be cut using an air-driven saber saw or snipper, using lubricated cutting oil to reduce friction and heat and to prevent possible sparks. Prior to the final cut, the plate shall be supported to prevent its falling into the tank.

3-6 Tank Entry.

3-6.1 Pre-entry Procedures.

Before entering tanks, personnel, including the standby person specified in 3-6.3, shall be familiar with the applicable procedures described in API 2015, *Safe Entry and Cleaning of Petroleum Storage Tanks*; API 2217, *Guidelines for Confined Space Work in the Petroleum Industry*; ANSI Z117.1, *American National Standard Safety Requirements for Confined Spaces*; NIOSH *Criteria for a Recommended Standard for Working in Confined Spaces*; and the OSHA *Code of Federal Regulations*, Title 29, Part 1910.126, "Permit-Required Confined Spaces," whichever are applicable.

3-6.2

Immediately prior to entry or re-entry of a tank, the atmosphere shall be tested and monitored as follows:

3-6.2.1 The oxygen content inside the tank shall be monitored with a properly calibrated oxygen analyzer.

3-6.2.2 The concentration of flammable vapors shall not exceed 10 percent of the lower flammable limit and shall be monitored with a properly calibrated combustible gas indicator.

3-6.2.3 Any other hazards that have been identified for the material(s) previously stored shall be appropriately monitored.

3-6.3

Personnel entering a tank shall be equipped with positive-pressure air-supplied equipment with full-face enclosure and a safety harness connected to a safety line tied off and held by a standby person outside the tank.

3-6.4

Protective clothing that is impervious to the stored product shall be required. Protective clothing shall cover the arms, legs, torso, and head. Clothing that becomes saturated with the stored product shall be removed immediately.

3-6.5 Post-entry Procedures.

Tests shall be performed continuously in the tank to ascertain that the tank vapors are 10 percent or less of the lower flammable limit and that oxygen levels are maintained at a minimum level of 19.5 percent. If the tank is perforated, product or vapors that have leaked into the soil might re-enter the tank through the perforation. If this condition exists, additional precautions might be necessary.

3-6.6

The vent line shall remain clear and unobstructed to allow continuous ventilation. All other lines and openings shall be plugged or capped off to ensure that no liquids or vapors can enter the tank.

3-7 Sludge Removal.

Sludge accumulation on the bottom of the tank shall be removed and placed in approved containers. Removal of sludge shall include removing all visible moisture and liquids with the use of an absorbent material and broom sweeping. During and after sludge removal, ventilation shall be continued to remove any vapors that might be generated.

Chapter 4 Precautions Prior to Hazardous Work

4-1

Tanks shall be cleaned thoroughly to ensure that there are no flammable materials present and that there are no substances such as greases, tars, or other materials that when subjected to heat might produce flammable vapors. Any of the following shall be permitted to be used:

(a) Sandblasting

(b) Low-pressure water (triple rinse)

(c) High-pressure waterblasting [25,000 to 40,000 psi (172,250 to 275,600 kPa)]

(d) High-pressure steam

(e) Special cleaning agents (solvents, degreasers, or emulsifiers).

CAUTION: Steam cleaning, use of special cleaning agents, or high-pressure waterblasting might result in the generation of static electric charges. See Section 4.7.2 of API 2015, *Safe Entry and Cleaning of Petroleum Storage Tanks*, for appropriate safeguards.

Chapter 5 Closing the Tank Access Opening

5-1

If an access opening has been cut into the tank, the opening shall be sealed, either temporarily or permanently, depending on the disposition of the tank. (*See API 1631, Interior Lining of Underground Storage Tanks, and NLPA 631, Entry, Cleaning, Interior Inspection, Repair, and Lining of Underground Storage Tanks*.)

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*, 1990 edition.

NFPA 70, *National Electrical Code*, 1993 edition.

6-1.2 Other Publications.

6-1.2.1 ANSI Publication. American National Standards Institute, 1430 Broadway, New York, NY 10018.

ANSI Z117.1-1989, *American National Standard Safety Requirements for Confined Spaces*.

6-1.2.2 API Publications. American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005.

API 2015-1991, *Safe Entry and Cleaning of Petroleum Storage Tanks*.

API 2217-1984, *Guidelines for Confined Space Work in the Petroleum Industry*.

6-1.2.3 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM D5-1986, *Standard Test Method for Penetration of Bituminous Materials*.

ASTM D323-1990, *Standard Test Method for Vapor Pressure of Petroleum Products (Reid Method)*.

6-1.2.4 U.S. Government Publications. U.S. Government Printing Office, Superintendent of Documents, Washington, DC 20402.

NIOSH *Criteria for a Recommended Standard for Working in Confined Spaces*.

OSHA, *Code of Federal Regulations*, Title 29, Part 1910.146, "Permit-Required Confined Spaces."

OSHA, *Code of Federal Regulations*, Title 29, Part 1926, Subpart P, "Excavations."

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-1-1.3

Situations might occur in which it is not possible to achieve or maintain a safe atmosphere within a tank, as described in this standard. In such situations, it may be necessary to provide an inert atmosphere inside the tank, usually by using nitrogen or carbon dioxide.

Appendix B Referenced Publications

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

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 69, *Standard on Explosion Prevention Systems*, 1992 edition.

NFPA 77, *Recommended Practice on Static Electricity*, 1993 edition.

NFPA 306, *Standard for the Control of Gas Hazards on Vessels*, 1993 edition.

NFPA 327, *Standard Procedures for Cleaning or Safeguarding Small Tanks and Containers Without Entry*, 1993 edition.

B-1.2 Other Publications.

B-1.2.1 AGA Publication. American Gas Association, 1515 Wilson Boulevard, Alexandria, VA 22209.

Purging Principles and Practices, 2nd edition.

B-1.2.2 API Publications. American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005.

API 1631-1992, *Interior Lining of Underground Storage Tanks*.

API 2003-1991, *Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents*.

API 2013-1991, *Cleaning Mobile Tanks in Flammable or Combustible Liquid Service*.

API 2217A-1987, *Guidelines for Work in Inert Confined Spaces in the Petroleum Industry*.

B-1.2.3 NLPA Publication. National Leak Prevention Association, 7685 Fields Ertel Road, Cincinnati, OH 45241.

NLPA 631-1991, *Entry, Cleaning, Interior Inspection, Repair, and Lining of Underground Storage Tanks*.

NFPA 327

1993 Edition

Standard Procedures for Cleaning or Safeguarding Small Tanks and Containers Without Entry

1993 Edition

This edition of NFPA 327, *Standard Procedures for Cleaning or Safeguarding Small Tanks and Containers Without Entry*, was prepared by the Technical Committee on Tank Leakage and Repair Safeguards, released by the Correlating Committee on Flammable Liquids, 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 327

This standard originated as the “Suggested Good Practice for Freeing Fuel Oil and Other Oil Tanks at Refineries, Tank Farms, Distilleries, and Other Industrial Plants of Flammable and Explosive Vapors Previous to Entering for Making Repairs or Other Purposes.” The original document was adopted by the Association in 1922 and appeared only in the Proceedings of that year's Annual Meeting.

Eventually, this suggested good practice was rewritten into a standard, NFPA 327, *Standard Procedures for Cleaning or Safeguarding Small Tanks and Containers*. The first edition of NFPA 327 was adopted in 1957, with further amendments adopted in 1962 and 1964. It was reconfirmed in 1970 and further revised in 1975, 1982, 1987, and 1993.

With the simultaneous adoption of NFPA 326, *Standard Procedures for the Safe Entry of Underground Storage Tanks*, the scope of the 1993 edition of NFPA 327 has been limited to those tanks or containers that cannot be entered or that are not entered during cleaning or safeguarding. This edition has been further revised to comply with the NFPA *Manual of Style*.

Committee on Flammable Liquids

Correlating Committee

Leon C. Schaller, *Chair*
The DuPont Company, DE

Robert P. Benedetti, *Secretary*
National Fire Protection Assn., MA
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Byron L. Briese, Professional Loss Control, Inc., TN

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Edward Hildebrandt, Village of Morton Grove, IL
Rep. Illinois Fire Inspectors Assn.

C. L. Kingsbaker, Atlanta, GA

Steven Landon, Trophy Club, TX

Joyce A. Rizzo, Lexicon Environmental Assoc., Inc., PA

Eugene S. Schmitt, Dept. of State Police, MI

Peter J. Gore Willse, Industrial Risk Insurers, CT

Committee Scope: To direct the activities of the Technical Committees assigned to it which have primary responsibility for the development and revision of NFPA codes, standards, recommended practices and manuals pertaining to the storage, transportation, handling, and use of flammable and combustible liquids.

Technical Committee on Tank Leakage and Repair Safeguards

Joyce A. Rizzo, *Chair*

Lexicon Environmental Assoc., Inc., PA

Barry L. Bedaw, Entek Environmental & Tech Services Inc., NY

Jon V. Brannan, Underwriters Laboratories Inc., IL

William C. Conklin, WCC Tank Technology, Inc., NY

Donald W. Fleischer, Veeder-Root Co., CT

Wayne Geyer, Steel Tank Inst., IL

Donald M. Johnson, Walnut Creek, CA
Rep. Western States Petroleum Assn.

Kenneth D. Lattimer, Star Enterprise (Texaco), GA
Rep. NFPA Industrial Fire Protection Section

George S. Lomax, Health Consultants Inc., PA
Rep. Int'l Assn. of Tank Testing Professionals

Paul I. Meli, Bridgeport Chemical Corp., FL

Henry L. Politi, Tanknology Corp. Int'l, FL
Rep. Leak Detection Technology Assn.

William J. Purpora, Protanic Inc., WI

Vernon Ray, Texas Commission of Fire Protection, TX

Frank P. Reisenauer, F. K. Fire Safety Consultants, WI

Robert N. Renkes, Petroleum Equipment Inst., OK

James R. Rocco, B. P. Oil Company, OH
Rep. American Petroleum Inst.

Thomas Schruben, Reliance Reinsurance Corp., PA

Todd G. Schwendeman, Groundwater Technology Inc., NY

Bruce R. Sharp, Armor Shield Inc., OH

Robert P. Siegel, 3M Co., MN

Alternate

Tony Rieck, Armor Shield Inc., OH

(Alt. to B. R. Sharp)

Robert P. Benedetti, 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 criteria for safeguarding against the fire and explosion hazards associated with cleaning and repair of tanks and containers that contained flammable or combustible liquids; safe entry into tanks and similar enclosures that contain or have contained flammable or combustible liquids; methods for detecting, controlling, and removing underground leakage; methods for controlling flammable and combustible liquids and gases found in manholes, sewers, vaults and similar underground structures.

NFPA 327
Standard Procedures for Cleaning or Safeguarding Small Tanks and Containers Without Entry

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 and Appendix B.

Foreword

Since the federal Environmental Protection Agency developed regulations for underground storage tanks, many tank owners have chosen to remove their tanks for disposal elsewhere. Unfortunately, in some instances, fatalities have resulted from careless practices associated with this task.

Incidents have occurred because of neglect during cleaning operations, safeguarding operations, and transporting of the tank. Explosions and injuries have also resulted from carelessness during removal, tank repair, scrapping, or disposal. Proper cleaning and continual verification of a safe atmosphere are prudent operations designed to avoid such needless tragedies.

These procedures are intended for cleaning of small tanks or containers that are not entered, that have contained flammable or combustible liquids, and that might contain flammable or combustible vapors or residues. The use of the word “small” has been historically interpreted in two distinct ways:

1. Tanks too small for human entry
2. Any tank capacity that can be effectively and safely cleaned without human entry.

A critical concern is the maximum tank capacity capable of effectively being cleaned without entry. Industry experts have noted that most fatalities have resulted when working on tanks larger than 42 in. in diameter or in least dimension, without entry, suggesting that larger tanks, where not entered, are riskier to clean and safeguard than smaller tanks. The Committee on Tank

Leakage and Repair Safeguards has tried to address the issue of tank size but has been unable to form a definitive conclusion as to its effect on safety.

Some fatalities have simply resulted from careless practices that ignored the standard procedures set forth in NFPA 327. However, this fact in itself suggests that extreme caution must be used when safeguarding tanks without entry, even where entry is not restricted by size.

In addition, a standard procedure has been developed in NFPA 326, *Standard Procedures for the Safe Entry of Underground Storage Tanks*, to address storage tanks that remain underground. A tank that is made safe enough to permit a wide range of ensuing work (i.e., lining, repairs, abrasive blasting, etc.) while underground will also eliminate or reduce risks to public safety after the tank has been removed from the ground. In all situations, the internal underground storage tank atmosphere must be checked continually and a safe atmosphere maintained.

Chapter 1 General Provisions

1-1 Scope.

These procedures shall apply only to the cleaning or safeguarding of small tanks or containers that are not entered, that have contained flammable or combustible liquids, and that might contain flammable or combustible vapors or residues.

These procedures shall not apply to the cleaning or safeguarding of tanks that are entered; tank vehicles or tank cars; tanks, bunkers, or compartments on ships or barges; gas plant equipment or gas distribution systems for natural or manufactured gas; or compressed and liquefied gas cylinders. Procedures for cleaning or safeguarding some of these tanks are covered separately in the following publications:

(a) AGA, *Purging Principles and Practices*

(b) ANSI Z117.1, *American National Standard Safety Requirements for Confined Spaces*

(c) API 1631, *Interior Lining of Underground Storage Tanks*

(d) API 2013, *Cleaning Mobile Tanks in Flammable or Combustible Liquid Service*

(e) API 2015, *Safe Entry and Cleaning of Petroleum Storage Tanks*

(f) NFPA 306, *Standard for the Control of Gas Hazards on Vessels*

(g) NFPA 326, *Standard Procedures for the Safe Entry of Underground Storage Tanks*

(h) NLPA 631, *Entry, Cleaning, Interior Inspection, Repair and Lining of Underground Storage Tanks*

(i) OSHA, *Code of Federal Regulations*, Title 29, Part 1910.146, "Permit-Required Confined Spaces."

1-2 Purpose.

The procedures described herein address the safe removal of flammable vapors, liquids, gases, or solids from small tanks, drums, or other containers, and safeguarding these vessels by other means. Such procedures are to permit hazardous work (welding or cutting) or other work that might create a potential fire or explosion hazard and, where necessary, for change of service or where desired for any other purpose.

1-3 Definitions.

For the purpose of this standard, the following definitions shall apply:

Bonding. The electrical interconnection (metallic bond wire or metal-to-metal contact) between two conductors that would otherwise be electrically isolated from each other.

Flammable Vapors. Any substance that exists in the gaseous state at normal atmospheric temperature and pressure and that is capable of being ignited and rapidly oxidized when mixed with proper proportions of air, oxygen, or other oxidizers.

Hazardous Work. Work involving a source of ignition that might include open flames, cutting, welding, sparking electrical equipment, grinding, buffing, drilling, chipping, sawing, or other similar operations that can create hot metal sparks or surfaces from friction or impact.

Inert Gas. Any gas that is nonflammable, nonreactive, and noncontaminating for the use intended.

Inerting. A technique by which a combustible mixture is rendered nonignitible by the addition of an inert gas.

Liquid. For the purpose of this standard, any material that has a fluidity greater than that of 300 penetration asphalt when tested in accordance with ASTM D5, *Test for Penetration for Bituminous Materials*. Where not otherwise identified, the term “liquid” shall mean both flammable and combustible liquids.

Combustible Liquid. A liquid having a closed-cup flash point at or above 100°F (37.8°C). Combustible liquids shall be subdivided as follows:

Class II liquids shall include those liquids having closed-cup flash points at or above 100°F (37.8°C) and below 140°F (60°C).

Class IIIA liquids shall include those liquids having closed-cup flash points at or above 140°F (60°C) and below 200°F (93.4°C).

Class IIIB liquids shall include those liquids having flash points above 200°F (93.4°C).

Flammable Liquid. A liquid having a closed-cup flash point below 100°F (37.8°C) and having a Reid vapor pressure not exceeding 40 psia (2068.8 mm Hg) at 100°F (37.8°C), as determined by ASTM D323, *Standard Method of Test for Vapor Pressure of Petroleum Products (Reid Method)*. Flammable liquids shall be subdivided as follows:

Class IA liquids shall include those liquids having closed-cup flash points below 73°F (22.8°C) and boiling points below 100°F (37.8°C).

Class IB liquids shall include those liquids having closed-cup flash points below 73°F (22.8°C) and boiling points at or above 100°F (37.8°C).

Class IC liquids shall include those liquids having closed-cup flash points at or above 73°F (22.8°C).

Purging. The process of displacing the flammable vapors from an enclosure.

Unstable (Reactive) Liquid. A liquid that, in the pure state or as commercially produced or transported, will vigorously polymerize, decompose, condense, or will become self-reactive under conditions of shock, pressure, or temperature.

1-4 Purpose and Extent of Cleaning.

The interior of and, in some cases, the exterior of small tanks and containers shall be permitted to be cleaned in preparation for hazardous work, change in tank or container service, or for other purposes.

1-4.1 Cleaning in Preparation for Hazardous Work.

Cleaning of a tank or container prior to hazardous work that might involve a potential source of ignition shall remove flammable vapors and liquid or solid residues that might release additional flammable vapors.

1-4.2 Cleaning for Change in Service.

Cleaning of a tank or container for change in service shall remove residues that could contaminate or be incompatible with new material in the tank or container. Selection of a cleaning procedure shall take into consideration the chemical nature and characteristics of the known or suspected contaminating material.

1-4.3 Cleaning for Other Purposes.

In some cases, where empty containers are to be transported or stored, it might be necessary to clean them. Selection of a cleaning procedure shall take into consideration the intended use of the container, chemical and physical properties of the new material to be stored, and the known or suspected contaminating material.

Chapter 2 General Precautions

2-1

Work on tanks or containers that have held liquids or gases shall be performed under the supervision of persons who understand the fire and explosion potential involved. Personnel shall be sufficiently skilled to safely carry out the operations necessary. The characteristics of the previous contents of the tank or container shall be determined.

2-1.1

Before cleaning work is started on tanks or containers that might be under pressure, the pressure shall be reduced to atmospheric. The contents of the tank or container shall be vented to a safe location.

2-1.2*

Information on cleaning tanks or containers that have held nitrocellulose, pyroxylin solutions, nitrates, chlorates, perchlorates, peroxides, and other materials that might contain enough oxygen to support combustion in an otherwise inerted atmosphere shall be obtained before cleaning operations are started.

2-1.3

Tanks or containers that have contained reactive or unstable materials shall not be cleaned until information is obtained on safe cleaning procedures. Special precautions shall be required for the selection of nonreactive cleaning materials.

2-1.4

The cleaning procedures selected from Chapter 3 shall establish and maintain a safe atmosphere within the tank or container. The atmosphere shall be compatible with the intended purpose of the tank or container cleaning operation.

2-1.5

After cleaning, the tank or container shall be inspected internally to determine the effectiveness of such cleaning. Special precautions shall be required. Such inspection shall be permitted to be made with the aid of a flashlight, with an internal inspection lamp approved for Class I, Division 1 hazardous locations, or with a mirror to reflect light into the container. (*See 3-4.2.6*.)

2-2

Any equipment that might provide a source of ignition shall not be permitted within the vicinity of a tank or container being cleaned until the area has been tested and found to be vapor free.

2-3*

To ensure a safe condition for hazardous work within, on, or near the tank or container, tests shall be made for flammable vapors, generally with the appropriate combustible gas indicator (1) before commencing alterations or repairs; (2) immediately before and after starting any welding, cutting, or heating operations; and (3) frequently during the course of the work. All work shall be stopped immediately if the concentration of flammable vapors exceeds 10 percent of the lower flammable limit. The source of the vapor release shall then be located and removed.

Chapter 3 Cleaning Procedures

3-1 General.

Cleaning operations shall be conducted in the open, if practical. Where indoor cleaning is necessary, ventilation shall be sufficient to prevent the accumulation of flammable vapors.

3-1.1

Sources of ignition shall be disconnected or removed from the vicinity of the tank or container before venting or cleaning operations are started.

3-1.2

Appropriate steps shall be taken to protect personnel from harmful exposure to toxic or corrosive vapors or gases.

3-1.3

The tank or container shall be emptied and drained of all contents. This shall include removal of liquids or gases from any internal piping, traps, and standpipes. If flushing is necessary, the proper cleaning liquid shall be used.

3-1.4

All piping and other connections to the tank or container being cleaned shall be disconnected, plugged, or blanked off. Reliance shall not be placed on valves to prevent flow of material unless a double-valve block and bleed arrangement is provided.

3-1.5

All liquids, rinseates, solid residues, and vapors that are generated as a result of these cleaning and safeguarding procedures shall be disposed of properly.

3-2 Removal of Flammable Vapors.

3-2.1 Displacement with Water.

Where the liquid or gas previously contained is known to be readily displaced by or easily soluble in water, it shall be permitted to be removed by completely filling the container with water and draining, repeating the operation several times. Under some circumstances, hot work shall be permitted to be performed on tanks or containers completely filled with water. Where this method is used, extreme care shall be taken to eliminate any vapor spaces by providing proper venting or by positioning of the container during the filling operation.

3-2.2 Displacement with Air.

Gas freeing shall be permitted to be accomplished by purging with air, and a safe atmosphere shall be permitted to be sustained by continuing the ventilation. Where openings of sufficient size are available, air movers that do not provide an ignition source shall be attached so that air is drawn through one opening and discharged through another opening. Where openings cannot accommodate an air mover, the container shall be purged by introducing air so that it will circulate through the tank or container and be discharged to the outside. Every precaution shall be taken to ensure that all ignition sources have been removed from the vicinity since the concentration of vapor in air in the tank or container might pass through the flammable range before a safe atmosphere is obtained. An effective bond shall be maintained between the air mover and the tank or container being cleaned.

3-2.3 Displacement with Inert Gas.

To minimize the hazards of passing through the flammable range, the tank or container shall be first purged with an inert gas and then ventilated with air.

3-2.4

Flammable vapors shall be permitted to be displaced by an adequate supply of steam in accordance with 3-4.1.

3-3 Inerting of Vapor Space.

If properly used, inerting shall be permitted as a means of safeguarding a container by reducing the oxygen content to the point where combustion cannot take place. However, individuals in direct charge of the work shall be thoroughly familiar with the limitations and characteristics of the inert gas being used. The oxygen content shall be maintained at substantially zero during the entire period that work is in progress. Attempting such work without proper knowledge or equipment can be hazardous, since it might create a false sense of security. Permissible inert gases commonly used are carbon dioxide and nitrogen. Both can be obtained in cylinders and in truck tanks. Carbon dioxide can also be obtained in solid form. Briefly, the procedures for inerting are specified in 3-3.1 through 3-3.7.

3-3.1

All openings in the tanks or containers shall be closed, with the exception of the filling connection and vent.

3-3.2

All cracks or other damaged sections shall be plugged.

3-3.3

The inert gas shall be introduced into the tank or container through a pipe or hose extending to a point near the bottom of the tank or container so that the inert gas produces a substantially oxygen-free atmosphere. Any metal components of the filling pipe or hose shall be bonded to the tank or container.

3-3.4

When using carbon dioxide, low pressure shall be used to avoid generation of static electricity. Portable carbon dioxide fire extinguishers shall not be used for this purpose.

3-3.5

If solid carbon dioxide is used, it shall be crushed and distributed evenly over the greatest possible area to ensure rapid evaporation. Skin contact with solid carbon dioxide shall be avoided, since it can produce burns.

3-3.6

In the case of a tank or container inerted with nitrogen, the oxygen content shall be measured directly by means of an oxygen indicator. Where carbon dioxide is used, the oxygen percentage shall be permitted to be calculated from the percentage of carbon dioxide in the container measured by means of a carbon dioxide indicator.

3-3.7

A sign shall be conspicuously posted that warns of the hazard of inhalation of inert gas, if partial entry is possible.

3-4 Removal of Residual Liquids or Solids.

In certain cases, it might be impossible to remove all potentially hazardous liquid or solid residues that will produce flammable vapors when heated. Such residues might be trapped behind heavy scale or rust and might not easily be detected. Whenever examination after cleaning indicates that this hazardous condition exists, hazardous work shall not proceed without additional precautions being taken. As a minimum, a continuous air purge or an inert atmosphere shall be maintained in the tank or container while hazardous work is in progress.

> CAUTION: Steam cleaning, chemical cleaning, and high-pressure waterblasting can generate static electric charges. (See Section 4.2.7 of API 2015, Safe Entry and Cleaning of Petroleum Storage Tanks, and *NFPA 77*, Recommended Practice on Static Electricity.)

3-4.1 Steam Cleaning.

Steam shall be introduced into the tank or container through a pipe inserted through an opening and bonded to the container or by connecting a steam hose directly to one of the vessel nozzles. The rate of supply of steam shall be sufficient to exceed the rate of condensation so that the whole tank or container is heated close to the boiling point of water. The vessel shall be steamed long enough to vaporize the residues from all portions of the walls (shell and heads). When testing the atmosphere in the vessel with a combustible gas indicator, the sample shall be drawn through a drying tube filled with calcium chloride or other drying agent to ensure that water vapor does not enter the instrument. If a drying agent is not available, the container shall be allowed to cool until excess water vapor has condensed before the gas test is made. (*See CAUTION in Section 3-4.*)

3-4.2 Chemical Cleaning.

If chemical cleaning is used, the use of goggles, gloves, and other necessary protective clothing shall be considered in order to guard against possible injury to the skin or eyes. When using a proprietary cleaning solution, the manufacturer's instructions shall be followed. (*See CAUTION in Section 3-4.*) Typical cleaning procedures using trisodium phosphate are specified in 3-4.2.1 through 3-4.2.8.

3-4.2.1 The hose shall be inserted through the filling connection or vent, and the container shall be filled with water until it overflows. The hose shall be extended to the bottom of the tank or container to promote agitation from the bottom upward, causing any remaining vapor, liquid, scum, or sludge to be carried upward and out of the tank or container where it can be removed to a safe location.

3-4.2.2 The tank or container shall be drained.

3-4.2.3 Sufficient trisodium phosphate shall be dissolved in hot water so that the final concentration of the solution is 2 to 4 oz/gal (15 to 30 grams/L) when the tank or container is liquid full. The solution shall be poured into the tank or container and the tank or container shall be filled with water.

3-4.2.4 Steam shall be introduced to the bottom of the tank or container either through a bottom connection or through a pipe to the bottom that enters the vessel through the filling connection or through the vent. The solution shall be maintained at a temperature of 170° to 190°F (76.7° to 87.8°C), and, at intervals during the steaming, enough water shall be added to allow discharge by overflowing of any volatile liquid, scum, or sludge that may have collected at the top. Ventilation of the area shall be provided for the removal of any flammable vapors, and means shall be provided for preventing potentially hazardous material from entering a public sewer system. It might be advisable in some cases to discharge the overflow water into another tank or container. Steaming shall be continued at maximum temperature for at least 15 minutes or until no appreciable amount of volatile liquid, scum, or sludge appears at the top of the tank or container.

3-4.2.5 The tank or container shall be drained.

3-4.2.6 The inside of the tank or container shall be inspected to see if it is clean, taking care to avoid inhalation of harmful vapors or gases that might still be present. (*See 2-1.5.*) If examination shows that the tank is not clean, the cleaning procedure shall be repeated.

3-4.2.7 If the tank or container appears to be clean, the atmosphere within the tank or container shall be tested with a combustible gas indicator. If the instrument indicates the presence of flammable vapor, this vapor shall be removed by one of the methods described in Section 3-2.

3-4.2.8 If steam is not available, the less effective method of a cold water solution, with the concentration of cleaning compounds (such as trisodium phosphate) increased to about 6 oz/gal (45 grams/L) of water, shall be permitted to be used. The solution shall then be agitated. After the tank or container has been drained, it shall be inspected and tested for the presence of flammable vapors, as in 3-4.2.6 and 3-4.2.7.

3-4.3 Nonflammable Solids.

Occasionally, hard solid deposits will be found in tanks or containers that cannot be removed by the above method and that do not produce flammable vapors. In such cases and in the absence of flammable vapors, cleaning shall be permitted to be supplemented by tumbling the container with a length of chain inside to assist in the removal of such solids.

Chapter 4 Testing Procedures

4-1* Testing for Flammability.

4-1.1

After cleaning, the interior of each tank or container shall be tested for flammable vapor concentration to ensure that the cleaning procedures have been effective.

4-1.2

During ventilation or air-purging of any tank or container, the flammable vapor concentration of the effluent shall be tested periodically for as long as ventilation or purging is in progress.

4-1.3

When testing a tank or container for hot work, any indication of flammable gas or vapor shall require recleaning or further safeguarding of the vessel by one of the methods described in this standard prior to performing any hot work.

4-1.4

All tests shall be done using a properly calibrated combustible gas indicator. Testing shall be done by a qualified operator.

4-2* Testing for Oxygen Content.

When testing for oxygen content, as for monitoring a tank or container that is being purged with inert gas, a properly calibrated portable oxygen indicator shall be used. Testing shall be done by a qualified operator.

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 ASTM Publications.

American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM D5-1986, *Standard Test Method for Penetration of Bituminous Materials*.

ASTM D323-1990, *Standard Test Method for Vapor Pressure of Petroleum Products (Reid Method).*

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-2-1.2

It should be understood that special procedures for cleaning might be required.

A-2-3

Tanks or containers that have held high flash point liquids can become hazardous during cutting and welding operations. Special precautions might be necessary in such cases.

A-4-1

Testing the interior of a tank or container for the presence of ignitable concentrations of flammable gas or vapor is the most important phase of the cleaning procedure and determines whether additional cleaning is needed. Most combustible gas indicators measure the concentration of vapor present as a percentage of the lower flammable limit. Where concentration of oxygen in a tank or container is less than about 5 percent by volume, the reading will be in error; although, for oxygen-lean atmospheres, the error will be on the high, or safe, side. It is essential that those using the indicator be well trained in its use and calibration and that the instrument is in good operating condition. Calibration should be done in accordance with manufacturers' instructions.

If an air mover is used to exhaust a tank or container, the discharge from the air mover will be diluted with air used in the device. The results of any tests made at this point will be indicative of the change in the vapor concentration inside the vessel and, when the desired low concentration is reached, the condition of the tank or container itself can be checked at appropriate points.

A-4-2

When purging a tank or container with an inert gas, a combustible gas indicator will not give a correct reading, as noted in A-4-1. Since the objective with inert gas purging is to dilute the oxygen concentration to a point below a certain safe value, an oxygen indicator should be used.

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 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 77, *Recommended Practice on Static Electricity*, 1993 edition.

NFPA 306, *Standard for the Control of Gas Hazards on Vessels*, 1993 edition.

NFPA 326, *Standard Procedures for the Safe Entry of Underground Storage Tanks*, 1993 edition.

B-1.2 Other Publications.

B-1.2.1 AGA Publication. American Gas Association, 1515 Wilson Boulevard, Alexandria, VA 22209.

Purging Principles and Practices, 2nd edition, 1975.

B-1.2.2 ANSI Publication. American National Standards Institute, 1430 Broadway, New York, NY 10018.

ANSI Z117.1-1989, *American National Standard Safety Requirements for Confined Spaces*.

B-1.2.3 API Publications. American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005.

API RP 1631, *Interior Lining of Underground Storage Tanks*, 1992 edition.

API Publication 2013, *Cleaning Mobile Tanks in Flammable or Combustible Liquid Service*, 1991 edition.

API Publication 2015, *Safe Entry and Cleaning of Petroleum Storage Tanks*, 1991 edition.

B-1.2.4 NLPA Publication. National Leak Prevention Association, 7685 Fields Ertel Road, Cincinnati, OH 45241.

NLPA 631-1991, *Entry, Cleaning, Interior Inspection, Repair and Lining of Underground Storage Tanks*.

B-1.2.5 U.S. Government Publication. U.S. Government Printing Office, Superintendent of Documents, Washington, DC 20402.

OSHA, *Code of Federal Regulations*, Title 29, Part 1910.146, “Permit-Required Confined Spaces.”

NFPA 328

1992 Edition

Recommended Practice for the Control of Flammable and

Combustible Liquids and Gases in Manholes, Sewers, and

1992 Edition

This edition of NFPA 328, *Recommended Practice for the Control of Flammable and Combustible Liquids and Gases in Manholes, Sewers, and Similar Underground Structures*, was prepared by the Technical Committee on Tank Leakage and Repair Safeguards, released by the Correlating Committee on Flammable Liquids, 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.

