NFPA 13
Standard for the Installation of Sprinkler Systems

1999 Edition

National Fire Protection Association, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101
An International Codes and Standards Organization

IMPORTANT NOTICE ABOUT THIS DOCUMENT

NFPA codes and standards, of which the document contained herein is one, are developed through a consensus standards development process approved by the American National Standards Institute. This process brings together volunteers representing varied viewpoints and interests to achieve consensus on fire and other safety issues. While the NFPA administers the process and establishes rules to promote fairness in the development of consensus, it does not independently test, evaluate, or verify the accuracy of any information or the soundness of any judgments contained in its codes and standards.

The NFPA disclaims liability for any personal injury, property or other damages of any nature whatsoever, whether special, indirect, consequential or compensatory, directly or indirectly resulting from the publication, use of, or reliance on this document. The NFPA also makes no guaranty or warranty as to the accuracy or completeness of any information published herein.

In issuing and making this document available, the NFPA is not undertaking to render professional or other services for or on behalf of any person or entity. Nor is the NFPA undertaking to perform any duty owed by any person or entity to someone else. Anyone using this document should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstances.

The NFPA has no power, nor does it undertake, to police or enforce compliance with the contents of this document. Nor does the NFPA list, certify, test or inspect products, designs, or installations for compliance with this document. Any certification or other statement of compliance with the requirements of this document shall not be attributable to the NFPA and is solely the responsibility of the certifier or maker of the statement.

NOTICES

All questions or other communications relating to this document and all requests for information on NFPA procedures governing its codes and standards development process, including information on the procedures for requesting Formal Interpretations, for proposing Tentative Interim Amendments, and for proposing revisions to NFPA documents during regular revision cycles, should be sent to NFPA headquarters, addressed to the attention of the Secretary, Standards Council, National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

Users of this document should be aware that this document may be amended from time to time through the issuance of Tentative Interim Amendments, and that an official NFPA document at any point in time consists of the current edition of the document together with any Tentative Interim Amendments then in effect. In order to determine whether this document is the current edition and whether it has been amended through the issuance of Tentative Interim Amendments, consult appropriate NFPA publications such as the *National Fire Codes*® Subscription Service, visit the NFPA website at www.nfpa.org, or contact the NFPA at the address listed above.

A statement, written or oral, that is not processed in accordance with Section 16 of the Regulations Governing Committee Projects shall not be considered the official position of NFPA or any of its Committees and shall not be considered to be, nor be relied upon as, a Formal Interpretation.

The NFPA does not take any position with respect to the validity of any patent rights asserted in connection with any items which are mentioned in or are the subject of this document, and the NFPA disclaims liability of the infringement of any patent resulting from the use of or reliance on this document. Users of this document are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

Users of this document should consult applicable federal, state, and local laws and regulations. NFPA does not, by the publication of this document, intend to urge action that is not in compliance with applicable laws, and this document may not be construed as doing so.

Licensing Policy

NFPA 13

Standard for the

Installation of Sprinkler Systems

1999 Edition

This edition of NFPA 13, *Standard for the Installation of Sprinkler Systems*, was prepared by the Technical Committee on Hanging and Bracing of Water-Based Fire Protection Systems, the Technical Committee on Sprinkler System Discharge Criteria, and the Technical Committee on Sprinkler System Installation Criteria, released by the Technical Correlating Committee on Automatic Sprinkler Systems, and acted on by the National Fire Protection Association, Inc., at its May Meeting held May 17–20, 1999, in Baltimore, MD. It was issued by the Standards Council on July 22, 1999, with an effective date of August 13, 1999, 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 13 was approved as an American National Standard on August 13, 1999.

Origin and Development of NFPA 13

NFPA 13 represents the first standard published under the auspices of the NFPA Committee on Automatic Sprinklers. Originally titled *Rules and Regulations of the National Board of Fire Underwriters for Sprinkler Equipments, Automatic and Open Systems*, the standard has been continuously updated to keep in step with change.

Full information about the NFPA actions on various changes will be found in the NFPA Proceedings. The dates of successive editions are as follows: 1896, 1899, 1902, 1905, 1907, 1908, 1912, 1913, 1915, 1916, 1917, 1919, 1920, 1921, 1922, 1923, 1924, 1925, 1926, 1927, 1928, 1929. In 1930, a separate standard was published on Class B systems. This was integrated into the 1931 edition. Further revisions were adopted in 1934, 1935, and 1936. A two-step revision was presented in the form of a progress report in 1939 and finally adopted in 1940. Further amendments were made in 1947, 1950, 1953, 1956, 1958, 1960, 1961, 1963, 1964, 1965, 1966, 1968, 1969, 1971, 1972, 1973, 1974, 1975, 1976, 1978, 1980, 1982, 1984, 1986, and 1989.

The 1991 edition incorporated an entire rewrite of the standard to make the overall format user friendly. Substantive changes were made to numerous terms, definitions, and descriptions, with additional refinements made in 1994.

The centennial (1996) edition included a significant rework of the requirements pertaining to the application, placement, location, spacing, and use of various types of sprinklers. Other changes provided information on extended coverage sprinklers and recognized the benefits of fast-response sprinkler technology.

The 1999 edition encompasses a major reorganization of NFPA's Sprinkler Project that included the establishment of a Technical Correlating Committee on Automatic Sprinkler Systems and four new sprinkler systems technical committees, the consolidation of NFPA's sprinkler system design and installation requirements, and the implementation of numerous technical changes.

The scope of NFPA 13 has been expanded to address all sprinkler system applications. The 1999 edition contains information on the installation of underground pipe from NFPA 24 and sprinkler system discharge criteria for on-floor and rack storage of Class I, II, III, IV, and plastic commodities, rubber tires, baled cotton, and roll paper that were previously located in NFPA 231, 231C, 231D, 231E, and 231F. Additionally, sprinkler system information for specialized hazards from over 40 NFPA documents has been either copied into NFPA 13 using NFPA's extract policy or specifically referenced. A new chapter has been also added to address the structural aspects of exposed and buried system piping. A table of cross-references to previous editions and material that was located in other NFPA documents is included at the end of this document.

More specific changes include a new sprinkler identification marking system and the designation of sprinkler sizes by nominal K-factors. New criteria for the use of steel pipe in underground applications has been added, as well as a new provision to guard against microbiologically influenced corrosion. Obstruction rules for specific sprinkler types and rules for locating sprinklers in concealed spaces have been revised. New limitations have been placed on the sprinkler sizes in storage applications, and criteria for the K-25 sprinkler has been added. Additionally, the requirements for protecting sprinklers against seismic events also has undergone significant revision.

Prior editions of this document have been translated into languages other than English, including French and Spanish.

Technical Correlating Committee on Automatic Sprinkler Systems (AUT-AAC)

John G. O'Neill, *Chair*
Gage-Babcock & Assoc. Inc., VA [SE]

Milosh T. Puchovsky, *Nonvoting Secretary*
Nat'l Fire Protection Assn., MA

Jose R. Baz, Int'l Engineered Systems, LTD, Inc., FL [M]
Rep. NFPA Latin American Section
Kerry M. Bell, Underwriters Laboratories Inc., IL [RT]
Eric H. Cote, Rolf Jensen & Assoc., Inc., MA [SE]
Russell P. Fleming, Nat'l Fire Sprinkler Assn., NY [M]
Joseph B. Hankins, Jr., Factory Mutual Research Corp., MA [I]
Roland J. Huggins, American Fire Sprinkler Assn., Inc., TX [IM]
Sultan M. Javeri, Protection Int'l, Ltd, France [I]
Andrew Kim, Nat'l Research Council of Canada, ON, Canada [RT]
Gerald R. Kirby, Marriott Int'l, Inc., DC [U]
Rep. American Hotel & Motel Assn.
B. J. Lukes, Grinnell Fire Protection System Co. Ltd/Tyco, Canada [M]
Rep. Canadian Automatic Sprinkler Assn.
Joseph W. Noble, Clark County Fire Dept., NV [E]
Donald R. Oliver, Wilson Fire/Rescue Services, NC [E]
Rep. Int'l Assn. of Fire Chiefs
James Retzloff, The Viking Corp., MI [M]
Chester W. Schirmer, Schirmer Engr Corp., NC [SE]
John Nigel Stephens, Loss Prevention Council, England [I]
Lynn K. Underwood, Wausau HPR Engr, WI [I]
John J. Walsh, UA Joint Apprenticeship Committee Local 669, MD [L]
Rep. United Assn. of Journeymen/Apprentices of Plumbing/Pipe Fitting

Alternates

Donald "Don" D. Becker, Midland Automatic Sprinkler Co., Inc., MO [IM]
(Alt. to R. J. Huggins)
Raymond A. Grill, Rolf Jensen & Assoc., Inc., VA [SE]
(Alt. to E. H. Cote)
Kenneth E. Isman, Nat'l Fire Sprinkler Assn., NY [M]
(Alt. to R. P. Fleming)
George E. Laverick, Underwriters Laboratories Inc., IL [RT]
(Alt. to K. M. Bell)
Donato A. Pirro E., Electro Sistemas De Panama, S.A., Panama [M]
(Alt. to J. R. Baz)
William E. Wilcox, Factory Mutual Research Corp., MA [I]
(Alt. to J. B. Hankins, Jr.)

Nonvoting

Edward K. Budnick, Hughes Assoc., Inc., MD [SE]
Rolf H. Jensen, Belleair, FL [SE]
(Member Emeritus)
William E. Koffel, Jr., Koffel Assoc. Inc., MD [SE]
Kenneth W. Linder, HSB Industrial Risk Insurers, CT [I]
Christopher T. Lummus, Insurance Services Office, Inc., TX [I]
Daniel Madrzykowski, U.S. Nat'l Inst. of Standards & Technology, MD [RT]
Peter Papavasiliou, Engr Professionals, Ltd, IL [SE]
J. William Sheppard, General Motors Corp., MI [U]

Milosh T. Puchovsky, 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. A key to classifications is found at the back of this document.

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

Committee Scope: The committee shall have overall responsibility for documents that pertain to the criteria for the design and installation of automatic, open and foam-water sprinkler systems, including the character and adequacy of water supplies, and the selection of sprinklers, piping, valves, and all materials and accessories. This committee does not cover the installation of fire pumps, nor the construction and installation of gravity and pressure tanks and towers, nor the installation, maintenance, and use of central station, proprietary, auxiliary, and local signaling systems for watchmen, fire alarm, supervisory service, nor the design of fire department hose connections.

Technical Committee on Hanging and Bracing of Water-Based Fire Protection Systems (AUT-HBS)

J. William Sheppard, *Chair*
General Motors Corp., MI [U]
Rep. NFPA Industrial Fire Protection Section

David S. Mowrer, *Secretary*
HSB Professional Loss Control, TN [I]

James B. Biggins, J&H Marsh & McLennan, IL [I]
Richard W. Bonds, Ductile Iron Pipe Research Assn., AL [M]
Antonio C. M. Braga, Factory Mutual Research Corp., CA [I]
Samuel S. Dannaway, S. S. Dannaway Assoc., Inc., HI [SE]
Russell P. Fleming, Nat'l Fire Sprinkler Assn., NY [M]
Thomas J. Forsythe, Gage-Babcock & Assoc., CA [SE]
Luke Hilton, Wausau HPR Engr, FL [I]
Rep. The Alliance of American Insurers
Terry Holst, Grinnell Fire Protection Systems Co., CA [M]
Rep. Nat'l Fire Sprinkler Assn.
Kraig Kirschner, AFCON, CA [M]
Rep. American Fire Sprinkler Assn., Inc.
Wayne M. Martin, Wayne Martin & Assoc. (WMA), CA [SE]
Emil W. Misichko, Underwriters Laboratories Inc., IL [RT]
Donald C. Moeller, Rolf Jensen & Assoc., Inc., CA [SE]
Randy Nelson, VFS Fire Protection Services, CA [IM]
Rep. American Fire Sprinkler Assn., Inc.
Janak B. Patel, Bechtel Savannah River Co., GA [U]
Robert J. Pearce, Jr., HSB Industrial Risk Insurers, CA [I]
Michael A. Rothmier, UA Joint Apprenticeship Committee Local 669, CO [L]
Rep. United Assn. of Journeymen/Apprentices of Plumbing/Pipe Fitting
James Tauby, Mason Industries, Inc., NY [M]
Jack Thacker, Allan Automatic Sprinkler Corp. of Southern California, CA [IM]
Rep. Nat'l Fire Sprinkler Assn.

Alternates

Sheldon Dacus, Security Fire Protection Co, TN [IM]
(Alt. to J. Thacker)
Daniel C. Duggan, Loos & Co. Inc., MO [M]
(Alt. to K. Kirschner)
David M. Gough, HSB Industrial Risk Insurers, CT [I]
(Alt. to R. J. Pearce, Jr.)
Tom Hinton, Smith Fire Systems, Inc., WA [IM]
(Alt. to R. Nelson)
George E. Laverick, Underwriters Laboratories Inc., IL [RT]
(Alt. to E. W. Misichko)
B. J. Lukes, Grinnell Fire Protection System Co. Ltd/Tyco, Canada [M]
(Alt. to T. Holst)
Allyn J. Vaughn, Rolf Jensen & Assoc., Inc., NV [SE]
(Alt. to D. C. Moeller)
George Von Gnatensky, Tolco, Inc., CA [M]
(Alt. to R. P. Fleming)
John J. Walsh, UA Joint Apprenticeship Committee Local 669, MD [L]
(Alt. to M. A. Rothmier)
William E. Wilcox, Factory Mutual Research Corp., MA [I]
(Alt. To A. C. M. Braga)

Milosh T. Puchovsky, 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. A key to classifications is found at the back of this document.

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

Committee Scope: The committee shall have primary responsibility for those portions of NFPA 13 that pertain to the criteria for the use and installation of components and devices used for the support of water-based fire protection system piping including protection against seismic events and the restraint of buried pipe.