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 328

Sufficient case histories of fires and explosions in underground structures fully justify a careful review of the material contained within this recommended practice. The sources of flammable vapor-air mixtures in these locations, coupled with a study of unsafe practices and protective practices contained herein, certainly will indicate the desirability of utilizing the applicable corrective measures suggested in the summary of this report. This recommended practice was first adopted in 1956, and subsequent editions were published in 1964, 1970, 1975, 1982, 1987, and 1992.

Minor amendments were made to Sections 2-4, 2-4.4, and 2-6 in this 1992 edition.

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NOTICE: Information on referenced publications can be found in Chapter 4.

Foreword

Manholes, sewers, and similar underground conduits have long been recognized as constituting areas where fire and explosion hazards of some severity might exist. The probability of an explosion within an underground space depends on two factors: (1) that the atmosphere contains a mixture of flammable vapor and air within the flammable range, and (2) that there be a coincident source of ignition. The severity of an individual explosion and its consequences depends on various factors. The possibility that any one explosion might result in a major catastrophe is always present.

This publication is limited to the control of hazards presented by flammable and combustible liquids and gases found in manholes, sewers, vaults, and similar underground structures. The underground structures include: sanitary sewers, storm drains, water lines, fuel gas distribution systems, electric light and power conduits, telephone and telegraph communication lines, street-lighting conduits, police and fire signal systems, traffic signal lines, refrigeration service lines, steam lines, and petroleum pipelines.

The term “underground structures” is not intended to include subways, tunnels, and the substructural areas of buildings such as underground garages.

The purpose of this publication is to give to enforcement officials, fire authorities, contractors, and owners of underground structures guidance on problems involving flammable and combustible liquids and gases that might be found in underground structures.

Chapter 1 The Problem

1-1 General.

With increasing congestion and for aesthetic considerations, the trend in civic planning is toward the installation of all types of utility services beneath the street surface. This results in a continuous program of excavation and construction, with frequent damage to existing structures.

1-2 Sources of Ignition.

1-2.1

The possibility of ignition of flammable gases or vapors that might collect in underground areas is limited by certain fundamental conditions. The vapor must be mixed with sufficient air to make a flammable mixture or it must be escaping into air at a point where a flammable mixture can be created. Heat of sufficient intensity to ignite the particular air-vapor mixture involved must be present at the place where a flammable mixture exists. Such heat might be caused by an open flame, an electric arc or spark, an incandescent heated particle, or a hot surface.

1-2.2

The flammable limits of the gases and vapors that have been found in underground structures are listed in Appendix A. Flammable mixtures are formed when the concentration of these gases in air is between the minimum and maximum shown.

1-2.3

Any open flame is a potential source of ignition. These can be encountered in everyday work operations. Little control can be exerted over the casual sources of ignition when flammable vapors are escaping from or into underground structures. Such casual sources of ignition include burners and warning lanterns used by street surface maintenance crews, automotive and other internal combustion engines, tar pots, and pedestrian smokers.

1-2.4

The heat of an electric arc occurring in electric underground structures can cause the distillation of insulating material, thus producing flammable gases that in turn can be ignited by the arc itself when the proper air-gas ratio is reached. This usually will occur when the arc reaches a manhole or vault after having started in a duct. Other gases or flammable vapors, if present, can also be ignited by such an arc.

1-2.5

Static electricity can be a source of ignition and its accumulation is generally greatest in an atmosphere of low humidity. The hazard appears when static accumulates to the extent where a spark discharge occurs. Static electricity can be generated when a liquid under pressure escapes from a pipe at high velocity. Particles of dust, scale, or rust, or liquid droplets, inside the pipe can become heavily charged with static when blown out by gas or vapor and, if they impinge on an electrically isolated body, the body will accumulate the charge and a spark discharge can occur.

1-3 Sources of Flammable and Combustible Liquids and Gases.

1-3.1

The condition created by the existence of gases and vapors in underground structures can be grouped into two classes: (1) flammable and (2) injurious to life. The latter condition results from the toxic or suffocating properties of the gases or vapors. Some of these liquids and gases fall into both classes. While this publication deals primarily with the flammable limits associated with liquids and gases, some of which are listed in Appendix A, additional precautions may be required to protect against health hazards. An example is hydrogen sulfide; its dangerous breathing concentration is only a small fraction of the lower flammable limit (LFL).

1-3.2 Natural Gas.

Natural gas is gas originating from naturally occurring gas- or oil-bearing strata. In oil- and natural gas-producing areas, cracks and faults in the underlying strata or abandoned wells may permit gas to permeate the soil and enter underground conduits and vaults. Within the boundaries of some cities, there are actively producing oil and gas fields and many of these underlie developed areas, residential and industrial, where underground structures are now installed.

1-3.3 Fuel Gas.

Fuel gases include natural gas, liquefied petroleum gases, coke-oven gas, coal gas, oil gas, carbureted water gas, water gas, producer gas, and blast-furnace gas. These gases, except liquefied petroleum gases, have specific gravities lower than that of air so that, when released in an underground space, they will tend to rise and diffuse rather rapidly above the point of leakage. These gases, when mixed with air within certain limits, produce flammable mixtures. Since the oxygen content of each of these gases when not mixed with air is usually below 1.0 percent, they can be classed as suffocating gases. With the exceptions of natural gas and liquefied petroleum gases, they are also highly toxic because of the high carbon monoxide content. Natural gas and other fuel gases, as distributed by utility companies in underground pipes, are also a source of flammable gas. These pipes are subject to damage caused by corrosion, electrolysis, structural failures, and adjacent excavating. These causes are discussed in greater detail in later paragraphs of this section.

1-3.4 Refrigerant Gases.

A number of the common refrigerants, such as ammonia, methyl chloride, ethyl chloride, methyl bromide, and ethyl bromide, have varying degrees of flammability. With the exception of ammonia, all of these refrigerants are heavier than air when in the vapor phase. Therefore, if they are released in large quantities in closed spaces, they will flow downward into the lowest areas. Of these, only ammonia has a sufficiently strong odor in dilute concentrations to indicate its presence. Exposure to ammonia vapors can cause severe burns even at concentrations below the flammable limits. Liquid ammonia is often distributed through underground street pipes for refrigeration service in the business districts of many large cities. This system of pipes is subject to the same exposure to physical damage as fuel gas pipes and petroleum pipelines.

1-3.5 Electric Cable and Other Insulating Material Gases.

This source of flammable gas is practically limited to severely overloaded electric underground circuits. A breakdown of cable insulation will produce an electric arc. If the protective fuses do not operate promptly, this electric arc will continue. The heat of the arc can, by destructive distillation of cable insulation (varnished cambric, rubber, or paper), produce flammable gases containing hydrogen, carbon monoxide, and hydrocarbons.

1-3.6 Chemicals.

Accidental spillage in chemical processing plants and disposal of waste chemical products through sewers by industrial plants are potential sources or contributing causes for explosive conditions. Examples of such products are carbon disulfide and ammonia. Calcium carbide will react with water to produce the flammable gas acetylene.

1-3.7 Sewage Gases.

Sewage gas results from the fermentation or decomposition of organic matter. These gases can be produced when organic matter has settled as a solid in sewer lines as a result of flat grades, crevices, sumps, or obstructions where consistent flow of sewage is lacking, or as a result of bacterial action on wood or other organic material immersed in water. These flammable gases are principally methane, hydrogen sulfide, and hydrogen and, on the basis of present evidence, they seldom reach explosive concentrations in sewers and drains. However, when they are mixed with other flammable liquids and gases present in sewers, explosive conditions might exist.

1-3.8 Flammable and Combustible Liquids.

Cleaning solvents and compounds washed down drains by industrial and domestic users can be the source of flammable vapors. Hydrocarbon liquids (for example, gasoline and kerosene at industrial plants, service stations, and garage wash racks) are occasionally sent to sewers and drains either accidentally or through negligence. Any leaking underground tank containing liquids, such as a service station's underground gasoline tanks, can also be a source of flammable vapors in underground structures (*see NFPA 329, Recommended Practice for Handling Underground Leakage of Flammable and Combustible Liquids*).

1-3.9 Petroleum Pipeline Liquids.

Liquid petroleum and liquefied petroleum gases are conveyed by pipelines installed beneath public streets and rights-of-way. These pipelines are exposed to the same sources of physical damage as fuel gas pipes, as discussed in detail later. If any of these pipelines should fail, the escaping liquids and gases can penetrate substructure walls or rise to the street surface. Liquids can be washed into drains or enter the ventilating openings in the manhole covers of underground structures. Escaping liquid petroleum products can evaporate in the ground, penetrate the surrounding ground, or enter a confined space to produce a flammable mixture.

1-3.10 Penetration of Structures by Gases.

Flammable gas present in the soil can enter conduits, sewers, drains, or basements because underground structures constructed of cement, concrete, brick, or vitreous tile generally are not built to be impervious to gas. If a flammable gas or liquid is present in the soil, as might be produced by decaying organic matter, there is some likelihood that it will penetrate an adjacent underground structure. Particular attention should be paid to landfill sites developed by the depositing of garbage and trash. Gas from this source, primarily methane, might not have an odor. Gas can enter the subsurface sections of buildings through cracks or around any underground conduits that penetrate the substructure walls.

1-3.11 Electric Circuit Oil Switches and Oil-Insulated Transformers.

This equipment is frequently installed in a street vault, and electrical failures will occasionally result in an explosion. The action of protective devices in shutting off current is usually very fast, approximately two seconds or less. This has the effect of limiting the damage to the vault in which the failure occurs. However, when the vault is adjacent to or within a large structure, such an explosion can result in heavy damage.

1-4 Damage to Underground Lines.

1-4.1 Corrosion.

One type of corrosion affecting gas lines and petroleum pipelines occurs when the soil composition and resistance are such that electric current from the development of local action cells can flow readily from anodic areas on the pipe surface through the soil to the cathodic areas on the same pipe. Such conditions may be due to the soil’s acid or alkali content, organic matter, variations of water or oxygen content, soil type, or the presence of certain bacteria in the soil. Corrosion can also occur as a result of chemical reaction between the pipe and surrounding soil. Corrosion of this type can be controlled with cathodic protection.

1-4.2 Stray Currents.

Another cause of corrosion in underground lines is stray electric currents originating from such sources as direct-current electric railways and trolley lines using rails to carry return currents; industrial plant direct-current machinery using the ground as a return conductor; stray currents from cross-connections with other structures carrying current; and leakage from foreign system cathodic protection rectifiers. These currents might not be destructive where they enter the piping system, but drainage of these stray currents to ground can cause corrosion at these points of discharge.

1-4.3 Structural Failures.

The allocation of insufficient space for the installation of underground structures can, in some situations, result in the encasement of gas and flammable and combustible liquid pipes in the walls of ducts and subsequently constructed masonry vaults. Such pipes from vaults might be fractured under certain conditions. Flood washouts, earthquakes, and landslides can cause the dislocation and movement of ground and are often responsible for pipe fractures. Rupture of water mains due to corrosion, electrolysis, or structural failure can, in turn, cause washout of soil that supports gas and flammable liquid pipes. Lacking support, these pipes can fracture.

1-4.4 Excavating.

Contractors doing excavation work often encounter gas mains and flammable and combustible liquid pipes. Even though aware of their presence, workers might unintentionally damage a pipe, resulting either immediately or ultimately in a leak. Damage such as this is not always reported and often inadequate repairs are attempted by the party responsible for the physical damage.

1-4.5 Fire Damage.

Fires in underground structures can result in spalling of concrete, destruction of protective linings, and deterioration of other interior surfaces. Such damage, if extensive, can weaken the structure.

1-5 Unsafe Practices.

1-5.1

Before washing spilled petroleum products from street surfaces into drains or sewers (a potentially dangerous action and often an unlawful practice), other disposal means, such as soaking up the substance with sand, rags, or mops, should be considered. If, in an emergency, no alternative is available, disposal into a drain or sewer should be done only on the decision of a qualified person, after appropriate public authorities have been notified.

1-5.2

Disastrous consequences can result from the thoughtless or deliberate dumping into drains of waste products that are either flammable or that, by reaction with organic matter in sewers, can produce a flammable mixture. Though the presence of a flammable material might be detected, its source can be difficult to determine.

Chapter 2 Protective Practices

2-1

The adoption of protective measures that will detect the presence of flammable materials in manholes and vaults and provide the means to prevent the accumulations of gas or vapor within the explosive range should reduce the incidence of explosions in underground structures. Such a defensive procedure is necessary because of the difficulty of eliminating the flammable material at its source.

2-2

Numerous sources of ignition can be found in underground structures. The operators of underground structures can materially reduce the number of ignitions by eliminating the use of flames in suspected areas. Experience has shown, though, that fire and explosion incidence can best be reduced by the elimination of flammable vapors from the atmosphere of the underground structure. It is all but impossible to remove all ignition sources.

2-3

Considering the diversity of contributing causes for flammable products in underground structures, protective practices should be designed to reduce to a minimum the quantity of flammable vapors. Where such vapors are found to be present, a complete purge of the manhole or vault atmosphere should be made and the source of the flammable vapors eliminated.

Manholes and vaults should be ventilated by forced draft when necessary to prevent concentrations of these vapors within the explosive range. After complete ventilation of the underground structure, the atmosphere should be tested with a combustible gas indicator before entering and before any hot work is performed. A low reading on the combustible gas indicator does not necessarily mean that the toxicity hazard has been eliminated. Adequate ventilation should be maintained and periodic gas analysis of the atmosphere during any such work should be made.

2-4 Detection Instruments.

There are a number of instruments that can be used to detect unsafe atmospheres found in underground structures. They should be used to determine the characteristics of any questionable situation. Ensure that instruments are properly calibrated before use.

2-4.1 Oxygen.

There are indicators that give a direct reading of oxygen concentration. Under no conditions should an area be entered without self-contained breathing apparatus unless it contains at least 19.5 percent oxygen.

2-4.2 Carbon Monoxide.

This gas in concentrations greater than 0.10 percent by volume results in unconsciousness in little more than an hour and death in four hours. Further increases in concentration reduce this time element. Its effect is to displace oxygen in the blood stream. Several instruments have been developed for the quick detection of carbon monoxide. Those capable of detecting the smallest concentrations considered hazardous are the carbon monoxide tester (palladium-molybdate complex) and the carbon monoxide indicator.

2-4.3 Hydrogen Sulfide.

This flammable and toxic gas is colorless and has an odor resembling rotten eggs. It is toxic in concentrations above 0.002 percent by volume. Continued exposure will paralyze the olfactory nerves. The hydrogen sulfide detector will detect the low toxic concentrations of this gas.

2-4.4 Fuel Gases and Vapors from Flammable and Combustible Liquids.

Combustible gas indicators are available in a number of different types to meet the requirements of the specific use to which they may be applied. The most common type is an “all-purpose” instrument suitable for the detection of flammable gases such as natural gas, manufactured gas, hydrogen, and acetylene and all vapor-air mixtures associated with fuel oils, gasoline (including leaded gasoline), alcohols, and acetone. This instrument indicates the presence of gases and vapors in percent of the lower flammable limit (LFL). It must be calibrated, used, and maintained in accordance with the manufacturer’s instructions. This instrument must be calibrated on the specific gas being sampled, i.e., natural or manufactured gas, and has a scale range of zero to 100 percent. A portable combustible gas indicator is also available for operation in explosive atmospheres.

2-4.5

Periodic checks for the presence of flammable vapors using appropriate instruments should be made in all water, gas, and electric underground structures. The frequency of such surveys will depend on the previous experience and the potential hazard.

2-4.6

Liquefied petroleum gases and utility gases are odorized to facilitate detection unless the odorant would serve no useful purpose as a warning agent, but such cases are relatively rare and practically all such gases distributed by underground pipelines are odorized. Experience has shown that odorants can be absorbed when traveling through the soil.

2-5

Volatile flammable liquids can enter a drainage system because of a spill or other emergency. Steps should be taken to minimize the hazard by exhausting the vapors with blowers or exhaust fans driven by explosionproof motors and by pumping out the liquid with pumps equipped with explosionproof motors. Floor drain openings into buildings in the area of the spill and for some distance downstream should be checked for escape of vapors. Water should be placed in any dry traps to seal them. Copious quantities of water should be used to flush any flammable or combustible liquid through the system quickly and to dilute it, if miscible with water.

2-6

Underground tanks of flammable liquids can be a source of leakage. When a tank is found to be leaking, its contents should be removed immediately. When such a tank is taken out of service, abandoned, or removed, the procedures described in Appendix C of NFPA 30, *Flammable and Combustible Liquids Code*, entitled Abandonment or Removal of Underground Tanks, should be followed.

2-7

Sewers and drains should be periodically flushed and cleaned to prevent deposits of organic material and slime growth. Periodic inspections should be made of industrial plants to prevent the discharge into sewers of waste that might produce explosive gases due to physical or chemical impurities, high temperatures, alkalies, or acids, unless the system is specifically designed for such materials.

2-8

Periodic checks of protective equipment in underground electric systems should be made. Efforts should be made to prevent the overloading of cables and to avoid arcing conditions that might form flammable gas by the breakdown of insulation.

Chapter 3 Summary

3-1

A review of all the factors relating to the problem of explosive hazards in underground structures, together with an analysis of causes of explosions, indicates that flammable material might at some time be present in an underground structure.

Control procedures and education are the proper approaches to the problem. Effective control cannot be maintained unless the various utilities involved, the administrative bodies of cities, and others cooperate in an adequate safety program.

3-2

Utility companies should maintain an adequate inspection program for the detection of leaks at street openings. This can best be accomplished by the use of combustible gas indicators, vegetation surveys, and other methods. Periodic inspection and testing of key equipment should be conducted with reasonable frequency as a part of regular maintenance operations. Such a distribution piping maintenance program could be carried out in accordance with the requirements of federal and state pipeline regulations.

3-3

Inactive gas services and mains should be abandoned in accordance with federal and state regulations.

3-4

Automatic or manually operated drains in industrial piping should be designed so as not to discharge their product into underground structures.

3-5

Owners and operators of underground pipelines carrying flammable and combustible liquids should maintain an adequate inspection program for the detection of escaping liquids.

3-6

RP 1621, *Recommended Practice for Bulk Liquid Stock Control at Retail Outlets*, published by the American Petroleum Institute, will be of value to operators of service stations.

3-7

An in-service training program for all employees whose occupation is associated with underground structures will teach them to recognize the presence of fire and toxic hazards and oxygen deficiencies and teach them how to take proper precautions against such possibilities.

3-8

Some public authorities have established a program to control or prevent the discharge into sewers and drains of all products likely to result in flammable atmospheres in vaults and manholes.

3-9

Sewers and drains should be designed to ensure that proper cleansing velocities and proper ventilation are maintained so as to prevent infiltration and to avoid the settling of heavy solids. Sewers and drains should be designed to minimize the danger of settlement and failure that in turn might break other adjacent underground structures.

3-10

Where ventilation of a vault or manhole is necessary and mechanical ventilation cannot be provided, the manhole or vault should be designed (depending on local conditions) so that effective natural ventilation for vapors or gases lighter than air can be obtained. Manholes for sewers should be regularly spaced to provide effective ventilation and explosion relief.

3-11

Every effort should be made to establish standard practice for the design, construction, and maintenance of all underground structures with respect to the elimination of explosive hazards and the contributory causes.

3-12

Close liaison should be established between the fire chief and industrial safety officials.

Mutually approved procedures should be developed to cope with emergencies so that fire fighters can act effectively in their line of duty.

3-13

All agencies having underground structures should be prepared to furnish contractors with the record of the locations of such adjacent structures or furnish a person who knows the location of these pipes. In the event the exact location of any underground structure is not known, the contractor should make a physical inspection of the entire right-of-way of the proposed excavation by employing underground detecting devices and visual inspection of adjacent structures.

3-14

Apart from direct damage to piping, contractors should take extra precautions to avoid damage to corrosion protecting coatings, anodes, electrodes, bonding facilities, and related devices. If these are disturbed or damaged, the owner of the structures should be notified before backfilling the excavation. Care should be taken in all excavations in which wire or metal is found, even though these are not immediately adjacent to a pipeline. They may be part of the protective system.

3-15

Public authorities should:

(a) Adopt an ordinance that would require a contractor before starting construction or excavation work (1) to obtain a permit, (2) to notify the owner of adjacent underground structures in writing of his intention to start work, and (3) to obtain from the owner the exact information on the location of the underground structures and pipes containing flammable materials. All agencies having underground structures should be prepared to furnish contractors with exact information on the location of such underground structures. This permit should prohibit the contractor from interference with the above-mentioned pipes without giving prior notice to the owner or operator.

(b) Require anyone conducting blasting operations to obtain a permit. The permit should not be granted until the owners of adjacent underground structures have been consulted. NFPA 495, *Explosive Materials Code*, contains additional information on this subject.

(c) Require anyone razing buildings to obtain a permit. The permit should not be granted until the owners of underground structures in the area have been consulted.

(d) Prohibit the encasement of pipes containing flammable materials within the constructed walls of new structures. This recommendation does not apply to piping entering buildings.

(e) Establish a procedure for connecting direct-current electrical equipment to ground on the premises of the user. This is to prevent the inclusion, directly or indirectly, of underground pipes carrying flammable materials in the return electric circuit.

(f) Promote cooperative efforts on the part of all organizations having underground facilities to reduce corrosion.

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 325M, *Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids*, 1991 edition

NFPA 329, *Recommended Practice for Handling Underground Leakage of Flammable and Combustible Liquids*, 1992 edition

NFPA 495, *Explosive Materials Code*, 1992 edition.

4-1.2 API Publications.

American Petroleum Institute, 1220 L St., NW, Washington, DC 20005.

API Recommended Practice 1621, *Bulk Liquid Stock Control at Retail Outlets*, Fourth Edition, 1987.

Appendix A

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

Properties of Some Flammable and Combustible Liquids and Gases That Have Been Found in Underground Structures[1]

		Flammable Limits in Air % by Vol			
	Flash Point Closed Cup Deg. F	**Lower**	**Upper**	**Specific Gravity of Liquid** (Water = 1)	**Vapor Density** (Air = 1)
Acetone	4	2.15	13.0	0.8	2.00
Acetylene	Gas	2.5	100.0	-	0.90
Ammonia	Gas	16.0	25.0	-	0.6
Benzene	12	1.3	7.1	0.9	2.8
Butadiene	Gas	2.0	12.0	-	1.9
Butane	Gas	1.6	8.5	-	2.00
Carbon Disulfide	22	1.3	50.0	1.30	2.60
Carbon Monoxide	Gas	12.5	74.0	-	1.0

Ethane	Gas	3.0	12.5	-	1.0
Ethyl Chloride	58	3.8	15.4	0.9	2.2
Gas Oil*	150*	0.5	5.0	<1	-
Gasoline (Values vary for different grades of gasoline)	45	1.4	7.6	0.8	3. 4.0
Hydrogen	Gas	4.0	75.0	-	0.1
Hydrogen Sulfide	Gas	4.0	44.0	-	1.2
Kerosene	100–162	0.7	5.0	<1	-
Methane	Gas	5.0	15.0	-	0.6
Methyl Bromide	Gas	10.0	15.0	-	3.3
(Practically nonflammable)					
Methyl Chloride	Gas	8.1	17.4	-	1.8
Natural Gas*	Gas	3.8	13.0	-	-
Petroleum	<0	1.1	5.9	0.6	2.5
Naphtha* (Petroleum Ether)					
Propane	Gas	2.1	9.5	-	1.6
Toluene	40	1.2	7.1	0.9	3.1

*These liquids and gases are mixtures, and their properties may vary depending on the composition.

1Properties of other flammable materials can be found in NFPA 325M, *Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids.*

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Recommended Practice for Handling Underground Releases of Flammable and Combustible Liquids

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This edition of NFPA 329, *Recommended Practice for Handling Underground Releases of Flammable and Combustible Liquids*, was prepared by the Technical Committee on Tank Leakage and Repair Safeguards, released by the Correlating Committee on Flammable Liquids, 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.

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Origin and Development of NFPA 329

This recommended practice began as a report (NFPA 30B), which was published until 1950. A manual on this subject was published in 1959. The manual was rewritten as a recommended practice in 1964, with subsequent revisions in 1965, 1972, 1977, 1983, 1987, and 1992.

Major changes incorporated in this 1992 edition include:

- A complete revision of Chapter 3, addressing techniques for identifying the source of a release.
- A completely new Chapter 4, “Release Detection for Underground Storage Tank Systems.”
- A complete revision of Chapter 5, addressing techniques for tracing the underground flow of released liquids.
- A complete revision of Chapter 6 on the proper removal and disposal of contaminated liquid and groundwater.
- New Appendixes A and B, discussing the basic principles of volumetric and nonvolumetric tightness testing.
- New Appendix C, discussing the basic principles of the flow of liquids underground.

The text of this 1992 edition does not conflict with current U.S. Environmental Protection Agency guidelines for underground storage tank systems.

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Rep. NFPA Industrial Fire Protection Section

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NFPA 329
Recommended Practice for
Handling Underground Releases of Flammable and Combustible Liquids

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NOTICE: Information on referenced publications can be found in Chapter 7 and Appendix E.

Chapter 1 Introduction

1-1 Scope.

This recommended practice provides appropriate methods for responding to fire and explosion hazards resulting from an underground release of a flammable or combustible liquid. Although this recommended practice is intended to address only these fire and explosion hazards, it should be recognized that other authorities should be consulted regarding the environmental impact of such releases.

1-2 Purpose.

The purpose of this recommended practice is to provide for the safe and efficient handling of flammable or combustible liquids when, for whatever reason, they are found unwanted or unconfined. Options are given for detecting and investigating the source of a release, for mitigating the fire and explosion hazards resulting from the release, and for tracing the released liquid back to its source. These options are not intended to be, nor should they be considered to be, all-inclusive or mandatory in any given situation. If better or more appropriate alternative methods are available, they should be used.

1-3 Caveat.

The National Fire Protection Association does not, by the publication of this recommended practice, recommend action that is not in compliance with applicable laws and regulations and should not be considered as doing so. Users of this recommended practice must consult all applicable federal, state, and local laws and regulations.

1-4 The Problem.

1-4.1

Flammable liquids [those having a flash point below 100°F (37.8°C)] and combustible liquids [those having a flash point at or above 100°F (37.8°C)] are used by the millions of gallons daily and, of necessity, are stored and handled in locations immediately adjacent to structures, facilities, and people. These liquids include chemicals, cleaning fluids, motor gasolines, diesel fuel, and heating oils. Motor gasolines are the most widely used of these liquids, and they are commonly stored underground at service stations.

1-4.2

In spite of constant effort to maintain and operate storage and transfer equipment properly, accidents do happen, equipment does fail, and people do make mistakes that sometimes permit the escape of these liquids. Leaks can develop from corrosion or be caused by mechanical damage, or some liquid can be spilled during transfer. Generally, the amount of liquid lost is small and is dissipated by evaporation or is otherwise assimilated before it creates a serious problem. However, it occasionally happens that some flammable or combustible liquid finds its way into an underground facility, such as a basement, utility conduit, sewer, or well. Whether or not it creates an immediate hazard will depend on many things, such as how much liquid or vapor is involved, where it is found, how it is confined, possible sources of ignition, etc. But, because a flammable or combustible liquid unconfined in the ground can move from place to place, any indication that such liquids have escaped into the ground must be considered as a potential, if not immediate, hazard.

1-5 Cooperation and Responsibility.

1-5.1

The responsibility for proper handling of a suspected escape of flammable or combustible liquids, or a potential hazard from such an escape, will fall on various individuals and organizations. The successful handling of these problems will depend on the best possible cooperation between them.

1-5.2

One of the prime purposes of this recommended practice is to provide a basis for this cooperation. Because of the almost infinite number of variables involved, it can't be a rule book in the strict sense of the word. It can, however, provide a definite course of cooperative action that will ensure the most effective use of skills and equipment and the fairest assessment of responsibility and will result in the best possible protection of life and property. A positive, cooperative attitude of anyone involved will benefit everyone, regardless of the final results. Lack of cooperation could result in inadequate protection of life and property.

1-5.3

Since leakage of flammable liquids, especially those liquids having low flash points, is a fire problem, necessary steps to be taken will normally be under the jurisdiction of the fire officials. It therefore becomes important for such officials to understand the many facets of the problem and to secure the cooperation of all involved parties as outlined above.

1-5.4

Recent developments, problems, and attitudes have now also involved health and environmental officials. Particularly when dealing with water pollution and the more persistent slow- or non-evaporating combustible liquids, the concern of these officials can be paramount.

1-5.5

The location of leaks, testing of tanks and piping, removal of leaky tanks, and removal of liquid in the ground will require equipment and facilities that might be more available to the industries involved than to the public authorities. In addition, much of the work is not the responsibility of the fire department or other agencies, but rather is the responsibility of the owner of the leaking equipment.

1-5.6

Regardless of the willingness of individuals or companies to cooperate with governmental agencies during an emergency, the agencies should recognize that they should officially request such cooperation.

1-5.7

When tanks are to be removed or other work, such as excavation, is to be done on private equipment or on private property, this work must be authorized by the owner. Such authorization generally is easy to secure if the work has been requested by officials. In some cases, these requests must of necessity be in the form of a written order. Regardless of conditions, leadership and a close spirit of cooperation should be established by the responsible agency.

1-5.8

In addition, those in industry having special qualifications in dealing with leakage should be called upon for help and guidance. Their knowledge and experience should merit careful consideration.

1-5.9

This recommended practice is intended for the information of all organizations and persons involved.

Chapter 2 Procedure When Life or Property Might Be in Danger

2-1 General.

The need for cooperative effort by many individuals and organizations is stressed in the introduction preceding this chapter. Good judgment must be used in assembling the various groups. Always seek assistance in the interests of safety, but avoid creating unnecessary alarm or unwarranted interruption of normal activities. Owners, operators, or others becoming aware of a hazardous condition should notify the fire department, police, or other proper authority. However, make every reasonable effort to determine the degree of the problem. Excessive alarming, such as might be caused by unwarranted evacuation or publicity, can create more hazard than the original problem. Good judgment applied to the following step-by-step guide will materially improve the chances for successful results.

2-2 Conditions.

The potential that unconfined flammable or combustible liquids exist underground will normally become known by discovery of one of the following conditions:

2-2.1

Combustible or flammable liquids or their vapors are reported in:

(a) Normally inhabited subsurface structures such as basements, subways, and tunnels;

(b) Other subsurface structures such as sewers, utility conduits, and observation wells near tanks;

(c) Groundwater such as that drawn from wells, on or in surface water, or emerging from cuts or slopes in the earth.

2-2.2

User reports loss of stock or presence of water in the storage facility. *Each condition requires different handling*:

2-3 Condition 2-2.1(a) - Normally Inhabited Subsurface Structures Such As Basements, Subways, and Tunnels.

2-3.1 General.

This condition implies a strong potential hazard to life or property, and immediate steps should be taken to protect the public from the danger of explosion and fire.

2-3.2 Eliminating Sources of Ignition.

2-3.2.1 Smoking or other sources of ignition should not be permitted in the suspected area. Lights and other electrical switches should not be turned on or off, and extension cords should not be removed from outlets. Any such action can create a spark capable of igniting flammable vapors. Use only those switches located well away from the contaminated area to disconnect electrical power. This might require that the electric utility effect a remote cutoff.

2-3.2.2 After the presence of flammable vapors has been verified, the electric and gas services to the building, where possible and feasible, should be disconnected or shut outside the structure. The shutting off of the gas service outside of the building removes the fuel from pilot lights and gas burners, which could be sources of ignition.

2-3.2.3 No one should enter the contaminated area except as described in 2-3.3. Where liquids or vapor within or above the flammable range are found in a building, the building should not be entered, and evacuation of building occupants, at least in areas exposed, should be ordered. Construction and layout as well as occupancy are factors to be considered in ordering evacuation. Traffic should be stopped through tunnels and subways until qualified personnel determine there is no danger of explosion or fire.

2-3.3 Entering the Area.

2-3.3.1 The presence of flammable vapors in a building is generally reported because of an odor. For example, most persons can detect gasoline vapor in concentrations as low as 0.25 parts per million. However, smell cannot be relied on to determine the type of vapor or its concentration. The use of a combustible gas indicator is the only practical, positive method to determine the presence and extent of a flammable vapor concentration.

2-3.3.2 To enter an area in which there is an undetermined concentration of some unknown vapor is to risk the possibility of fire or explosion. Entry should not be made until the vapor concentration has been checked with a combustible gas indicator. Portable combustible gas indicators are reasonable in price and are recommended for use by all fire departments. If the fire department does not have such an indicator, arrangements should be made for securing one or more from utilities, oil companies, or others who might have them available. The combustible gas indicator should be well maintained and used by a trained operator.

2-3.3.3 Also, an additional life hazard might exist because of toxic vapors or insufficient oxygen. If these conditions are suspected, instruments to detect toxic vapors or insufficient oxygen should be used.

2-3.3.4 Use the combustible gas indicator continuously to determine the range of vapor concentrations in the affected area. If areas of vapor concentration above 50 percent of the lower flammable limit (LEL on indicators) are exposed to a source of ignition, leave the area and evacuate everyone within the danger zone. Ventilate the area to remove or reduce the flammable vapors and thus reduce the fire or explosion hazard. As soon as the flammable vapor has been reduced below 50 percent of the lower flammable limit, entry can be made to locate and eliminate the source of vapor. Wear self-contained breathing apparatus when entering.

2-3.4 Ventilating the Area.

Natural ventilation provided by opening doors and windows might be adequate. Grounded mechanical exhaust ventilating equipment might be required to remove vapors from all areas, particularly from low, confined spaces. Use fans driven by motors approved for Class I, Group D locations, hand-driven fans, or air eductors to remove vapors. (*See Figure 2-3.4.*) Eliminate sources of ignition near the exhaust outlets. Provide openings for free entry of fresh air, but never force air into the area. A water hose with the nozzle set in a spray pattern can be used for ventilating the area when set in a window and discharging outwardly.

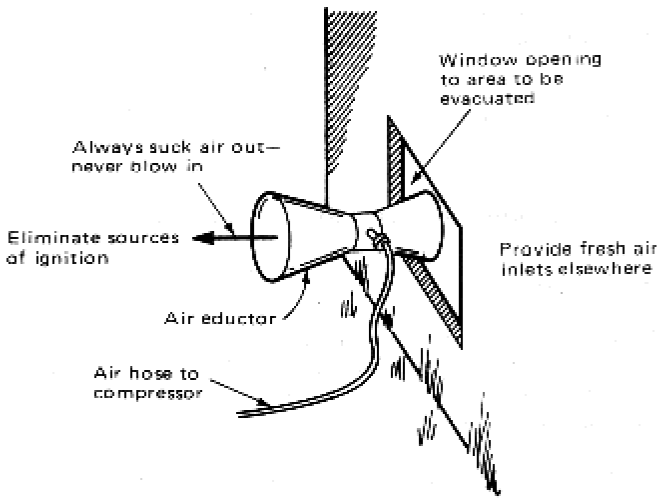


Figure 2-3.4 Exhaust venting.

2-3.5 Locating Seepage into Building.

When the area has been made safe for entry, it can be examined to determine the source of the flammable vapors. If the place or places of entry of the liquid or vapors can be determined, appropriate steps should be taken to seal them off. Untrapped drains, dry traps, pipes, or other openings through floors or foundations are common sources of liquid or vapor entry. Check any gas pipes in the area; the flammable vapor might be fuel gas. If this appears to be the source, call the gas company.

2-3.6 Preventing Seepage into Buildings.

2-3.6.1 Entrance of vapors or liquids through drains, pipes, or other openings can be stopped by plugging such openings. Sewer pipes might be the source of entry. If only vapor is entering through a sewer pipe, it might be because the trap is dry. Filling the trap with water is an effective means of blocking further gas or vapor entry.

2-3.6.2 The nature of seepage might be such that it cannot be effectively stopped from inside the structure. In this case, an intercepting hole or trench, holes for pumps, or well points can be used outside the contaminated structure, between it and the suspected source. (*See Chapter 6 for details.*)

2-4 Condition 2-2.1(b) - Other Subsurface Structures Such As Sewers, Utility Conduits, and Observation Wells Near Tanks.

2-4.1

Liquids or vapors in such structures imply a potential for explosion or fire but, generally, a low potential of hazard to life and property other than to the structure involved. If the detection of flammable or combustible liquids or their vapors indicates an unusual condition wherein vapors are escaping from the sewer or conduit into an area similar to Condition 2-2.1(a), or if the proximity to other structures or facilities is such that an explosion or fire would be relatively as serious as Condition 2-2.1(a), then proceed with the guidelines of 2-2.1(a) in addition to the following procedures.

2-4.1.1 Contact those directly responsible for the facility involved: the municipal sanitary department or highway or street department for sewers; the electrical or telephone, or gas companies' engineering departments for conduit. Normally, the maintenance and engineering departments of such organizations will be well equipped to take charge of the situation; police, if needed, can be asked to keep the public clear of the danger areas. The fire department might be needed to assist in fire control and purging. Those involved with facilities that store and handle flammable and combustible liquids that might be the source of the problem should offer all possible assistance. (*See NFPA 328, Recommended Practice for the Control of Flammable and Combustible Liquids and Gases in Manholes, Sewers, and Similar Underground Structures, and Chapter 5 of this recommended practice for further details.*)

2-4.2 Entering the Area.

Procedures are basically the same as for Condition 2-2.1(a); however, the flammable vapors in a sewer or conduit might not originate from flammable liquids. They might be vapors from overheated insulation, sewer-generated gases, fuel gases, or industrial gases. Consequently, special instruments, equipment, and skills might be needed. The guidance of the utility owning and operating the facility should be solicited and followed.

2-4.3 Ventilating the Area.

2-4.3.1 Some type of grounded mechanical ventilating will normally be required. Use explosionproof equipment if the vapors are drawn out. Remove all sources of ignition from the vicinity of vapor exit.

2-4.3.2 Water flushing might be the better means of purging the area of flammable vapors. For example, the generation of sewer gas can be stopped or significantly reduced by this method. In a similar fashion, flammable and combustible liquids can be removed from the area.

2-4.3.3 In any case, follow the guidance of the owner or operator of the facility, as that person will be most familiar with its characteristics and the consequences of any action taken.

2-4.4 Locating the Seepage.

Assist the facility owner in any way practicable. See Chapter 5 for information on tracing liquids underground.

2-4.5 Preventing Continued Seepage.

2-4.5.1 When leakage is detected in a sewer, the source of the leak should be located by backtracking with combustible gas indicators. If points of entry to the sewer system are limited in number, interception of the leak can be achieved by use of trenches, well holes, or well points.

(*See API Publication 1628, Guide to the Assessment and Remediation of Underground Petroleum Releases.*)

2-4.5.2 If entry of liquid or vapor into the conduit or sewer is to be stopped, and the inside of the facility is not accessible, probe or drill alongside the facility to determine the extent of its exposure to the saturated soil. Uncover the exposed area and caulk the facility from the outside.

2-5 Condition 2-2.1(c) - Groundwater Such As That Drawn from Wells, on or in Surface Water, or Emerging from Cuts or Slopes in the Earth.

2-5.1 General.

These liquid seepages on water will often be more of a problem because of pollution than as an explosion or fire hazard. However, until the source of the flammable or combustible liquid is found and stopped and all liquid and vapor safely removed, there is a potential hazard of explosion or fire.

2-5.2 Wells.

2-5.2.1 When flammable or combustible liquids are found in well water, stop pumping and avoid any source of ignition around well houses and water storage tanks until vapor concentrations are checked. Disconnect electrical power outside any well house or similar trap that might collect vapors from the well or stored water.

2-5.2.2 If vapor concentrations are below 50 percent of the lower explosive limit, pumping can be resumed if desirable for purging. (*See Chapter 6 for details.*)

2-5.3 Surface Water.

2-5.3.1 Where flammable or combustible liquids are found on surface water or water emerging from hillsides or cuts, explosive vapor concentrations can develop in ditches or collection points. Normally, the amount of flammable or combustible liquid found on the surface water will be in such a thin layer that it will not create a fire hazard. This is the case where the liquid is dispersed into small bubbles or pools, or where only color patterns are visible on the surface of the water.

2-5.3.2 However, if the entire surface of the water is covered, or there are large pools in the order of 20 ft (6 m) or more across, a fire hazard does exist. If this occurs in an inhabited area or along a street or highway, and the police and fire department are not present, they should be called. Traffic should be stopped, and the public kept away from the area. If large amounts of vapor are being generated, check the wind and remove all sources of ignition within at least 100 ft (30 m) downwind of the source. It is unlikely that vapors will be in the flammable range farther than 100 ft (30 m) away. However, if large amounts are involved, and the air is relatively still, a combustible gas indicator should be used to determine the extent of the hazardous area. Its use is desirable in any event if flammable liquids are involved.

2-5.3.3 Normally, the only effective means to stop further accumulation will be to find the source of the release and stop it. (*See Chapters 5 and 6.*) It may be desirable to construct dikes or dams to prevent further spreading of the liquids or of contaminated water.

2-5.3.4 Floating booms can be used on flowing water to hold the contaminating liquid. (*See Chapter 6 for details.*)

2-5.3.5 Once the source of flammable or combustible liquids is stopped, evaporation or normal dispersal and dilution will often be the best means of removal. Collection with adsorbents or skimming devices or filtering devices might be necessary. (*See Chapter 6 for details.*)

2-6 Condition 2-2.2 - User Reports Loss of Product or Presence of Water in Storage Facility.

An inventory loss, or water in tanks, does not directly imply a hazard of fire and explosion. Check the immediate vicinity for any signs of escaping liquid; if any exist, follow the procedures given for Conditions 2-2.1(a), 2-2.1(b), or 2-2.1(c), as appropriate. Otherwise, proceed in accordance with Chapter 4, "Testing for Underground Leaks."

Chapter 3 Searching for the Source

3-1 General.

3-1.1

After all necessary precautions have been taken to mitigate fire and explosion hazards, the next most important step is to locate the source of the flammable or combustible liquid and prevent any further release.

3-1.2

Generally, the source of the liquid will be relatively near the location where unconfined liquid or vapor has been discovered. However, liquids can travel hundreds of feet or even miles underground, through porous soil or rock, through trenches filled with porous material, alongside pipes or conduits, or in sewer pipes. Consequently, the location from which a released liquid might have originated can be remote and extensive and can include many facilities that handle and store flammable or combustible liquids. Also, the source of the release might be an abandoned underground storage tank. If a check of potential sources adjacent to or within several hundred feet of the discovery is not conclusive, then the investigation should be expanded to include other potential sources in the general area of the discovery. Some potential sources are:

(a) Automotive service stations, both retail and private;

(b) Automotive garages or dealerships;

(c) Fleet operations, such as taxicab companies, municipal garages, dairies, bakeries, etc.;

(d) Contractors or equipment dealers who store fuels on their premises;

(e) Motor fuel and heating fuel distributors;

(f) Cleaning establishments, including dry cleaners;

(g) Industrial and chemical process plants;

(h) Airports and marinas;

(i) Underground petroleum or gas transmission lines;

(j) Any abandoned tanks that stored flammable or combustible liquids in the past;

(k) Any other property on which flammable or combustible liquids are or may be stored.

3-1.3

Efforts should be made to secure information on groundwater flow patterns from the regional U.S. Geological Survey (USGS) office, local public works departments, or similar agencies, and search efforts should be initiated up-gradient from the leak.

3-1.4

Obtain or sketch a map of the area, mark each facility found on the map, and record all the information obtained. Well-organized, accurate data will prove invaluable in subsequent efforts to solve the problem.

3-1.5

Organize search teams of as many qualified persons as are necessary to conduct the search. One efficient method is to assign a two-person team to each specific zone on the map. One of the team members should represent the local public authority. Begin with the nearest and most obvious potential sources and work out from the point of discovery, moving uphill, up-gradient of groundwater flow, or upstream of sewer or conduit flows.

3-1.6

Often the source can be found by inquiry or simple inspection. Begin with the procedure outlined in Section 3-2. If an obvious or very likely source is not found within several hours, it is then advisable, while the primary search continues, to begin testing the closest and most probable sources, such as equipment, underground storage tanks, or underground piping, for concealed points of release.

3-2 Search Procedure.

3-2.1

Flammable and combustible liquids will most likely escape into the ground for the following reasons:

(a) Liquid has been spilled during transfer and has reached an underground conduit or soaked into porous soil;

(b) A leak has developed in a storage, transportation, or handling system.

Use the lists in this section as a guide in checking for spills or other possible sources of the release by asking questions and by careful inspection of the premises and equipment. Unless an obvious source that is large enough to account for the release is found, do not stop the search at the first sign of a potential source. First impressions can be misleading. It is useful to check available public records for any prior history of releases.

Also, because liquids can travel slowly through the ground or not move at all until the groundwater table rises, a considerable amount of time can pass between the actual release of liquid and its discovery. Therefore, record all history or evidence of potential leaks or spills, regardless of how long ago they occurred. Do not eliminate any potential source on the basis of time until all information is available and its analysis justifies elimination of that source.

3-2.2

The following questions should be asked of all facility operators in the area of the search:

(a) Has there been a spill during loading or unloading?

(b) Is any storage or handling equipment leaking or has there been a leak? Check for excavations or other evidence of repairs that might have damaged underground facilities.

(c) Has there been any maintenance on pipes, tanks, or other equipment that might have resulted in a release?

(d) Has there been any odor or other signs of liquids in areas where there should not be?

(e) Are inventory and use records kept? Do they show any indication of a release?

(f) Has water been found in any underground storage system?

(g) Is there any knowledge of an accident that might have released liquids from a tank vehicle, container, or storage tank? A check with local law enforcement agencies is useful here.

(h) Ask about the age of underground facilities. If subsequent tests are made, the older equipment might be suspect.

(i) Have any problems been encountered during pumping and liquid transfer?

3-2.3

If inquiry fails to disclose any potential source, ask each premises owner or operator for cooperation in checking equipment. If an operator refuses because he or she is not the owner, then obtain permission from the owner. If necessary, enlist the assistance of local governmental officials to secure such cooperation.

3-2.4

The following guidance will be helpful in checking equipment:

(a) Inspect on-site leak detection equipment for proper operation and for indications of a leak.

(b) Check the areas around fill pipes where liquid is transferred from tank vehicles to storage tanks for signs of spillage. Saturated or darkened soil, stained concrete, or disintegrated asphalt indicates that repeated spills might have occurred and accumulated underground.

(c) Check the areas around aboveground tanks for similar signs of leakage.

(d) Check all exposed piping for signs of leaks.

(e) Check dispensing equipment for leaks. It is advisable to use a combustible gas indicator when checking dispensers of the type used at automotive service stations. Open the cover of the dispenser just enough to insert the indicator probe into the area beneath the dispenser. Opening the cover wide might provide enough ventilation to dilute any vapors present and give a reading low enough to indicate no leak. IF THE VAPOR CONCENTRATION INDICATES A POTENTIAL RELEASE, REMOVE THE DISPENSER COVER AND INSPECT PIPING, VALVES, AND FITTINGS FOR SIGNS OF LEAKS. Check the dispensing nozzle and hose also.

(f) If a remote pumping unit is used, check its housing or pit with a combustible gas indicator before opening. Then open the unit for inspection.

(g) Check automotive repair areas for signs of waste liquids being dumped into inappropriate floor drains or sumps.

The use of any equipment found to be leaking should be stopped until repairs are effected. Any storage tank or piping that is found to be leaking should be emptied if liquid is still escaping.

3-2.5

If all the equipment appears to be in order and there is no obvious sign of spilling or dumping into sumps or sewers, check the grounds and areas around the premises. The following guidance will be helpful in checking the area:

(a) Look for signs of waste liquids having been dumped onto the ground.

(b) Check nearby streams and bodies of water for signs of flammable or combustible liquids. Look for a sheen or slick on the surface of the water and along the banks.

(c) Check vegetation for indication of damage by spilling, dumping, or contaminated groundwater.

(d) Using a combustible gas indicator, check sewers and other underground conduits and cavities, such as utility manholes, for the presence of vapors and make visual inspection for signs of foreign liquids on the surface of any standing water in these areas.

(e) Check the barrels of any fire hydrants in the area.

(f) Check nearby excavations and steep cuts or natural slopes down-gradient from the potential source for signs of liquid.

3-2.6

Keep in mind that dumping or spilling flammable or combustible liquids into sewers or on the ground might be a violation of state or federal law and should be reported to the proper authorities immediately.

3-2.7

Keep in mind that small spills do occur inadvertently and might indicate a release that is much larger than it really is. For example, a small amount of liquid (one cup of fuel, for example) spilled onto a wet pavement will spread over a relatively large area. Small spills that spread out over a large area will dissipate rapidly and are not likely sources of underground contamination. The significant releases are large spills and repeated small spills that can flow to points of access into underground structures or porous soils and then reach the groundwater table.

3-3 Procedures to Verify the Source.

3-3.1

Once an obvious source or one or more likely sources has been found and further release of liquid has been stopped, further search efforts can be temporarily suspended. It now must be determined if each identified source is, in fact, the actual source of the release. While removal and protective measures are taken, monitor and record the flow of the liquid, the amount of liquid, and the vapor concentrations at those locations where the problem exists. If a distinct and continuous decrease occurs, then it can be assumed that the source of the release has been identified. The decrease might not occur immediately; it might, in fact, take days or weeks for liquid that has accumulated underground to be removed or to dissipate. Refer to Chapter 5 for further information on estimating the time required for a decrease to occur at the monitored point.

3-3.2

If after a reasonable length of time, as determined in accordance with Chapter 5, the flow of liquid to the affected area does not stop or show a definite decrease, further investigation should be conducted simultaneously using the two procedures described below. These two paths should also be followed in cases where an obvious or likely source is not found.

(a) Conduct release detection tests on any liquid storage or handling system in the vicinity of the affected area. These tests will identify those systems that are, in fact, releasing liquid. Refer to Chapter 4, “Release Detection for Underground Storage Tank Systems.”

(b) Trace the path of the liquid underground from its point of discovery to the source. Tracing will determine the actual extent of the release, its direction of flow, and any potential, more remote sources. Refer to Chapter 5, “Tracing Liquids Underground.”

Chapter 4 Release Detection for Underground Storage Tank Systems

4-1 General.

4-1.1

Before actual equipment testing is undertaken, review the results of applicable search procedures conducted in accordance with Chapter 3. This review might reveal information that will eliminate the need for further testing or be useful in making further tests.

4-1.2

Ensure that spills or deliberate disposal are not the leakage source, keeping in mind the possible movement of liquids by trenches and underground water. (*See Chapter 5.*)

4-1.3

Check stock records for indications of loss.

4-1.4

Review all data previously gathered to determine the most efficient method or methods of testing. There are several quick and simple methods described in this chapter that can reveal a leak under certain circumstances. If one of these preliminary techniques does not reveal the source of a suspected leak, it cannot be concluded that the liquid-handling system is tight. But the possibility of quickly solving the problem will often warrant the limited effort involved before a tightness test or other release detection method is undertaken.

4-1.5

Regardless of the procedure involved, keep in mind that liquid-handling equipment should be evaluated in a manner that is as close as possible to normal operating conditions. Excessive pressures or tests by nonrepresentative liquids might indicate a leak where none exist or might conceal leaks that do, in fact, exist. For example, perforation of a tank shell might not be detected due to impermeable backfill, the water table, sludge, or rust plugs, all of which can inhibit release of product from the tank.

4-1.6

Tests conducted to determine the tightness of underground liquid-handling equipment or to evaluate whether there has been a release to the subsurface environment will have to be conducted where:

(a) The search and tracing procedures of Chapter 3 indicate a probable or likely source of the release, but the actual cause is not determined from surface observation;

(b) There is a suspicion of a leak because of reported stock losses;

(c) There is an unexplained accumulation of water in a tank.

4-2 Action Preliminary to Release Detection/Tightness Testing.

4-2.1 Checking Underground Tanks.

4-2.1.1 Review the information obtained from the search procedures described in Chapter 3. Ask about, observe, and note in particular:

(a) Method of filling tanks. Damaged fill pipes, poorly maintained tight-fill connections or hose couplings, driver carelessness, or even overemphasis on full deliveries might cause some of the product to be spilled around the pipe when a delivery is made. Particularly check fill pipes installed under covers.

(b) Any evidence of ground settlement around tanks and any sign of work that might have damaged the tank or its fittings.

(c) History of past or recent work on the tanks or attached piping.

(d) The presence of excessive amounts of water in the tank and any history of past water removal. (Use water-finding paste on the gauge stick.) If possible, determine whether the water increases during periods of heavy rainfall and remains constant or diminishes during dry spells. Also, if possible, determine the depth of the water table (i.e., the static level of the groundwater) by using an easily drilled, probed, or excavated area close to the tank(s) or some existing undrained opening.

(e) The age of the facility.

(f) The location and flow of liquid found underground by gas sensors or visual inspection.

All of this information will be useful in guiding subsequent inspection and testing.

4-2.1.2 When Water Is Reported to Be Entering a Tank.

(a) Check the fill pipe to ensure that water is not entering through a loose fill cap.

(b) Check the surface area around vent lines for evidence that water might be entering by this route. Standing water over vent lines could be the source. Note this possibility for future use.

(c) If no explanation other than a possible leak is found for water in the tank, carefully record the depth of water using water-finding paste or other appropriate means on the gauge stick and tightly close and lock the fill cap. After 8 to 12 hours, remove the cap and again check for water. If the rise in 12 hours exceeds $^1/_2$ in. (12.7 mm), close and lock the cap and check after another 8 to 12 hours. If the rise in the second period closely matches that of the first, a leak is probable. A rise of less than $^1/_4$ in. (6.4 mm) in 8 hours is inconclusive due to the inability to measure increments to within $^1/_4$ in. (6.4 mm). Longer test periods will have to be used to determine if a leak does, in fact, exist. Best results will be obtained if the water depth is less than 3 in. (75 mm) at the beginning of the test.

(d) The above test is not conclusive if the water table is above the top of the tank, as water could be entering around pipe connections into the tank top or through unused, plugged, or capped openings in the top of the tank that are not watertight. Also, if water is entering the tank at these top openings, it is not significant from the standpoint of tank leakage. Likewise, these tests are not conclusive if the tank is full, or substantially full, of product.

(e) In fact, water might not enter the tank if the level of product is at or above the level of the water table outside the tank. This test is relatively effective if the tank is practically empty and the water table is high but still below the tank top. A tank that is partially below the water table can have water enter or can lose product through the same leak, depending on the relative levels of the groundwater and the product in the tank.

4-2.2 Checking Underground Piping.

4-2.2.1 Check for:

(a) Recent digging, driveway repair, or other work in the area that might have damaged underground piping.

(b) Any recent repairs that might have created the leak due to faulty workmanship or that might indicate a previous leak.

(c) Any evidence of shifting ground, such as a frost heave, that might have damaged piping.

(d) Soft spots in asphalt paving indicating solvent action of liquids or vapor.

(e) Evidence of abandoned, capped, or disconnected piping, such as unused dispensing islands or other unused ancillary facilities.

(f) Evidence of improper operation of in-line leak detection devices.

4-2.2.2 If information on the location of liquid underground has been compiled by methods described in Chapter 5. Review this information for possible patterns that indicate a specific pipe to be the source. It might be advisable to drive or drill additional holes to determine exactly where the liquids are and how they are flowing. (*In particular, see Section 5-2.*)

4-2.2.3 Preliminary Testing of Piping Systems. The test to be used on piping will depend on whether the stored liquid is moved by suction or pressure.

4-2.2.4 Testing of Suction Piping.

(a) If the pump used in moving the liquid is above ground and the supply pipe operates under vacuum or suction, certain pumping characteristics will indicate either a leaking check valve or a leaking pipe. Air will enter the pipe through a leaking check valve or through a pipe leak as liquid drains back into the tank. The presence of this air will be indicated by the action of the pump in the first few seconds of operation after an idle period. If the pump is equipped with a meter and cost/quantity display device such as is found in a gasoline service station, pumping of air might be indicated by “skipping” of the volume display, a rattling sound in the pump, or erratic liquid flow due to mixing of air and liquid. Another indication is overspeed of the pump when first turned on, followed by slowing of the pump as it begins to move liquid. A third indication is “churning” of the pump, i.e., running, but not moving liquid at all.

(b) If any of the preceding conditions indicate a leak in the suction line, the check valve should be inspected first. Some check valves are located close to the pump inlet, others are mounted in the underground pipe just above the tank, and some are installed on the end of the suction stub inside the tank. Some of these valves located in the pipe above the tank can be inspected and repaired from the surface of the ground through a special extractor mechanism installed with the valve. If the valve is inside the tank, it might be necessary to dig down to the tank to check the valve or disconnect and seal off the pipe for a hydrostatic pressure test.

(c) Generally, digging down to the check valve or tank should be delayed until other, more easily performed surface tests have failed to reveal the leak. If there is any doubt that the check valve seats tightly, repair it, replace it, or seal it off. Then repeat the pumping test and, if air is still entering the suction line, it can be assumed that the pipe is leaking underground and it should be exposed for inspection. Dig carefully to avoid any damage to the pipe that might make it impossible to verify whether a leak actually existed prior to excavation.

(d) If the pump does not exhibit symptoms of a leak, as described above, but there is still reason to suspect a pipe leak, or if a complete system check has been performed and it is now necessary to isolate and check the piping system, individual pipe runs can be isolated and hydrostatic pressure tested.

4-2.2.5 Testing of Pressurized Piping.

(a) Quite often, pumps are located remote from the dispensing devices, either in the tank or, on rare occasions, just above the tank. In such cases, the pipe to the dispensing equipment operates under pressure. A leak in this line will cause rapid loss of pressure after the pump is turned off. This can be checked using the following procedure. The method described is specific to pressurized piping at vehicle refueling operations. At other types of facilities, a comparable method might have to be used.

(i) At the dispenser end of the pipe, close the emergency shutoff valve at the base of each dispenser served or close all valves upstream of any hose to hold pressure at the dispenser end. The pump end can be sealed off by setting the check and relief valves in the head of the pump. The check valve is readily accessible in the manhole over the pump and most are equipped with a screw or bolt for the specific purpose of positively seating these valves for line checking.

(ii) Install a pressure gauge in the line. A minimum 3-in. (76-mm) dial with maximum 60 psi (3100 mm Hg) range should be used to clearly show graduations of 1 psi (51.72 mm Hg). Generally, the best location for the gauge is at the emergency shutoff valve under the dispenser where $^1/_4$-in. or other small-size plugs are installed for this purpose.

(iii) Start the pump, note the maximum pressure, seat the check valve, then turn off the pump and observe any pressure drop. The test should be maintained for at least 10 minutes. If the pressure drops, it indicates the possibility of a leak in the piping. However, it should be noted that a loss of liquid pressure can be attributed to the following: a line leak, a decrease in liquid temperature in the line, piping distortion due to the liquid pressure, or vapor trapped in the piping.

(b) If the preceding test does not reveal a leak, the procedures described in Section 4-3 should be followed.

4-2.3 Checking Inventory Records.

4-2.3.1 A careful check of inventory records will be very helpful in determining the course of further investigation. (*See Appendix D for a description of inventory control procedures*.)

4-2.3.2 If the reason for the check is a report of loss of inventory but no liquid or vapor has been reported in unexpected locations, check the following:

(a) Loss due to meters that are not correctly calibrated.

(b) Loss by contraction due to lower temperatures.

(c) Theft.

(d) Use of a conversion chart that does not conform to actual tank geometry.

(e) Malfunctioning automatic tank gauging probe.

In any of these cases, further testing is not necessary.

4-2.3.3 If a loss of inventory cannot be attributed to any of the causes noted in 4-2.3.2, or if a statistical inventory reconciliation procedure discloses a loss of product, further testing is necessary. It also indicates that a potential hazard might develop from the escaped liquid, and a check of the surrounding area should be made for signs of contamination. (*See Chapter 3*.)

4-2.3.4 If the reason for the check is the discovery of escaped liquid or vapor underground:

(a) Evidence of inventory loss strongly implies the source has been found but subsequent checks to determine how the loss has occurred should be made before definite conclusions can be drawn.

(b) Any loss that is partially or totally explained by off-calibration meters, temperature shrinkage, or theft cannot be considered as conclusive evidence that the site in question is not a source. Records are often incorrect or inadequate. Unless another source is found and considered to be a satisfactory solution to the problem, other tests must be performed to draw definite conclusions.

4-2.3.5 Temperature change may falsely indicate a loss. The volume of petroleum products is highly sensitive to temperature change. A drop of 1°F will shrink 1000 gal (3785 L) of gasoline by 0.7 gal (2.2 L). Obviously, a temperature increase would have the opposite effect and could actually conceal a physical loss.

4-2.3.6 In summary, there are other factors to consider. Further checking should be performed before a facility is implicated on inventory losses alone. Theft or meter inaccuracies might be the actual cause.

4-3 Release Detection Methods.

4-3.1

With the information gained from the search procedures of Chapter 3 as a basis, use the techniques described in 4-3.2 through 4-3.7 in a logical process of elimination.

(a) Means and methods of release detection conducted or installed in accordance with federal or state regulations should be operated in accordance with manufacturers' recommended procedures. Personnel utilizing these methods should be properly trained in their use and operation. Proper documentation of procedures and results should be provided. Additional information regarding recommended procedures is provided in EPA/530/UST-89 1012, *Detecting Leaks: Successful Methods Step-by-Step*.

(b) Methods of release detection must comply with applicable local, state, and federal environmental regulations.

(c) Means and methods of release detection should be documented relative to their detection capabilities in accordance with local, state, and federal regulatory requirements. Third party validation is recommended.

(d) If a release is indicated by any of the described methods, further investigation is required by either confirming testing (*see Section 4-4*) or the tracing techniques described in Chapter 5, whichever is most appropriate.

(e) If no release is indicated by the described methods, the investigation should be expanded to other off-site potential sources.

4-3.2 Manual Tank Gauging.

For tanks of 1,000 gallons (3785 L) capacity or less, a manual tank gauge can be used, if the liquid level measurements are taken at the beginning and end of a period that is at least 36 hours long and during which no liquid is added or removed from the tank. See Appendix D.

4-3.3 Automatic Tank Gauging.

If the tank is equipped with an automatic tank gauging system that has a "leak test" mode, a "leak test" should be conducted in accordance with the manufacturer's operating instructions. Automatic tank gauging equipment must be capable of detecting a leak rate at least as low as 0.2 gallon per hour (0.8 L per hour) from any portion of the tank that routinely contains product, with a probability of detection of 0.95 and a probability of false alarm of 0.05.

4-3.4 Tank Systems Equipped with Secondary Containment.

4-3.4.1 If the tank system is of double wall construction or is installed with a secondary containment system, the interstitial space monitor point or the well(s) located within the secondary containment area, whichever is applicable, should be checked for the indication of a release. When groundwater is present, the monitoring method utilized must be capable of detecting the presence of at least $^{1}/_{8}$ in. (3.2 mm) of free product.

4-3.4.2 Interstitial monitors might indicate either the presence of leaked liquid or gaseous products or monitors can check for a change in condition indicating a breach (for example, by loss of vacuum or change in a liquid level established between the walls of a tank). Monitoring can be continuous or intermittent. Even a dipstick can be used at the lowest point of containment to check for leaks.

WARNING: The interstitial space of a double wall tank should not be tested with pressure beyond the manufacturer's recommendations, particularly since materials and construction techniques vary.

4-3.5 Vapor or Groundwater Monitoring Wells.

If vapor or groundwater monitoring wells have been installed in the tank system excavation area, they should be checked for indication of a release. When groundwater is present, the monitoring method utilized must be capable of detecting the presence of at least $^1/_8$ in. (3.2 mm) of free product.

4-3.6 Underground Piping Line Leak Detectors.

If line leak detector(s) are installed on pressurized product piping systems, operational testing should be conducted.

4-3.7

If inventory records have been analyzed by quantitative statistical methods, the analysis should be examined for indications of a probable release, assuming that the data can be analyzed conclusively.

4-3.8

Other methods might be approved by the local regulatory agency.