Technical Committee on Sprinkler System Discharge Criteria (AUT-SSD)

Edward K. Budnick, *Chair*
Hughes Assoc., Inc., MD [SE]

Kerry M. Bell, Underwriters Laboratories Inc., IL [RT]
Robert B. Combs, J&H Marsh & McLennan, WA [I]
Russell P. Fleming, Nat'l Fire Sprinkler Assn., NY [M]
James G. Gallup, Rolf Jensen & Assoc., Inc., FL [SE]
James Golinveaux, Central Sprinkler Corp., PA [M]
Rep. Nat'l Fire Sprinkler Assn.
Joseph B. Hankins, Jr., Factory Mutual Research Corp., MA [I]
Stephen R. Hoover, Kemper Nat'l Insurance Cos., IL [I]
Roland J. Huggins, American Fire Sprinkler Assn., Inc., TX [IM]
Sultan M. Javeri, Protection Int'l, Ltd, France [I]
Larry Keeping, Vipond Fire Protection, Inc., ON, Canada [IM]
Rep. Canadian Automatic Sprinkler Assn.
Andrew Kim, Nat'l Research Council of Canada, ON, Canada [RT]
Jerome P. Merkel, United Sprinkler, Inc., MN [IM]
Andy Miller, Hallmark Cards Inc., MO [U]
Rep. NFPA Industrial Fire Protection Section
Azarang Mirkhah, Las Vegas Fire Dept., NV [E]
Gene V. Paolucci, Yasuda Fire & Marine Insurance Co. of America, NY [I]
Rep. American Insurance Services Group, Inc.
Paul E. Rousseau, HFP Corp., MA [IM]
Rep. American Fire Sprinkler Assn., Inc.
Chester W. Schirmer, Schirmer Engr Corp., NC [SE]
Todd E. Schumann, HSB Industrial Risk Insurers, IL [I]
Peter A. Smith, Int'l Paper Co., TN [U]
Sandra Stanek, Rural Metro Fire Dept., AZ [E]
David W. Stroup, U.S. Nat'l Inst. of Standards & Technology, MD [RT]
Jack Thacker, Allan Automatic Sprinkler Corp. of Southern California, CA [IM]
Rep. Nat'l Fire Sprinkler Assn.
William J. Tomes, Tomes, VanRickley & Assoc., GA [U]
Rep. The Home Depot

Alternates

Carl F. Baldassarra, Schirmer Engr Corp., IL [SE]
(Alt. to C. W. Schirmer)
William M. Carey, Underwriters Laboratories Inc., IL [RT]
(Alt. to K. M. Bell)
John August Denhardt, Strickland Fire Protection, Inc., MD [IM]
(Alt. to P. E. Rousseau)
David Dixon, Security Fire Protection, TN [IM]
(Alt. to J. Thacker)
Michael L. Edwards, Rolf Jensen & Assoc., Inc., VA [SE]
(Alt. to J. G. Gallpup)
J. Grayson Gilbert, HSB Industrial Risk Insurers, GA [I]
(Alt. to T. E. Schumann)
Christopher M. Goddard, Zeneca Inc., DE [U]
(Alt. to A. Miller)
Daniel Madrzykowski, U.S. Nat'l Inst. of Standards & Technology, MD [RT]
(Alt. to D. W. Stroup)
Thomas Multer, Reliable Automatic Sprinkler Co, GA [M]
(Alt. to R. P. Fleming)
Allan M. Neilsen, City of Henderson Fire Dept., NV [E]
(Alt. to A. Mirkhah)
Donald B. Pounder, Grinnell Corp./Tyco, RI [M]
(Alt. to J. Golinveaux)
William P. Thomas, Jr., Kemper Nat'l Insurance Cos., IL [I]
(Alt. to S. R. Hoover)
Richard E. Thonnings, American Insurance Services Group, Inc., NY [I]
(Alt. to G. V. Paolucci)
Tom Vincent, Life Safety Systems, ON, Canada [IM]
(Alt. to L. Keeping)
William E. Wilcox, Factory Mutual Research Corp., MA [I]
(Alt. to J. B. Hankins, Jr.)

Nonvoting

Barry M. Lee, Tyco Int'l, Australia [M]

Milosh T. Puchovsky, 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. A key to classifications is found at the back of this document.

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

Committee Scope: The committee shall have primary responsibility for those portions of NFPA 13 that pertain to the classification of various fire hazards and the determination of associated discharge criteria for sprinkler systems employing automatic and open sprinklers.

Technical Committee on Sprinkler System Installation Criteria (AUT-SSI)

Kenneth W. Linder, *Chair*
HSB Industrial Risk Insurers, CT [I]

Phillip A. Brown, American Fire Sprinkler Assn., Inc., TX [IM]
Edward K. Budnick, Hughes Assoc., Inc., MD [SE]
Robert E. Duke, Fire Control Inc., IL [IM]
Ralph Gerdes, Ralph Gerdes Consultants, LLC, IN [SE]
Rep. American Inst. of Architects
Christopher M. Goddard, Zeneca Inc., DE [U]
Rep. NFPA Industrial Fire Protection Section
Kenneth E. Isman, Nat'l Fire Sprinkler Assn., NY [M]
Elwin G. Joyce, Kentucky Division of Building Code Enforcement, KY [E]
Larry Keeping, Vipond Fire Protection, Inc., ON, Canada [IM]
Rep. Canadian Automatic Sprinkler Assn.
George E. Laverick, Underwriters Laboratories Inc., IL [RT]
Ausmus S. Marburger, Fire Protection Industries, Inc., PA [IM]
Rep. Nat'l Fire Sprinkler Assn.
Maurice Marvi, Insurance Services Office, NY [I]
Rodney A. McPhee, Canadian Wood Council, ON, Canada [U]
Francis J. Mikloucich, Eastman Kodak Co., NY [U]
Ernest (Russ) Mower, City of Plano, TX [E]
Rep. NFPA Fire Service Section
David S. Mowrer, HSB Professional Loss Control, TN [I]
Joseph W. Noble, Clark County Fire Dept., NV [E]
Chester W. Schirmer, Schirmer Engr Corp., NC [SE]
Gerald R. Schultz, Gage-Babcock & Assoc. Inc., IL [SE]
Mahendra "Kumar" H. Sheth, B.I.C. Design Co., MO [IM]
Rep. American Fire Sprinkler Assn., Inc.
Sandra Stanek, Rural Metro Fire Dept., AZ [E]
Craig R. Studer, Rolf Jensen & Assoc., Inc., IL [SE]
William L. Testa, Grinnell Fire Protection Systems Co. Inc./Tyco, RI [M]
Rep. Nat'l Fire Sprinkler Assn.
Lynn K. Underwood, Wausau HPR Engr, WI [I]
John J. Walsh, UA Joint Apprenticeship Committee Local 669, MD [L]
Rep. United Assn. of Journeymen/Apprentices of Plumbing/Pipe Fitting
William E. Wilcox, Factory Mutual Research Corp., MA [I]

Alternates

Michael A. Amar, Gage-Babcock & Assoc., Inc., CA [SE]
(Alt. to G. R. Schultz)
Daniel L. Arnold, Rolf Jensen & Assoc., Inc., GA [SE]
(Alt. to C. R. Studer)
Hamid R. Bahadori, Hughes Assoc., Inc., FL [SE]
(Alt. to E. K. Budnick)
Carl F. Baldassarra, Schirmer Engr Corp., IL [SE]
(Alt. to C. W. Schirmer)
Kerry M. Bell, Underwriters Laboratories Inc., IL [RT]
(Alt. to G. E. Laverick)
Antonio C. M. Braga, Factory Mutual Research Corp., CA [I]
(Alt. to W. E. Wilcox)
Robert G. Caputo, Consolidated Fireprotection, Inc., CA [IM]
(Alt. to P. A. Brown)
Herbert N. Davidson, Liberty Mutual Group, MA [I]
(Alt. to L. K. Underwood)
James Golinveaux, Central Sprinkler Corp., PA [M]
(Alt. to K. E. Isman)
Peter J. McWilliams, Eastman Kodak Co., NY [U]
(Alt. to F. J. Miklouich)
Michael F. Meehan, Virginia Sprinkler Co., Inc., VA [IM]
(Alt. to M. H. Sheth)
Thomas H. Miller, Varley-Campbell & Assoc., Inc./Village of Glen Ellyn, IL [SE]
(Alt. to E. Mower)
Richard Oliver, Oliver Sprinkler Co., Inc., PA [IM]
(Alt. to A. S. Marburger)
Robert J. Pearce, Jr., HSB Industrial Risk Insurers, CA [I]
(Alt. to K. W. Linder)
Michael A. Rothmier, UA Joint Apprenticeship Committee Local 669, MD [L]
(Alt. to J. J. Walsh)
Peter Thomas, The Viking Corp., MI [M]
(Alt. to W. L. Testa)
Tom Vincent, Life Safety Systems, ON, Canada [IM]
(Alt. to L. Keeping)

Nonvoting

Barry M. Lee, Tyco Int'l, Australia [M]

Milosh T. Puchovsky, 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. A key to classifications is found at the back of this document.

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

Committee Scope: The committee shall have primary responsibility for those portions of NFPA 13 that pertain to the criteria for the use and installation of aboveground and buried sprinkler system components (with the exception of those components used for support of piping), positioning of sprinklers, types of systems, plans and calculations, water supplies, and acceptance testing.

Contents

NFPA 13

Standard for the

Installation of Sprinkler Systems

1999 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Appendix A.

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 can be found in Appendix C.

A reference in parentheses () at the end of a section or paragraph indicates that the material has been extracted from another NFPA document. The bold number in parentheses indicates the document number and is followed by the section number where the extracted material can be found in that document. The complete title and current edition of an extracted document can be found in the chapter on referenced publications.

Information on referenced publications can be found in Chapter 13 and Appendix E.

Chapter 1 General Information

1-1 Scope. This standard provides the minimum requirements for the design and installation of automatic fire sprinkler systems and exposure protection sprinkler systems, including the character and adequacy of water supplies and the selection of sprinklers, fittings, piping, valves, and all materials and accessories, including the installation of private fire service mains. This standard encompasses "combined service mains" used to carry water for both fire service and other uses as well as mains for fire service use only.

1-2* Purpose. The purpose of this standard is to provide a reasonable degree of protection for life and property from fire through standardization of design, installation, and testing requirements for sprinkler systems, including private fire service mains, based on sound engineering principles, test data, and field experience. This standard endeavors to continue the excellent records that have been established by sprinkler systems while meeting the needs of changing technology. Nothing in this standard is intended to restrict new technologies or alternate arrangements, provided the level of safety prescribed by this standard is not lowered. Materials or devices not specifically designated by this standard shall be utilized in complete accord with all conditions, requirements, and limitations of their listings.

1-2.1 A sprinkler system and private fire service mains are specialized fire protection systems and require knowledgeable and experienced design and installation.

1-3 Retroactivity Clause. The provisions of this document are considered necessary to provide a reasonable level of protection from loss of life and property from fire. They reflect situations and the state of the art at the time the standard was issued. Unless otherwise noted, it is not intended that the provisions of this document be applied to facilities, equipment, structures, or installations that were existing or approved for construction or installation prior to the effective date of this document.

Exception: In those cases where it is determined by the authority having jurisdiction that the existing situation involves a distinct hazard to life or property, this standard shall apply.

1-4 Definitions.

1-4.1 NFPA Definitions.

Approved.* Acceptable to the authority having jurisdiction.

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

Listed.* Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Standard. A document, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions shall be located in an appendix, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

1-4.2 General Definitions.

Compartment. A space completely enclosed by walls and a ceiling. The compartment enclosure is permitted to have openings to an adjoining space if the openings have a minimum lintel depth of 8 in. (203 mm) from the ceiling.

Drop-Out Ceiling. A suspended ceiling system, which is installed below the sprinklers, with listed translucent or opaque panels that are heat sensitive and fall from their setting when exposed to heat.

Dwelling Unit. One or more rooms arranged for the use of one or more individuals living together, as in a single housekeeping unit normally having cooking, living, sanitary, and sleeping facilities. For purposes of this standard, dwelling unit includes hotel rooms, dormitory rooms, apartments, condominiums, sleeping rooms in nursing homes, and similar living units.

Fire Control. Limiting the size of a fire by distribution of water so as to decrease the heat release rate and pre-wet adjacent combustibles, while controlling ceiling gas temperatures to avoid structural damage.

Fire Suppression. Sharply reducing the heat release rate of a fire and preventing its regrowth by means of direct and sufficient application of water through the fire plume to the burning fuel surface.

High-Challenge Fire Hazard. A fire hazard typical of that produced by fires in combustible high-piled storage.

High-Piled Storage. Solid-piled, palletized, rack storage, bin box, and shelf storage in excess of 12 ft (3.7 m) in height.

Hydraulically Designed System. A calculated sprinkler system in which pipe sizes are selected on a pressure loss basis to provide a prescribed water density, in gallons per minute per square foot (mm/min), or a prescribed minimum discharge pressure or flow per sprinkler, distributed with a reasonable degree of uniformity over a specified area.

Limited-Combustible Material. As applied to a building construction material, a material not complying with the definition of noncombustible material that, in the form in which it is used, has a potential heat value not exceeding 3500 Btu per lb (8141 kJ/kg) and complies with one of the following, (a) or (b). Materials subject to increase in combustibility or flame spread rating beyond the limits herein established through the effects of age, moisture, or other atmospheric condition shall be considered combustible. (a) Materials having a structural base of noncombustible material, with a surfacing not exceeding a thickness of $^1/_8$ in. (3.2 mm) that has a flame spread rating not greater than 50. (b) Materials, in the form and thickness used, other than as described in (a), having neither a flame spread rating greater than 25 nor evidence of continued progressive combustion and of such composition that surfaces that would be exposed by cutting through the material on any plane would have neither a flame spread rating greater than 25 nor evidence of continued progressive combustion.

Miscellaneous Storage.* Storage that does not exceed 12 ft (3.66 m) in height and is incidental to another occupancy use group. 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 (7.62 m).