4-4 Testing.

4-4.1

If the release detection methods described in Section 4-3 are not available or do not yield conclusive identification of the potential source of a release, testing of the piping, tank, or both, might be necessary. The test procedures should detect a leak anywhere in the complete underground storage and handling system unless other information has eliminated some portion of the system from the search. Certain test methods might allow additional product to be released from the system or might cause structural damage to the tank or piping during the test. Where it is reasonable to assume that a leak exists, the effects on safety and the environment should be considered when determining which test method to use.

4-4.2

Tightness testing of the tank and piping must be capable of detecting a leak of as little as 0.10 gallon (380 ml) per hour, with a probability of detection of 0.95 and a probability of false alarm of 0.05. This is a performance standard to determine the detection capabilities of the testing device and procedure. The detection threshold for declaring a leak will vary based on individual manufacturer's specifications. Additional information on volumetric and nonvolumetric tightness test methods is provided in Appendix A and B, respectively.

4-4.3

If the results of a tightness test indicate that a leak might exist, either appropriate corrective action or additional testing to confirm the leak should be performed.

4-4.4 Pressure Testing.

4-4.4.1 Pressure Testing with Air or Other Noninert Gases.

WARNING: Pressure testing with air or other noninert gases of tanks or piping that contain flammable or combustible liquid is not recommended, should not be required by regulations or ordinances, and should be discouraged in practice.

4-4.4.2 Testing with Inert Gases. Inert or unique gases can be used for the purpose of detecting a leak for both tank and piping systems. The pressure exerted by both the product and the inert gas must not exceed the limits recommended by the tank manufacturer. The use of pressure-limiting devices is required in this application.

4-4.4.3 Atmospheric underground storage tanks are normally fabricated according to standards established by a trade association or a testing laboratory and recognized by the authority having jurisdiction. Tanks are tested in accordance with these recognized standards. To prevent structural damage, tests used to determine tank tightness, whether positive or negative pressure, should not exceed the limits recommended by the tank manufacturer. Consideration for hydrostatic and geotechnical influences should also be provided in the test procedure.

4-4.5 Hydrostatic Testing of Piping.

Hydrostatic testing of piping is a relatively simple test that can quickly indicate a leak. If the pressure drops, it indicates the possibility of a leak in the piping, and it is recommended that a volumetric tightness test be performed. It should be noted that a loss of liquid pressure can be attributed to the following: a line leak, a decrease in liquid temperature in the line, piping distortion due to the liquid pressure, or vapor trapped in the piping.

4-4.5.1 Pressurized Piping. Isolate the piping and conduct a hydrostatic pressure test at 150 percent of the maximum anticipated pressure of the system, but not less than 5 psi (34.48 kPa) gauge at the highest point of the system. The test should be maintained for at least 10 minutes.

4-4.5.2 Suction Piping. A liquid volumetric pressure test can be performed on a suction line by connecting to the exit port of the air eliminator or other appropriate fitting. This connection will permit pressure to be applied to the suction piping from the pump to the check valve. In this test, the hydrostatic pressure should not exceed 15 psi (103.4 kPa) to prevent damage to the pump.

Chapter 5 Tracing Liquids Underground

5-1 General.

Although the following guidelines are given in an approximate order of importance, they are not necessarily in the preferred order for all cases. The actual sequence of procedures and the actual choice of test methods will depend on the circumstances of the problem, information gained from the primary search, and any previous test results.

5-2 Procedure for Determining Underground Flow.

5-2.1

On a sketch of the local area (preferably on a scale of 1 in. = 100 ft), note any undergound facility as illustrated in Figure C-10. Also note any pertinent geological data that is available and the locations of manholes, tanks, fill pipes, vent risers, and pumps. Include any abandoned ditches or stream beds that have been filled and covered. Some sources for this information are:

(a) Municipal and state public works agencies, water departments, and sewer departments.

(b) Local, state, and federal geological departments.

(c) Utility companies.

(d) Facility owners and local residents. (Pay special attention to elderly and long-time residents. They will often provide valuable information about the area prior to its development.)

5-2.2

If necessary, use metal detectors to locate and trace buried steel pipe.

5-2.3

Information gathered and plotted on the sketch up to this point might indicate that a specific nearby facility is a very likely source. If so, proceed with tests to verify this, as described in Chapter 4.

5-2.4

Check potential liquid flow paths as follows:

(a) Visually check manholes, inlet boxes, wells, open trenches, exposed slopes and cuts, etc. Samples of water should be taken to test for the presence of flammable or combustible liquids.

(b) A combustible gas indicator should be used to determine the presence of vapors.

(c) If checking underground structures does not give a clear indication of the direction of movement of the underground flow, a more detailed search can be conducted in porous backfill or pervious strata by testing for vapors in the soil. This testing can be conducted in a number of ways. The simplest method is to drive a $^{3}/_{4}$-in. to 1-in. (19 to 25 mm) diameter bar into the ground with a sledge hammer, then test the atmosphere in the hole with a portable detection instrument. Alternatively, a hand-operated soil augur can be used to drill the hole, thereby reducing the risk of damage to any underground utility line or structure. Another method is to drive a hollow soil probe into the ground and pump vapors out of the probe to a portable detection instrument. The soil probe method is more sensitive than the driven bar or soil augur methods because there is less opportunity for surface air to mix with and dilute the atmosphere in the hole, thus making detection of flammable or combustible vapors more accurate. Care should be taken to avoid damage to underground utilities. If there is any question about the presence or absence of such, then investigation in that area should be suspended until specific locations can be identified.

5-2.5

If the potential for natural gas or sewer gas exists, make particular note of the readings of a combustible gas indicator relative to the location of sewer and gas lines.

5-2.6

When this testing has determined the probable direction from which the contamination is coming, extend the search upgradient using these same methods to determine the next most likely source. Check on both sides of the direction of flow to determine its width.

5-2.7

As the area of the search expands beyond the original sketch, obtain a smaller scale map or sketch and plot all additional data. As the area becomes larger, the data become more important to the search and subsequent handling of the contamination.

5-2.8

If the initial efforts (about one day's checking) fail to establish a clearly defined problem, additional expert assistance should be obtained. Local industries might be able to provide some of this assistance. Whenever possible, obtain the help of a local geologist who is familiar with the local geology.

5-2.9

It is beyond the scope of this recommended practice to cover the problem in all its potential complexities; that is the purpose for seeking expert assistance. Other methodologies such as soil gas analysis and test wells can be beneficial.

5-2.10

If the investigation fails to locate an active source of release, it is possible that the problem could be a result of an accumulation from a previous equipment failure, spill, or improper disposal of the liquid. Experience has indicated that many such residual deposits have existed and remained undetected for long periods of time before becoming large enough to make their presence known.

5-2.11

As the problem becomes more complex, other methods of testing and tracing might be useful. However, the advantages and disadvantages of each test procedure must be recognized if valid conclusions are to be reached.

5-3 Dye Tracing.

The use of a dye tracer is often suggested as a means of tracing the flow of liquid. The method involves adding a strong dye to the storage system suspected as the source of the release, then seeing if the dyed liquid appears at the point of discovery.

5-4 Chromatographic and Spectrographic Analysis.

The chromatograph and the spectrograph are instruments capable of detecting traces of the elements of almost any compound. For example, they can detect a trace quantity of an element that is unique to a particular method of manufacture, thus identifying the source. They can also detect the amount of the element present. These are relatively inexpensive tests and only involve a small sample taken at the point of discovery. These tests should be used in cases that involve complex mixtures, such as petroleum liquids. However, these tests might not be conclusive because some identifying component can be lost in the ground or a component not originally present can be picked up from the ground or from contact with buried materials.

5-5 Other Chemical Analysis.

Other methods of chemical analysis are available. They are essentially the same as the tests described in Section 5-4, and the same comments apply. One significant factor that can sometimes be determined by chemical analysis is the age of the contaminant.

Chapter 6 Removal and Disposal of Contaminated Liquid

6-1 General.

6-1.1

The presence of unconfined flammable or combustible liquid will continue to present a hazard until the contamination has been reduced to a safe level. While methods by which this can be accomplished will depend on the physical circumstances of the contaminated areas, the most effective results are obtained when the efforts of all interested parties and authorities are coordinated by the local or state fire official, usually the fire marshal. It is their inherent authority to enforce compliance with all rules pertaining to the cleanup operation, and it is their recognized responsibility to the public to exercise this responsibility from the time of discovery until safety is assured.

6-1.2

Removal and disposal methods will depend on the liquid involved and on the contaminated area.

6-1.3

The characteristics of liquids that are significant to the methods of removal and disposal are:

(a) Liquids that rapidly evaporate at ambient temperature will leave little or no residue. Typical liquids are volatile solvents and gasolines.

(b) Liquids that do not readily evaporate will tend to remain in place for long periods of time and will leave residues. Typical liquids are heating oils, food processing oils, and other nonvolatile liquids.

6-1.4

In general, purging a structure or enclosure of vapors of volatile liquids is primarily a matter of ventilation, while nonvolatile liquids must be physically collected and removed.

6-1.5

The principal categories of receptors involved are:

(a) Normally inhabited subsurface structures, such as basements, subways, tunnels, and mines.

(b) Normally uninhabited subsurface structures, such as crawlspaces, sewers, and utility tunnels.

(c) Bodies of water and groundwater.

(d) Soil.

6-2 Basements.

6-2.1

With very few exceptions, the quantity of liquid that will be found in a basement will be relatively small, because the liquid will normally be detected before significant quantities can accumulate and additional flow can be intercepted or stopped. Where volatile liquids and their vapors are involved, the primary removal and disposal action is ventilation, as described in Chapter 2. Small amounts of liquid that remain can be removed with commercial absorbents.

6-2.2

Contaminated absorbents should be placed in covered metal containers to prevent the further spread of vapors. Once all liquids have been removed, final cleanup can be accomplished by flushing out basement sumps and floor drains with water and washing down all contaminated surfaces with a biodegradable surfactant. Ventilation and checking with a combustible gas indicator should be continued throughout the cleanup procedure.

6-2.3

In the rare cases involving relatively large volumes of volatile liquids, ventilation might not sufficiently reduce the vapor concentration to a safe level due to the continued evaporation of the liquid. In these cases, bail or pump the liquid into barrels, drums, or other suitable containers or into portable tanks or tank vehicles. It might be necessary to dig an interceptor trench between the source of the release and the affected structure.

6-2.4

When nonvolatile liquids, such as fuel oils, are involved, ventilation is ineffective because the liquid evaporates at such a low rate. Absorbents should be used for thin films of liquid on water surfaces or on solid surfaces. Whenever possible, remove liquids with pumps or by bailing. Contaminated water should be put into barrels or other containers to allow separation by settling. The water can then be siphoned off and the remaining liquid brought to a disposal facility. (*See Figure 6-2*.) If final cleanup requires flushing sumps and drains and washing surfaces, check with local sanitation and environmental authorities before flushing such liquids to sanitary sewers.

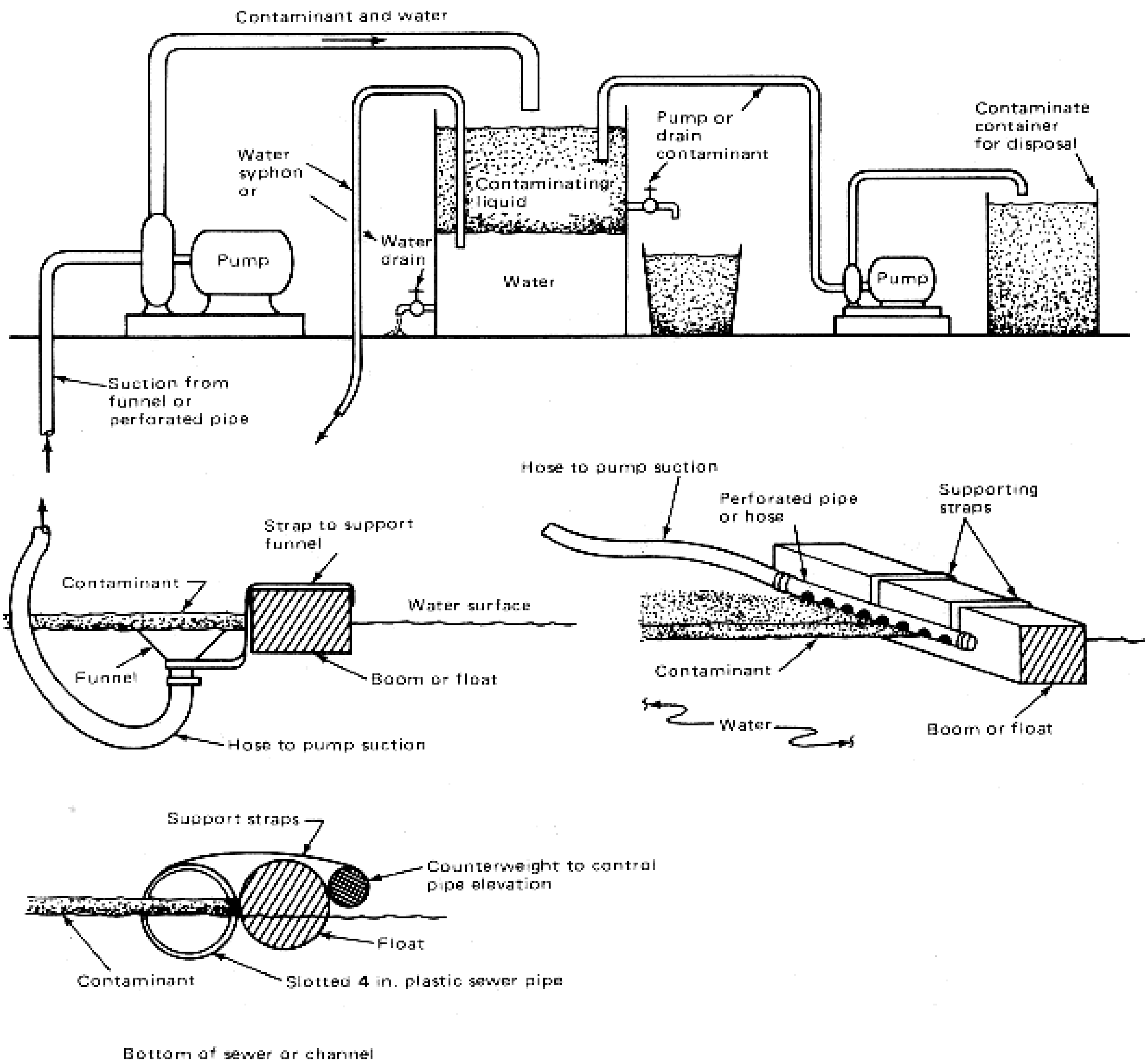


Figure 6-2 Typical skimming and gravity settling installation.

6-3 Subways, Tunnels, Mines, Etc.

6-3.1

If only small amounts of volatile liquids are involved, ventilation alone might be adequate to permit safe entry and possibly continued use of the facility. In such cases, the same removal and disposal methods as described previously for basements can be used. However, added precautions must be employed due to the greater potential exposure to the public and, normally, due to the greater exposure to potential ignition sources. The authority responsible for the facility, the fire department, and other public safety officials should effect a cooperative effort for maximum public safety.

6-3.2

Subways, tunnels, and mines will normally be more prone to underground seepage than other subterranean structures, such as basements. Consequently, even though entry of a flammable liquid is thought to have been stopped, monitoring with a combustible gas indicator should be continued for an extended period of time after remediation to check for recurrence.

Maintain a constant check for at least 24 hours after remediation has been completed. If results are negative, extend the check periods to an 8-, 12-, or 24-hour cycle, depending on the use of the facility. Subsequent checks should be continued to include periods of extreme changes in groundwater levels. Significant rainfall and rising groundwater can carry with it more liquid.

6-3.3

If a relatively large amount of liquid is involved or if leakage continues, it might be necessary to close the facility to the public and suspend normal operations. It might also be necessary to deactivate any high voltage electric lines or electric transit tracks in the vicinity of the seepage. Maintain ventilation and provide a collection point for intercepting seepage and pumping it out. Use only a non-sparking or air-operated pump motor.

Use a drum or small tank for liquid settling and separation; transfer the separated volatile liquid to drums or tanks for transport to a disposal facility. Consult with the facility operator to determine the degree to which cleanup and remediation are necessary. Normally, once further entry of volatile liquids has been stopped, such facilities can be adequately purged of vapors with reasonable periods of ventilation.

6-3.4

If nonvolatile liquids are involved, the potential for ignition is greatly reduced. However, make sure that continued use or operation does not present a potential ignition source. It might still be necessary to disconnect any electric services near the seepage, as explained in 6-3.3.

Absorb, bail, or pump the liquid, whichever is more appropriate, using drums or tanks for separation by settling, and remove the liquid for transport to a disposal facility. Consult with the facility operator to determine the acceptability of using detergents, dispersants, or coagulants for final flushing and cleaning. As with volatile liquids, periodic monitoring must be performed to detect any possible recurrence. Use the same time periods and groundwater changes as described in 6-3.3.

6-4 Utility Conduits.

6-4.1

Removal and disposal methods for utility conduits differ from those described for other subterranean structures previously covered for the following reasons:

(a) Concentrations of contaminating liquids will normally be higher because early discovery and preventive measures are unlikely.

(b) Access to entry points and contaminated areas is usually from manholes, but such access might not be available.

(c) Exposure and danger to the public are greatly reduced.

The utility operator should be consulted on all details of the remediation effort and the proposed purging procedures. The operator's special knowledge will be essential to selecting the exact procedures and techniques to be used.

6-4.2

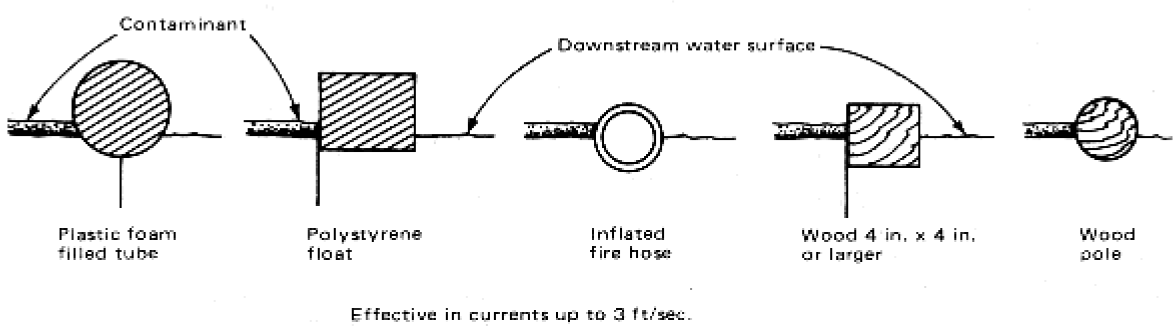
Where water is mixed with the contaminating liquid, it is preferable to separate the two by settling in drums or tanks to avoid downstream drainage facilities.

6-5 Sewers.

6-5.1

On occasion, sewers can collect flammable or combustible liquids from a surrounding contaminated area. It is seldom practical to seal off all entry points into the sewer. Consequently, removal of contaminating liquids will normally be a continuing effort until the entire area is purged. When relatively large amounts of liquid are involved, every reasonable effort should be taken to divert the affected sewer flow to a separator.

If this is not practical, it might be possible to set up a skimming facility at some point on the stream flow. One method is to float a boom or inflated tube (such as a fire hose) across the stream. If the contaminant is mostly on the surface of the stream flow, and flow is not turbulent, significant amounts of the contaminating liquid can be trapped behind the boom and can be removed with skimmer pumps or absorbents. [*See Figures 6-2 and 6-5(a).*] Weirs can also be used in the same way by installing them in such a manner that water can flow underneath, trapping the liquid behind the upper part of the weir. Weirs should be used whenever possible because of their greater efficiency, particularly where the stream flow exceeds 3 ft per second (1m/sec). [*See Figure 6-5(b).*]



For SI Units: 1 ft = 0.305 m; 1 in. = 25.4 mm.

Figure 6-5(a) Typical floats and booms for trapping contaminants floating on water.

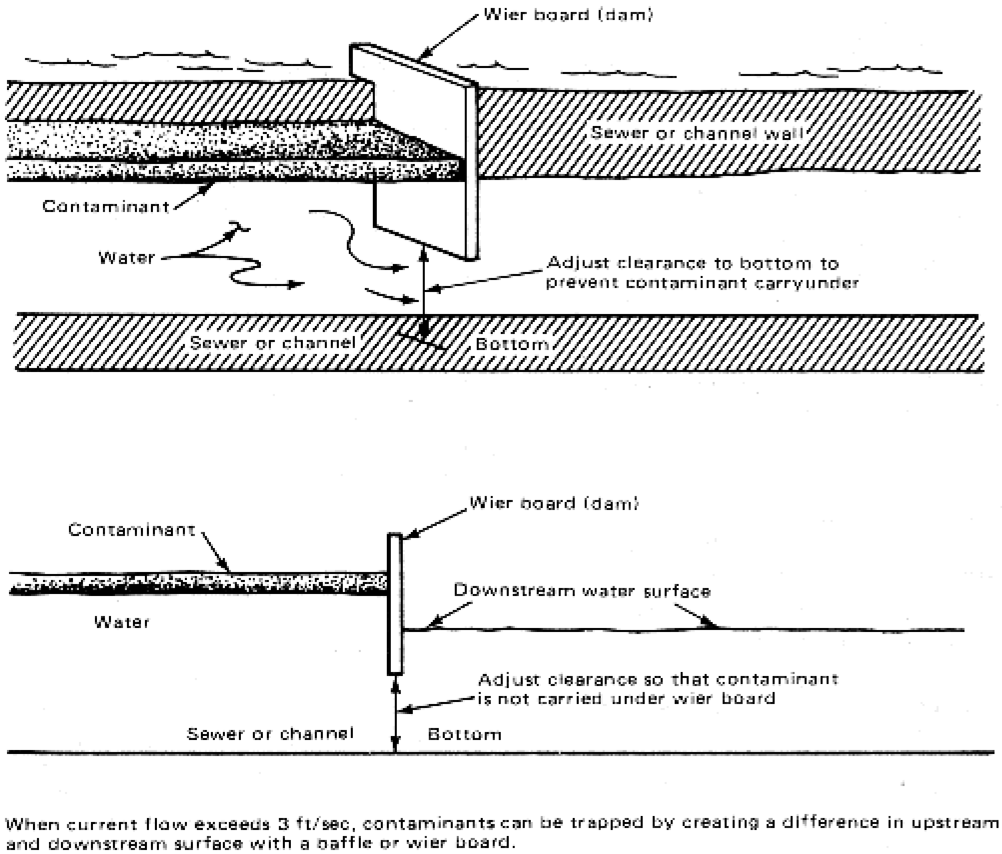


Figure 6-5(b) Typical installation of a wier in a flowing stream.

6-5.2

Where relatively small amounts of liquid are involved or where the contaminating liquid is mixed with the water, settling tanks or basins must be used for separating the contaminant from the water. Sewage treatment plants might have such facilities. Note that this is only applicable to liquids that are immiscible with water.

6-5.3

Where contamination exists on the surface of a body of water that is directly exposed to the open atmosphere, the problem should be referred to the appropriate environmental authority.

6-6 Underground Contamination.

A knowledge of the local geology is basic to effective removal of flammable or combustible liquid contamination from subsurface soils. A geologist who is familiar with the area should be consulted before field activities are begun. Subsurface assessment will most likely be required to further determine the movement of contamination, to define the extent of the contamination, and to properly design the remediation efforts. Additional information can be found in API Publication 1628, *Guide to the Assessment and Remediation of Underground Petroleum*

Releases.

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 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 Publication.

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

NFPA 328, *Recommended Practice for the Control of Flammable and Combustible Liquids and Gases in Manholes, Sewers, and Similar Underground Structures*, 1992 edition.

7-1.2 API Publication.

American Petroleum Institute, 1220 L St., NW, Washington, DC 20005.

API Publication 1628, *Guide to the Assessment and Remediation of Underground Petroleum Releases*, Second Edition, 1989.

7-1.3 U.S. Government Publication.

Office of Underground Storage Tanks, U.S. Environmental Protection Agency, Washington, DC 20460.

EPA 530/UST-89 1012, *Detecting Leaks: Successful Methods Step-by-Step*, November 1989.

Appendix A Volumetric Tightness Testing

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

A-1 Definition.

The term *volumetric tightness test*, as used in this recommended practice, refers to any test that fulfills the detection capabilities set forth in Section 4-4 and quantifies a leak rate. There are a number of variables that affect the ability of any particular tightness testing technology to perform within these detection capabilities. The following information addresses some, but not all, of the variables that might be encountered. An understanding of these variables and how they are handled is essential to effective performance of the test. Each manufacturer of a volumetric tightness testing technology should identify in writing a procedure or means of dealing with the variables described in this Appendix, as applicable.

A-2 Variables Affecting Volumetric Tightness Testing.

The variables that are addressed here are as follows:

- Temperature
- Tank deflection
- Water table

- Entrapped air/vapor
- Evaporation
- Tank volume
- Vibration
- Wind

- Operator error
- Product characteristics
- Tank configuration
- Preexisting soil or groundwater contamination
- Testing with water

A-2.1 Temperature.

Liquids expand or contract with a change in temperature. Table A-2 lists the thermal coefficient of expansion for some of the more common flammable and combustible liquids. For example, note that a temperature decrease of only 0.04°F (0.022°C) in one hour in a 6,000 gal (22,710 L) tank containing gasoline would cause a volumetric decrease of 0.04°F (0.022°C) × 0.0007 × 6,000 gal (22,710 L) = 0.168 gal (636 ml), which exceeds the 0.10 gal (380 ml) leak detection capability. If this temperature change were not detected and accounted for in a test, a leak would be assumed where none existed. And, in a like manner, if the temperature increased, a leak could be concealed by volumetric expansion if the temperature change was not detected.

Table A-2 Coefficients of Thermal Expansion for Some Common Liquids

	Volumetric Coefficient of Thermal Expansion per °F
Acetone	0.00085
Amyl Acetate	0.00068
Benzene	0.00071
Carbon Disulfide	0.00070
Ethyl Ether	0.00098
Ethyl Acetate	0.00079
Ethyl Alcohol	0.00062
Fuel Oil No. 1 & Kerosene*	0.00050
Fuel Oil No. 2 & Diesel Fuel*	0.00045
Gasoline*	0.00070
Methyl Alcohol	0.00072
Toluene	0.00063

Water (at 68°F)	0.000115

*The coefficient of thermal expansion given for each of these liquids is typical for that liquid, but may vary depending on the components of the liquid and on temperature. See ASTM D1250-80, *Petroleum Measurement Tables*, for further information.

It is sometimes proposed that this problem can be overcome by filling the tank 10 to 12 hours before a test run, on the assumption that the product temperature will stabilize. Extensive tests have shown that this is seldom, if ever, true. When liquid is added to fill a tank for testing, it will often require several days for the liquid to stabilize to ground temperature, which in itself is constantly changing. The rate of temperature change in the first day or two will generally be in the range of 0.02°F (0.011°C) per hour to 0.25°F (0.7°C) per hour. In addition, the rate of temperature change will vary depending on the temperature and volume of the product in the tank, as well as the product added. Obviously, the test must be capable of detecting temperature changes to the accuracy necessary to ensure compliance with Chapter 4.

Another temperature effect that must be recognized and accounted for is temperature stratification or "layering." Layering occurs when a product of a different temperature is added to a product already in a tank (i.e., the product added is colder than the product already in the tank). In addition, layering occurs as a result of ground temperature variations with depth. Temperature measurement must include a method for averaging any differences in temperature throughout the tank.

A-2.2 Tank Deflection.

Some techniques require filling the tank to a point above grade. This increase in the height of the liquid increases the pressure inside the underground tank above its normal operating pressure and will deflect the tank ends outward. This is illustrated in Figure A-2.2(a).

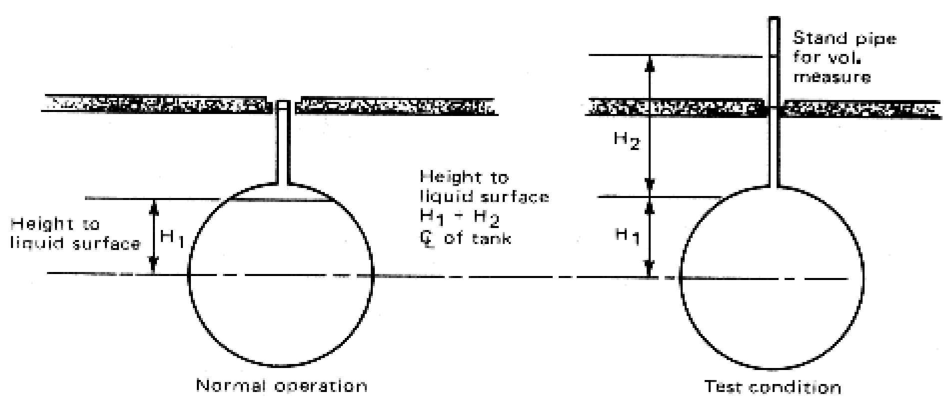


Figure A-2.2(a) Static pressure on tank shell — normal operation vs. test condition.

In a 6 ft (1.8 m) diameter tank, the average pressure on the end or "head" of a tank that is filled with gasoline is 0.98 psi (50 mm Hg). If the tank is buried 3 ft (1 m) below grade (typical for most gasoline tanks), the average pressure on the tank head will increase to approximately 2.95 psi (153 mm Hg) when the fill pipe and standpipe are filled to a level 3 ft (1 m) above grade.

This increase in pressure of approximately 1.95 psi (100 mm Hg) exerts an additional force on the end or “head” of the tank of about 8,000 pounds, or 4 tons. The ends of most tanks typical of underground use are made of $^{1}/_{4}$-in. (6.4-mm) thick steel plate and will deflect outward as pressure inside the tank increases, as shown in Figure A-2.2(b). Although most fiberglass tanks have dished or hemispherical ends, the same phenomenon of expansion will occur due to flexure between the ribs on the side of the tank.

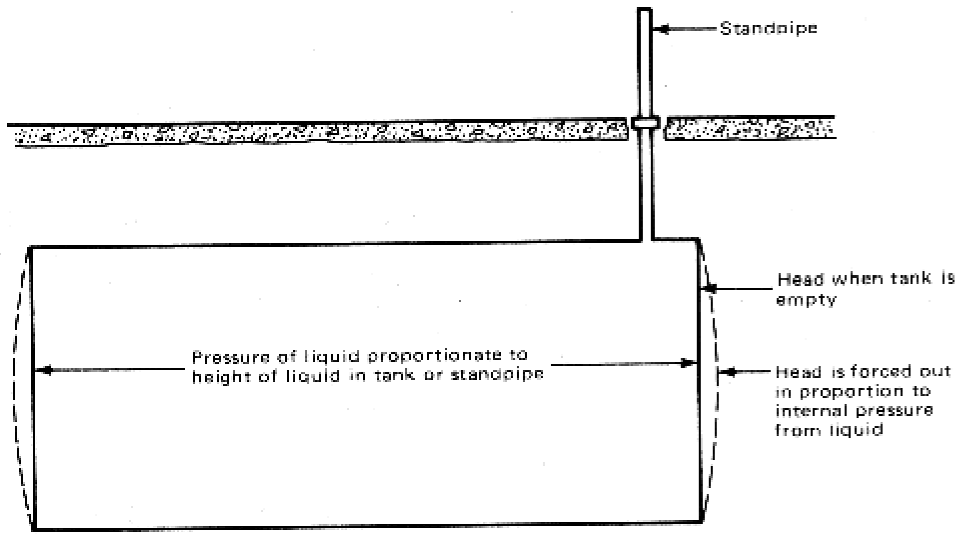


Figure A-2.2(b) Tank end deflection.

If the tank is located above ground and the heads are not supported in any way, it is possible to predict the amount of movement that will result from any given change in pressure and, when the amount of movement is known, the resulting increase in volume of the tank can be calculated. However, when tanks are located underground they are subject to an infinite variation in the mechanical support from the surrounding soil, and it is not possible to predict how much movement will take place. Very solid soil can sometimes provide close to full support. But normally soils will consolidate to some degree, particularly if they are wet, thereby allowing tank expansion and end deflection.