Noncombustible Material. A material that, in the form in which it is used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat. Materials that are reported as passing ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, shall be considered noncombustible materials.

Pipe Schedule System. A sprinkler system in which the pipe sizing is selected from a schedule that is determined by the occupancy classification and in which a given number of sprinklers are allowed to be supplied from specific sizes of pipe.

Shop-Welded. As used in this standard, *shop* in the term *shop-welded* means either (1) a sprinkler contractor's or fabricator's premise or (2) an area specifically designed or authorized for welding, such as a detached outside location, maintenance shop, or other area (either temporary or permanent) of noncombustible or fire-resistive construction free of combustible and flammable contents and suitably segregated from adjacent areas.

Small Rooms. A room of light hazard occupancy classification having unobstructed construction and floor areas not exceeding 800 ft^2 (74.3 m^2) that are enclosed by walls and a ceiling. Openings to the adjoining space are permitted if the minimum lintel depth is 8 in. (203 mm) from the ceiling.

Sprinkler System.* For fire protection purposes, an integrated system of underground and overhead piping designed in accordance with fire protection engineering standards. The installation includes one or more automatic water supplies. The portion of the sprinkler system aboveground is a network of specially sized or hydraulically designed piping installed in a building, structure, or area, generally overhead, and to which sprinklers are attached in a systematic pattern. The valve controlling each system riser is located in the system riser or its supply piping. Each sprinkler system riser includes a device for actuating an alarm when the system is in operation. The system is usually activated by heat from a fire and discharges water over the fire area.

System Working Pressure. The maximum anticipated static (nonflowing) or flowing pressure applied to sprinkler system components exclusive of surge pressures.

Thermal Barrier. A material that will limit the average temperature rise of the unexposed surface to not more than 250°F (121°C) after 15 minutes of fire exposure, which complies with the standard time–temperature curve of NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*.

1-4.3 Sprinkler System Type Definitions.

Antifreeze Sprinkler System. A wet pipe sprinkler system employing automatic sprinklers that are attached to a piping system that contains an antifreeze solution and that are connected to a water supply. The antifreeze solution is discharged, followed by water, immediately upon operation of sprinklers opened by heat from a fire.

Circulating Closed-Loop Sprinkler System. A wet pipe sprinkler system having non–fire protection connections to automatic sprinkler systems in a closed-loop piping arrangement for the purpose of utilizing sprinkler piping to conduct water for heating or cooling, where water is not removed or used from the system but only circulated through the piping system.

Combined Dry Pipe-Preaction Sprinkler System. A sprinkler system employing automatic sprinklers attached to a piping system containing air under pressure with a supplemental detection system installed in the same areas as the sprinklers. Operation of the detection system actuates tripping devices that open dry pipe valves simultaneously and without loss of air pressure in the system. Operation of the detection system also opens listed air exhaust valves at the end of the feed main, which usually precedes the opening of sprinklers. The detection system also serves as an automatic fire alarm system.

Deluge Sprinkler System. A sprinkler system employing open sprinklers that are attached to a piping system that is connected to a water supply through a valve that is opened by the operation of a detection system installed in the same areas as the sprinklers. When this valve opens, water flows into the piping system and discharges from all sprinklers attached thereto.

Dry Pipe Sprinkler System. A sprinkler system employing automatic sprinklers that are attached to a piping system containing air or nitrogen under pressure, the release of which (as from the opening of a sprinkler) permits the water pressure to open a valve known as a dry pipe valve, and the water then flows into the piping system and out the opened sprinklers.

Gridded Sprinkler System.* A sprinkler system in which parallel cross mains are connected by multiple branch lines. An operating sprinkler will receive water from both ends of its branch line while other branch lines help transfer water between cross mains.

Looped Sprinkler System.* A sprinkler system in which multiple cross mains are tied together so as to provide more than one path for water to flow to an operating sprinkler and branch lines are not tied together.

Preaction Sprinkler System.* A sprinkler system employing automatic sprinklers that are attached to a piping system that contains air that might or might not be under pressure, with a supplemental detection system installed in the same areas as the sprinklers.

Wet Pipe Sprinkler System. A sprinkler system employing automatic sprinklers attached to a piping system containing water and connected to a water supply so that water discharges immediately from sprinklers opened by heat from a fire.

1-4.4* System Component Definitions.

Branch Lines. The pipes in which the sprinklers are placed, either directly or through risers.

Cross Mains. The pipes supplying the branch lines, either directly or through risers.

Feed Mains. The pipes supplying cross mains, either directly or through risers.

Flexible Listed Pipe Coupling. A listed coupling or fitting that allows axial displacement, rotation, and at least 1 degree of angular movement of the pipe without inducing harm on the pipe. For pipe diameters of 8 in. (203.2 mm) and larger, the angular movement shall be permitted to be less than 1 degree but not less than 0.5 degree.

Risers. The vertical supply pipes in a sprinkler system.

Sprig-up. A line that rises vertically and supplies a single sprinkler.

Supervisory Device. A device arranged to supervise the operative condition of automatic sprinkler systems.

System Riser. The aboveground horizontal or vertical pipe between the water supply and the mains (cross or feed) that contains a control valve (either directly or within its supply pipe) and a waterflow alarm device.

1-4.5 Sprinkler Definitions.

1-4.5.1* The following are characteristics of a sprinkler that define its ability to control or extinguish a fire.

(a) Thermal sensitivity. A measure of the rapidity with which the thermal element operates as installed in a specific sprinkler or sprinkler assembly. One measure of thermal sensitivity is the response time index (RTI) as measured under standardized test conditions.

(1) Sprinklers defined as fast response have a thermal element with an RTI of 50 $(\text{meters-seconds})^{1/2}$ or less.
(2) Sprinklers defined as standard response have a thermal element with an RTI of 80 $(\text{meters-seconds})^{1/2}$ or more.

(b) Temperature rating.

(c) Orifice size *(see Chapter 2)*.

(d) Installation orientation *(see 1-4.5.3)*.

(e) Water distribution characteristics (i.e., application rate, wall wetting).

(f) Special service conditions *(see 1-4.5.4)*.

1-4.5.2 The following sprinklers are defined according to design and performance characteristics.

Early Suppression Fast-Response (ESFR) Sprinkler.* A type of fast-response sprinkler that meets the criteria of 1-4.5.1(a)(1) and is listed for its capability to provide fire suppression of specific high-challenge fire hazards.

Extended Coverage Sprinkler. A type of spray sprinkler with maximum coverage areas as specified in Sections 5-8 and 5-9 of this standard.

Large Drop Sprinkler. A type of sprinkler that is capable of producing characteristic large water droplets and that is listed for its capability to provide fire control of specific high-challenge fire hazards.

Nozzles. A device for use in applications requiring special water discharge patterns, directional spray, or other unusual discharge characteristics.

Old-Style/Conventional Sprinkler. A sprinkler that directs from 40 percent to 60 percent of the total water initially in a downward direction and that is designed to be installed with the deflector either upright or pendent.

Open Sprinkler. A sprinkler that does not have actuators or heat-responsive elements.

Quick-Response Early Suppression (QRES) Sprinkler.* A type of quick-response sprinkler that meets the criteria of 1-4.5.1(a)(1) and is listed for its capability to provide fire suppression of specific fire hazards.

Quick-Response Extended Coverage Sprinkler. A type of quick-response sprinkler that meets the criteria of 1-4.5.1(a)(1) and complies with the extended protection areas defined in Chapter 5.

Quick-Response (QR) Sprinkler. A type of spray sprinkler that meets the criteria of 1-4.5.1(a)(1) and is listed as a quick-response sprinkler for its intended use.

Residential Sprinkler. A type of fast-response sprinkler that meets the criteria of 1-4.5.1(a)(1) that has been specifically investigated for its ability to enhance survivability in the room of fire origin and is listed for use in the protection of dwelling units.

Special Sprinkler. A sprinkler that has been tested and listed as prescribed in 5-4.9.

Spray Sprinkler. A type of sprinkler listed for its capability to provide fire control for a wide range of fire hazards.

Standard Spray Sprinkler. A spray sprinkler with maximum coverage areas as specified in Sections 5-6 and 5-7 of this standard.

1-4.5.3 The following sprinklers are defined according to orientation.

Concealed Sprinkler. A recessed sprinkler with cover plates.

Flush Sprinkler. A sprinkler in which all or part of the body, including the shank thread, is mounted above the lower plane of the ceiling.

Pendent Sprinkler. A sprinkler designed to be installed in such a way that the water stream is directed downward against the deflector.

Recessed Sprinkler. A sprinkler in which all or part of the body, other than the shank thread, is mounted within a recessed housing.

Sidewall Sprinkler. A sprinkler having special deflectors that are designed to discharge most of the water away from the

nearby wall in a pattern resembling one-quarter of a sphere, with a small portion of the discharge directed at the wall behind the sprinkler.

Upright Sprinkler. A sprinkler designed to be installed in such a way that the water spray is directed upwards against the deflector.

1-4.5.4 The following sprinklers are defined according to special application or environment.

Corrosion-Resistant Sprinkler. A sprinkler fabricated with corrosion-resistant material, or with special coatings or platings, to be used in an atmosphere that would normally corrode sprinklers.

Dry Sprinkler.* A sprinkler secured in an extension nipple that has a seal at the inlet end to prevent water from entering the nipple until the sprinkler operates.

Intermediate Level Sprinkler/Rack Storage Sprinkler. A sprinkler equipped with integral shields to protect its operating elements from the discharge of sprinklers installed at higher elevations.

Ornamental/Decorative Sprinkler. A sprinkler that has been painted or plated by the manufacturer.

1-4.6 Construction Definitions.

Obstructed Construction.* Panel construction and other construction where beams, trusses, or other members impede heat flow or water distribution in a manner that materially affects the ability of sprinklers to control or suppress a fire.

Unobstructed Construction.* Construction where beams, trusses, or other members do not impede heat flow or water distribution in a manner that materially affects the ability of sprinklers to control or suppress a fire. Unobstructed construction has horizontal structural members that are not solid, where the openings are at least 70 percent of the cross-section area and the depth of the member does not exceed the least dimension of the openings, or all construction types where the spacing of structural members exceeds $7^1/_2$ ft (2.3 m) on center.

1-4.7 Private Water Supply Piping Definitions.

Private Fire Service Main.* Private fire service main, as used in this standard, is that pipe and its appurtenances on private property (1) between a source of water and the base of the riser for water-based fire protection systems, (2) between a source of water and inlets to foam-making systems, (3) between a source of water and the base elbow of private hydrants or monitor nozzles, and (4) used as fire pump suction and discharge piping, (5) beginning at the inlet side of the check valve on a gravity or pressure tank.

1-4.8 General Storage Definitions.

Array, Closed. A storage arrangement where air movement through the pile is restricted because of 6-in. (152-mm) or less vertical flues.

Array, Open.* 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 upon which the commodity classification is based.

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.

Encapsulation. 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* does not apply. The term *encapsulated* does not apply to plastic-enclosed products or packages inside a large, nonplastic, enclosed container.

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 include powder, pellets, flakes, or random-packed small objects [e.g., razor blade dispensers, 1-oz to 2-oz (28-g to 57-g) bottles].

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.

Pile Stability, Unstable Piles.* Those arrays where collapse, spillage of contents, or leaning of stacks across flue spaces occurs soon after initial fire development.

Roof Height. The distance between the floor and the underside of the roof deck within the storage area.

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.

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.

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.

1-4.9 Rack Storage Definitions.

Aisle Width.* The horizontal dimension between the face of the loads in racks under consideration. *[See Figure A-1-4.9(a).]*

Bulkhead. A vertical barrier across the rack.

Cartoned. A method of storage consisting of corrugated cardboard or paperboard containers fully enclosing the commodity.

Conventional Pallets.* A material-handling aid designed to support a unit load with openings to provide access for material-handling devices. *[See Figure A-1-4.9(b).]*

Face Sprinklers. Standard sprinklers that are located in transverse flue spaces along the aisle or in the rack, are within 18 in. (0.46 m) of the aisle face of storage, and are used to oppose vertical development of fire on the external face of storage.

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.

Longitudinal Flue Space.* The space between rows of storage perpendicular to the direction of loading. *[See Figure A-1-4.9(c).]*

Rack.* Any combination of vertical, horizontal, and diagonal members that supports stored materials. Some rack structures use solid shelves. Racks can be fixed, portable, or movable *[see Figures A-1-4.9 (a) through (m)]*. Loading can be either manual — using lift trucks, stacker cranes, or hand placement — or automatic — using machine-controlled storage and retrieval systems.

Racks, Double-Row. 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.

Racks, Movable. 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.

Racks, Multiple-Row. 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).

Racks, Portable. Racks that are not fixed in place. They can be arranged in any number of configurations.

Racks, Single-Row. Racks that have no longitudinal flue space and that have a width up to 6 ft (1.8 m) with aisles at least 3.5 ft (1.1 m) from other storage.

Slave Pallet. A special pallet captive to a material-handling system. *[See Figure A-1-4.9(b).]*

Solid Shelving. 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 A-1-4.9(c).]*

1-4.10 Rubber Tire Storage Definitions.

Banded Tires. A storage method in which a number of tires are strapped together.

Horizontal Channel. Any uninterrupted space in excess of 5 ft (1.5 m) in length between horizontal layers of stored tires. Such channels can be formed by pallets, shelving, racks, or other storage arrangements.

Laced Tire Storage. Tires stored where the sides of the tires overlap, creating a woven or laced appearance. *[See Figure A-1-4.10.1(g).]*

Miscellaneous Tire 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). On-tread storage piles, regardless of storage method, shall not exceed 25 ft (7.6 m) in the direction of the wheel holes. Acceptable storage arrangements 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 multirow fixed or portable rack storage on-side or on-tread up to 5 ft (1.5 m) high; (d) single-row fixed or portable rack storage on-side or on-tread up to 12 ft (3.7 m) high; and (e) laced tires in racks up to 5 ft (1.5 m) in height.

On-Side Tire Storage. Tires stored horizontally or flat.