Extensive study and testing have revealed that, in almost all cases, tank movement that is significant enough to affect tightness tests occur. It will happen suddenly because of the time required to consolidate the soil. Under a constant increased pressure, it will normally take several hours for the tank to stabilize. Table A-2.2(c) shows the volume increase as a function of tank end deflection. The numbers underlined are the maximum normally encountered with underground steel tanks; the last figure in each horizontal row is the maximum possible for the tank size in that row. Similar information is not yet available for fiberglass tanks. The latest data indicate that expansion due to side flexure might exceed that for flexure of steel tanks.

The test method employed should be capable of clearly indicating the possible effects of tank end deflection and should provide a means of compensation or elimination of the effects.

Table A-2.2(c) Increase in Volume, in Gallons, of Tank Due to Tank End Deflection

Apparent Loss of Liquid Volume in Gallons Due to Increased Pressure in a Tank

Outward Deflection at Center of Head in Inches

Tank Dia. Inches	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1
48	.49	.98	1.47	1.95	2.44	2.93	3.42					
64	.87	1.74	2.61	3.48	4.35	5.22	6.10	6.97				
72	1.10	2.20	3.31	4.41	5.51	6.62	7.72	8.82	11.0			
84	1.50	3.00	4.50	6.00	7.50	9.00	10.50	12.00	15.0	18.0	21.0	
96	1.96	3.91	5.87	7.82	9.77	11.75	13.70	15.65	19.6	23.5	27.4	31.3
102	2.21	4.42	6.65	8.25	11.06	13.30	15.50	17.70	22.6	26.6	31.0	35.4
120	3.06	6.12	9.18	12.25	15.30	18.4	21.4	24.5	30.6	36.7	42.8	49.0

For SI Units: 1 in. = 25.4 mm.

A-2.3 Water Table.

As stated in 4-2.1.2, there are many instances where water might enter a tank system. The relationship of the water table to the depth of burial of the tank system has a direct bearing on volumetric tightness testing procedures and results. The test method employed should be able to indicate clearly the possible effects of water in the back fill area around the tank system and provide a means of compensation or elimination of the effects.

A-2.4 Entrapped Air/Vapor.

Stored materials combined with air in the form of a pocket of air/vapor mixture will be affected by both temperature and pressure changes. Volume expansion or contraction will occur. Volumetric tightness test methods employed should be able to indicate the presence of entrapped vapor or air that might affect the results of the test. The test method must require the removal of the entrapped vapor or compensate for the effects of the entrapped vapor.

A-2.5 Evaporation.

Some liquids, especially highly volatile liquids, have high rates of evaporative losses if exposed to the ambient atmosphere. The volumetric tightness test method employed should be able to clearly indicate the possible effects of evaporative losses and compensate for them.

A-2.6 Tank Volume.

Differences in the nominal volume and the actual true volume of an underground storage tank can affect the accuracy of the measurement technology employed during a volumetric tightness test. The best sources of information regarding the true volume of an underground tank are the “strapping” charts supplied with the tank being tested or by checking with the tank manufacturer. If these charts are not available, then volume charts based on design specification and not true volume must be used. Under no circumstance should testing personnel “best guess” the true volume of the tank.

If there is no other reasonable means of determining the true volume, a metered delivery of product could be made and the tank size calculated.

A-2.7 Vibration.

Vibration in the test area can affect the capabilities of test and measurement equipment. Tightness testing equipment having a computer-driven metering pump associated with the volume measurement systems or a manual tightness tester with an auto-leveler on the volume measurement system are two means often used to eliminate or minimize this variable.

A-2.8 Wind.

Wind can affect the accuracy of some volume measurement devices. Shielding the measurement equipment from the effects of the wind should compensate for this. If the testing system is operated by a microprocessor-based computer, it might be possible to calculate out the effects. Where a volumetric tightness test is being performed “in the tank” (below the tank top), winds across the vent can also interfere in the accuracy of the test.

A-2.9 Operator Error.

The more complicated the testing procedure, the greater the potential for operator error. Typically, this is minimized or reduced by using trained and experienced operators to conduct the testing. All testing personnel should have documentation as to training and qualifications for the testing equipment being used.

Having been trained on the technical aspects of the testing equipment is not sufficient. A good general working knowledge of the mechanical components of the tank system is also necessary to avoid testing problems and a potential release of product as a result of operator error.

A-2.10 Product Characteristics.

Most tightness testing technologies have been developed for use with motor fuels or other petroleum-based liquids and water. Petroleum products that have a greater viscosity than motor or aviation fuels may not be easily tested by most testing technologies. For example, No. 6 fuel oil at a stored temperature less than 120°F is normally not free flowing. Although a release detection technology might be able to measure observed volume changes in the tank despite the viscosity of the product, a leak might not be detected.

Testing non-petroleum-based solvents can also be a problem due to incompatibility of the stored material with the test equipment.

A-2.11 Tank Configuration.

Most tightness testing technologies are designed to be used on tank systems of a specific configuration. Usually tanks are horizontal cylinders with flat or hemispherical ends and a number of vertical access ports or a manway. Where a computerized tester is involved, the data base is often designed to measure temperature and volume change in a tank of this configuration. If the same tightness testing system is used to test a vertical cylinder or a square concrete fuel bunker, modification of the mechanical components of the data base might be necessary.

The mechanical components of a tightness testing system often require direct access to the tank through a vertical fill pipe. If the tank system has only a remote fill pipe (i.e., pipe where there is no direct access to the tank), mechanical modification of the tank components might be necessary.

When a product level-sensitive detection method is used to determine leaks in an underground storage tank, tank inclination can affect detection accuracy. In an inclined tank, the volume change per unit of level change is different than in a level tank. This is due to the difference between cross-sectional areas. This effect can be corrected by measurement of the level changes due to a known product volume change.

Some tightness testing technologies detect an ingress of water. Where a tank is installed on an incline, water sensing equipment might not be capable of detecting an ingress.

A-2.12 Preexisting Soil or Groundwater Contamination.

Tightness testing technologies that detect an ingress of water might fail to sound an alarm or might indicate a tight tank where there is a substantial concentration of free product in the soil around the tank prior to the test.

A-2.13 Testing with Water.

Tests that involve adding water to a tank can be useful when tanks are empty. However, water is difficult to use in cold weather. It will not detect leaks of less viscous liquids, and contamination of the storage and dispensing system can be a major problem (and result in frozen pipes in cold weather). If a tank previously contained a petroleum product and a test using water is considered, it might be more difficult to dispose of the product-contaminated water than to fill the tank with product for the test. Water is often used for an initial test of a new tank system that has not yet contained any product. Also, water has a greater surface tension than some petroleum products. If a test is performed using water, it is recommended that a surfactant be used to lower the surface tension of the water to near that of the product stored for a more accurate test. Contact the manufacturer of the tightness testing method regarding the use of a surfactant and check with local authorities regarding the disposal of the water after the test.

Appendix B Nonvolumetric Tightness Testing

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

B-1 Definition.

The term *non-volumetric tightness test*, as used in this recommended practice, refers to any test that fulfills the detection capabilities set forth in Section 4-4 and that does not quantify a leak rate. There are a number of variables that affect the ability of any particular tightness testing technology to perform within these detection capabilities. The following information addresses some, but not all, of the variables that might be encountered. An understanding of these variables and how they are handled is essential to effective performance of the test. Each manufacturer of a non-volumetric tightness testing technology should identify in writing a procedure or means of dealing with the variables described in this Appendix, as applicable.

B-2 Variables Affecting Nonvolumetric Tightness Testing.

The variables that are addressed here are as follows:

- Extraneous noise

- Water table/impermeable soils
- Operator error
- Product characteristics
- Tank characteristics
- Preexisting soil or groundwater contamination

B-2.1 Extraneous Noise.

Extraneous noise can be a factor where the chosen non-volumetric tightness testing technology relies on sound-sensitive signals to detect a release. Elimination of the source of the extraneous noise might be necessary for completion of a valid test.

B-2.2 Water Table/Impermeable Soils.

Some non-volumetric tightness testing technologies employ the use of tracer materials to detect a leak. The movement of these tracer materials can sometimes be inhibited by impermeable soils or groundwater, thereby reducing the detection capability of the testing technology or causing an extension of the test time.

B-2.3 Operator Error.

The more complicated the testing procedure, the greater the potential for operator error. Typically, this is minimized or reduced by using trained and experienced operators to conduct the testing. All testing personnel should have documentation as to training and qualifications for the testing equipment being used.

Having been trained on the technical aspects of the testing equipment is not sufficient. A good general working knowledge of the mechanical components of the tank system is also necessary to avoid testing problems and a potential release of product as a result of operator error.

B-2.4 Product Characteristics.

Most tightness testing technologies have been developed for use with motor fuels or other petroleum-based liquids and water. Petroleum products that have a greater viscosity than motor or aviation fuels may not be easily tested by most testing technologies. For example, No. 6 fuel oil at a stored temperature less than 120°F is normally not free flowing. Although a release detection technology might be able to measure observed volume changes in the tank despite the viscosity of the product, a leak might not be detected.

Testing non-petroleum-based solvents can also be a problem due to incompatibility of the stored material with the test equipment.

B-2.5 Tank Configuration.

The mechanical components of a tightness testing system often require direct access to the tank through a vertical fill pipe. If the tank system has only a remote fill pipe (i.e., pipe where there is no direct access to the tank), mechanical modification of the tank components might be necessary.

Some tightness testing technologies detect an ingress of water. Where a tank is installed on an incline, water sensing equipment may not be capable of detecting an ingress.

B-2.6 Preexisting Soil or Groundwater Contamination.

Tightness testing technologies that detect an ingress of water might fail to sound an alarm or indicate a tight tank where there is a substantial concentration of free product in the soil around the tank prior to the test.

B-3 Internal Inspection.

If warranted, an internal inspection of the tank should be conducted to evaluate the condition of the tank interior. Proper procedures for safe entry should be followed.

Appendix C Basic Principles and Concepts of Underground Flow

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

C-1

The principal characteristic that permits liquids to enter, accumulate, and flow through soil or rock is porosity: the space or voids that exist between the particles that make up the soil or rock. The size of the voids will vary from large, as in gravel, through small, as in sand and topsoil, to essentially zero, as in fine, dense clay. Rock almost never has large voids, but sandstones and limestones have voids similar to a fine sand.

Crystalline rocks, such as granite and marble, are essentially impervious, but these rocks often have fractures and cracks that will permit flow. The rate of flow through rock fractures will vary from large continuous cracks that will act like a pipe, to very small irregular cracks that result in flows similar to what would be found in fine sand.

The rate of flow through soils and rocks depends largely on the size of the voids, with flows ranging from 6 ft per year in fine clays to 6 ft per day in gravels. The term used to describe soils that allow flow is *pervious*. A very pervious soil will allow rapid flow of liquid, while an impervious soil will allow only very slow flow. When the word *impervious* is used alone, it implies absolutely no flow; for example, glass is impervious to the flow of water. It should be understood that porosity does not always mean a pervious condition. In order for the soil or rock to be pervious, the pores must be interconnected. A porous rock whose pores are isolated from each other will be impervious.

C-2

Almost all flammable and combustible liquids are lighter than water and will float on the water, unless the liquid is water soluble. When these liquids escape into the ground, they will normally flow downward until they encounter a layer of groundwater. Then they will flow along with the groundwater. Understanding the flow of groundwater is essential to tracing the flow of a flammable or combustible liquid underground.

C-3

Water is almost universally found underground at some level in soil or rock. It might be in very limited quantities and only able to dampen the soil. But when it fills all the pores and voids in the soil and saturates the soil or rock up to a certain level, it becomes somewhat like water in a bucket and establishes a definite top surface, called a water table. Figure C-3(a) shows that groundwater can occur in several layers underground. A porous layer between two impervious layers might be completely filled or might be only partially filled and have its own water table. However, other layers must be considered, since, even though these might be very deep at one location, they can be close to the surface at others. See Figure C-3(b).

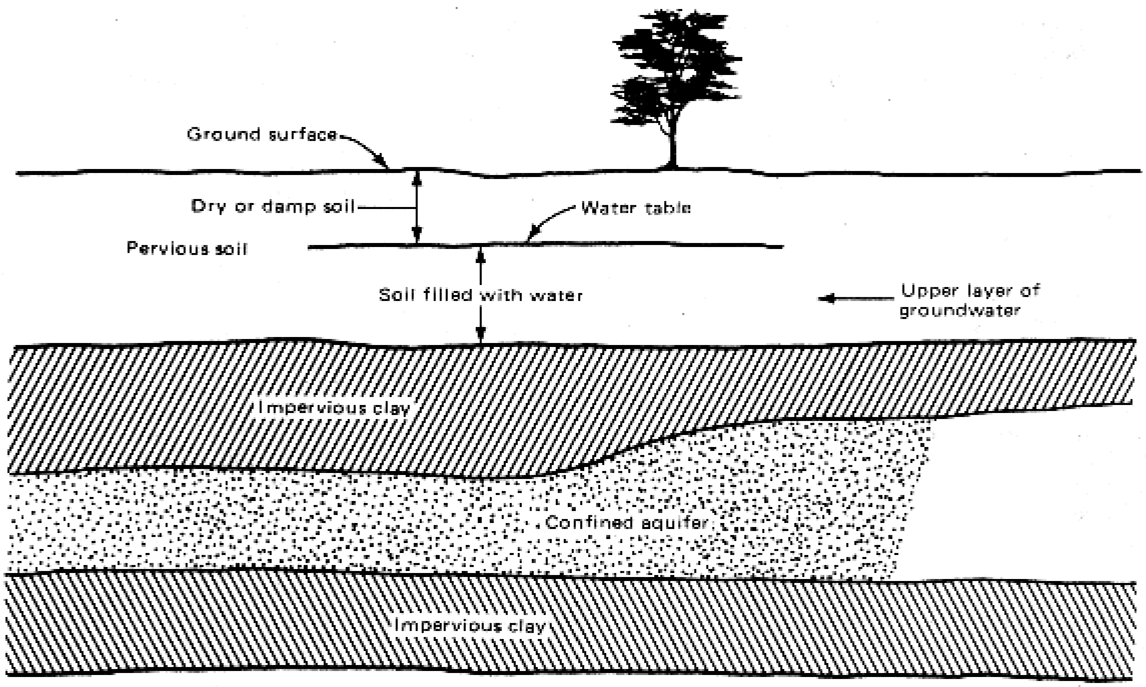


Figure C-3(a) “Layering” of groundwater between and above impervious strata.

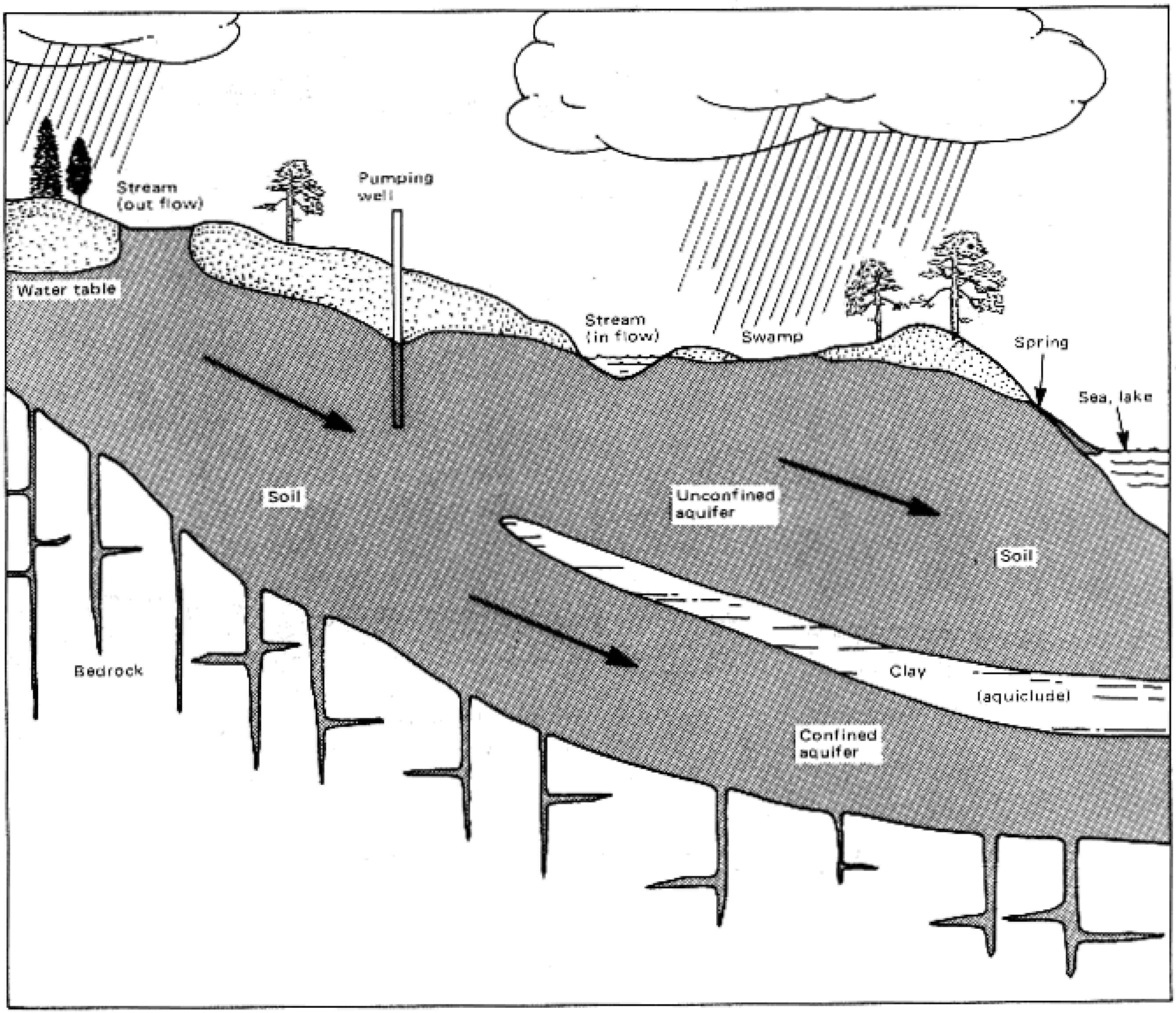


Figure C-3(b) Hypothetical groundwater systems showing significant features.

C-4

All groundwater, with the exception of narrow bands along the seacoast, originates as rain or snowfall that seeps into the soil. As shown in Figure C-3(b), at any given location, the water might have come from precipitation on the surface immediately above or it might have flowed underground for long distances through pervious soil or rock from a point where the pervious layer "outcrops" or intercepts the surface. Of course, water from precipitation can also flow to lakes and rivers and then into underground layers.

C-5

Water tends to seek its own level underground, just as it does on the surface. However, water flowing underground will not flow as fast as on the surface because of the resistance of the soil particles. This has the effect of steepening the slope of the water table. The water does not flow to lower levels as fast as it fills the soils at shallower depths. The same effect is shown where a lake or other body of water supplies water to the pervious soil. Expressed another way, pressure is required to overcome the resistance to flow and the increase in elevation provides the necessary pressure.

C-6

The height or elevation of the water table will depend not only on how fast the water flows out of the strata (layers), but also on how fast it is fed into the strata by rain or melting snow. When no water is being added, the water table drops, as water flows out at springs and wells and as it “wicks” through dry soil to evaporate at the surface. When water is added faster than it can flow out, the water table rises. This rise and fall can be several feet in a few days, as the weather changes from dry to wet and vice versa.

C-7

In summary, the principal factors that are important to tracing unconfined liquids underground are:

(a) Most flammable and combustible liquids will float on water.

(b) When unconfined in the ground, flammable and combustible liquids will float on the top of the water table and will flow along with it.

(c) Groundwater will flow through pervious soil or rock toward lower elevations at a flow rate that will vary from several feet per day to several feet per year.

(d) The top of the water (the water table) will slope downward in the direction of flow.

(e) The water table will rise and fall (in some cases, several feet in a few days), depending on the supply of rain or melting snow.

C-8

Figure C-8(a) and (b) show the effect of the slope of the underground strata on the direction of liquid flow. The figures show identical surface conditions, but differing subsurface conditions. A 4-story building lies approximately midway between two streets that are 400 ft apart. A 5 percent grade from left to right places the street on the right about 20 ft higher than the street on the left.

In Figure C-8(a), the underground strata follows the general slope of the surface and groundwater in the sand and gravel layers flows from right to left. Under these conditions, if gasoline liquid or vapors were found in the subbasement of the building, the source of that gasoline would most likely be from the service station to the right, at the higher elevation, or from other tanks farther up the hill.

In Figure C-8(b), the situation is such that the service station downhill is the most likely source. The water-bearing strata of sand and gravel slopes down from left to right, opposite to that of the surface of the ground. Groundwater flow would also be from left to right and would carry any gasoline escaping from the service station on the left to the subbasement of the building.

One other condition shown in Figure C-8(a) is the effect of a rising and falling water table.

During a dry season, when the water table is below the subbasement floor of the building, gasoline floating on the water table would not be able to enter the subbasement. But, as the water table rises, the gasoline will be lifted along with it, eventually reaching the subbasement level. There have been many cases where this has been the reason for the alternating appearance and disappearance of contaminating liquid.

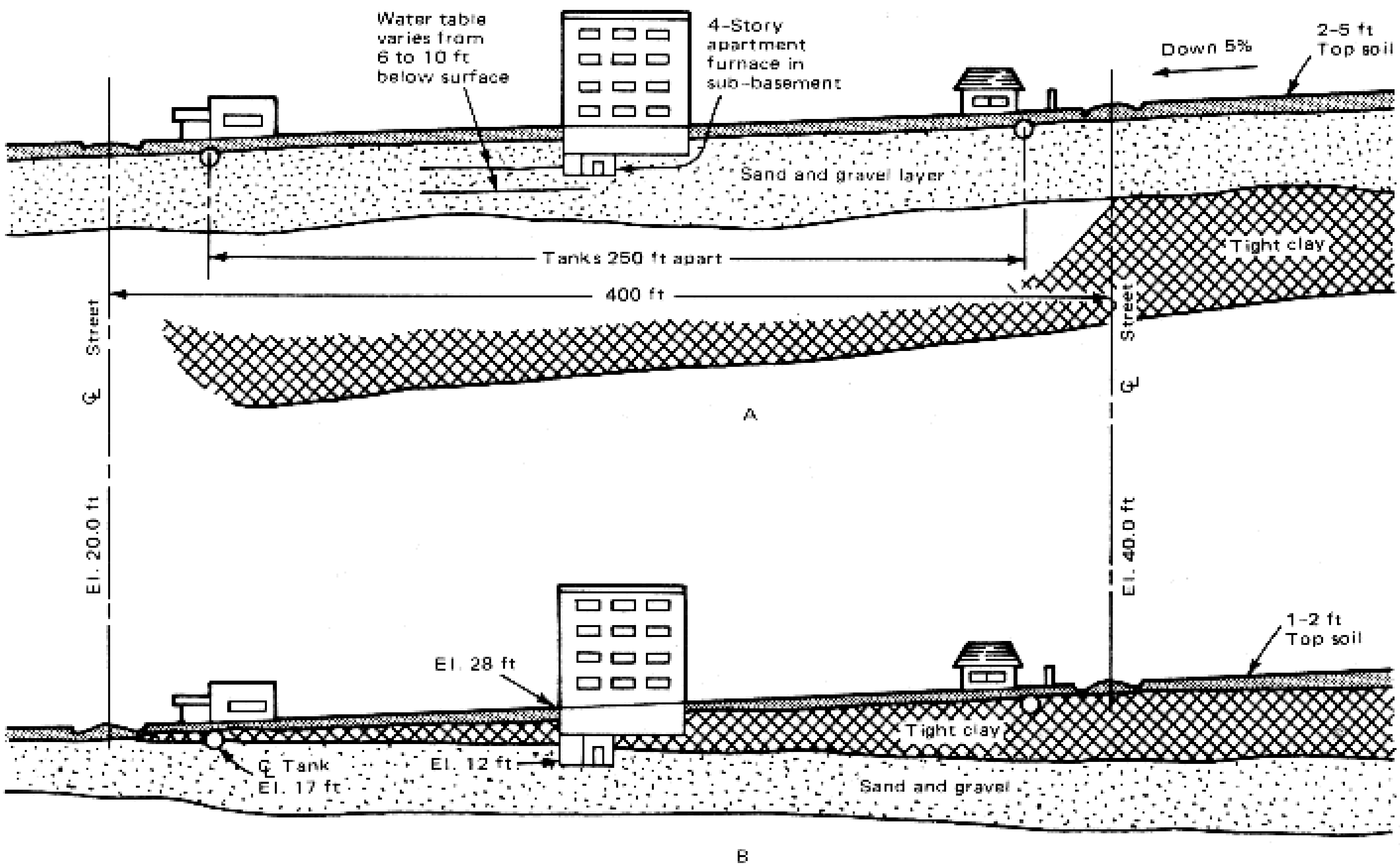


Figure C-8 Effect of slope of underground strata on groundwater flow.

C-9

Figure C-9 illustrates another example of how underground flow can be contrary to the slope of the ground above. In this case, flammable liquids are stored in a tank that is some distance above a small body of water. From the surface, it would appear that escaping liquid would flow into the pond. But, because the tank is over a pervious strata that slopes away from the pond, the liquid flows in that direction, contaminating wells that serve buildings at a much higher elevation than the tank. Note also that if the wells were not present, discovery would be delayed, probably until the release reached the ground on the other side of the hill. This could be several miles away.

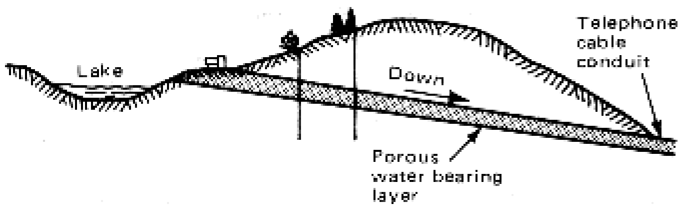


Figure C-9

C-10

Figures C-10(a) and (b) illustrate some other aspects of a rising and falling water table and the ability of trenches to behave like interconnected piping, especially when dug in relatively impervious soil, then backfilled with a more porous material. Figure C-10(a) shows a tank installed in an excavation dug in clay and backfilled with sand. Product supply and vent lines are likewise in trenches dug in clay and backfilled with the same material as the tank. Figure C-10(b) shows the layout of a tank installed next to a building with a basement. The water supply line to the building is also in a trench backfilled with sand, as is the city water main and sewer line. Finally, a low area between the buildings is filled with sand and gravel.

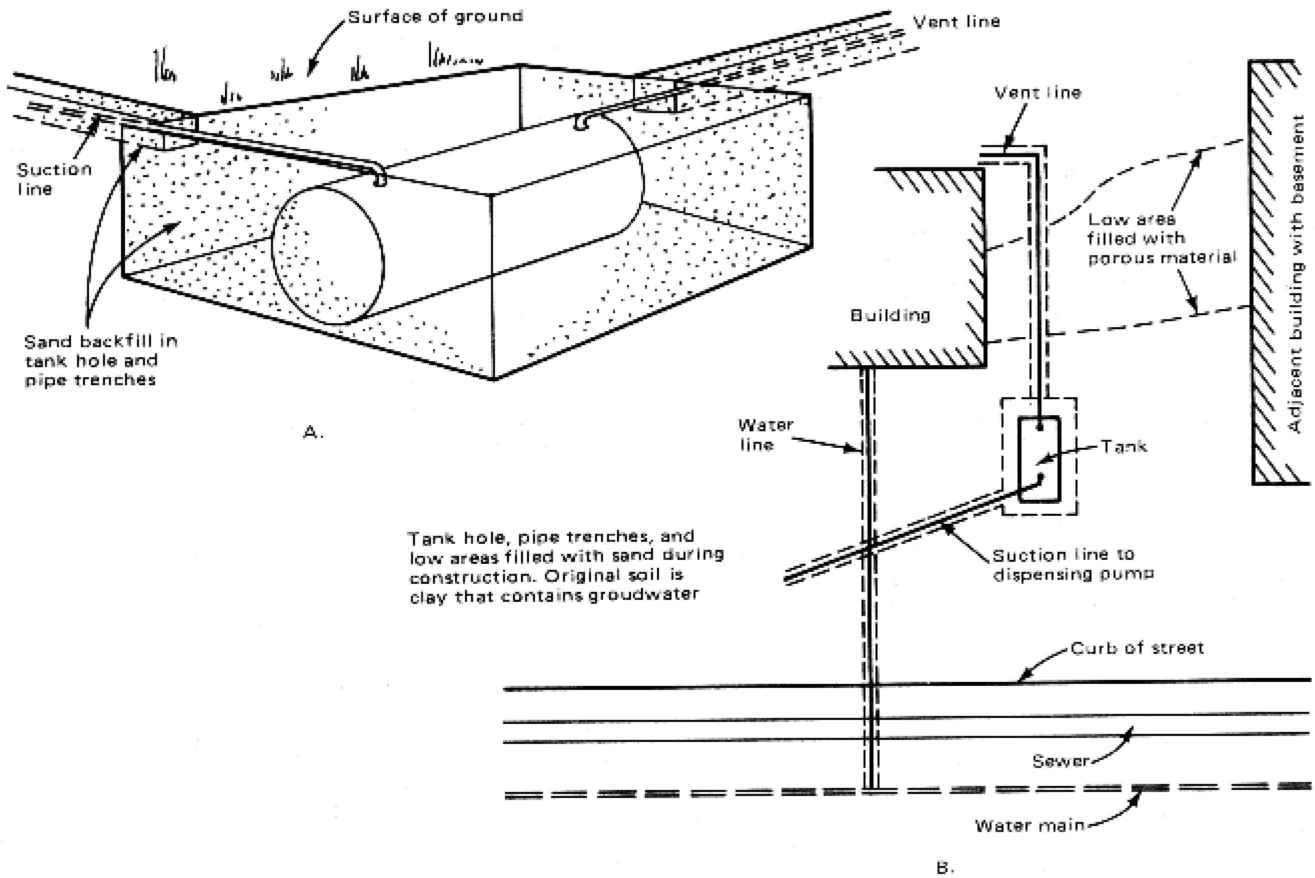


Figure C-10

The parent or original soil is clay. A water table that exists in this clay will have little horizontal flow, due to the resistance of the clay. Consequently, the water table rises and falls with changes in the weather. For this example, assume that the water table is within 1 ft of the surface during wet periods, but falls to a level below the bottom of the tank excavation during dry periods.

It is easy to see that a leak in the tank will result in contaminating liquid collecting on the bottom of the excavation, as if it were in an open square tank. If rainfall raises the water table to a level above the bottom of the pipe trenches, then the contaminated groundwater can flow along the pipe trenches, much as it would flow through a pipe. By means of intersections with other trenches or with zones of more pervious fill, this contaminated water can spread to the adjacent buildings or to the sewer and water main trenches. Note that it will not necessarily enter the sewer pipe in the street. It might flow along the trench, outside of the pipes themselves and not appear until it comes to a point where it can seep into a manhole or catch basin.

Another condition illustrated here is the potential for the contaminating liquid to move without the presence of groundwater. If a serious leak were to occur in the suction piping, pure liquid could flow along the trenches.

C-11 Summary.

The principles and concepts discussed in this Appendix point out the importance of a knowledge of the underground soil conditions and subterranean features when tracing the movement of escaped liquids from the point of discovery back to the source. It will not always be possible to obtain all the data desired, but the effort must be made for remediation to be successful.

Appendix D Inventory Control Procedures

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

D-1 Tanks with Metered Dispensing.

For this method to be effective, all meters that measure liquid dispensed from the underground system should be properly calibrated to local standards for meter calibration or an accuracy of 6 $in.^3/gal$ for every 5 gal (approximately 5 ml per Liter) of products withdrawn. A meter that reads significantly higher than actual volume pumped can hide a leak. Conversely, a meter that indicates less than the true volume might suggest a leak where one does not exist.

D-1.1 Daily Procedures.

At the beginning of each business day (or each shift, if preferred), the tank volume should be manually measured using a gauge stick, or other means, and a calibration chart to convert the tank level into gallons. Level measurements should be based on the average of two consecutive stick readings. This gauging operation should be carried out with great care to ensure maximum accuracy. Opening meter totalizer readings should also be recorded for each dispenser.