On-Tread Tire Storage. Tires stored vertically or on their treads.

Palletized Tire Storage. Storage on portable racks of various types utilizing a conventional pallet as a base.

Pyramid Tire Storage. On-floor storage in which tires are formed into a pyramid to provide pile stability.

Rubber Tires. Pneumatic tires for passenger automobiles, aircraft, light and heavy trucks, trailers, farm equipment, construction equipment (off-the-road), and buses.

1-4.10.1* Rubber Tire Rack Illustrations. See Figures A-1-4.10.1(a) through (g).

1-4.11 Baled Cotton Definitions.

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-1-4.11.)*

Block Cotton 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.

Naked Cotton Bale. A bale secured with wire or steel straps without wrapping.

1-4.12 Roll Paper Definitions.

Array, Closed (Paper). 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].

Array, Open (Paper). A vertical storage arrangement in which the distance between columns in both directions is lengthy (all vertical arrays other than closed or standard).

Array, Standard (Paper).* 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.

Banded Roll Paper Storage. Rolls provided with a circumferential steel strap [$^3/_8$ in. (9.5 mm) or wider] at each end of the roll.

Column. A single vertical stack of rolls.

Core. The central tube around which paper is wound to form a roll.

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.

Roll Paper Storage, Horizontal. Rolls stored with the cores in the horizontal plane (on-side storage).

Roll Paper Storage, Vertical. Rolls stored with the cores in the vertical plane (on-end storage).

Roll Paper Storage, Wrapped.* Rolls provided with a complete heavy kraft covering around both sides and ends.

Roll Paper Storage Height.* The maximum vertical distance above the floor at which roll paper is normally stored.

1-5 Abbreviations. The standard abbreviations in Table 1-5 shall be used on the hydraulic calculation form discussed in Chapter 8.

1-6 Level of Protection.

1-6.1 A building, where protected by an automatic sprinkler system installation, shall be provided with sprinklers in all areas.

Exception: This requirement shall not apply where specific sections of this standard permit the omission of sprinklers.

1-6.2 Limited Area Systems. When partial sprinkler systems are installed, the requirements of this standard shall be used insofar as they are applicable. The authority having jurisdiction shall be consulted in each case.

Table 1-5 Hydraulic Symbols

Symbol or Abbreviation	Item
p	Pressure in psi
gpm	U.S. gallons per minute
q	Flow increment in gpm to be added at a specific location
Q	Summation of flow in gpm at a specific location
P_t	Total pressure in psi at a point in a pipe
P_f	Pressure loss due to friction between points indicated in location column
P_e	Pressure due to elevation difference between indicated points. This can be a plus value or a minus value. If minus, the (−) shall be used; if plus, no sign need be indicated.
P_v	Velocity pressure in psi at a point in a pipe
P_n	Normal pressure in psi at a point in a pipe
E	90° ell
EE	45° ell
Lt.E	Long-turn elbow
Cr	Cross
T	Tee-flow turned 90°
GV	Gate valve
BV	Butterfly (wafer) check valve
Del V	Deluge valve
ALV	Alarm valve
DPV	Dry pipe valve
CV	Swing check valve
WCV	Butterfly (wafer) check valve
St	Strainer
psi	Pounds per square inch
v	Velocity of water in pipe in feet per second

1-7 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 1-7 with conversion factors.

Table 1-7 SI Units and Conversion Factors

Name of Unit	Unit Symbol	Conversion Factor
liter	L	1 gal = 3.785 L
millimeter per minute	mm/min	1 gpm/ft^2 = 40.746 mm/min = 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 = 105 Pa

For additional conversions and information, see ASTM SI 10, *Standard for Use of the International System of Units (SI): The Modern Metric System.*

1-7.1 If a value for measurement as given in this standard is followed by an equivalent value in other units, the first stated is to be regarded as the requirement. A given equivalent value might be approximate.

1-7.2 The conversion procedure for the SI units has been to multiply the quantity by the conversion factor and then round the result to the appropriate number of significant digits.

Chapter 2 Classification of Occupancies and Commodities

2-1* Classification of Occupancies. Occupancy classifications for this standard shall relate to sprinkler design, installation, and water supply requirements only. They shall not be intended to be a general classification of occupancy hazards.

2-1.1* Light Hazard Occupancies. Light hazard occupancies shall be occupancies or portions of other occupancies where the quantity and/or combustibility of contents is low and fires with relatively low rates of heat release are expected.

2-1.2 Ordinary Hazard Occupancies.

2-1.2.1* Ordinary Hazard (Group 1). Ordinary hazard (Group 1) occupancies shall be occupancies or portions of other occupancies where combustibility is low, quantity of combustibles is moderate, stockpiles of combustibles do not exceed 8 ft (2.4 m), and fires with moderate rates of heat release are expected.

2-1.2.2* Ordinary Hazard (Group 2). Ordinary hazard (Group 2) occupancies shall be occupancies or portions of other occupancies where the quantity and combustibility of contents is moderate to high, stockpiles do not exceed 12 ft (3.7 m), and fires with moderate to high rates of heat release are expected.

2-1.3 Extra Hazard Occupancies.

2-1.3.1* Extra Hazard (Group 1). Extra hazard (Group 1) occupancies shall be occupancies or portions of other occupancies where the quantity and combustibility of contents is very high and dust, lint, or other materials are present, introducing the probability of rapidly developing fires with high rates of heat release but with little or no combustible or flammable liquids.

2-1.3.2* Extra Hazard (Group 2). Extra hazard (Group 2) occupancies shall include occupancies with moderate to substantial amounts of flammable or combustible liquids or occupancies where shielding of combustibles is extensive.

2-1.4* Special Occupancy Hazards.

2-2*† Commodity Classification.

2-2.1 General.

2-2.1.1* Classification of Commodities. Commodity classification and the corresponding protection requirements shall be determined based on the makeup of individual storage units (i.e., unit load, pallet load).

2-2.1.2 Mixed Commodities. Protection requirements shall not be based on the overall commodity mix in a fire area. Mixed commodity storage shall be protected by the requirements for the highest classified commodity and storage arrangement.

Exception No. 1: Up to 10 pallet loads of a higher hazard commodity, as described in 2-2.3 and 2-2.4, shall be permitted to be present in an area not exceeding 40,000 ft^2 (3716 m^2). The higher hazard commodity shall be randomly dispersed with no adjacent loads in any direction (including diagonally). If the ceiling protection is based on Class I or Class II commodities, then the allowable number of pallet loads for Class IV or Group A plastics shall be reduced to five.

Exception No. 2: The higher hazard material shall be permitted to be confined to a designated area and properly protected for that area.

2-2.2 Pallet Types. When loads are palletized, the use of wooden or metal pallets shall be assumed in the classification of commodities. When plastic pallets are used, the classification of the commodity unit shall be increased one class (i.e., Class III will become Class IV and Class IV will become Group A plastics). No increase shall be required for Group A plastic commodity.

Exception: When specific test data is available, the data shall take precedence in determining classification of commodities.

2-2.3* Commodity Classes.

2-2.3.1* Class I. A Class I commodity shall be defined as a noncombustible product that meets one of the following criteria:

(1) Placed directly on wooden pallets
(2) Placed in single layer corrugated cartons, with or without single-thickness cardboard dividers, with or without pallets
(3) Shrink-wrapped or paper-wrapped as a unit load with or without pallets

2-2.3.2* Class II. A Class II commodity shall be defined as a noncombustible product that is in slatted wooden crates, solid wood boxes, multiple-layered corrugated cartons, or equivalent combustible packaging material, with or without pallets.

2-2.3.3* Class III. A Class III commodity shall be defined as a product fashioned from wood, paper, natural fibers, or Group C plastics with or without cartons, boxes, or crates and with or without pallets. Such a product shall be permitted to contain a limited amount (5 percent by weight or volume) of Group A or Group B plastics.

2-2.3.4* Class IV. A Class IV commodity shall be defined as a product, with or without pallets, that meets one of the following criteria:

(1) Constructed partially or totally of Group B plastics.
(2) Consists of free-flowing Group A plastic materials.
(3) Contains within itself or its packaging an appreciable amount (5 percent to 15 percent by weight or 5 percent to 25 percent by volume) of Group A plastics. The remaining materials shall be permitted to be metal, wood, paper, natural or synthetic fibers, or Group B or Group C plastics.

2-2.4* Classification of Plastics, Elastomers, and Rubber. Plastics, elastomers, and rubber shall be classified as Group A, Group B, or Group C.

2-2.4.1* Group A. The following materials shall be classified as 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, with plasticizer content greater than 20 percent) (rarely found)
SAN (styrene acrylonitrile)
SBR (styrene-butadiene rubber)

2-2.4.2 Group B. The following materials shall be classified as Group B:

Cellulosics (cellulose acetate, cellulose acetate butyrate, ethyl cellulose)
Chloroprene rubber
Fluoroplastics (ECTFE — ethylene-chlorotrifluoro-ethylene copolymer; ETFE — ethylene-tetrafluoroethylene-copolymer; FEP — fluorinated ethylene-propylene copolymer)
Natural rubber (not expanded)
Nylon (nylon 6, nylon 6/6)
Silicone rubber

2-2.4.3 Group C. The following materials shall be classified as Group C:

Fluoroplastics (PCTFE — polychlorotrifluoroethylene; PTFE —polytetrafluoroethylene)
Melamine (melamine formaldehyde)
Phenolic
PVC (polyvinyl chloride — flexible — PVCs with plasticizer content up to 20 percent)
PVDC (polyvinylidene chloride)
PVDF (polyvinylidene fluoride)
PVF (polyvinyl fluoride)
Urea (urea formaldehyde)

2-2.5* Classification of Rolled Paper Storage. 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.

2-2.5.1 Heavyweight Class. Heavyweight class shall include paperboard and paper stock having a basis weight [weight per 1000 ft^2 (92.9 m^2)] of 20 lb (9.1 kg).

2-2.5.2 Mediumweight Class. Mediumweight class shall include all 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).

2-2.5.3 Lightweight Class. Lightweight class shall include all papers having a basis weight [weight per 1000 ft^2 (92.9 m^2)] of 10 lb (4.5 kg).

2-2.5.4 Tissue. Tissue shall include the broad range of papers of characteristic gauzy texture, which, in some cases, are fairly transparent. For the purposes of this standard, tissue shall be 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 System Components and Hardware

3-1 General. This chapter provides requirements for correct use of sprinkler system components.

3-1.1* All materials and devices essential to successful system operation shall be listed.

Exception No. 1: Equipment as permitted in Table 3-3.1, Table 3-5.1, and the Exceptions to 6-1.1 and 6-1.1.1 shall not be required to be listed.

Exception No. 2: Components that do not affect system performance such as drain piping, drain valves, and signs shall not be required to be listed. The use of reconditioned valves and devices other than sprinklers as replacement equipment in existing systems shall be permitted.

3-1.2 System components shall be rated for the maximum system working pressure to which they are exposed but shall not be rated at less than 175 psi (12.1 bar).

3-2 Sprinklers.

3-2.1 Only new sprinklers shall be installed.

3-2.2* Sprinkler Identification. All sprinklers shall be permanently marked with a one- or two-character manufacturer symbol, followed by up to four numbers, so as to identify a unique model of sprinkler for every change in orifice size or shape, deflector characteristic, and thermal sensitivity. This rule shall become effective on January 1, 2001.

3-2.3 Sprinkler Discharge Characteristics.

3-2.3.1* The K-factor, relative discharge, and marking identification for sprinklers having different orifice sizes shall be in accordance with Table 3-2.3.1.

Exception No. 1: Listed sprinklers having pipe threads different from those shown in Table 3-2.3.1 shall be permitted.

Exception No. 2: Sprinklers listed with nominal K-factors greater than 28 shall increase the flow by 100 percent increments when compared with a nominal K-5.6 sprinkler.

Exception No. 3: Residential sprinklers shall be permitted with K-factors other than those specified in Table 3-2.3.1.

3-2.3.2 Large drop and ESFR sprinklers shall have a minimum nominal K-factor of 11.2. The ESFR sprinkler orifice shall be selected as appropriate for the hazard. *(See Chapter 7.)*

Table 3-2.3.1 Sprinkler Discharge Characteristics Identification

Nominal K-factor gpm/(psi)$^{1/2}$	K-factor Range gpm/(psi)$^{1/2}$	K-factor Range dm^3/min/(kPa)$^{1/2}$	Percent of Nominal K-5.6 Discharge	Thread Type
1.4	1.3–1.5	1.9–2.2	25	$^1/_2$ in. NPT
1.9	1.8–2.0	2.6–2.9	33.3	$^1/_2$ in. NPT
2.8	2.6–2.9	3.8–4.2	50	$^1/_2$ in. NPT
4.2	4.0–4.4	5.9–6.4	75	$^1/_2$ in. NPT
5.6	5.3–5.8	7.6–8.4	100	$^1/_2$ in. NPT
8.0	7.4–8.2	10.7–11.8	140	$^3/_4$ in. NPT or $^1/_2$ in. NPT
11.2	11.0–11.5	15.9–16.6	200	$^1/_2$ in. NPT or $^3/_4$ in. NPT
14.0	13.5–14.5	19.5–20.9	250	$^3/_4$ in. NPT
16.8	16.0–17.6	23.1–25.4	300	$^3/_4$ in. NPT
19.6	18.6–20.6	27.2–30.1	350	1 in. NPT
22.4	21.3–23.5	31.1–34.3	400	1 in. NPT
25.2	23.9–26.5	34.9–38.7	450	1 in. NPT
28.0	26.6–29.4	38.9–43.0	500	1 in. NPT

3-2.4 Limitations.

3-2.4.1 Sprinklers shall not be listed for protection of a portion of an occupancy classification.

Exception No. 1: Residential sprinklers.

Exception No. 2: Special sprinklers shall be permitted to be listed for protection of a specific construction feature in a portion of an occupancy classification. (See 5-4.9.)

3-2.4.2 For light hazard occupancies not requiring as much water as is discharged by a sprinkler with a nominal K-factor of 5.6 operating at 7 psi (0.5 bar), sprinklers having a smaller orifice shall be permitted subject to the following restrictions:

(1) The system shall be hydraulically calculated *(see Chapter 7).*
(2) Sprinklers with K-factors of less than 5.6 shall be installed in wet systems only.

Exception: Sprinklers with K-factors of less than 5.6 installed in conformance with Section 4-7 for protection against exposure fires shall be permitted.

(3) A listed strainer shall be provided on the supply side of sprinklers with nominal K-factors of less than 2.8.

3-2.4.3 Sprinklers having a K-factor exceeding 5.6 and having $^1/_2$-in. (12.7-mm) National Pipe Thread (NPT) shall not be installed in new sprinkler systems.

3-2.5* Temperature Characteristics.

3-2.5.1 The standard temperature ratings of automatic sprinklers are shown in Table 3-2.5.1. Automatic sprinklers shall have their frame arms colored in accordance with the color code designated in Table 3-2.5.1.

Exception No. 1: A dot on the top of the deflector, the color of the coating material, or colored frame arms shall be permitted for color identification of corrosion-resistant sprinklers.

Exception No. 2: Color identification shall not be required for ornamental sprinklers such as factory-plated or factory-painted sprinklers or for recessed, flush, or concealed sprinklers.

Exception No. 3: The frame arms of bulb-type sprinklers shall not be required to be color coded.

3-2.5.2 The liquid in bulb-type sprinklers shall be color coded in accordance with Table 3-2.5.1.

Table 3-2.5.1 Temperature Ratings, Classifications, and Color Codings

Maximum Ceiling Temperature		Temperature Rating		Temperature Classification	Color Code	Glass Bulb Colors
°F	°C	°F	°C			
100	38	135–170	57–77	Ordinary	Uncolored or black	Orange or red
150	66	175–225	79–107	Intermediate	White	Yellow or green
225	107	250–300	121–149	High	Blue	Blue
300	149	325–375	163–191	Extra high	Red	Purple
375	191	400–475	204–246	Very extra high	Green	Black
475	246	500–575	260–302	Ultra high	Orange	Black
625	329	650	343	Ultra high	Orange	Black

3-2.6 Special Coatings.

3-2.6.1* Listed corrosion-resistant sprinklers shall be installed in locations where chemicals, moisture, or other corrosive vapors sufficient to cause corrosion of such devices exist.

3-2.6.2* Corrosion-resistant coatings shall be applied only by the manufacturer of the sprinkler.

Exception: 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 the approved manner so that no part of the sprinkler will be exposed after installation has been completed.

3-2.6.3* Unless applied by the manufacturer, sprinklers shall not be painted, and any sprinklers that have been painted shall be replaced with new listed sprinklers of the same characteristics, including orifice size, thermal response, and water distribution.

Exception: Factory-applied paint or coating to sprink'ler frames in accordance with 3-2.5.1 shall be permitted.

3-2.6.4 Ornamental finishes shall not be applied to sprinklers by anyone other than the sprinkler manufacturer, and only sprinklers listed with such finishes shall be used.

3-2.6.5 Sprinklers protecting spray areas and mixing rooms in resin application areas shall be protected against overspray residue so that they will operate quickly in the event of fire. If covered, cellophane bags having a thickness of 0.003 in. (0.076 mm) or less or thin paper bags shall be used. Coverings shall be replaced frequently so that heavy deposits of residue do not accumulate. Sprinklers that have been painted or coated, except by the sprinkler manufacturer, shall be replaced with new listed sprinklers having the same characteristics.

3-2.7 Escutcheon Plates.

3-2.7.1 Nonmetallic escutcheon plates shall be listed.

3-2.7.2* Escutcheon plates used with a recessed or flush-type sprinkler shall be part of a listed sprinkler assembly.

3-2.8* Guards and Shields Sprinklers subject to mechanical injury shall be protected with listed guards.

3-2.9 Stock of Spare Sprinklers.

3-2.9.1 A supply of spare sprinklers (never fewer than six) shall be maintained on the premises so that any sprinklers that have operated or been damaged in any way can be promptly replaced. These sprinklers shall correspond to the types and temperature ratings of the sprinklers in the property. The sprinklers shall be kept in a cabinet located where the temperature to which they are subjected will at no time exceed 100°F (38°C).

3-2.9.2 A special sprinkler wrench shall also be provided and kept in the cabinet to be used in the removal and installation of sprinklers.

3-2.9.3 The stock of spare sprinklers shall include all types and ratings installed and shall be as follows:

(1) For systems having less than 300 sprinklers, not fewer than six sprinklers
(2) For systems with 300 to 1000 sprinklers, not fewer than 12 sprinklers
(3) For systems with over 1000 sprinklers, not fewer than 24 sprinklers

3-3 Aboveground Pipe and Tube.

3-3.1 Pipe or tube shall meet or exceed one of the standards in Table 3-3.1 or be in accordance with 3-3.5. In addition, steel pipe shall be in accordance with 3-3.2 and 3-3.3, copper tube shall be in accordance with 3-3.4, and chlorinated polyvinyl chloride (CPVC) and polybutylene pipe shall be in accordance with 3-3.5 and with the portions of the ASTM standards specified in Table 3-3.5 that apply to fire protection service.

Table 3-3.1 Pipe or Tube Materials and Dimensions

Materials and Dimensions	Standard
Ferrous Piping (Welded and Seamless)	
Specification for Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Fire Protection Use	ASTM A 795
Specification for Welded and Seamless Steel Pipe	ANSI/ASTM A 53
Wrought Steel Pipe	ANSI B36.10M
Specification for Electric-Resistance-Welded Steel Pipe	ASTM A 135
Copper Tube (Drawn, Seamless)	
Specification for Seamless Copper Tube	ASTM B 75
Specification for Seamless Copper Water Tube	ASTM B 88
Specification for General Requirements for Wrought Seamless Copper and Copper-Alloy Tube	ASTM B 251
Fluxes for Soldering Applications of Copper and Copper-Alloy Tube	ASTM B 813
Brazing Filler Metal (Classification BCuP-3 or BCuP-4)	AWS A5.8
Solder Metal, 95-5 (Tin-Antimony-Grade 95TA)	ASTM B 32
Alloy Materials	ASTM B 446

3-3.2* When steel pipe listed in Table 3-3.1 is used and joined by welding as referenced in 3-6.2 or by roll-grooved pipe and fittings as referenced in 3-6.3, the minimum nominal wall thickness for pressures up to 300 psi (20.7 bar) shall be in accordance with Schedule 10 for pipe sizes up to 5 in. (127 mm), 0.134 in. (3.40 mm) for 6-in. (152-mm) pipe, and 0.188 in. (4.78 mm) for 8- and 10-in. (203- and 254-mm) pipe.

Exception: Pressure limitations and wall thickness for steel pipe listed in accordance with 3-3.5 shall be in accordance with the listing requirements.

3-3.3 When steel pipe listed in Table 3-3.1 is joined by threaded fittings referenced in 3-6.1 or by fittings used with pipe having

cut grooves, the minimum wall thickness shall be in accordance with Schedule 30 pipe [in sizes 8 in. (203 mm) and larger] or Schedule 40 pipe [in sizes less than 8 in. (203 mm)] for pressures up to 300 psi (20.7 bar).

Exception: Pressure limitations and wall thickness for steel pipe specially listed in accordance with 3-3.5 shall be in accordance with the listing requirements.

3-3.4* Copper tube as specified in the standards listed in Table 3-3.1 shall have a wall thickness of Type K, Type L, or Type M where used in sprinkler systems.

3-3.5* Other types of pipe or tube investigated for suitability in automatic sprinkler installations and listed for this service, including but not limited to polybutylene, CPVC, and steel, differing from that provided in Table 3-3.5 shall be permitted where installed in accordance with their listing limitations, including installation instructions. Pipe or tube shall not be listed for portions of an occupancy classification. Bending of pipe conforming to 3-3.5 shall be permitted as allowed by the listing.

Exception: Pipe or tube listed for light hazard occupancies shall be permitted to be installed in ordinary hazard rooms of otherwise light hazard occupancies where the room does not exceed 400 ft^2 (13 m^2).

Table 3-3.5 Specially Listed Pipe or Tube Materials and Dimensions

Materials and Dimensions	Standard
Nonmetallic Piping Specification for Special Listed Chlorinated Polyvinyl Chloride (CPVC) Pipe	ASTM F 442
Specification for Special Listed Polybutylene (PB) Pipe	ASTM D 3309

3-3.6 Pipe Bending. Bending of Schedule 10 steel pipe, or any steel pipe of wall thickness equal to or greater than Schedule 10 and Types K and L copper tube, shall be permitted when bends are made with no kinks, ripples, distortions, or reductions in diameter or any noticeable deviations from round. For Schedule 40 and copper tubing, the minimum radius of a bend shall be 6 pipe diameters for pipe sizes 2 in. (51 mm) and smaller and 5 pipe diameters for pipe sizes $2^1/_2$ in. (64 mm) and larger. For all other steel pipe, the minimum radius of a bend shall be 12 pipe diameters for all sizes.

3-3.7 Pipe Identification. All pipe, including specially listed pipe allowed by 3-3.5, shall be marked continuously along its length by the manufacturer in such a way as to properly identify the type of pipe. This identification shall include the manufacturer's name, model designation, or schedule.

3-4* Underground Pipe.

3-4.1* Piping shall be listed for fire protection service and comply with the AWWA standards in Table 3-4.1, where applicable. Steel piping shall not be used unless specifically listed for underground service in private fire service main applications.

Exception: Where externally coated and wrapped and internally galvanized, steel pipe shall be permitted to be used between the check valve and the outside hose coupling for the fire department connection.

Table 3-4.1 Manufacturing Standards for Underground Pipe

Materials	Standard
Cement Mortar Lining for Ductile Iron Pipe and Fittings for Water	AWWA C104
Polyethylene Encasement for Ductile Iron Pipe Systems	AWWA C105
Ductile Iron and Gray Iron Fittings, 3-in. Through 48-in., for Water and Other Liquids	AWWA C110
Rubber-Gasket Joints for Ductile Iron Pressure Pipe and Fittings	AWWA C111
Flanged Ductile Iron Pipe with Ductile Iron or Gray Iron Threaded Flanges	AWWA C115
Thickness Design of Ductile Iron Pipe	AWWA C150
Ductile Iron Pipe, Centrifugally Cast for Water	AWWA C151
Steel Water Pipe 6 in. and Larger	AWWA C200
Coal-Tar Protective Coatings and Linings for Steel Water Pipelines Enamel and Tape — Hot Applied	AWWA C203
Cement-Mortar Protective Lining and Coating for Steel Water Pipe 4 in. and Larger — Shop Applied	AWWA C205
Field Welding of Steel Water Pipe	AWWA C206
Steel Pipe Flanges for Waterworks Service — Sizes 4 in. Through 144 in.	AWWA C207
Dimensions for Fabricated Steel Water Pipe Fittings	AWWA C208
Reinforced Concrete Pressure Pipe, Steel-Cylinder Type for Water and Other Liquids	AWWA C300
Prestressed Concrete Pressure Pipe, Steel-Cylinder Type, for Water and Other Liquids	AWWA C301
Reinforced Concrete Pressure Pipe, Non-Cylinder Type, for Water and Other Liquids	AWWA C302
Reinforced Concrete Pressure Pipe, Steel-Cylinder Type, Pretensioned, for Water and Other Liquids	AWWA C303
Asbestos-Cement Distribution Pipe, 4 in. Through 16 in., for Water and Other Liquids	AWWA C400
Selection of Asbestos-Cement Water Pipe	AWWA C401
Installation of Ductile Iron Water Mains and Their Appurtenances	AWWA C600
Cement-Mortar Lining of Water Pipe Lines 4 in. and Larger — in Place	AWWA C602
Installation of Asbestos-Cement Water Pipe	AWWA C603
Polyvinyl Chloride (PVC) Pressure Pipe, 4 in. Through 12 in., for Water Distribution	AWWA C900
Steel Pipe — A Guide for Design and Installation	AWWA M11

3-4.2* The type and class of pipe for a particular installation shall be determined through consideration of its fire resistance, the maximum system working pressure, the laying conditions under which the pipe is to be installed, soil conditions, corrosion, and susceptibility of pipe to other external loads, including earth loads, installation beneath buildings, and traffic or vehicle loads.

3-4.3 Pipe used in private fire service shall be designed to withstand a system working pressure of not less than 150 psi (10.3 bar).

3-4.4* Lining of Buried Pipe. All ferrous metal pipe shall be lined.

3-5 Fittings.

3-5.1 Fittings used in sprinkler systems shall meet or exceed the standards in Table 3-5.1 or be in accordance with 3-5.2. In addition to the standards in Table 3-5.1, CPVC fittings shall also be in accordance with 3-5.2 and with the portions of the ASTM standards specified in Table 3-5.2 that apply to fire protection service.

Table 3-5.1 Fittings Materials and Dimensions

Materials and Dimensions	Standard
Cast Iron	
Cast Iron Threaded Fittings, Class 125 and 250	ASME B16.4
Cast Iron Pipe Flanges and Flanged Fittings	ASME B16.1
Malleable Iron	
Malleable Iron Threaded Fittings, Class 150 and 300	ASME B16.3
Steel	
Factory-Made Wrought Steel Buttweld Fittings	ASME B16.9
Buttwelding Ends for Pipe, Valves, Flanges, and Fittings	ASME B16.25
Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures	ASTM A 234
Steel Pipe Flanges and Flanged Fittings	ASME B16.5
Forged Steel Fittings, Socket Welded and Threaded	ASME B16.11
Copper	
Wrought Copper and Bronze Solder Joint Pressure Fittings	ASME B16.22
Cast Bronze Solder Joint Pressure Fittings	ASME B16.18

3-5.2* Other types of fittings investigated for suitability in automatic sprinkler installations and listed for this service including, but not limited to, polybutylene, CPVC, and steel differing from that provided in Table 3-5.2, shall be permitted when installed in accordance with their listing limitations, including installation instructions.