When liquid is added to the underground tank, the tank volume should be gauged both before and after the delivery. The operator should also check the tank for presence of water to the nearest $^1/_8$ in. using, for example, water-finding paste or other appropriate means. This procedure, however, is not applicable to water-miscible liquids. Water that is detected should be accounted for in the inventory procedures and any significant accumulation [i.e., greater than $^1/_2$ in. (12.7 mm)] should be promptly removed.

At the close of the business day (or the end of the shift), tank volume should again be gauged and meter totalizer readings recorded. The difference between the opening and closing totalizer readings is the sales for the inventory period. All readings that are recorded as part of this procedure should be kept in a safe location and retained for a minimum of one year. Detailed instructions covering tank gauging, water gauging, meter calibration checks, and record keeping are contained in American Petroleum Institute Publication 1621, *Recommended Practice for Bulk Liquid Stock Control at Retail Outlets.*

D-1.2 Daily Reconciliation.

Inventory reconciliation consists of comparing the measured closing inventory to the book inventory, which is obtained by adding deliveries and subtracting sales and on-site usage from the measured inventory. Due to variables inherent in the process, this reconciliation will rarely balance exactly to the gallon, and small daily “over” or “short” figures are to be expected. By observation of daily variances, the operator is able to identify trends over time; daily fluctuations tend to cancel out over the long term.

D-1.3 Inventory Reviews.

The operator of an underground tank system storing flammable or combustible liquids should review the daily inventory records once a week. The operator should be concerned with small but growing daily losses or sudden unexplained changes from the established pattern. Either of these symptoms could indicate a potential leak.

For a facility that stores more than one variety of similar liquids (such as a retail service station), the operator should compare inventory records for the various tank systems. This will mitigate the effect of the temperature-induced errors on the inventory accounting. Since the impact of temperature should be roughly the same, a significant difference in the inventory variance from one product to the next might indicate a leak. The first step in investigating this would be to check the meter calibrations on the dispenser system.

At the end of each month, the operator should again review the daily inventory accounting and perform a monthly reconciliation. According to U.S. Environmental Protection Agency regulations, a leak is suspected if, for two consecutive months, the monthly inventory shortage exceeds 1 percent of the system throughout plus 130 gal (492 L). The operator should look closely to see if the negative variance is a one-time fluctuation or if there is a consistent negative trend throughout the inventory period.

D-2 Tanks without Metered Dispensing.

For these systems, the inventory review is complicated by the fact that all withdrawals can only be measured by gauging the tank. For tanks of 2,000 gal (7570 L) or less, manual tank gauging can be used to determine if a release has occurred. Tank liquid level measurements are taken at the beginning and ending of at least a 36-hour period during which no liquid is added to or removed from the tank. Level measurements are based on an average of two consecutive gauge readings at both the beginning and ending period.

According to U.S. Environmental Protection Agency regulations, a leak is suspected if the weekly or monthly standards exceed the values shown in Table D-2.

Table D-2 Standard Deviations for Inventory Reconciliation

Tank Capacity (Nominal)	Weekly Standard (One Test)	Monthly Std. (Avg. of 4 Wkly Tests)
550 Gal or Less	10 Gal	5 Gal
551–1000 Gal	13 Gal	7 Gal
1001–2000 Gal	26 Gal	13 Gal

For tanks larger than 2,000 gallons (7570 L), tank levels should be accurately gauged and recorded before and after any input or withdrawal. To determine if the storage system is losing liquid, the operator should compare the volume before an input or withdrawal with the measured volume after the previous input or withdrawal. This loss or gain figure for each period of tank inactivity should be carried forward and cumulative variance maintained by adding the gain or subtracting the loss from the previous number. Since tank gauging errors are completely random, they should tend to cancel out from one measurement to the next. A consistent and increasing negative or positive trend indicates a potential leak that should be investigated.

For additional information on the subject, see the following:

(a) American Petroleum Institute Publication 1621, *Recommended Practice for Bulk Liquid Stock Control at Retail Outlets*, Fourth Edition, 1987.

(b) *Analysis of Factors Affecting Service Station Inventory Control*, report prepared for the API by the Radian Corporation, July 1984.

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 ASTM Publication.

The American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103.

ASTM D1250-80, *Petroleum Measurement Tables*.

E-1.2 API Publications.

American Petroleum Institute, 1220 L St., NW, Washington, DC 20005.

API 1621-87, *Recommended Practice for Bulk Liquid Stock Control at Retail Outlets.*

Analysis of Factors Affecting Service Station Inventory Control, report prepared for the API by the Radian Corporation, July 1984..

NFPA 385

1990 Edition

Standard for Tank Vehicles for Flammable and Combustible

1990 Edition

This edition of NFPA 385, *Standard for Tank Vehicles for Flammable and Combustible Liquids*, was prepared by the Technical Committee on Transportation of Flammable Liquids, released by the Correlating Committee on Flammable Liquids, 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 385

This standard was initiated in 1926, first officially adopted in 1929, and revised and issued in the following earlier editions: 1933, 1948, 1953, 1954, 1955, 1957, 1958, 1959, 1960, 1963, 1964, 1966, 1971, 1974, 1979, and 1985. Editions prior to 1948 had different titles.

This 1990 edition contains a single amendment to the 1985 edition: the addition of paragraph 6-2.6.1.

Committee on Flammable Liquids

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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.

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 385
Standard for
Tank Vehicles for Flammable andCombustible Liquids

1990 Edition

NOTICE: Information on referenced publications can be found in Chapter 7 and Appendix B.

Chapter 1 General Provisions

1-1 Scope.

1-1.1

This standard applies to tank vehicles to be used for the transportation of asphalt or normally stable flammable and combustible liquids with a flash point below 200°F (93.4°C). It is intended to provide minimum requirements for the design and construction of cargo tanks and their appurtenances and to set forth certain matters pertaining to tank vehicles.

NOTE: Normally stable materials are those having the relative capacity to resist changes in their chemical composition that would produce violent reactions or detonations despite exposure to air, water, or heat, including the normal range of conditions encountered in handling, storage, or transportation. Unstable (reactive) flammable and combustible liquids are liquids that in the pure state or as commercially produced or transported will vigorously polymerize, decompose, condense, or become self-reactive under conditions of shock, pressure, or temperature.

1-1.2

Additional safeguards may be necessary for tank vehicles used for the transportation of flammable and combustible liquids having characteristics introducing additional factors such as high rates of expansion, instability, corrosiveness, and toxicity.

1-1.3

Attention is directed to the fact that some cutback asphalts have flash points in the range of Class I liquids. Also, liquids having a flash point higher than 200°F (93.4°C), such as asphalt, may assume the characteristics of lower flash point liquids when heated. Under such conditions it shall be appropriate to apply the provisions of this standard unless otherwise specifically exempted.

1-1.4

The requirements for aircraft fuel servicing tank vehicles are contained in NFPA 407, *Standard for Aircraft Fuel Servicing*.

1-1.5

A tank vehicle transporting a flammable or combustible liquid in interstate service shall be considered to be in conformity with this standard while it is in interstate service if it meets the requirements of the U.S. Department of Transportation Hazardous Materials Regulations.

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 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.

Baffle. A nonliquidtight transverse partition in a cargo tank.

Bulkhead. A liquidtight transverse closure between compartments of a cargo tank.

Cargo Tank. Any tank having a liquid capacity in excess of 110 gal (418 L) used for carrying flammable and combustible liquids or asphalt and mounted permanently or otherwise upon 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 tank vehicle upon which it is mounted.

Compartment. A liquidtight division in a cargo tank.

Flash Point. The minimum temperature of a liquid at which sufficient vapor is given off to form an ignitible mixture with the air near the surface of the liquid within the vessel as determined by appropriate test procedure and apparatus as specified.

The flash point of liquids having a viscosity less than 45 SUS at 100°F (37.8°C) and a flash point below 200°F (93.4°C) shall be determined in accordance with ASTM D-56-87, *Standard Method of Test for Flash Point by the Tag Closed Tester*.

The flash point of liquids having a viscosity of 45 SUS or more at 100°F (37.8°C) or a flash point of 200°F (93.4°C) or higher shall be determined in accordance with ASTM D-93-85, *Standard Method of Test for Flash Point by the Pensky-Martens Closed Tester*.

Head. A liquidtight transverse closure at the end of a cargo tank.

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.

Liquid. For the purpose of this standard, liquid shall mean any material that has a fluidity greater than that of 300 penetration asphalt when tested in accordance with ASTM D-5-86, *Test for Penetration for Bituminous Materials*. When not otherwise identified, the term liquid shall include both flammable and combustible liquids.

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 (93.4°C).
Class IIIB Liquids shall include those having flash points at or above 200°F (93.4°C).

This standard does not cover Class IIIB liquids (*see 1-1.1*). Where the term combustible liquids is used in this standard, it shall mean only Class II and Class IIIA liquids.

NOTE: The upper limit of 200°F (93.4°C) is given because the application of this standard does not extend to liquids having flash points above 200°F (93.4°C), and this limitation should not be construed as indicating that liquids with higher flash points are noncombustible.

Flammable Liquid. A liquid having a flash point below 100°F (37.8°C) and having a vapor pressure not exceeding 40 psia (2068 mm Hg) at 100°F (37.8°C) shall be known as a Class I liquid.

Class I liquids shall be subdivided as follows:

Class IA Liquids 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 Liquids 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 Liquids shall include those having flash points at or above 73°F (22.8°C) and below 100°F (37.8°C).

The volatility of liquids is increased when artificially heated to temperatures equal to or higher than their flash points. When so heated Class II and III liquids shall be subject to the applicable requirements for Class I or II liquids. This standard may also be applied to high flash point liquids when so heated even though these same liquids when not heated are outside of its scope.

NOTE: This classification does not apply to:

(a) Liquids without flash points that may be flammable under some conditions, such as certain halogenated hydrocarbons and mixtures containing petroleum fractions and halogenated hydrocarbons,

(b) Mists, sprays, or foams.

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.

Tank Full-Trailer. Any vehicle with or without auxiliary motive power, equipped with a cargo tank mounted thereon or built as an integral part thereof, used for the transportation of flammable and combustible liquids or asphalt, and so constructed that practically all of its weight and load rests on its own wheels.

Tank Semi-Trailer. Any vehicle with or without auxiliary motive power, equipped with a cargo tank mounted thereon or built as an integral part thereof, used for the transportation of flammable and combustible liquids or asphalt, and so constructed that, when drawn by a tractor by means of a fifth wheel connection, some part of its load and weight rests upon the towing vehicle.

Tank Truck. Any single self-propelled motor vehicle equipped with a cargo tank mounted thereon and used for the transportation of flammable and combustible liquids or asphalt.

Tank Vehicle. Any tank truck, tank full-trailer, or tractor and tank semi-trailer combination.

Vapor Pressure. The pressure measured in psia (mm Hg) exerted by a liquid, as determined by

ASTM D-323-82, *Standard Method of Test for Vapor Pressure of Petroleum Products (Reid Method).*

Chapter 2 Tank Vehicle Design

2-1 General.

2-1.1

Design of the tank vehicle shall give engineering consideration to the structural relationship between the cargo tank, the propulsion equipment, and the supporting members, if any, with due regard to the weight and temperature of the cargo, road performance, braking, and required ruggedness. The metal thicknesses specified in this chapter are minimum thicknesses dictated by the structure of the tank itself, and it may be necessary that these thicknesses be increased where the tank shell is to be subjected to additional stress. The general design of the cargo tank and vehicle chassis shall be arranged to give the best combination of structural characteristics and vehicle performance. The design of the suspension system shall incorporate features to help assure lateral or tipping stability when turning corners.

2-1.2

Any cargo tank designed for transporting materials at liquid temperatures above ambient temperatures shall have a metal warning plate not subject to corrosion located in a conspicuous place on the right side near the front. Such plate shall be permanently affixed to the tank or tank frame. Upon it shall be marked in characters at least $^1/_2$ in. (1.2 cm) high by stamping, embossing, or other means of forming letters into or on the metal of the plate itself at least the following information:

"Maximum allowable cargo temperature is ___°F (___°C)."

This maximum allowable cargo temperature shall be specified by the manufacturer of the cargo tank.

2-1.3

Cargo tanks used for transporting flammable and combustible liquids at temperatures equal to or above their boiling points shall be constructed in accordance with Section 2-2.

NOTE: Possible temperature rise during transfer as well as the loading temperature and altitude must be considered when determining if the flammable and combustible liquid will be transported at or above its boiling point. Where an accurate boiling point is unavailable for the material in question, or for mixtures that do not have a constant boiling point, the 10 percent point of a distillation performed in accordance with ASTM D-86-82, *Standard Method of Test for Distillation of Petroleum Products*, may be used as the boiling point of the liquid.

2-1.4

Cargo tanks used for transporting flammable and combustible liquids at a temperature below their boiling points shall be constructed in accordance with the provisions of Section 2-3.

2-1.5

The material used in the construction of the cargo tanks shall be compatible with the chemical characteristics of the flammable and combustible liquid to be transported.

NOTE: In case of doubt, the supplier or producer of the flammable and combustible liquid or other competent authority should be consulted as to the suitability of the material of construction to be used.

2-1.6

A single cargo tank may be divided into compartments of different specification construction. Each such compartment shall conform to specification requirements concerned and be so identified with a permanent metal plate.

2-2 Cargo Tanks, Piping, and Connections Designed for Transporting Flammable and Combustible Liquids at Temperatures at or above Their Boiling Points.

Cargo tanks, piping, and connections designed for transporting flammable and combustible liquids above their boiling points shall be built in accordance with Specifications MC-307 or MC-331 of Part 178 of Title 49, *Code of Federal Regulations*, or in accordance with Chapter 6 of NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*. Continued use of cargo tanks constructed on or before December 1, 1967, to Specifications MC-304 and MC-330 shall be permitted.

2-3 Cargo Tanks, Piping, and Connections Designed for Transfer of Flammable and Combustible Liquids at Temperatures below Their Boiling Points.

2-3.1 General.

Cargo tanks constructed after the effective date of this standard shall be constructed in accordance with Section 2-3 as contained herein. Continued use of existing cargo tanks constructed in accordance with the 1966 edition of NFPA 385 and earlier editions shall be permitted, but new construction is not permitted.

2-3.2 Material.

All sheet and plate material for shell, heads, bulkheads, and baffles for cargo tanks that are not required to be constructed in accordance with the ASME *Boiler and Pressure Vessel Code* shall meet the following minimum applicable requirements.

NOTE: Minimum requirements for materials listed below are duplicated from 49 CFR, Section 178.341, in effect as of January 1, 1974.

(a) **Aluminum Alloys (AL)**. Only aluminum alloy material suitable for fusion welding and in compliance with one of the following ASTM specifications shall be used:

ASTM B-209 Alloy 5052	ASTM B-209 Alloy 5254
ASTM B-209 Alloy 5086	ASTM B-209 Alloy 5454
ASTM B-209 Alloy 5154	ASTM B-209 Alloy 5652

All heads, bulkheads, baffles, and ring stiffeners may use 0 temper (annealed) or stronger tempers. All shells shall be made of materials with properties equivalent to H32 or H34 tempers, except that lower ultimate strength tempers may be used if the minimum shell thicknesses in Table 2-2 are increased in inverse proportion to the lesser ultimate strength.

(b) **Steel**.

	Mild steel (MS)	High strength low alloy steel (HSLA)	Austenitic stainless steel (SS)

Yield	25,000 psi	45,000 psi	25,000 psi
Ultimate strength	45,000 psi	60,000 psi	70,000 psi
Elongation, 2-in. samples	20%	25%	30%

2-3.3 Thickness of Sheets, Heads, Bulkheads, and Baffles.

2-3.3.1 Material Thickness. The minimum thicknesses of tank material authorized shall be predicated on not exceeding the maximum allowable stress level but in no case less than those indicated in Tables 2-1 and 2-2.

2-3.3.2 Product Density. The material thicknesses contained in Tables 2-1 and2-2 are minimums based on a maximum 7.2 lb per gal (3.24 kg) product weight. If the tank is designed to haul products weighing more than 7.2 lb per gal (3.24 kg), the gallon per inch value used to determine the minimum thickness of heads, bulkheads, baffles, or shell sheets shall be the actual section capacity required in gallons per inch multiplied by the actual product density in pounds per gallon divided by 7.2.

2-3.3.3 When aluminum is used for cargo tanks intended to transport cargoes at liquid temperatures above 250°F (121.1°C) the minimum thicknesses shall be increased by 1 percent for each 10°F (5.56°C) or portion thereof above 250°F (121.1°C). When the liquid temperatures are above 500°F (260°C) there shall be an additional 1 percent for each 10°F (5.56°C) or portion thereof above 500°F (260°C). Aluminum shall not be used for cargo tanks transporting cargoes at temperatures above 550°F (288°C).

2-3.4 Structural Integrity.

2-3.4.1 Maximum Stress Values. The maximum calculated stress value shall not exceed 20 percent of the minimum ultimate strength of the material as authorized except when ASME pressure vessel design requirements apply (see Section VIII, *ASME Boiler and Pressure Vessel Code*, 1983 edition).

2-3.4.2 Loadings. Cargo tanks shall be provided with additional structural elements as necessary to prevent resulting stresses in excess of those permitted in 2-3.4.1. Consideration shall be given to forces imposed by each of the following loads individually and, where applicable, a vector summation of any combination thereof:

(a) Dynamic loading under all product load configurations.

(b) Internal pressure.

(c) Superimposed loads such as operating equipment, insulation, linings, hose tubes, cabinets, and piping.

(d) Reactions of supporting lugs and saddles or other supports.

(e) Effect of temperature gradients resulting from product and ambient temperature extremes. Thermal coefficients of dissimilar materials where used shall be accommodated.

Table 2-1 Minimum Thickness of Heads, Bulkheads, and Baffles. Mild Steel (MS), High Strength Low Alloy Steel (HSLA), Austenitic Stainless Steel (SS), in U.S. Standard Gage; Aluminum Alloy (AL) - Expressed in Decimals of an Inch.

	Volume capacity in gal per in.											
	10 or less			Over 10 to 14			14 to 18			18 and over		
		HSLA,			HSLA,			HSLA,			HSLA,	
	MS	SS	AL	MS	SS	AL	MS	SS	AL	MS	SS	AL
Thickness	14	15	0.096	13	14	0.109	12	13	0.130	11	12	0.151

Table 2-2 Minimum Thickness of Shell Sheets. Mild Steel (MS), High Strength Low Allow Steel (HSLA), Austenitic Stainless Steel (SS), in U.S. Standard Gage; Aluminum Alloy (AL) - Expressed in Decimals of an Inch.

Maximum shell radius	Distance between bulkheads, baffles, or ring stiffeners	Volume capacity in gal per in.											
		10 or less			Over 10 to 14			14 to 18			18 and over		
			HSLA,			HSLA,			HSLA,			HSLA,	
		MS	SS	AL	MS	SS	AL	MS	SS	AL	MS	SS	AL
Less than 70 in.	36 in. or less	14	16	0.087	14	16	0.087	14	15	0.096	13	14	0.109
	Over 36 in. to 54 in.	14	16	.087	14	15	.096	13	14	.109	12	13	.130
	54 in. through 60 in.	14	15	.096	13	14	.109	12	13	.130	11	12	.151
70 in. or more, less than 90 in.	36 in or less	14	16	.087	14	15	.096	13	14	.109	12	13	.130
	Over 36 in. to 54 in.	14	15	.096	13	14	.109	12	13	.130	11	12	.151
	54 in. through 60 in.	13	14	.109	12	13	.130	11	12	.151	10	11	.173
90 in. or more, less than 125 in.	36 in. or less	14	15	.096	13	14	.109	12	13	.130	11	12	.151
	Over 36 in. to 54 in.	13	14	.109	12	13	.130	11	12	.151	10	11	.173
	54 in. through 60 in.	12	13	.130	11	12	.151	10	11	.173	9	10	.194
125 in. or more	36 in. or less ...	13	14	.109	12	13	.130	11	12	.151	10	11	.173
	Over 36 in to 54 in.	12	13	.130	11	12	.151	10	11	.173	9	10	.194
	54 in. through 60 in.	11	12	.151	10	11	.173	9	10	.194	8	9	.216

2-3.5 Joints.

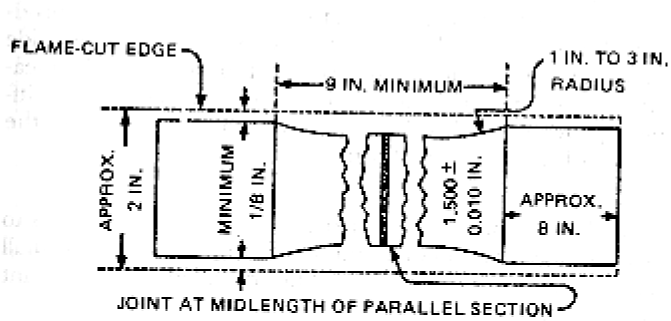
2-3.5.1 Method of Joining. All joints between tank shells, heads, baffles (or baffle attaching rings), and bulkheads shall be welded in accordance with the requirements contained in this section.

2-3.5.2 Strength of Joints [Aluminum Alloy (AL)]. All welded aluminum alloy joints shall be made in accordance with recognized good practice, and the efficiency of a joint shall not be less than 85 percent of the properties of the adjacent material. Aluminum alloys shall be joined by an inert gas arc welding process using aluminum-magnesium type of filler metals that are consistent with the material supplier's recommendations.

2-3.5.3 Strength of Joints [Mild Steel (MS), High Strength Low Alloy (HSLA), Austenitic Stainless Steel (SS)]. Joints shall be welded in accordance with recognized good practice, and the efficiency of any joint shall not be less than 85 percent of the mechanical properties of the adjacent metal in the tank.

2-3.5.4 Combinations of mild steel (MS), high strength low alloy (HSLA), and/or austenitic stainless steel (SS) may be used in the construction of a single tank, provided that each material, where used, shall comply with the minimum requirements specified for the material used in the construction of that section of the tank. Whenever stainless steel sheets are used in combination with sheets of other types of steel, joints made by welding shall be formed by the use of stainless steel electrodes or filler rods and the stainless steel electrodes or filler rods used in the welding shall be suitable for use with the grade of stainless steel concerned according to the recommendations of the manufacturer of the stainless steel electrodes or filler rods.

2-3.5.5 Compliance Test. Compliance with the requirements contained in 2-3.5.2 or 2-3.5.3 for the welded joints indicated in 2-3.5.1 shall be determined by preparing, from materials representative of those to be used in tanks subject to this specification and by the same technique of fabrication, two test specimens conforming to the figure as shown below and testing them to failure in tension. One pair of test specimens may represent all the tanks to be made of the same combination of materials by the same technique of fabrication, and in the same shop, within six months after the tests on such samples have been completed. The butt welded specimens tested shall be considered qualifying other types or combinations of types of weld using the same filler material and welding process as long as parent metals are of the same types of material.



TENSILE SPECIMEN

2-3.6 Supports and Anchoring.

2-3.6.1 Cargo tanks with frames not made integral with the tank as by welding shall be provided with restraining devices to eliminate any relative motion between the tank and frame that may result from the stopping, starting, or turning of the vehicle. Such restraining devices shall be readily accessible for inspection and maintenance, except that insulation and jacketing are permitted to cover the restraining devices.

2-3.6.2 Any cargo tank designed and constructed so that it constitutes in whole or in part the structural member used in lieu of a frame shall be supported in such a manner that the resulting stress levels in the cargo tank do not exceed those specified in 2-3.4.1. The design calculations of the support elements shall include loadings imposed by stopping, starting, and turning in addition to those imposed as indicated in 2-3.4.2 using 20 percent of the minimum ultimate strength of the support material.

2-3.7 Circumferential Reinforcement.

2-3.7.1 Tanks with shell thicknesses less than $^3/_8$ of an in. (0.93 cm) shall, in addition to the reinforcement provided by the tank heads, be circumferentially reinforced with either bulkheads, baffles, or ring stiffeners. It is permissible to use any combination of the aforementioned reinforcements in a single cargo tank.

2-3.7.2 Location. Such reinforcement shall be located in such a manner that the maximum unreinforced portion of the shell be as specified in Table 2-2 and in no case more than 60 in. (150 cm). Additionally, such circumferential reinforcement shall be located within 1 in. (2.5 cm) of points where discontinuity in longitudinal shell sheet alignment exceeds 10 degrees unless otherwise reinforced with structural members capable of maintaining shell sheet stress levels permitted in 2-3.6.

2-3.7.3 Baffles. Baffles or baffle attaching rings if used as reinforcement members shall be circumferentially welded to the tank shell. The welding shall not be less than 50 percent of the total circumference of the vessel, and the maximum unwelded space on this joint shall not exceed 40 times the shell thickness.

2-3.7.4 Double Bulkheads. Whenever double bulkheads are provided, they shall be separated by an air space. This air space shall be vented and be equipped with drainage facilities that shall be kept operative at all times (*see 6-1.7*).

2-3.7.5 Ring Stiffeners. Ring stiffeners when used to comply with this section shall be continuous around the circumference of the tank shell and shallhave a section modulus about the neutral axis of the ring section parallel to the shell at least equal to that determined by the following formula:

$$\frac{I}{C} \text{ (Min)} = 0.00027 \text{ WL (MS, HSLA, \& SS) Steel}$$

$$\frac{I}{C} \text{ (Min)} = 0.000467 \text{ WL (AL) Aluminum Alloy}$$

where

$\frac{I}{}$ = section modulus (in.^{3});

C

W = tank width or diameter (in.);

L = ring spacing (in.); i.e., the maximum distance from the midpoint of the unsupported shell on one side of the ring stiffener to the midpoint of the unsupported shell on the opposite side of the ring stiffener.

2-3.7.5.1 If a ring stiffener is welded to the tank shell (with each circumferential weld not less than 50 percent of the total circumference of the vessel and the maximum unwelded space on this joint not exceeding 40 times the shell thickness), a portion of the shell may be considered as part of the ring section for purposes of computing the ring section modulus. The maximum portion of the shell to be used in these calculations is as follows:

Circumferential ring stiffener to tank shell welds	Distance between parallel circumferential ring stiffener to shell welds	Shell section credit
1		20t
2	Less than 20t	20t + W
2	20t or more	40t

where

t = shell thickness;

W = distance between parallel circumferential ring stiffener to shell welds.

2-3.7.5.2 If configuration of internal or external ring stiffener encloses an air space, this air space shall be arranged for venting and be equipped with drainage facilities that shall be kept operative at all times.

2-3.8 Accident Damage Protection.

2-3.8.1 The design, construction, and installation of any appurtenance to the shell or head of the cargo tank must be such as to minimize the possibility of appurtenance damage or failure adversely affecting the product retention integrity of the tank.

2-3.8.2 Structural members, such as the suspension subframe, overturn protection, and external rings, when practicable, shall be utilized as sites for attachment of appurtenances and any other accessories to a cargo tank.

2-3.8.3 Except as prescribed in 2-3.8.5, the welding of any appurtenance to a shell or head must be made by attachment to a mounting pad. The thickness of a mounting pad must not be less than that of the shell or head to which it is attached. A pad must extend at least 2 in. (5 cm) in each direction from any point of attachment of an appurtenance. Pads must have rounded corners or otherwise be shaped in a manner to preclude stress concentrations on the shell or head. The mounting pad must be attached by a continuous weld around the pad.

2-3.8.4 The appurtenance must be attached to the mounting pad so there will be no adverse affect upon the product-retention integrity of the tank if any force is applied to the appurtenance, in any direction, except normal to the tank, or within 45 degrees of normal.

2-3.8.5 Skirting structures, conduit clips, brakeline clips, and similar lightweight attachments, which are of a metal thickness, construction, or material appreciably less strong but not more than 72 percent of the thickness of the tank shell or head to which such a device is attached, may be secured directly to the tank shell or head if each device is so designed and installed that damage to it will not affect the product retention integrity of the tank. These lightweight attachments must be secured to the tank shell by continuous weld or in such manner as to preclude formation of pockets, which may become sites for incipient corrosion.

2-3.8.6 Rear Bumpers. Every cargo tank shall be provided with a rear bumper to protect the tank and piping in the event of a rear-end collision and minimize the possibility of any part of the colliding vehicle striking the tank. The bumper shall be located at least 6 in. (15 cm) to the rear of any vehicle component that is used for loading or unloading purposes or may at any time contain lading while in transit. Dimensionally, the bumper shall conform to 49 C.F.R. & 393.86. Structurally, the bumper shall be designed to successfully absorb (no damage that will cause leakage of product) the impact of the vehicle with rated payload, with a deceleration of 2 “g” using a factor of safety of two based on the ultimate strength of the bumper material. For purposes of these regulations such impact shall be considered uniformly distributed and applied horizontally (parallel to the ground) from any direction at an angle not exceeding 30 degrees to the longitudinal axis of the vehicle.

2-3.8.7 Overturn Protection. All closures for filling, manhole, or inspection openings shall be protected from damage that will result in leakage of lading in the event of overturning of the vehicle by being enclosed within the body of the tank or dome attached to the tank or by guards.

2-3.8.7.1 When guards are required, they shall be designed and installed to withstand a vertical load of twice the weight of the loaded tank and a horizontal load in any direction equivalent to one-half the weight of the loaded tank. These design loads may be considered independently. Ultimate strength of the material shall be used as a calculation base. If more than one guard is used each shall carry its proportionate share of the load. If protection other than guards are considered, the same design load criteria are applicable.

2-3.8.7.2 Except for pressure-actuated vents no overturn protection is required for nonoperating nozzles or fittings less than 5 in. (12.5 cm) in diameter (which do not contain product while in transit) that project a distance less than the inside diameter of the fitting. This projected distance may be measured either from the shell or the top of an adjacent ring stiffener provided such stiffener is within 30 in. (75 cm) of the center of the nozzle or fitting.

2-3.8.7.3 If the overturn protection is so constructed as to permit accumulation of liquid on the top of the tank, it shall be provided with drainage facilities directed to a safe point of discharge.

2-3.8.8 Piping.

2-3.8.8.1 Product discharge piping shall be provided with protection in such a manner as to reasonably assure against the accidental escape of contents. Such protection may be provided by:

(a) A shear section located outboard of each emergency valve seat and within 4 in. (10 cm) of the vessel, which will break under strain and leave the emergency valve seat and its attachment to the vessel and the valve head intact and capable of retaining product. The shear section shall be machined in such a manner as to abruptly reduce the wall thickness of the adjacent piping (or valve) material by at least 20 percent; or

(b) By suitable guards capable of successfully absorbing a concentrated horizontal force of at least 8,000 lb (3600 kg) applied from any horizontal direction, without damage to the discharge piping, which will adversely affect the product retention integrity of the discharge valve.

2-3.8.8.2 Minimum Road Clearance. The minimum allowable road clearance of any cargo tank component or protection device located between any two adjacent axles on avehicle or vehicle combination shall be at least $^1/_2$ in. (1.2 cm) for each ft separating such axles and in no case less than 12 in. (30 cm).

2-3.8.8.3 Strength of Piping, Fittings, Hose, and Hose Couplings. Hose, piping, and fittings for tanks to be unloaded by pressure shall be designed for bursting pressure of at least 100 psig (689.5 kPa) and not less than four times the pressure to which, in any instance, it may be subjected in service by the action of any vehicle-mounted pump or other device (not including safety relief valves), the action of which may be subject to certain portions of the tank piping and hose to pressures greater than the design pressure of the tank. Any coupling used on hose to make connections shall be designed for a working pressure not less than 20 percent in excess of the design pressure of the hose and shall be so designed that there will be no leakage when connected.

2-3.8.8.4 Provision for Expansion and Vibration. Suitable provisions shall be made in every case to allow for and prevent damage due to expansion, contraction, jarring, and vibration of all pipe. Slip joints shall not be used for this purpose.

2-3.8.8.5 Heater Coils. Heater coils, when installed, shall be so constructed that the breaking-off of their external connections will not cause leakage of contents of tank.

2-3.8.8.6 Gaging, Loading, and Air-Inlet Devices. Gaging, loading, and air-inlet devices, including their valves, shall be provided with adequate means for their secure closure, and means shall also be provided for the closing of pipe connection of valves.

2-3.9 Closures for Fill Openings and Manholes.

Each compartment in excess of 2,500 gal (9500 L) capacity shall be accessible through a manhole of at least 11 in. × 15 in. (27.5 cm × 37.5 cm). Manhole and/or fill opening covers shall be designed to provide secure closure of the openings. They shall have structural capability of withstanding internal fluid pressures of 9 psig (62 kPa) without permanent deformation. Safety devices to prevent the manhole and/or fill cover from opening fully when internal pressure is present shall be provided.

2-3.10 Vents for Cargo Tanks in Other than Asphalt Service.

2-3.10.1 Each cargo tank compartment shall be provided with safety relief devices in accordance with the requirements contained in this section. All of such devices shall communicate with the vapor space. Shut off valves shall not be installed between the tank opening and any safety device. Safety relief devices shall be so mounted, shielded, or drained as to eliminate the accumulation of water, the freezing of which could impair the operation or discharge capability of the device.

2-3.10.2 Normal Venting. Each cargo tank compartment shall be provided with pressure and vacuum vents having a minimum through area of 0.44 sq in. (2.86 cm^2). All pressure vents shall be set to open at no more than 1 psig (6.9 kPa) and all vacuum vents at no more than 6 oz (168 g). Pressure and vacuum vents shall be designed to prevent loss of liquid through the vent in case of vehicle overturn.

2-3.10.3 Loading and Unloading Venting Protection. If the tank is designed to be loaded or unloaded with the dome cover closed, the vent or vents as described in 2-3.10.2 above or additional vents shall limit the vacuum to 1 psig (6.9 kPa) and the tank pressure to 3 psig (20.7 kPa) based on maximum product transfer rate. Unless effective protection against overfilling is made, the pressure vent shall also have sufficient liquid capacity to prevent the pressure from exceeding 3 psig (20.7 kPa) in case of accidental overfilling. This pressure vent may be pressure operated or interlocked with the tank loading device and shall be designed to prevent loss of liquid through the vent under any condition of vehicle rollover attitude.

2-3.11 Emergency Venting for Fire Exposure.

2-3.11.1 Total Capacity. The total emergency venting capacity [cu ft/hr (m^3/s)] of each cargo tank compartment shall be not less than that determined from Table 2-3.

Table 2-3 Minimum Emergency Vent Capacity in Cubic Feet Free Air/Hour [14.7 psia (101.3 kPa) and 60°F (15.6°C)]

Exposed Area Sq Ft	Cu Ft Free Air per Hr	Exposed Area Sq Ft	Cu Ft Free Air per Hr
20	15,800	275	214,300
30	23,700	300	225,100
40	31,600	350	245,700
50	39,500	400	265,000
60	47,400	450	283,200
70	55,300	500	300,600
80	63,300	550	317,300
90	71,200	600	333,300
100	79,100	650	348,800
120	94,900	700	363,700
140	110,700	750	378,200
160	126,500	800	392,200
180	142,300	850	405,900

200	158,100	900	419,300
225	191,300	950	432,300
250	203,100	1,000	445,000

Note: Interpolate for intermediate sizes.

2-3.11.2 Pressure-Actuated Venting. Each cargo tank compartment shall be equipped with pressure-actuated vent or vents set to open at not less than 3 psig (20.685 kPa) and close when pressure drops to 3 psig (20.7 kPa) or below. The minimum venting capacity for pressure-actuated vents shall be 6,000 cu ft (170 m^3, of free air per hr [14.7 psia (101.3 kPa) and 60°F (15.6°C)] from a tank pressure of 5 psig (34.5 kPa). Pressure-actuated devices shall be designed so as to prevent leakage of liquid past the device in case of surge or vehicle upset, except that they shall function in case of pressure rise under any condition of vehicle rollover attitude.

2-3.11.3 Fusible Venting. If the pressure-actuated venting required by 2-3.11.2 does not provide the total venting capacity required by 2-3.11.1, additional capacity shall be provided by adding fusible venting devices, each having a minimum area of 1.25 sq in. (8.1 cm^2). Such fusible elements shall be so located as to not be in contact with the tank lading under normal operating conditions. The fusible vent or vents shall be actuated by elements that operate at a temperature not exceeding 250°F (121.1°C). The venting capacity of these devices shall be rated at not more than 5 psig (34.5 kPa). When fusible venting devices are used, no less than two such devices shall be used on any cargo tank or tank compartment over 2,500 gal (9500 L) in capacity, and at least one such device shall be located close to each end of the cargo tank or tank compartment.

2-3.11.4 Flow Testing and Marking of Vents. Each type and size of venting device shall be flow tested in the range specified in the applicable preceding paragraphs. The actual rated flow capacity of the vent in cubic feet of free air per hour at the pressure in psig at which the flow capacity is determined shall be stamped on the device. The fusible vent or vents shall have their flow rating determined at 5 psig (34.5 kPa) differential.

2-3.11.5 These flow tests may be conducted by the manufacturer, if certified by a qualified impartial observer, or may be delegated to an outside agency.

NOTE: Information on suitable methods for conducting such tests is provided in API Standard 2000 available from the American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005.

2-4 Emergency-Discharge Control.

2-4.1 Liquids Having Viscosities Less than 45 SUS.

2-4.1.1 The outlets of each cargo tank or compartment used for transportation of Class I liquids, and trucks constructed hereafter for transportation of Class II and Class IIIA liquids having a viscosity less than 45 SUS at 100°F (37.8°C), shall be equipped with a self closing shut-off valve, designed, installed, and operated so as to ensure against the accidental escape of contents. These valves shall be located inside the tank or at a point outside the tank where the line enters or leaves the tank. The valve seat shall be located inside the tank or within the welded flange, its companion flange, nozzle, or coupling and designed so that the valve must be kept closed except during loading and unloading operations.

NOTE: The 45-second viscosity limit is included for the purposes of requiring internal valves when transporting free-flowing distillate oils, such as kerosene, diesel oil, and domestic heating oil, and of excluding this requirement when transporting viscous oils such as residual fuel oil, bunker fuel oil, and asphalt products, which may congeal and cause malfunctioning of the valve.

2-4.1.2 The operating mechanism for the valve shall be provided with a secondary control, remote from the fill openings and discharge connections, for use in the event of accidents or fire during delivery operations.

2-4.1.3 The control mechanism shall be provided with at least one fusible element that becomes effective at a temperature not over 250°F (121.1°C) permitting the valve to close automatically in case of fire. At least one fusible element shall be in the open where it would be exposed to the heat of a fire under the vehicle.

2-4.1.4 In every case there shall be provided a shear section located outboard of each emergency valve seat and within 4 in. (10 cm) of the vessel that will break under strain and leave the emergency valve seat and its attachment to the vessel and the valve head intact and capable of retaining product. The shear section shall be machined in such a manner as to abruptly reduce the wall thickness of the adjacent piping (or valve) material by at least 20 percent.

2-5 Liquids of Viscosities of 45 SUS or More.

The outlets of each cargo tank used for the transportation of liquids having a viscosity equal to or greater than 45 SUS at 100°F (37.8°C) shall be equipped with (1) a suitable shutoff valve, located internally, designed so that the valve will remain operable if the external connection is sheared off, or (2) a front-or rear-head mounted valve securely reinforced and protected against shock or road hazards.

2-6 Tests.

2-6.1

At the time of manufacture, every cargo tank shall be tested by a minimum air or hydrostatic pressure of 3 psig (20.7 kPa) or at least equal to the tank design pressure, whichever is greater. If compartmented, each individual compartment shall be similarly tested with adjacent compartments empty and at atmospheric pressure. Air pressure, if used, shall be held for a period of at least 5 minutes during which the entire surface of all joints under pressure shall be coated with a solution of soap and water, heavy oil, or other material suitable for the purpose, foaming or bubbling of which indicates the presence of leaks. Hydrostatic pressure, if used, shall be done by using water or other liquid having a similar viscosity, the temperature of which shall not exceed 100°F (37.8°C) during the test, and applying pressure as prescribed above, gaged at the top of the tank, at which time all joints under pressure shall be inspected for the issuance of liquid to indicate leaks. All closures shall be in place while test by either method is made. During these tests, operative relief devices shall be clamped, plugged, or otherwise rendered inoperative; such clamps, plugs, and similar devices shall be removed immediately after the test is finished.

2-6.2

The test in 2-6.1 shall be repeated following alteration or repairs that involve tank integrity. If there is any leakage, undue distortion, or if failure impends or occurs, the cargo tank shall not be placed in service unless an adequate repair is made. The adequacy of the repair shall be determined by the same method of test.

2-7 Separation to Prevent Intermixing.

Tank vehicles designed to transport Class I liquid in one or more compartments and Class II or Class III liquid in other compartment or compartments, or to transport chemically noncompatible liquids, shall be provided with double bulkheads and shall be equipped with separate piping, pumps, meters, and hoses for such classes of product.

2-8 Lighting.

Lighting circuits shall have suitable overcurrent protection (fuses or automatic circuit breakers). The wiring shall have sufficient carrying capacity and mechanical strength and shall be secured, insulated, and protected against physical damage, in keeping with recognized good practice.

Chapter 3 Asphalt Tank Vehicles

3-1 General.

Cargo tanks shall be free of water or volatile liquids before they are loaded with hot asphalt.

3-2 Vents for Cargo Tanks in Asphalt Service.

3-2.1

Each cargo tank used in asphalt service shall be provided with a vent having an effective opening at least equivalent to a nominal 2-in. pipe.

3-2.2

Each cargo tank for asphalt service shall be provided with a manhole having a free opening of at least 15 in. (381 mm) in diameter designed to relieve internal pressure at between 2 and 3 psig (0.095 and 0.143 kPa) or an equivalent relief device.

3-3 Overflows and Drains for Asphalt Tank Vehicles.

Overflow protection for asphalt tank vehicles shall be provided in the form of reservoirs or flashing around fill and vent pipes. Overflow and drain pipes shall have thicknesses heavier than the tank shell and shall be designed so that hot asphalt will not spill onto tires, brakes, burner equipment, or vehicle's exhaust system.

3-4 Burner and Burner Tubes for Asphalt Tank Vehicles.

3-4.1

Fuel tanks for the vehicle engine and fuel tanks for the burners on asphalt trucks shall be located remotely from the burner or protected by a noncombustible shield from the burner to prevent flashback.

3-4.2

Burner tubes shall be properly installed and maintained.

3-4.3

The bottom of internal burner tubes shall be located as low in the tank as proper design and functioning will permit.

3-4.4

Instructions for the proper method of operating the burner equipment and the pumping equipment, if so equipped, shall be provided. These instructions shall accompany the vehicle at all times.

3-4.5

A legible red warning sign shall be permanently attached near the burners on any tank vehicle equipped with burners and shall contain at least the following information:

“WARNING

> This burner equipment must not be operated while the vehicle is being loaded or is in transit, or when the burner tubes are not completely submerged.”

Chapter 4 Marking on Tank Vehicles

4-1 Marking.

4-1.1

Every tank vehicle used for the transportation of any flammable or combustible liquids, regardless of the quantity being transported, or whether loaded or empty, shall be conspicuously and legibly marked in accordance with the requirements of the U.S. Department of Transportation Hazardous Materials Regulations.

4-1.2 Manufacturer’s Certificate.

A certificate signed by a responsible official of the manufacturer of the cargo tank, or from a competent testing agency, certifying that each such cargo tank is designed, constructed, and tested in compliance with this standard shall be procured, and such certificate shall be retained in the files of the carrier during the time that such cargo tank is employed by him, plus one year.

4-1.3

In addition to this certificate, there shall be on every cargo tank (or tank compartment if constructed to different specification) a metal plate not subject to corrosion located on the right side, near the front, in a place readily accessible for inspection. Such plate shall be permanently affixed to the tank by means of soldering, brazing, welding, or other equally suitable means; and upon it shall be marked in characters at least $^{3}/_{16}$ in. (0.47 cm) high by stamping, embossing, or other means of forming letters into or on the metal of the plate itself at least the information indicated below. The plate shall not be so painted as to obscure the markings thereon.

Vehicle manufacturer ....

Manufacturer’s serial no. ....

Specification identification DOT MC 306; or MC 307;
or MC 312 ....

Date of manufacture ....

Original test date ....

Certificate date ....
Design pressure... psig
Test pressure .... psig
Head material ....
Shell material ....
Weld material ....
Lining material ....
Nominal tank capacity by compartment (front to rear)
.... U.S. gal
Maximum product load.. lbs
Loading limits.. gpm and/or psig
Unloading limits .... gpm and/or psig

4-1.4

If a cargo tank is to be physically altered to meet another specification (or to accommodate a commodity not requiring a specification tank) such combinations shall be indicated beside specification identification.

4-1.5

If the cargo tank has a metal certification plate for MC 306 specification, the characters “NFPA 385” may be added to the specification identification line on the metal plate.

Chapter 5 Auxiliary Equipment

5-1 Auxiliary Internal Combustion Engines.

5-1.1

Internal combustion engines, other than those providing propulsive power, installed or carried on a tank vehicle transporting Class I liquids for the purpose of providing power for the operation of pumps or other devices, shall meet the following requirements.

5-1.2

The engine air intake shall be equipped with an effective flame arrester, or an air cleaner having effective flame arrester characteristics, substantially installed and capable of preventing emission of flame from the intake side of the engine in event of backfiring.

5-1.3

The fuel system shall be so located or constructed as to minimize the fire hazard. If the fuel tank is located above or immediately adjacent to the engine, suitable shielding shall be provided to prevent spillage during the filling operation, or leakage from the tank or fuel system, from coming in contact with the engine or any parts of the ignition and exhaust systems. All parts of the fuel system shall be constructed and installed in a proficient manner.

5-1.4

Pumps and other appurtenances shall be so located in relation to the engine that spillage or leakage from such parts shall be prevented from coming in contact with the engine or any parts of the ignition and exhaust system, or adequate shielding shall be provided to attain the same purpose. The engine cooling fan shall be so positioned, rotated, or shielded as to minimize the possibility of drawing flammable vapors toward the engine.

5-1.5

When the engine is located in a position where spillage from the cargo tank or its appurtenances or from side racks might constitute a hazard, suitable shielding shall be provided to prevent such spillage from contacting the engine or engine exhaust system and for draining such spillage away from the vicinity of the engine.

5-1.6

Where the engine is carried within an enclosed space, adequate provision shall be made for air circulation at all times to prevent accumulation of explosive vapors and to avoid overheating.

5-1.7

The exhaust system shall be substantially constructed and installed and free from leaks. The exhaust line and muffler shall have adequate clearance from combustible materials, and the exhaust gases shall be discharged at a location that will not constitute a hazard. When engines are carried as in 5-1.6, the exhaust gases shall be discharged outside of each such enclosed space.

5-1.8

The ignition wiring shall be substantially installed with firm connections, and spark plug and all other terminals shall be suitably insulated to prevent sparking in event of contact with conductive materials. The ignition switch shall be of the enclosed type.

5-2 Auxiliary Electric Generators and Motors.

5-2.1

Electrical equipment installed or carried upon a tank vehicle transporting Class I liquids for the operation of pumps or other devices used for the handling of product and operating product handling accessories shall meet the following requirements.

5-2.2

Generators that are mounted on the engine providing propulsive power for the vehicle or an auxiliary engine, or located in the immediate vicinity of such engine or its exhaust system, may have general purpose enclosure. Generators located elsewhere shall be provided with explosionproof enclosures.

5-2.3

Motors having sparking contacts shall be provided with explosionproof enclosures.

5-2.4

Wiring shall be adequate for maximum loads to be carried and shall be installed so as to be protected from physical damage and contact with possible product spill either by location or by being enclosed in metal conduit or other oil-resistant protective covering. Junction boxes shall be sealed.

5-2.5

Switches, overload protection devices, and other sparking equipment shall be located and enclosed as provided for generators in 5-2.2.

5-2.6

Where the generator or motor is located within an enclosed space, adequate provision shall be made for air circulation to prevent overheating and possible accumulation of explosive vapor.

5-3 Pumps and Hose.

5-3.1

When a pump is used to deliver products, automatic means shall be provided to prevent pressure in excess of the design working pressures of the accessories, piping, and hose.

5-3.2

Each length of hose used for delivery of product by pump shall be marked to indicate the manufacturer's recommended working pressure.

5-3.3

All pressure hoses and couplings shall be inspected at intervals appropriate to the service. With the hose extended, apply pressure to the hose and couplings to the maximum operating pressure. Any hose showing material deteriorations, signs of leakage, or weakness in its carcass or at the couplings shall be withdrawn from service and repaired or discarded.

Chapter 6 Operation of Tank Vehicles

6-1 General Operating Conditions.

6-1.1

Drivers shall be thoroughly trained in the proper method of operating tank vehicles and in the proper procedures for loading and unloading tank vehicles. Tank vehicles shall not be operated unless they are in proper repair, devoid of accumulation of grease, oil, or other flammables, and free of leaks.

6-1.2

Dome covers shall be closed and latched while the tank vehicle is in transit.

6-1.3

No tank vehicle shall be operated with a cargo temperature above the maximum allowable cargo temperature specified on the warning sign required by 2-1.2.

6-1.4

No material shall be loaded into or transported in a cargo tank at a temperature above its ignition temperature, unless properly safeguarded in a manner approved by the authority having jurisdiction.

6-1.5

Flammable and combustible liquids, which are loaded at or above their boiling points or may reach their boiling point temperature during transit, shall be loaded only into cargo tanks constructed in accordance with Section 2-2.

6-1.6

Flammable and combustible liquids shall be loaded only into cargo tanks whose material used in construction shall be compatible with the chemical characteristics of the liquid. The flammable and combustible liquid being loaded shall also be chemically compatible with the liquid hauled on the previous load unless the cargo tank has been cleaned.

NOTE: In case of doubt, the supplier or producer of the flammable or combustible liquid or other competent authority should be consulted.

6-1.7

Class II or Class III liquids shall not be loaded into an adjacent compartment to Class I liquids unless double bulkheads are provided, nor shall chemically noncompatible chemicals be loaded into adjacent compartments unless separated by double bulkheads.

6-1.8

To prevent a hazard from a change in flash point of liquids, no cargo tank, or any compartment thereof, that has been utilized for Class I liquid shall be loaded with Class II or Class III liquid until such tank or compartment and all piping, pumps, meters, and hose connected thereto have been completely drained. A tank, compartment, piping, pump, meter, or hose that does not drain completely shall be flushed at the loading point with a quantity of Class II or Class III liquid equal to twice the capacity of piping, pump, meter, and hose, to clear any residue of Class I liquid from the system.

NOTE: To reduce the danger of static ignition when changing from Class I to Class II or Class III (switch loading), other precautions may be necessary. (*See Appendix A for further information.*)

6-1.9

No repairs shall be made to any tank vehicle unless the repairs can be made without hazard, nor shall any loaded motor vehicle be repaired in a closed garage.

6-1.10

No cargo tank shall be repaired by any method employing a flame, arc, or other source of ignition, unless the tank is maintained gas free or otherwise made safe in an approved manner.

6-2 Loading and Unloading Tank Vehicles.

6-2.1

Loading and unloading of tank vehicles shall only be done in approved locations.

6-2.2

The driver, operator, or attendant of any tank vehicle shall not remain in the vehicle but shall not leave the vehicle unattended during the loading or unloading process. Delivery hose, when attached to a tank vehicle, shall be considered to be a part of the tank vehicle.

6-2.3

When transferring Class I liquids, motors of tank vehicles or motors of auxiliary or portable pumps shall be shut down during making and breaking hose connections. If loading or unloading is done without requiring the use of the motor of the tank vehicle, the motor shall be shut down throughout the transfer operations of Class I liquids.

6-2.4

If portable pumps are used for transferring Class I liquids, the portable pumps shall comply with the applicable provisions of Section 5-1 or 5-2.

6-2.5

No cargo tank or compartment thereof used for the transportation of any flammable or combustible liquid or asphalt shall be loaded liquid full. Sufficient space (outage) shall be provided in every case to prevent leakage from such tank or compartment by expansion of the contents due to rise in temperature in transit and in no case less than 1 percent.

6-2.6

Delivery of Class I liquids to underground tanks of more than 1,000 gal (3800 L) capacity shall be made by means of tight connections between the hose and the fill pipe.

6-2.6.1 In all cases where underground tanks are equipped with any type of vapor recovery system, all connections required to be made for the safe and proper functioning of the particular vapor recovery process shall be made. Such connections shall be designed to prevent release of vapors at grade level and shall remain connected throughout the loading or unloading process.

6-2.7

When a cargo tank is filled through bottom loading, a positive means shall be provided for loading a predetermined quantity of liquid, and an automatic secondary shutoff control shall be installed in each compartment to prevent overfill.

6-2.8

The secondary shutoff control system shall be labeled as to manufacturer and type. Any electrical system shall be labeled as to manufacturer and type. Any electrical system used for secondary shutoff must be in accordance with NFPA 70, *National Electrical Code®*.

6-2.9

When bottom loading vehicles are equipped for vapor recovery and vapor recovery is not required, the tank vapor system must be open to the atmosphere to prevent pressurization of the tank and the vapor system.

6-2.10

When a dry disconnect vapor recovery adapter is used, provisions must be made to assure the vapor recovery system is fully vented before unloading to prevent collapse of the tank. This applies to both bottom and top loading.

6-2.11

When bottom loading a tank equipped with a vapor recovery system, the vapor recovery connection must be used to conduct vapor away from the loading area using the terminal vapor recovery system, discharge standpipe, or by opening the tank fill openings (manholes).

6-2.12

When a cargo tank is filled through a top opening, the cargo tank shall be bonded to the fill stem or some part of the rack structure which is electrically interconnected with the fill stem piping.

Exception No. 1: Loading asphalt, crude oil, or a product containing substantial proportions of crude residuum.

Exception No. 2: Tank vehicles used exclusively for transporting Class II and Class III liquids when loaded at locations where no Class I liquids are handled.

6-2.13

The bond-wire connection shall be made prior to opening the dome covers. It shall be maintained in place during the entire filling operation and the dome covers shall be securely closed before the bond wire is disconnected from the cargo tank.

NOTE: Bond wires may be insulated or noninsulated. A noninsulated wire permits ready visual inspection for continuity of bond. Insulated types should be electrically tested or inspected periodically for continuity of the entire bond circuit including clamps and connectors.

6-2.14

No external bond-wire connection or bond-wire integral with a hose is needed for the unloading of flammable and combustible liquids into underground tanks nor when a tank vehicle is loaded or unloaded through tight connections such as to an aboveground tank or through bottom connections.

6-2.15

Smoking on or about any tank vehicle while loading or unloading any flammable or combustible liquid is forbidden. Extreme care shall be taken in the loading or unloading of any flammable liquid into or from any cargo tank to keep fire away and to prevent persons in the vicinity from smoking, lighting matches, or carrying any flame or lighted cigar, pipe, or cigarette.

6-2.16

No flammable or combustible liquid shall be transferred to or from any tank vehicle unless the parking brake is securely set and all other reasonable precautions have been taken to prevent motion of the vehicle.

6-3 Fire Extinguishers.

6-3.1

Each tank vehicle shall be provided with at least one portable fire extinguisher having at least a 20-B,C rating or, when more than one is provided, each extinguisher shall have at least a 10-B,C rating. Each tank vehicle manufactured after January 1, 1980 shall be provided with at least one portable fire extinguisher having at least a 2-A, 20-B,C rating, in lieu of the above. Ratings shall be in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*.

6-3.2

Fire extinguishers shall be kept in good operating condition at all times, and they shall be located in an accessible place on each tank vehicle. Extinguishers shall be maintained in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*.

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 current 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 10-1988, *Standard for Portable Fire Extinguishers*

NFPA 58-1989, *Standard for the Storage and Handling of Liquefied Petroleum Gases*

NFPA 70-1990, *National Electrical Code*

NFPA 407-1985, *Standard for Aircraft Fuel Servicing.*

7-1.2 ASTM Publications.

American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM D-5-86, *Test for Penetration for Bituminous Materials*

ASTM D-56-87, *Standard Method of Test for Flash Point by the Tag Closed Tester*

ASTM D-93-85, *Standard Method of Test for Flash Point by the Pensky-Martens Closed Tester*

ASTM D-323-82, *Standard Method of Test for Vapor Pressure of Petroleum Products (Reid Method)*

ASTM B-209-88, *Specification for Aluminum and Aluminum-Alloy Sheet and Plate.*

7-1.3 ASME Publication.

American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017.

ASME *Boiler and Pressure Vessel Code*.

7-1.4 Federal Regulation.

U.S. Government Printing Office, Washington, DC 20402.

Code of Federal Regulations, Title 49, Transportation, Part 178.

Appendix A Precautions against Ignition by Static Electricity

Chapter 6 of NFPA 385 includes requirements directed at preventing the occurrence of static-caused fires or explosions in the operation of tank vehicles.

This Appendix provides background information concerning the generation, accumulation, and release of static charges (sparks) in such operations and explains the reasons for the required precautions.

For a more detailed discussion of static electricity and methods for its control for the purpose of eliminating or mitigating its fire hazard, see NFPA 77, *Recommended Practice on Static Electricity*.

Generation.

Static electricity almost always results from the intimate contact and subsequent separation of two substances, most often dissimilar substances. While the most widely recognized manifestations involve the separation of solids, liquid-solid separation is also a generating means and the one most important in the operation of tank vehicles.

The flow of any fluid (even water) past a surface, such as the wall of a pipe, results in the separation of electric charge. If the fluid is a conductor of electricity, such as water, the separated charges quickly reunite, and there is no conspicuous evidence that charge separation had ever occurred. But if the liquid is a poor conductor, as are many oils, this recombination may be hindered, and a persistent charge may accumulate.

If a metallic vessel insulated from its surroundings is filled in this manner, the charge carried by the liquid can be communicated to the vessel. In other words, the vessel can become "charged," or assume an electrical potential different from that of its surroundings. If a wire connected to some other body or to earth is brought close to the vessel being filled, this charge can be released in the form of a spark.

In a somewhat different but analogous manner, a charge may accumulate on the surface of the fluid in an area remote from the vessel walls, even though the vessel is itself "grounded," and this surface charge can, under certain circumstances, be released in the form of a spark.

Both of these means of spark production are important and will be dealt with separately.

Charging Tendency.

The words "charging tendency" or "static-generating ability" have come into use in describing the capability of a fluid to generate and hold a dangerous charge of static electricity. In the following, the word "oil" will be used to typify such a fluid irrespective of origin. Actually, such fluids range from pure chemicals to complex mixtures such as kerosene and other products of petroleum; some have a charging tendency and some do not.

The static-generating capability of any oil is influenced in a complex manner by the presence of ionizable components and its electrical resistivity, as discussed in detail in NFPA 77. Product name is not a reliable means of distinguishing one oil from another as regards static-generating capability. Hence, the precautions listed in NFPA 385 are based on the concept that all oils are suspect, with the important exception that crude oil and all materials containing more than a very small amount of the heavy residuum of crude oil distillation are known to be nonaccumulators because of their relatively high conductivity. Alcohols or other chemicals containing appreciable amounts of dissolved water and certain chemicals with low resistivities fall into the same category.

Since all oils under handling conditions have at least some small conductivity, such that a charge will eventually leak off, it obviously follows that the persistence of a charge must represent an equilibrium between the generating rate and the leakage rate. Generating rate depends on the rate of motion of the fluid.

In some cases the linear velocity of flow in a pipe is considered important from the standpoint of static generation. A special case involves pumping oil through filters, where the intimate contact between the oil and the filter element is known to produce a high degree of electrification.

In either case if, after leaving the place of high generation, the oil reaches a place involving a lesser degree of turbulence, some of the charge will leak away, or "relax," and "relaxation time" has become a consideration in many instances.

Ignition Hazard.

The development of electrical charges does not of itself constitute a fire or explosion hazard. There must also be present a means of accumulating or storing the charge and some place (a spark gap) where the stored energy can be released in the form of a spark in the presence of a mixture that is ignitible. The hazard does not exist if any one of these three requirements — generation means, spark gap, or ignitible mixture — is absent. It follows naturally that no precautions need be taken if one of these three requirements is known to be absent, and that where this is not assured, corrective measures will be directed toward eliminating one of them.

Examples:

(a) In filling a tank vehicle through a top opening, a bond wire between the cargo tank and the fill stem (*6-2.12*) will maintain the tank and fill pipe at the same electrical potential and hence prevent a spark in an area where it is suspected that a flammable mixture might be present [*see exceptions in (b) below*].

It should be emphasized that this bond does not prevent the accumulation of a charge on the liquid surface, and additional precautions may be necessary (*see "Switch Loading"*).

(b) No such precaution (bond wire) is required under circumstances where it is assured that there can be no ignitible mixture present. An example of such a situation is when tank vehicles are used exclusively for transporting Class II and Class III liquids (*6-2.12, Exception No. 2*). Since Class II and Class III liquids do not produce ignitible mixtures at ordinary temperatures, there will be nothing to ignite in the tanks transporting such liquids. The word exclusively is important. There are many tank vehicles operated by fuel oil dealers that, by the nature of the operation, fall into this category. The exception "where no Class I liquids are handled" is included both to guard against inadvertent filling with a Class I liquid and to recognize the desirability of having uniform bonding practices at a terminal handling Class I as well as Class II or Class III liquids.

(c) No bond wire is necessary (*6-2.12, Exception No. 1*) when loading or unloading asphalt, crude oil, or a product containing substantial proportions of crude residuum or other liquids that are known to have low resistivities. These oils are not susceptible to accumulation of dangerous static charges on the liquid surface, nor do they produce dangerous charges on the container, because the conductivity of the liquid is high enough to permit rapid neutralization of any charges separated during transfer.

(d) Static protective practices are not necessary, irrespective of the liquid being handled, where the physical arrangement is such that there is no chance of a spark occurring in the presence of a flammable mixture. Paragraph 6-2.14 lists several such situations.

1. In filling underground tanks, the fill nozzle is invariably in contact with the fill opening. In these cases the nozzle and tank are at the same electrical potential because of their contact. Furthermore, no spark gap exists.

2. Loading or unloading through tight connections. Prior to making the connection, there is no flow and no generating mechanism exists. During transfer there may be static generation within the flow system, but there is no place for a spark to occur in the presence of an ignitible mixture. Flow is shut down before the connection is broken, and there can be no potential difference to cause a spark because the two parts to be separated are in contact and at the same potential up to the instant of separation. Bottom filling is a special case of closed connection, and no bonding is necessary.

Switch Loading.

The term “switch loading” (*6-1.8*) has come into use to describe a situation that warrants special consideration.

When a tank is emptied of a cargo of Class I liquid, there is left a mixture of vapor and air, which may be, and often is, within the flammable range. When such a tank is refilled with a Class I liquid, any charge that reaches the tank shell will be bled off by the required bond wire (*6-2.12*). Also, there will be no flammable mixture at the surface of the rising oil level because the Class I liquid produces at its surface a mixture too rich to be ignitible. This is the situation commonly existing in tank vehicles in gasoline service. If, as occasionally happens, a static charge does accumulate on the surface sufficient to produce a spark, it occurs in a too rich, non-ignitible atmosphere and thus causes no harm.

A very different situation arises if the liquid is “switch loaded,” that is, when a Class II or Class III liquid is loaded into a tank vehicle that previously contained a Class I liquid. Class II or Class III liquids are not necessarily more potent static generators than the Class I liquid previously loaded, but the atmosphere in contact with the rising oil surface is not enriched to bring it out of the flammable range. If circumstances are such that a spark should occur either across the oil surface or from the oil surface to some other object, the spark occurs in a mixture that can be within the flammable range, and an explosion can result.

It is emphasized that bonding the tank to the fill stem is not sufficient; a majority of the recorded explosions have occurred when it was believed the tank had been adequately bonded. The electrostatic potential that is responsible for the spark exists inside the tank on the surface of the liquid and cannot be removed by bonding. Measures to reduce the chance of such internal static ignition can be one or more of the following:

(a) Avoid spark promoters. Conductive objects floating on the oil surface increase the chance of sparking to the tank wall. Metal gage rods or other objects projecting into the vapor space can create a spark gap as the rising liquid level approaches the projection. A common precaution is to require that fill pipes (downspouts) reach as close to the bottom of the tank as practicable. Any operation such as sampling, taking oil temperature, or gaging that involves lowering a conductive object through an opening into the vapor space on the oil should be deferred until at least 1 minute after flow has ceased. This will permit any surface charge to relax.