Table 3-5.2 Specially Listed Fittings Materials and Dimensions

Materials and Dimensions	Standard
Chlorinated Polyvinyl Chloride (CPVC) Specification for Schedule 80 CPVC Threaded Fittings	ASTM F 437
Specification for Schedule 40 CPVC Socket-Type Fittings	ASTM F 438
Specification for Schedule 80 CPVC Socket-Type Fittings	ASTM F 439

3-5.3* Fittings shall be extra-heavy pattern where pressures exceed 175 psi (12.1 bar).

Exception No. 1: Standard weight pattern cast-iron fittings 2 in. (51 mm) in size and smaller shall be permitted where pressures do not exceed 300 psi (20.7 bar).

Exception No. 2: Standard weight pattern malleable iron fittings 6 in. (152 mm) in size and smaller shall be permitted where pressures do not exceed 300 psi (20.7 bar).

Exception No. 3: Fittings shall be permitted for system pressures up to the limits specified in their listings.

3-5.4* Couplings and Unions. Screwed unions shall not be used on pipe larger than 2 in. (51 mm). Couplings and unions of other than screwed-type shall be of types listed specifically for use in sprinkler systems.

3-5.5 Reducers and Bushings. A one-piece reducing fitting shall be used wherever a change is made in the size of the pipe.

Exception No. 1: Hexagonal or face bushings shall be permitted in reducing the size of openings of fittings when standard fittings of the required size are not available.

Exception No. 2: Hexagonal bushings as permitted in 5-13.20.1 are acceptable.

3-5.6* Buried Fittings. Fittings shall be of an approved type with joints and pressure class ratings compatible with the pipe used.

3-6 Joining of Pipe and Fittings.

3-6.1 Threaded Pipe and Fittings.

3-6.1.1 All threaded pipe and fittings shall have threads cut to ASME B1.20.1, *Pipe Threads, General Purpose (Inch).*

3-6.1.2* Steel pipe with wall thicknesses less than Schedule 30 [in sizes 8 in. (203 mm) and larger] or Schedule 40 [in sizes less than 8 in. (203 mm)] shall not be joined by threaded fittings.

Exception: A threaded assembly investigated for suitability in automatic sprinkler installations and listed for this service shall be permitted.

3-6.1.3 Joint compound or tape shall be applied only to male threads.

3-6.2* Welded Pipe and Fittings.

3-6.2.1 Welding methods that comply with the applicable requirements of AWS B2.1, *Specification for Qualification of Welding Procedures and Welders for Piping and Tubing*, are acceptable means of joining fire protection piping.

3-6.2.2* Sprinkler piping shall be shop welded.

Exception No. 1: Welding of tabs for longitudinal earthquake bracing to in-place piping shall be permitted where the welding process is performed in accordance with NFPA 51B, Standard for Fire Prevention During Welding, Cutting, and Other Hot Work.

Exception No. 2: Where the design specifications call for all or part of the piping to be welded in place, welding of sprinkler piping in place shall be permitted where the welding process is performed in accordance with NFPA 51B and the mechanical fittings required by 5-13.17 and 5-13.22 are provided.

3-6.2.3 Fittings used to join pipe shall be listed fabricated fittings or manufactured in accordance with Table 3-5.1. Such fittings joined in conformance with a qualified welding procedure as set forth in this section shall be an acceptable product under this standard, provided that materials and wall thickness are compatible with other sections of this standard.

Exception: Fittings shall not be required where pipe ends are buttwelded.

3-6.2.4 No welding shall be performed if there is impingement of rain, snow, sleet, or high wind on the weld area of the pipe product.

3-6.2.5 When welding is performed, the following procedures shall be completed.

(1) *Holes in piping for outlets shall be cut to the full inside diameter of fittings prior to welding in place of the fittings.
(2) Discs shall be retrieved.
(3) Openings cut into piping shall be smooth bore, and all internal slag and welding residue shall be removed.
(4) Fittings shall not penetrate the internal diameter of the piping.
(5) Steel plates shall not be welded to the ends of piping or fittings.
(6) Fittings shall not be modified.
(7) Nuts, clips, eye rods, angle brackets, or other fasteners shall not be welded to pipe or fittings.

Exception: Only tabs welded to pipe for longitudinal earthquake braces shall be permitted. (See 6-4.5.8.)

3-6.2.6 When the pipe size in a run of piping is reduced, a reducing fitting designed for that purpose shall be used.

3-6.2.7 Torch cutting and welding shall not be permitted as a means of modifying or repairing sprinkler systems.

3-6.2.8 Qualifications.

3-6.2.8.1 A welding procedure shall be prepared and qualified by the contractor or fabricator before any welding is done. Qualification of the welding procedure to be used and the performance of all welders and welding operators is required and shall meet or exceed the requirements of AWS B2.1, *Specification for Qualification of Welding Procedures and Welders for Piping and Tubing*.

Exception: Welding procedures qualified under standards recognized by previous editions of this standard shall be permitted to be continued in use.

3-6.2.8.2 Contractors or fabricators shall be responsible for all welding they produce. Each contractor or fabricator shall have available to the authority having jurisdiction an established written quality assurance procedure ensuring compliance with the requirements of 3-6.2.5.

3-6.2.9 Records.

3-6.2.9.1 Welders or welding machine operators shall, upon completion of each weld, stamp an imprint of their identification into the side of the pipe adjacent to the weld.

3-6.2.9.2 Contractors or fabricators shall maintain certified records, which shall be available to the authority having jurisdiction, of the procedures used and the welders or welding machine operators employed by them, along with their welding identification imprints. Records shall show the date and the results of procedure and performance qualifications.

3-6.3 Groove Joining Methods.

3-6.3.1 Pipe joined with grooved fittings shall be joined by a listed combination of fittings, gaskets, and grooves. Grooves cut or rolled on pipe shall be dimensionally compatible with the fittings.

3-6.3.2 Grooved fittings including gaskets used on dry pipe systems shall be listed for dry pipe service.

3-6.4* Brazed and Soldered Joints Joints for the connection of copper tube shall be brazed.

Exception No. 1: Solder joints shall be permitted for exposed wet pipe systems in light hazard occupancies where the temperature classification of the installed sprinklers is ordinary or intermediate.

Exception No. 2: Solder joints shall be permitted for wet pipe systems in light hazard and ordinary hazard (Group 1) occupancies where the piping is concealed, irrespective of sprinkler temperature ratings.

3-6.4.1* Soldering fluxes shall be in accordance with Table 3-3.1. Brazing fluxes, if used, shall not be of a highly corrosive type.

3-6.5 Other Joining Methods. Other joining methods investigated for suitability in automatic sprinkler installations and listed for this service shall be permitted where installed in accordance with their listing limitations, including installation instructions.

3-6.6 End Treatment. After cutting, pipe ends shall have burrs and fins removed.

3-6.6.1 Pipe used with listed fittings and its end treatment shall be in accordance with the fitting manufacturer's installation instructions and the fitting's listing.

3-6.7* Buried Joints. Joints shall be of an approved type.

3-7* Hangers.

3-8 Valves.

3-8.1 Types of Valves to Be Used.

3-8.1.1 All valves controlling connections to water supplies and to supply pipes to sprinklers shall be listed indicating valves. Such valves shall not close in less than 5 seconds when operated at maximum possible speed from the fully open position.

Exception No. 1: A listed underground gate valve equipped with a listed indicator post shall be permitted.

Exception No. 2: A listed water control valve assembly with a reliable position indication connected to a remote supervisory station shall be permitted.

Exception No. 3: A nonindicating valve, such as an underground gate valve with approved roadway box, complete with T-wrench, and accepted by the authority having jurisdiction, shall be permitted.

3-8.1.2 When water pressures exceed 175 psi (12.1 bar), valves shall be used in accordance with their pressure ratings.

3-8.1.3 Wafer-type valves with components that extend beyond the valve body shall be installed in a manner that does not interfere with the operation of any system components.

3-8.2 Drain Valves and Test Valves. Drain valves and test valves shall be approved.

3-8.3* Identification of Valves. All control, drain, and test connection valves shall be provided with permanently marked weatherproof metal or rigid plastic identification signs. The sign shall be secured with corrosion-resistant wire, chain, or other approved means.

3-9 Fire Department Connections.

3-9.1 The fire department connection(s) shall use an NH internal threaded swivel fitting(s) with an NH standard thread(s). At least one of the connections shall be the 2.5–7.5 NH standard thread, as specified in NFPA 1963, *Standard for Fire Hose Connections.*

Exception No. 1: Where local fire department connections do not conform to NFPA 1963, the authority having jurisdiction shall designate the connection to be used.

Exception No. 2: The use of threadless couplings shall be permitted where required by the authority having jurisdiction and where listed for such use.

3-9.2 Fire department connections shall be equipped with listed plugs or caps, properly secured and arranged for easy removal by fire departments.

3-9.3 Fire department connections shall be of an approved type.

3-10 Waterflow Alarms.

3-10.1 Waterflow alarm apparatus shall be listed for the service and so constructed and installed that any flow of water from a sprinkler system equal to or greater than that from a single automatic sprinkler of the smallest orifice size installed on the system will result in an audible alarm on the premises within 5 minutes after such flow begins and until such flow stops.

3-10.2 Waterflow Detecting Devices.

3-10.2.1 Wet Pipe Systems. The alarm apparatus for a wet pipe system shall consist of a listed alarm check valve or other listed waterflow-detecting alarm device with the necessary attachments required to give an alarm.

3-10.2.2 Dry Pipe Systems. The alarm apparatus for a dry pipe system shall consist of listed alarm attachments to the dry pipe valve. When a dry pipe valve is located on the system side of an alarm valve, connection of the actuating device of the alarms for the dry pipe valve to the alarms on the wet pipe system shall be permitted.

3-10.2.3 Preaction and Deluge Systems. The alarm apparatus for deluge and preaction systems shall consist of alarms actuated independently by the detection system and the flow of water.

3-10.2.4* Paddle-type waterflow alarm indicators shall be installed in wet systems only.

3-10.3 Attachments — General.

3-10.3.1* An alarm unit shall include a listed mechanical alarm, horn, or siren or a listed electric gong, bell, speaker, horn, or siren.

3-10.3.2* Outdoor water motor–operated or electrically operated bells shall be weatherproofed and guarded.

3-10.4 All piping to water motor–operated devices shall be galvanized or brass or other corrosion-resistant material acceptable under this standard and of a size not less than $^{3}/_{4}$ in. (19 mm).

3-10.5* Attachments — Electrically Operated.

3-10.5.1 Electrically operated alarm attachments forming part of an auxiliary, central station, local protective, proprietary, or remote station signaling system shall be installed in accordance with NFPA 72, *National Fire Alarm Code.*

Exception: Sprinkler waterflow alarm systems that are not part of a required protective signaling system shall not be permitted to be supervised and shall be installed in accordance with NFPA 70, National Electrical Code®, Article 760.

3-10.5.2 Outdoor electric alarm devices shall be listed for outdoor use.

3-10.6 Drains from alarm devices shall be so arranged that there will be no overflowing at the alarm apparatus, at domestic connections, or elsewhere with the sprinkler drains wide open and under system pressure. *(See 5-14.2.6.1.)*

Chapter 4 System Requirements

4-1 Wet Pipe Systems.

4-1.1 Pressure Gauges. A listed pressure gauge conforming to 5-15.3.2 shall be installed in each system riser. Pressure gauges shall be installed above and below each alarm check valve where such devices are present.

4-1.2 Relief Valves. A gridded wet pipe system shall be provided with a relief valve not less than $^{1}/_{4}$ in. (6.4 mm) in size set to operate at pressures not greater than 175 psi (12.1 bar).

Exception No. 1: When the maximum system pressure exceeds 165 psi (11.4 bar), the relief valve shall operate at 10 psi (0.7 bar) in excess of the maximum system pressure.

Exception No. 2: Where auxiliary air reservoirs are installed to absorb pressure increases, a relief valve shall not be required.

4-1.3 Auxiliary Systems. A wet pipe system shall be permitted to supply an auxiliary dry pipe, preaction, or deluge system, provided the water supply is adequate.

4-2* Dry Pipe Systems.

4-2.1 Pressure Gauges. Listed pressure gauges conforming with 5-15.3.2 shall be connected as follows:

(1) On the water side and air side of the dry pipe valve

(2) At the air pump supplying the air receiver where one is provided
(3) At the air receiver where one is provided
(4) In each independent pipe from air supply to dry pipe system
(5) At exhausters and accelerators

4-2.2 Upright Sprinklers. Only upright sprinklers shall be installed on dry pipe systems.

*Exception No. 1: *Listed dry sprinklers shall be permitted.*

Exception No. 2: Pendent sprinklers installed on return bends shall be permitted where both the sprinklers and the return bends are located in a heated area.

Exception No. 3: Horizontal sidewall sprinklers, installed so that water is not trapped, shall be permitted.

4-2.3* Size of Systems.

4-2.3.1* Volume Limitations. Not more than 750 gal (2839 L) system capacity shall be controlled by one dry pipe valve.

Exception: Piping volume shall be permitted to exceed 750 gal (2839 L) for nongridded systems if the system design is such that water is delivered to the system test connection in not more than 60 seconds, starting at the normal air pressure on the system and at the time of fully opened inspection test connection.

4-2.3.2 Gridded dry pipe systems shall not be installed. *(See 5-14.2.5.3.3.)*

4-2.4 Quick-Opening Devices.

4-2.4.1 Dry pipe valves shall be provided with a listed quick-opening device where system capacity exceeds 500 gal (1893 L).

Exception: A quick-opening device shall not be required if the requirements of the Exception to 4-2.3.1 can be met without such a device.

4-2.4.2 The quick-opening device shall be located as close as practical to the dry pipe valve. To protect the restriction orifice and other operating parts of the quick-opening device against submergence, the connection to the riser shall be above the point at which water (priming water and back drainage) is expected when the dry pipe valve and quick-opening device are set, except where design features of the particular quick-opening device make these requirements unnecessary.