(b) Reduce the static generation by one or more of the following:

1. Avoid splash filling and upward spraying of oil where bottom filling is used.

2. Employ reduced fill rates at the start of filling through downspouts, until the end of the spout is submerged. Some consider 3 ft (0.914 m) per sec to be a suitable pre- caution.

3. Where filters are employed, provide relaxation time in the piping downstream from the filters. A relaxation time of 30 seconds is considered by some to be a suitable pre- caution.

(c) Eliminate the flammable mixture before switch loads by gas freeing or inerting.

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 current 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 77 1988, *Recommended Practice on Static Electricity.*

B-1.2 ASTM Publication.

American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM D-86-82, *Standard Method of Test for Distillation of Petroleum Products*.

NFPA 386

1990 Edition

Standard for Portable Shipping Tanks for Flammable and Combustible Liquids

1990 Edition

This edition of NFPA 386, *Standard for Portable Shipping Tanks for Flammable and Combustible Liquids*, was prepared by the Technical Committee on Transportation of Flammable Liquids, released by the Correlating Committee on Flammable Liquids, 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 standard has been approved by the American National Standards Institute.

Origin and Development of NFPA 386

This standard was first officially adopted in 1970 and was revised in 1974 and 1979. The 1979 edition was reconfirmed in 1985 and in 1990.

Committee on Flammable Liquids

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NFPA 386

Standard for Portable Shipping Tanks for Flammable and Combustible Liquids

1990 Edition

NOTICE: Information on referenced publications can be found in Chapter 5.

Chapter 1 General Provisions

1-1 Scope and Application.

1-1.1

This standard applies to portable shipping tanks with capacity larger than 60 gal (227 L) and not exceeding 660 gal (2498 L) used for the transportation of normally stable flammable and combustible liquids having a flash point below 200 °F (93.4 °C) and handled at temperatures below their boiling point.

NOTE: Normally stable materials are those having the relative capacity to resist changes in their chemical composition that would produce violent reactions or detonations despite exposure to air, water, or heat, including the normal range of conditions encountered in handling, storage, or transportation. Unstable (reactive) flammable and combustible liquids are liquids that in the pure state or as commercially produced or transported will vigorously polymerize, decompose, condense, or become self-reactive under conditions of shock, pressure, or temperature.

1-1.2

Attention is directed to the fact that cutback asphalts can have flash points in the range of Class I liquids. Also liquids having a flash point higher than 200 °F (93.4 °C) may assume the characteristics of lower flash point liquids when heated. Under such conditions it shall be appropriate to apply the provisions of this standard unless otherwise specifically exempted.

1-1.3

Additional safeguards may be necessary for portable shipping tanks used in the transportation of liquids having special properties that dictate safeguards in addition to those specified here.

1-1.4

This standard does not apply to:

1-1.4.1 The use of portable shipping tanks as storage containers. See NFPA 30, *Flammable and Combustible Liquids Code*, for information on storage.

1-1.4.2 Drums as defined by the United States Department of Transportation when constructed according to specifications of the United States Department of Transportation.

NOTE: For construction and use of portable shipping tanks exceeding 660 gal (2498 L) capacity, reference may be made to the specifications of the United States Department of Transportation or equivalent authorities having jurisdiction.

1-2 Definitions.

Asphalt. The term asphalt shall include other materials having similar characteristics when heated above ambient temperatures.

Baffle. A nonliquidtight partition in a portable shipping tank.

Compartment. A liquidtight division in a portable shipping tank.

Flash Point. The minimum temperature of a liquid at which sufficient vapor is given off to form an ignitible mixture with the air near the surface of the liquid within the tank as determined by appropriate test procedure and apparatus as specified.

The flash point of liquids having a viscosity less than 45 SUS at 100 °F (37.8 °C) and a flash point below 200 °F (93.4 °C) shall be determined in accordance with ASTM D-56-87, *Standard Method of Test for Flash Point by the Tag Closed Tester*.

The flash point of liquids having a viscosity of 45 SUS or more at 100 °F (37.8 °C) or a flash point of 200 °F (93.4 °C) or higher shall be determined in accordance with ASTM D-93-85, *Standard Method of Test for Flash Point by the Pensky-Martens Closed Tester*.

Liquid. For the purpose of this standard, liquid shall mean any material that has a fluidity greater than that of 300 penetration asphalt when tested in accordance with ASTM D-5-86, *Test for Penetration for Bituminous Materials*. When not otherwise identified, the term liquid shall include both flammable and combustible liquids.

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 (93.4 °C).

Class IIIB Liquids shall include those having flash points at or above 200 °F (93.4 °C).

This standard does not cover Class IIIB liquids (*see 1-1.1*). Where the term combustible liquids is used in this standard, it shall mean only Class II and Class IIIA liquids.

NOTE: The upper limit of 200 °F (93.4 °C) is given because the application of this standard does not extend to liquids having flash points above 200 °F (93.4 °C) and should not be construed as indicating that liquids with higher flash points are noncombustible.

Flammable Liquids. A liquid having a flash point below 100 °F (37.8 °C) and having a vapor pressure not exceeding 40 psia (2,068 mm Hg) at 100 °F (37.8 °C) and shall be known as a Class I liquid.

Class I liquids shall be subdivided as follows:

Class IA liquids 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 Liquids 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 Liquids shall include those having flash points at or above 73 °F (22.8 °C) and below 100 °F (37.8 °C).

NOTE: This classification does not apply to:

(a) Liquids without flash points that may be flammable under some conditions, such as certain halogenated hydrocarbons and mixtures containing petroleum fractions and hydrocarbons.

(b) Mists, sprays, or foams.

Portable Shipping Tank. Any container having a liquid capacity in excess of 60 U.S. gal (227 L) and not exceeding 660 U.S. gal (2498 L) that is readily movable from place to place either with or without special handling equipment and that is not permanently attached to its transporting vehicle.

Vapor Pressure. The pressure measured in psia (mm Hg) exerted by a volatile liquid, as determined by ASTM D-323-82, *Standard Method of Test for Vapor Pressure of Petroleum Products (Reid Method).*

Chapter 2 Design and Construction of Portable Shipping Tanks

2-1 Basic Design.

2-1.1

Portable shipping tanks shall be of all welded construction and fabricated in accordance with good engineering practice.

2-1.2

Portable shipping tanks built under Specifications of the United States Department of

Transportation shall be permitted when used in accordance with the conditions specified by the United States Department of Transportation.

2-1.3

The material used in the construction of tanks shall be compatible with the chemical characteristics of the liquid to be transported. In case of doubt, the supplier or producer of the liquid, or other competent authority, shall be consulted as to the suitablility of the material to be used in construction.

2-1.4 Tank Mountings.

Tanks shall be designed and fabricated with mountings to provide a secure base while in transit. “Skids” or similar devices shall be deemed to be included within this requirement.

2-1.5 Safety Factor.

All tank mountings such as skids, fastenings, brackets, and lifting or hold-down lugs shall be permanently secured to tanks and shall be designed to withstand static loadings in any direction equal to twice the weight of the tank and attachments when filled with the product being carried without significant permanent deformation.

2-2 Construction Materials.

2-2.1

Steel used in the construction of mild steel (MS) tanks shall meet the following minimum requirements:

Yield Point, minimum .... 25,000 lb per sq in.
Ultimate Strength, minimum .... 45,000 lb per sq in.
Minimum Elongation, standard
2-in. (50.8-mm) sample.. 20 percent

2-2.2

Steel used in the construction of low alloy, low carbon (high tensile) steel (HS) tanks shall meet the following minimum requirements:

Yield Point, minimum .... 45,000 lb per sq in.
Ultimate Strength, minimum .... 60,000 lb per sq in.
Minimum Elongation, standard
2-in. (50.8-mm) sample.. 25 percent

2-2.3

Steel used in the construction of stainless steel (SS) tanks shall meet the following minimum requirements:

Yield Point, minimum .... 25,000 lb per sq in.
Ultimate Strength, minimum .... 70,000 lb per sq in.
Minimum Elongation, standard
2-in. (50.8-mm) sample.. 30 percent

2-2.4

Aluminum used in the construction of tanks of aluminum alloys for high strength welded construction shall meet the following minimum requirements:

All sheets for shells including tops and bottoms, baffles, and bulkheads of portable shipping tanks shall be of aluminum alloys (commercial designation) 5052, 5454, 5154, 5086, 5254, or 5652, conforming to ASTM B-209-88, *Specification for Aluminum and Aluminum-Alloy Sheet and Plate*. All bulkheads, baffles, tops and bottoms, and other shell stiffeners may use O temper (annealed) or stronger tempers. All shells shall be of H32 temper or H34 temper, except that when shell thicknesses of 0.250 in. or thicker are used, the H112 temper is additionally permitted.

2-2.5

Material thickness shall not be less than shown in the following table:

	Mild Steel		High Tensile Steel		Stainless Steel		Aluminum
	Gage No.*	**Approx. Thick. Decimals of In.**	**Gage No.***	**Approx. Thick. Decimals of In.**	**Gage No.***	**Approx. Thick. Decimals of In.**	**Approx. Thick. Decimals of In.**
Cylindrical							
120-300	13	0.0897	14	0.0747	14	0.0747	.090
301-450	13	0.0897	14	0.0747	14	0.0747	.125
451-660	11	0.1196	12	0.1046	12	0.1046	.125
Bottoms of vertical and ends of horizontal tanks	7	0.1793	7	0.1793	10	0.1345	.250
Tops of vertical tanks	13	0.0897	14	0.0747	14	0.0747	.125
Cubical Tanks							
Sides and Tops							
120-300	11	0.1196	12	0.1046	14	0.0747	.250
301-500	9	0.1495	10	0.1345	12	0.1046	.250
501-660	7	0.1793	7	0.1793	12	0.1046	.250
Bottoms							
120-300	7	0.1793	7	0.1793	12	0.1046	.250
301-500	7	0.1793	7	0.1793	10	0.1345	.250
501-660	7	0.1793	7	0.1793	10	0.1345	.3125

*Manufacturers Standard Gage.

2-3 Construction of Tanks.

2-3.1 Joints.

All side, top, and bottom joints shall be welded.

2-3.2 Aluminum Alloys.

All welded aluminum joints shall be made in accordance with recognized good engineering practice, and the strength of a joint shall be not less than 85 percent of that of the adjacent metal. Alloys shall be jointed by an inert gas arc welding process using aluminum- magnesium-type filler metal that is consistent with material suppliers' recommendations.

2-3.3 Mild Steel, High Tensile Steel, Stainless Steel.

Joints shall be welded in accordance with recognized good engineering practice, and the efficiency of all joints shall be not less than 85 percent of that of the adjacent metal in the portable shipping tank.

2-3.3.1 Combinations of mild steel (MS), high tensile steel (HS), or stainless steel (SS) may be used in the construction of a single tank, provided that each material, where used, shall comply with the minimum requirements specified in Section 2-2 for the material used in the construction of that section of the tank. Whenever stainless steel sheets are used in combination with sheets of other types of steel, joints made by welding shall be formed by the use of stainless steel electrodes or filler metal, on condition that the stainless steel electrodes or filler metal used in the welding be suitable for use with the grade of stainless steel concerned, according to the recommendations of the manufacturer of the stainless steel electrodes or filler metal.

2-4 Tests.

2-4.1

Portable shipping tanks shall be tested at the time of manufacture, when alteration or repairs are made that involve tank integrity, when there is an indication of necessity for a retest.

2-4.2

Portable shipping tanks shall be tested to a minimum pressure of 7.5 psig (51.7 kPa). Such pressure shall be maintained for a period of at least 5 minutes. Hydrostatic pressure, if used, shall be gaged at the top of the tank.

Chapter 3 Appurtenances

3-1 Acceptability and Protection.

3-1.1

All valves, piping, and appurtenances shall be acceptable to the authority having jurisdiction and shall be attached to the tank in a substantial manner.

3-1.2

All valves, piping, fittings, accessories, and safety devices shall be adequately protected against handling damage, overturn, or other mechanical forces.

3-2 Vents.

3-2.1 Emergency Venting for Fire Exposure.

Tanks shall be provided with one or more devices installed in the top with sufficient venting capacity to limit the tank internal pressure under fire exposure conditions to 10 psig (68.9 kPa) or not to exceed 30 percent of the bursting pressure of the tank, whichever is greater. At least one pressure-actuated vent shall be used. It shall be set to open at not less than 5 psig (34.4 kPa) and have a minimum through area of at least 0.44 sq in. (287.8 mm^2). If fusible vents are used to meet the additional emergency venting requirements, they shall be activated by elements that operate at a temperature not less than 220 °F (104.4 °C) and not exceeding 300 °F (148.9 °C) when the tank pressure is between 5 and 10 psig (34.4 and 68.9 kPa).

3-2.2 Capacity.

The total emergency venting capacity shall not be less than that determined from Table 3-2.2 using the entire external surface of the tank as the exposed area.

Table 3-2.2 Minimum Emergency Vent Capacity in Cubic Feet Free Air/Hour [14.7 psia (101.3 kPa) and 60 °F (15.6 °C)]

Exposed Area Square Feet	Cu Ft Free Air per Hour
20	15,800
30	23,700
40	31,600
50	39,500
60	47,400
70	55,300
80	63,300
90	71,200
100	79,100
120	94,900
140	110,700
160	126,500

NOTE 1: Interpolate for intermediate sizes.

NOTE 2: The venting capacities have been calculated on the basis of 75 percent of the sq ft of the total exposed area of the cargo tank, using the formulas for heat input contained in NFPA 30, *Flammable and Combustible Liquids Code*, where the derivation of these formulas is explained.

3-2.3 Tank Openings.

Tanks shall have at least one opening in the top not less than 6 in. (152.4 mm) in diameter provided with an approved closure device. Provision shall be made to prevent cover from fully opening when there is internal pressure. The closure shall be liquid- and vaportight and shall be left closed while the tank is in transit. If gaskets are used, they shall be compatible with the product being transported. In addition, there shall be on the top of the tank a $1^1/_2$-in. or larger nominal pipe size threaded opening for attaching vent piping for “off highway” use. Openings in the tank shall not release vapor or liquid at pressure below 5 psig (34.4 kPa) while the tank is in transit.

3-2.4 Outlet Valves, Fittings, or Piping.

The drawoff outlet of each tank shall be equipped with a suitable shutoff valve, located internally, designed so the valve will remain closed if the external piping is broken off.

Exception No. 1: When exterior valve or piping is provided with substantial and adequate protection against damage in handling. Bottom outlet equipment shall not extend closer than 1 in. (25.4 mm) to the bottom bearing surface of the skids or tank mountings. Discharge or drawoff valve shall be equipped with liquidtight plugs or caps while in transit.

Exception No. 2: When drawoff outlet is located on top of tank.

3-2.5 Bottom Connection.

Bottom internal valves or drawoff piping shall be attached directly to a welded flange or boss except that threaded joints may be used if such opening does not exceed $2^1/_2$-in. nominal pipe size.

Chapter 4 Operation and Use

4-1 Filling and Emptying.

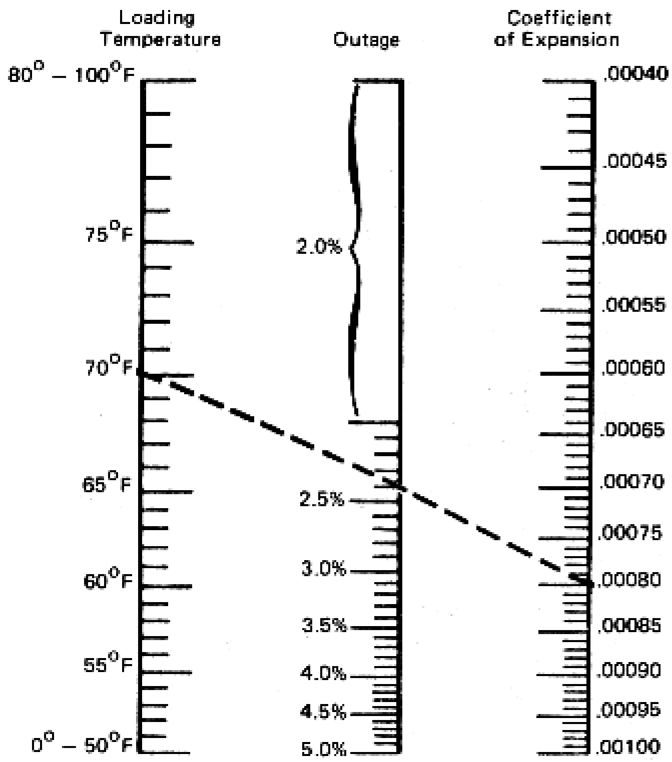
4-1.1 Outage.

No tank shall be filled liquid full. To prevent leakage from or distortion of the tank by expansion of its contents due to rise of temperature while in transit, outage shall not be less than 5 percent of the total tank volume when filled, unless outage calculated by the method in 4-1.2 demonstrates a lesser outage is adequate.

NOTE: In portable containers containing alcohol, cologne spirits, high wines, or other distilled spirits of 150 proof or over, the vacant interior space must be the maximum permitted by law such as the United States Internal Revenue Regulations, Alcohol Tax Unit.

4-1.2

The following chart page may be used to determine the required outage when filling portable shipping tanks.



The following coefficients of expansion, per degree Fahrenheit, of the principal flammable liquids shall be used in determining outages:

Acetone	0.00085
Amyl acetate	.00068
Benzol (benzene)	.00071
Carbon bisulfide	.00070
Ether	.00098
Ethyl acetate	.00079
Ethyl (grain) alcohol	.00062
Methyl (wood) alcohol	.00072
Toluol (toluene)	.00063
Gasoline or Naphtha:	
50-55° API[1]	.00055
55.1-60° API[1]	.00060
60.1-65° API[1]	.00065
65.1-70° API[1]	.00070
70.1-75°API[1]	.00075

75.1-80° API[1]	.00080
80.1-85° API[1]	.00085
85.1-90° API[1]	.00090

[1]API (American Petroleum Institute), according to the following formula:

$$°API = \frac{141.5}{\text{Specific Gravity}} - 131.5$$

Example: Suppose the temperature of the liquid at time of loading is 70 °F (21.1 °C) and its coefficient of expansion is 0.0080; lay a ruler on the chart running from 70 degrees to 0.00080 as shown by the dotted line and the required outage is 2.4 percent where the ruler crosses the outage scale.

4-1.3 Partial Deliveries Prohibited.

Portable shipping tanks shall be filled at the point of origin, and, except for sampling, no product shall be withdrawn therefrom until the tank has been properly placed at its point of final use.

4-2 Designation of Contents.

Every portable shipping tank used for the transportation of any flammable or combustible liquid shall be marked in accordance with the requirements of the U.S. Department of Transportation Hazardous Materials Regulations.

4-3 Transporting Vehicle.

4-3.1

When tanks are loaded on vehicles for transit, they shall be secured to the transporting vehicle in accordance with the applicable provisions of the U.S. Department of Transportation, Federal Motor Carrier Safety Regulations.

4-3.2 Exhaust Systems.

The exhaust system of transporting vehicle, including muffler (or silencer) and exhaust line, shall have ample clearance between it and the fuel system or any combustible materials and shall not be exposed to leakage or spillage of product or accumulations of grease, oil, or gasoline.

4-3.3 Fire Extinguishers.

Vehicles transporting one or more tanks shall be equipped with at least one approved fire extinguisher in accordance with NFPA 512, *Standard for Truck Fire Protection*.

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 current 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 30-1987, *Flammable and Combustible Liquids Code*

NFPA 512-1990, *Standard for Truck Fire Protection.*

5-1.2 ASTM Publications.

American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM B-209-88, *Specification for Aluminum and Aluminum-Alloy Sheet and Plate*

ASTM D-5-86, *Test for Penetration of Bituminous Materials*

ASTM D-56-87, *Standard Method of Test for Flash Point by the Tag Closed Tester*

ASTM D-93-85, *Standard Method of Test for Flash Point by the Pensky-Martens Closed Tester*

ASTM D-323-82, *Standard Method of Test for Vapor Pressure of Petroleum Products (Reid Method).*

NFPA 395

1993 Edition

Standard for the Storage of Flammable and Combustible

Liquids at Farms and Isolated Sites

1993 Edition

This edition of NFPA 395, *Standard for the Storage of Flammable and Combustible Liquids at Farms and Isolated Sites*, was prepared by the Technical Committee on Flammable and Combustible Liquids, released by the Correlating Committee on Flammable Liquids, 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 395

This standard was first adopted by the Association in 1947 as the *Standard for Farm Storage of Flammable Liquids*. It was developed to provide guidance for safe storage of flammable liquids in rural locations where exposures were minimal and compliance with the more restrictive requirements of NFPA 30, *Flammable and Combustible Liquids Code*, was not justified. The 1947 edition of NFPA 395 was reconfirmed in 1952. In 1959, the scope of NFPA 395 was expanded to include isolated construction projects, and further amendments were adopted in 1965, 1972, 1977, 1980, 1984, and 1988.

In 1991, the Technical Committee on Flammable and Combustible Liquids completely revised NFPA 395, primarily to comply with NFPA's *Manual of Style*. In addition, the Committee again expanded the scope of NFPA 395 so that it could be applied to any isolated site, not just construction projects, subject to the approval of the authority having jurisdiction.

Other changes to the 1988 edition include:

- Incorporation of statements of equivalency and retroactivity, in accordance with the NFPA *Manual of Style* and with NFPA policy.

- Addition of A-2-3.3 to explain the derivation of the required vent sizes given in Subsection 2-3.3.

- Addition of A-2-4.2 to caution the user that separation might be necessary from combustible storage or combustible structures other than buildings.

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Robert P. Benedetti, 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 fire and explosion hazards associated with the general storage, handling, and use of flammable and combustible liquids; and also for documents presenting criteria for the storage of flammable and combustible liquids on farms and isolated construction projects.

NFPA 395
Standard for the Storage of Flammable and Combustible Liquids at Farms and Isolated Sites

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 3 and Appendix B.

Chapter 1 General

1-1 Scope.

1-1.1*

This standard shall apply to the storage of Class I flammable liquids and Class II and Class IIIA combustible liquids, as herein defined, in containers or tanks that do not exceed 1,100 gal (4,164 L) individual capacity:

(a) On farms and in rural areas;

(b) At isolated construction sites and isolated earth-moving projects, including gravel pits, quarries, and borrow pits, where, in the opinion of the authority having jurisdiction, it is not necessary to comply with the more restrictive requirements of NFPA 30, *Flammable and Combustible Liquids Code*; and

(c) At any private site where isolation or separation from other structures or where temporary use makes it unnecessary, in the opinion of the authority having jurisdiction, to comply with the more restrictive requirements of NFPA 30, *Flammable and Combustible Liquids Code*.

1-1.2

This standard shall not apply to:

(a) The storage, handling, and use of fuel tanks and containers that are installed or used in accordance with 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*; and NFPA 30A, *Automotive and Marine Service Station Code*, and

(b) The storage of 25 gal (95 L) or less of Class I flammable liquid and Class II and Class III combustible liquids in containers that do not exceed a capacity of 5 gal (19 L).

1-2 Purpose.

The purpose of this standard shall be to provide reasonable requirements for the storage of Class I flammable and Class II and Class IIIA combustible liquids that are less restrictive than the requirements of NFPA 30, *Flammable and Combustible Liquids Code*, for use in the specific situations set forth in 1-1.1.

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, or 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 purpose.

1-4 Retroactivity.

The provisions of this standard are 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 prevalence at the time the standard was issued. Unless otherwise indicated, it is not intended that the provisions of this standard be applied to facilities, equipment, structures, or installations that were existing or approved for construction or installation prior to the effective date of this standard, except in those cases where it is determined that the existing situation involves a distinct hazard to life or adjacent property.

1-5 Definitions.

For the purposes of this standard, the following terms shall be defined as shown 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."

Liquid. Any material that has a fluidity greater than that of 300 penetration asphalt when tested in accordance with ASTM D5, *Test for Penetration for Bituminous Materials*. Where not otherwise identified, the term "liquid" shall mean both flammable and combustible liquids.

(a) *Combustible Liquid.* A liquid that has a closed-cup flash point at or above 100°F (37.8°C), as determined by appropriate methods of test. Combustible liquids shall be classified as follows:

1. Class II liquids shall include any liquid that has a closed-cup flash point at or above 100°F (37.8°C), but below 140°F (60°C).

2. Class IIIA liquids shall include any liquid that has a closed-cup flash point at or above 140°F (60°C), but below 200°F (93.4°C).

(b) *Flammable Liquid.* A liquid that has a closed-cup flash point below 100°F (37.8°C), as determined by appropriate methods of test. Flammable liquids shall be classified as follows:

1. Class IA liquids shall include any liquid that has a closed-cup flash point below 73°F (22.8°C) and a boiling point below 100°F (37.8°C).

2. Class IB liquids shall include any liquid that has a closed-cup flash point below 73°F (22.8°C) and a boiling point at or above 100°F (37.8°C).

3. Class IC liquids shall include any liquid that has a closed-cup flash point at or above 73°F (22.8°C), but below 100°F (37.8°C).

Chapter 2 Specific Requirements

2-1 Types of Approved Storage.

2-1.1

Storage of Class I, Class II, and Class IIIA liquids, as covered by this standard, shall be permitted in any of the following:

(a) In aboveground or underground tanks that meet the requirements of Section 2-2 and Chapter 3 of NFPA 30, *Flammable and Combustible Liquids Code*;

(b) In containers that meet the requirements of Section 4-2 of NFPA 30, *Flammable and Combustible Liquids Code*;

(c) In containers that do not exceed 60 gal (227 L), in accordance with Section 2-2 of this standard; and

(d) In tanks of more than 60 gal (227 L) but not more than 1,100 gal (4,164 L) capacity, in accordance with Section 2-3 of this standard.

2-2 Individual Containers Not Exceeding 60 Gallons Capacity.

2-2.1

Storage of liquids shall be in containers approved by the U.S. Department of Transportation or in other approved containers.

2-2.2

Capacity of containers shall not exceed 60 gal (227 L).

2-2.3

Dispensing or transfer devices that require the container to be pressurized shall be prohibited.

2-2.4

Pumping devices and faucets shall be well maintained to prevent leakage.

2-2.5

Individual containers shall not be interconnected or manifolded and shall be kept tightly closed when not in use.

2-2.6

Containers used for the storage of Class I liquids shall be kept outside and at least 10 ft (3 m) from any building.

Exception: As allowed in 2-2.7.

2-2.7

Containers shall be permitted to be stored inside any building that is used exclusively for the storage of Class I, Class II, and Class IIIA liquids and is located at least 10 ft (3 m) from any other building.

2-2.7.1 The building shall be provided with cross ventilation using at least 2 vents, each having a net open area of 64 $in.^2$ (413 cm^2) and each placed at floor level. The vents shall be located opposite from each other.

2-3 Tanks of 60 to 1,100 Gallons Capacity.

2-3.1

Tanks shall be of single-compartment design and constructed in accordance with good engineering practice. Joints shall be riveted and caulked, riveted and welded, or welded. Tank heads that are greater than 6 ft (2 m) in diameter shall be dished, stayed, braced, or reinforced.

2-3.1.1 Tanks shall meet the following minimum plate thickness:

Capacity		Minimum Steel Thickness
Gallons	**Liters**	**Mfrs. Standard Gauge No.**
60 to 560	230 to 2,120	14
561 to 1,100	2,120 to 4,165	12

2-3.2

Each tank shall be provided with a fill opening that is equipped with a closure that is designed to be locked. The fill opening shall be separate from the vent opening.

2-3.3*

Each tank shall be provided with a free-opening vent that shall relieve either the vacuum or the pressure that might develop during normal operation or fire exposure. The vent shall have the following nominal pipe size:

Capacity		Vent Diameter	
Gallons	**Liters**	**Inches**	**Millimeters**
Up to 275	1,040	11/2	38
276 - 660	1,040 - 2,500	2	51
661 - 900	2,500 - 3,410	21/2	64
900 - 1,100	3,410 - 4,165	3	76

2-3.4

Vents shall be arranged to discharge so as to prevent localized overheating of or direct flame impingement on any part of the tank in the event that vapors from the vent are ignited.

2-3.5

Tanks shall be located outside and at least 40 ft (12 m) from any building. They shall also be located so that any vehicle, equipment, or container that is filled directly from the tanks is at least 40 ft (12 m) from any building.

2-3.6

Tanks provided for in this section shall be permitted to have top openings only or shall be permitted to be elevated for gravity discharge.

2-3.6.1 Tanks that have top openings only shall be mounted and equipped as follows:

(a) Stationary tanks shall be mounted on timbers or blocks 6 in. (150 mm) in height so as to protect the bottom of the tank from corrosion due to contact with the ground and to maintain the tank in a stable position.

(b) Movable tanks shall be equipped with attached metal legs that rest on shoes or runners designed so that the tank is supported in a stable position and so that the tank and its supports can be moved as a single unit.

(c) Tanks shall be equipped with a tightly and permanently attached approved pumping device having an approved hose of sufficient length for filling the vehicles, equipment, or containers to be served by the tank.

(d) The dispenser nozzle and hose shall be equipped so that it can be padlocked to its hanger to prevent tampering.

(e) The pump discharge shall be equipped with an effective antisiphoning device, or the discharge hose shall be equipped with a self-closing nozzle.

(f) Siphons or internal pressure discharge devices shall be prohibited.

2-3.6.2 Tanks elevated for gravity discharge shall be mounted and equipped as follows:

(a) Tanks shall be supported on steel or wood supports having adequate strength and design to provide stability. Alternately, tanks shall be permitted to be placed on a pile of earth or near the edge of a cut bank to provide the necessary elevation and shall be supported on timbers or blocks for stability and to prevent corrosion from contact with the ground.

(b) Discharge connections shall be made to the bottom or to the end of the tank.

(c) The discharge connection shall be equipped with a valve that shall automatically close in the event of a fire by means of operation of an effective heat-actuated device. This valve shall be located adjacent to the tank shell. If this valve cannot be operated manually, an additional valve that can be manually operated shall be provided.

(d) The discharge connection shall be provided with an approved hose of sufficient length for filling vehicles, equipment, and containers to be served by the tank. The hose shall be provided with a self-closing nozzle at the discharge end.

(e) The hose shall be equipped so that it can be padlocked to its hanger to prevent tampering.

2-4 Marking of Tanks and Containers.

2-4.1

Tanks and containers shall be conspicuously marked with the name of the product contained and with the following marking: "FLAMMABLE - KEEP FIRE AND FLAME AWAY."

2-4.2*

Tanks shall also bear the following marking: "KEEP 40 FT FROM BUILDINGS."

2-5 Fire Prevention and Control.

2-5.1

Storage areas shall be kept free of weeds and other extraneous combustible materials.

2-5.2

Open flames and smoking materials shall not be permitted in areas where Class I liquids are stored.

Chapter 3 Referenced Publications

3-1

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.

3-1.1 NFPA Publication.

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

NFPA 30, *Flammable and Combustible Liquids Code*, 1993 edition.

3-1.2 ASTM Publication.

American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM D5-1986, *Test for Penetration for Bituminous Materials.*

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

On isolated construction and earth-moving projects and on other similarly isolated sites, it is customary for the property owner or the contractor to obtain fuel in bulk and to dispense the fuel under his or her direct control.

A-2-3.3

Vent sizes are based on limiting the internal pressure of the tank to 3.0 psig (20.7 kPa) [120 percent of 2.5 psig (17.2 kPa), the maximum internal pressure allowed for an atmospheric storage tank], using an orifice coefficient of 0.8 and an environmental factor of 0.5. The 0.5 environmental factor recognizes the limited time that a small tank will be exposed to fire, loss of fuel by absorption into the soil, and drainage of liquid away from the tank. Calculations are based on 2-3.5 of NFPA 30, *Flammable and Combustible Liquids Code*.

A-2-4.2

This 40-ft (12.2-m) clearance distance should also apply to other combustible structures, haystacks, etc.

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 30A, *Automotive and Marine Service Station 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*, 1990 edition.