4-2.4.3 A soft disc globe or angle valve shall be installed in the connection between the dry pipe sprinkler riser and the quick-opening device.

4-2.4.4 A check valve shall be installed between the quick-opening device and the intermediate chamber of the dry pipe valve. If the quick-opening device requires pressure feedback from the intermediate chamber, a valve type that will clearly indicate whether it is opened or closed shall be permitted in place of that check valve. This valve shall be constructed so that it can be locked or sealed in the open position.

4-2.4.5 A listed antiflooding device shall be installed in the connection between the dry pipe sprinkler riser and the quick-opening device.

Exception: A listed antiflooding device shall not be required where the quick-opening device has built-in antiflooding design features.

4-2.5* Location and Protection of Dry Pipe Valve.

4-2.5.1 The dry pipe valve and supply pipe shall be protected against freezing and mechanical injury.

4-2.5.2 Valve rooms shall be lighted and heated. The source of heat shall be of a permanently installed type. Heat tape shall not be used in lieu of heated valve enclosures to protect the dry pipe valve and supply pipe against freezing.

4-2.5.3 The supply for the sprinkler in the dry pipe valve enclosure shall be from the dry side of the system.

4-2.5.4 Protection against accumulation of water above the clapper shall be provided for a low differential dry pipe valve. An automatic high water level signaling device or an automatic drain device shall be permitted.

4-2.6 Air Pressure and Supply.

4-2.6.1 Maintenance of Air Pressure. Air or nitrogen pressure shall be maintained on dry pipe systems throughout the year.

4-2.6.2* Air Supply. The compressed air supply shall be from a source available at all times and have a capacity capable of restoring normal air pressure in the system within 30 minutes.

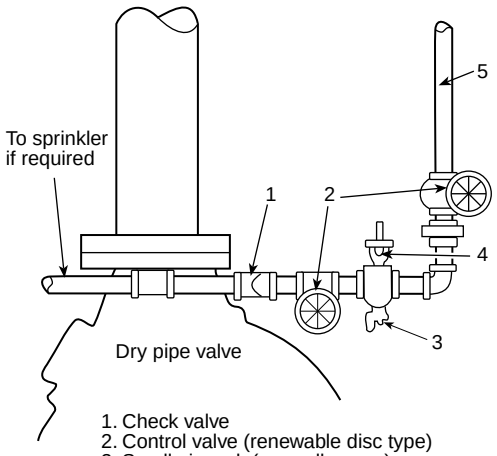
Exception: In refrigerated spaces maintained below 5°F (–15°C), normal system air pressure shall be restored within 60 minutes.

4-2.6.3 Air Filling Connection. The connection pipe from the air compressor shall not be less than $^1/_2$ in. (13 mm) in diameter and shall enter the system above the priming water level of the dry pipe valve. A check valve shall be installed in this air line, and a shutoff valve of the renewable disc type shall be installed on the supply side of this check valve and shall remain closed unless filling the system.

4-2.6.4 Relief Valve. A listed relief valve shall be provided between the compressor and controlling valve and shall be set to relieve at a pressure 5 psi (0.3 bar) in excess of maximum air pressure carried in the system.

4-2.6.5 Shop Air Supply. Where the air supply is taken from a shop system having a normal pressure greater than that required for dry pipe systems and an automatic air maintenance device is not used, the relief valve shall be installed between two control valves in the air line, and a small air cock, which is normally left open, shall be installed in the fitting below the relief valve. *(See Figure 4-2.6.5.)*

Figure 4-2.6.5 Air supply from shop system.



4-2.6.6 Automatic Air Compressor. Where a dry pipe system is supplied by an automatic air compressor or plant air system, any device or apparatus used for automatic maintenance of air pressure shall be of a type specifically listed for such service and capable of maintaining the required air pressure on the dry pipe system. Automatic air supply to more than one dry pipe system shall be connected to enable individual maintenance of air pressure in each system. A check valve or other positive backflow prevention device shall be installed in the air supply to each system to prevent airflow or waterflow from one system to another.

4-2.6.7 System Air Pressure. The system air pressure shall be maintained in accordance with the instruction sheet furnished with the dry pipe valve, or shall be 20 psi (1.4 bar) in excess of the calculated trip pressure of the dry pipe valve, based on the highest normal water pressure of the system supply. The permitted rate of air leakage shall be as specified in 10-2.3.

4-2.6.8 Nitrogen. Where used, nitrogen shall be introduced through a pressure regulator set to maintain system pressure in accordance with 4-2.6.7.

4-3 Preaction Systems and Deluge Systems.

4-3.1* General.

4-3.1.1 All components of pneumatic, hydraulic, or electrical systems shall be compatible.

4-3.1.2 The automatic water control valve shall be provided with hydraulic, pneumatic, or mechanical manual means for operation that is independent of detection devices and of the sprinklers.

4-3.1.3 Pressure Gauges. Listed pressure gauges conforming with 5-15.3.2 shall be installed as follows:

(1) Above and below preaction valve and below deluge valve

(2) On air supply to preaction and deluge valves

4-3.1.4 A supply of spare fusible elements for heat-responsive devices, not less than two of each temperature rating, shall be maintained on the premises for replacement purposes.

4-3.1.5 Hydraulic release systems shall be designed and installed in accordance with manufacturer's requirements and listing for height limitations above deluge valves or deluge valve actuators to prevent water column.

4-3.1.6 Location and Spacing of Detection Devices. Spacing of detection devices, including automatic sprinklers used as detectors, shall be in accordance with their listing and manufacturer's specifications.

4-3.1.7 Devices for Test Purposes and Testing Apparatus.

4-3.1.7.1 Where detection devices installed in circuits are located where not readily accessible, an additional detection device shall be provided on each circuit for test purposes at an accessible location and shall be connected to the circuit at a point that will assure a proper test of the circuit.

4-3.1.7.2 Testing apparatus capable of producing the heat or impulse necessary to operate any normal detection device shall be furnished to the owner of the property with each installation. Where explosive vapors or materials are present, hot water, steam, or other methods of testing not involving an ignition source shall be used.

4-3.1.8 Location and Protection of System Water Control Valves.

4-3.1.8.1 System water control valves and supply pipes shall be protected against freezing and mechanical injury.

4-3.1.8.2 Valve rooms shall be lighted and heated. The source of heat shall be of a permanently installed type. Heat tape shall not be used in lieu of heated valve enclosure rooms to protect preaction and deluge valves and supply pipe against freezing.

4-3.2 Preaction Systems.

4-3.2.1 Preaction systems shall be one of the following types.

(a) *Single Interlock System.* A single interlock system admits water to sprinkler piping upon operation of detection devices.

(b) *Non-Interlock System.* A non-interlock system admits water to sprinkler piping upon operation of detection devices or automatic sprinklers.

(c) *Double Interlock System.* A double interlock system admits water to sprinkler piping upon operation of both detection devices and automatic sprinklers.

4-3.2.2 Size of Systems. Not more than 1000 automatic sprinklers shall be controlled by any one preaction valve.

Exception: For preaction system types described in 4-3.2.1(c), not more than 750 gal (2839 L) shall be controlled by one preaction valve unless the system is designed to deliver water to the system test connection in not more than 60 seconds, starting at the normal air pressure on the system, with the detection system operated and at the time of fully opened inspection test connection. Air pressure and supply shall comply with 4-2.6.

4-3.2.3* Supervision. Sprinkler piping and fire detection devices shall be automatically supervised where there are more than 20 sprinklers on the system. All preaction system types described in 4-3.2.1(b) and 4-3.2.1(c) shall maintain a minimum supervising air pressure of 7 psi (0.5 bar).

4-3.2.4 Upright Sprinklers. Only upright sprinklers shall be installed on preaction systems.

*Exception No. 1: *Listed dry sprinklers shall be permitted.*

Exception No. 2: Pendent sprinklers installed on return bends shall be permitted where both the sprinklers and the return bends are located in a heated area.

Exception No. 3: Horizontal sidewall sprinklers, installed so that water is not trapped, shall be permitted.

4-3.2.5 System Configuration. Preaction systems of the type described in 4-3.2.1(c) shall not be gridded.

4-3.3* Deluge Systems.

4-3.3.1 The detection devices or systems shall be automatically supervised.

4-3.3.2 Deluge systems shall be hydraulically calculated.

4-4 Combined Dry Pipe and Preaction Systems.

4-4.1* General.

4-4.1.1* Combined automatic dry pipe and preaction systems shall be so constructed that failure of the detection system shall not prevent the system from functioning as a conventional automatic dry pipe system.

4-4.1.2 Combined automatic dry pipe and preaction systems shall be so constructed that failure of the dry pipe system of automatic sprinklers shall not prevent the detection system from properly functioning as an automatic fire alarm system.

4-4.1.3 Provisions shall be made for the manual operation of the detection system at locations requiring not more than 200 ft (61 m) of travel.

4-4.1.4 Upright Sprinklers. Only upright sprinklers shall be installed on combined dry pipe and preaction systems.

*Exception No. 1: *Listed dry sprinklers shall be permitted.*

Exception No. 2: Pendent sprinklers installed on return bends shall be permitted where both sprinklers and return bends are located in a heated area.

Exception No. 3: Horizontal sidewall sprinklers, installed so that water is not trapped, shall be permitted.

4-4.2 Dry Pipe Valves in Combined Systems.

4-4.2.1 Where the system consists of more than 600 sprinklers or has more than 275 sprinklers in any fire area, the entire system shall be controlled through two 6-in. (152-mm) dry pipe valves connected in parallel and shall feed into a common feed main. These valves shall be checked against each other. *(See Figure 4-4.2.1.)*

4-4.2.2 Each dry pipe valve shall be provided with a listed tripping device actuated by the detection system. Dry pipe valves shall be cross-connected through a 1-in. (25.4-mm) pipe connection to permit simultaneous tripping of both dry pipe valves. This 1-in. (25.4-mm) pipe connection shall be equipped with an indicating valve so that either dry pipe valve can be shut off and worked on while the other remains in service.

4-4.2.3 The check valves between the dry pipe valves and the common feed main shall be equipped with $^1/_2$-in. (13-mm) bypasses so that a loss of air from leakage in the trimmings of a dry pipe valve will not cause the valve to trip until the pressure in the feed main is reduced to the tripping point. An indicating valve shall be installed in each of these bypasses so that either dry pipe valve can be completely isolated from the main riser or feed main and from the other dry pipe valve.

4-4.2.4 Each combined dry pipe and preaction system shall be provided with listed quick-opening devices at the dry pipe valves.

4-4.3* Air Exhaust Valves. One or more listed air exhaust valves of 2-in. (51-mm) or larger size controlled by operation of a fire detection system shall be installed at the end of the common feed main. These air exhaust valves shall have soft-seated globe or angle valves in their intakes. Also, approved strainers shall be installed between these globe valves and the air exhaust valves.

4-4.4 Subdivision of System Using Check Valves.

4-4.4.1 Where more than 275 sprinklers are required in a single fire area, the system shall be divided into sections of 275 sprinklers or less by means of check valves. If the system is installed in more than one fire area or story, not more than 600 sprinklers shall be supplied through any one check valve. Each section shall have a $1^1/_4$-in. (33-mm) drain on the system side of each check valve supplemented by a dry pipe system auxiliary drain.

4-4.4.2 Section drain lines and dry pipe system auxiliary drains shall be located in heated areas or inside heated cabinets to enclose drain valves and auxiliary drains for each section.

4-4.4.3 Air exhaust valves at the end of a feed main and associated check valves shall be protected against freezing.

4-4.5 Time Limitation. The sprinkler system shall be so constructed and the number of sprinklers controlled shall be so limited that water shall reach the farthest sprinkler within a period of time not exceeding 1 minute for each 400 ft (122 m) of common feed main from the time the heat-responsive system operates. The maximum time permitted shall not exceed 3 minutes.

4-4.6 System Test Connection. The end section shall have a system test connection as required for dry pipe systems.

4-5 Antifreeze Systems.

4-5.1* Where Used. The use of antifreeze solutions shall be in conformity with state and local health regulations.

4-5.2* Antifreeze Solutions.

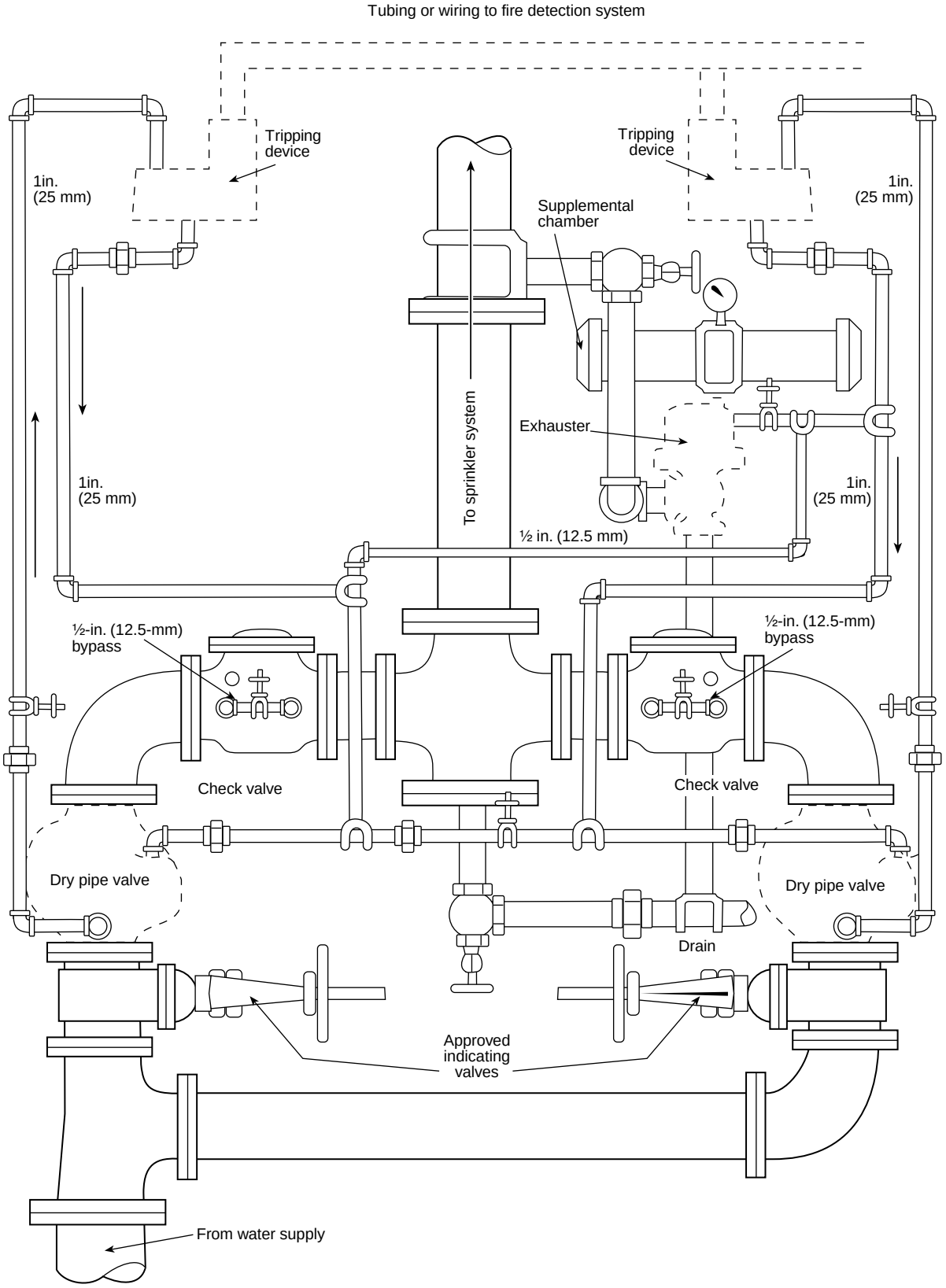
4-5.2.1 Where sprinkler systems are supplied by potable water connections, the use of antifreeze solutions other than water solutions of pure glycerine (C.P. or U.S.P. 96.5 percent grade) or propylene glycol shall not be permitted. Suitable glycerine-water and propylene glycol-water mixtures are shown in Table 4-5.2.1.

Table 4-5.2.1 Antifreeze Solutions to Be Used if Potable Water Is Connected to Sprinklers

Material	Solution (by volume)	Specific Gravity at 60°F (15.6°C)	Freezing Point °F	Freezing Point °C
Glycerine	50% water	1.133	–15	–26.1
C.P. or U.S.P. grade*	40% water	1.151	–22	–30.0
	30% water	1.165	–40	–40.0
Hydrometer scale 1.000 to 1.200				
Propylene glycol	70% water	1.027	+9	–12.8
	60% water	1.034	–6	–21.1
	50% water	1.041	–26	–32.2
	40% water	1.045	–60	–51.1
Hydrometer scale 1.000 to 1.200 (subdivisions 0.002)				

*C.P. — chemically pure; U.S.P. — United States pharmacopoeia 96.5%.

Figure 4-4.2.1 Header for dry pipe valves installed in parallel for combined systems; standard trimmings not shown. Arrows indicate direction of fluid flow.



4-5.2.2 If potable water is not connected to sprinklers, the commercially available materials indicated in Table 4-5.2.2 shall be permitted for use in antifreeze solutions.

Table 4-5.2.2 Antifreeze Solution to Be Used If Nonpotable Water Is Connected to Sprinklers

Material	Solution (by volume)	Specific Gravity at 60°F (15.6°C)	Freezing Point °F	Freezing Point °C
Glycerine	See Table 4-5.2.1.			
Diethylene glycol	50% water	1.078	–13	–25.0
	45% water	1.081	–27	–32.8
	40% water	1.086	–42	–41.1
Hydrometer scale 1.000 to 1.120 (subdivisions 0.002)				
Ethylene glycol	61% water	1.056	–10	–23.3
	56% water	1.063	–20	–28.9
	51% water	1.069	–30	–34.4
	47% water	1.073	–40	–40.0
Hydrometer scale 1.000 to 1.120 (subdivisions 0.002)				
Propylene glycol	See Table 4-5.2.1.			

4-5.2.3* An antifreeze solution shall be prepared with a freezing point below the expected minimum temperature for the locality. The specific gravity of the prepared solution shall be checked by a hydrometer with suitable scale or a refractometer having a scale calibrated for the antifreeze solution involved. *[See Figures 4-5.2.3(a) and (b).]*

Figure 4-5.2.3(a) Densities of aqueous ethylene glycol solutions (percent by weight).

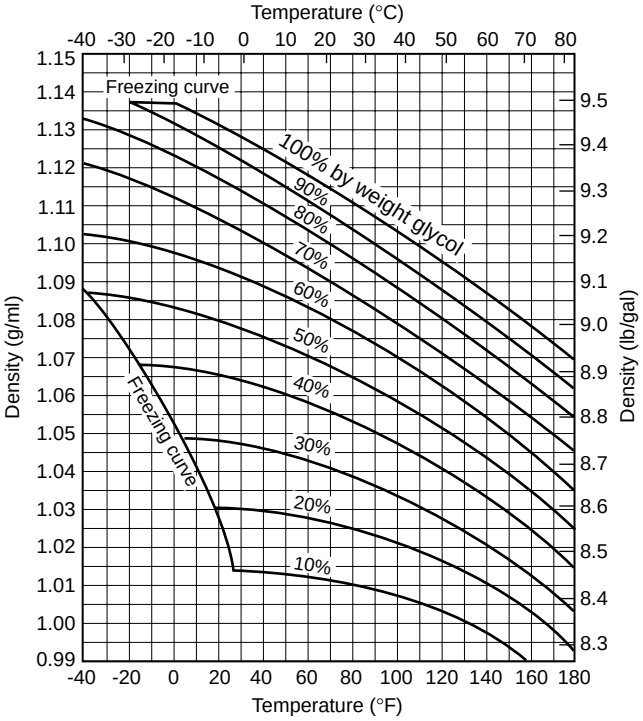
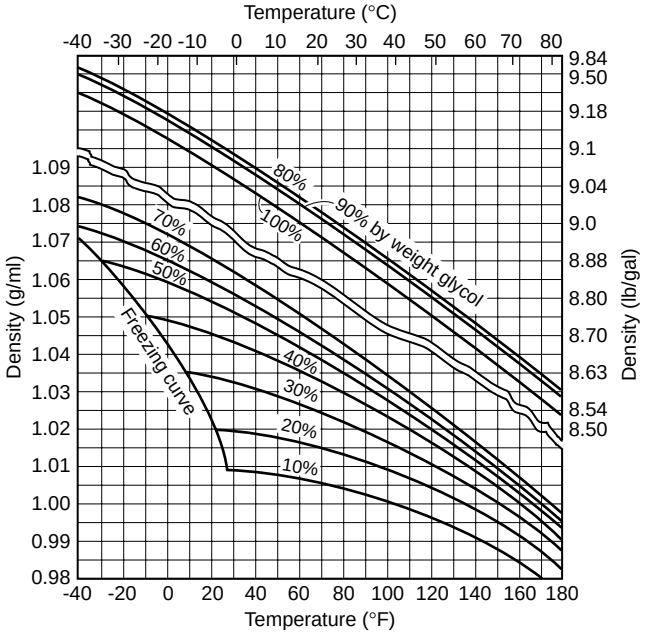


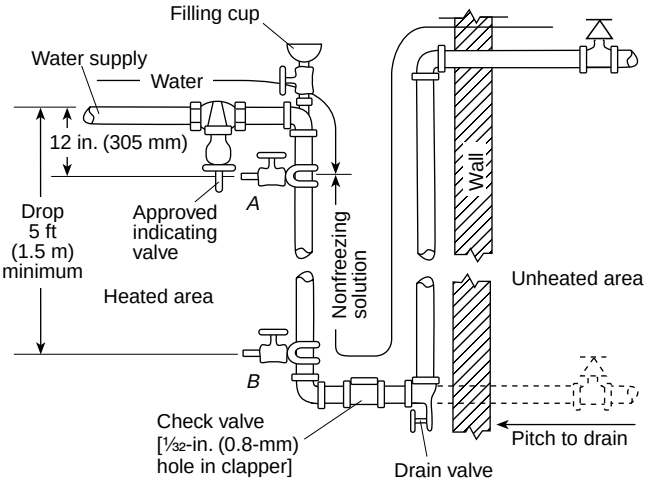
Figure 4-5.2.3(b) Densities of aqueous propylene glycol solutions (percent by weight).



4-5.3 Arrangement of Supply Piping and Valves.

4-5.3.1* Where the connection between the antifreeze system and the wet pipe system does not incorporate a backflow prevention device, piping and valves shall be installed as illustrated in Figure 4-5.3.1.

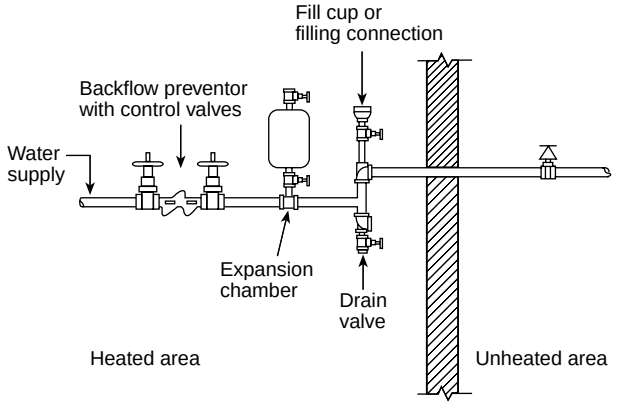
Figure 4-5.3.1 Arrangement of supply piping and valves.



Notes:
1. Check valve shall be permitted to be omitted where sprinklers are below the level of valve *A*.
2. The 1/32-in. (0.8-mm) hole in the check valve clapper is needed to allow for expansion of the solution during a temperature rise, thus preventing damage to sprinklers.

4-5.3.2* Where the connection between the antifreeze system and the wet pipe system incorporates a backflow prevention device, piping and valves shall be installed as illustrated in Figure 4-5.3.2. A listed expansion chamber of appropriate size and pre-charged air pressure shall be provided to compensate for thermal expansion of the antifreeze solution as illustrated in Figure 4-5.3.2.

Figure 4-5.3.2 Arrangement of supply piping with backflow device.



4-6 Automatic Sprinkler Systems with Non-fire Protection Connections.

4-6.1 Circulating Closed-Loop Systems.

4-6.1.1 System Components.

4-6.1.1.1 A circulating closed-loop system is primarily a sprinkler system and shall comply with all provisions of this standard such as those for control valves, area limitations of a system, alarms, fire department connections, sprinkler spacing, and so forth.

Exception: This requirement shall not apply to items otherwise specified within 4-6.1.

4-6.1.1.2 Piping, fittings, valves, and pipe hangers shall meet the requirements specified in Chapter 3.

4-6.1.1.3 A dielectric fitting shall be installed in the junction where dissimilar piping materials are joined (e.g., copper to steel).

Exception: Dielectric fittings shall not be required in the junction where sprinklers are connected to piping.

4-6.1.1.4 It shall not be required that other auxiliary devices be listed for sprinkler service; however, these devices, such as pumps, circulating pumps, heat exchangers, radiators, and luminaries, shall be pressure rated at 175 psi or 300 psi (12.1 bar or 20.7 bar) (rupture pressure of five times rated water system working pressure) to match the required rating of sprinkler system components.

4-6.1.1.5 Auxiliary devices shall incorporate materials of construction and be so constructed that they will maintain their physical integrity under fire conditions to avoid impairment to the fire protection system.

4-6.1.1.6 Auxiliary devices, where hung from the building structure, shall be supported independently from the sprinkler portion of the system, following recognized engineering practices.

4-6.1.2* Hydraulic Characteristics. Piping systems for attached heating and cooling equipment shall have auxiliary pumps or an arrangement made to return water to the piping system in order to assure the following.

(a) Water for sprinklers shall not be required to pass through heating or cooling equipment. At least one direct path shall exist for waterflow from the sprinkler water supply to every sprinkler. Pipe sizing in the direct path shall be in accordance with the design requirements of this standard.

(b) No portions of the sprinkler piping shall have less than the sprinkler system design pressure, regardless of the mode of operation of the attached heating or cooling equipment.

(c) There shall be no loss or outflow of water from the system due to or resulting from the operation of heating or cooling equipment.

(d) Shutoff valves and a means of drainage shall be provided on piping to heating or cooling equipment at all points of connection to sprinkler piping and shall be installed in such a manner as to make possible repair or removal of any auxiliary component without impairing the serviceability and response to the sprinkler system. All auxiliary components, including the strainer, shall be installed on the auxiliary equipment side of the shutoff valves.

4-6.1.3 Water Temperature.

4-6.1.3.1 Maximum. In no case shall maximum water temperature flowing through the sprinkler portion of the system exceed 120°F (49°C). Protective control devices listed for this purpose shall be installed to shut down heating or cooling systems when the temperature of water flowing through the sprinkler portion of the system exceeds 120°F (49°C). When the water temperature exceeds 100°F (37.8°C), intermediate or higher temperature rated sprinklers shall be used.

4-6.1.3.2 Minimum. Precautions shall be taken to ensure that temperatures below 40°F (4°C) are not permitted.

4-6.1.4 Obstruction to Discharge. Automatic sprinklers shall not be obstructed by auxiliary devices, piping, insulation, and so forth, from detecting fire or from proper distribution of water.

4-6.1.5 Signs. Caution signs shall be attached to all valves controlling sprinklers. The caution sign shall be worded as follows:

> This valve controls fire protection equipment. Do not close until after fire has been extinguished. Use auxiliary valves when necessary to shut off supply to auxiliary equipment.
>
> **CAUTION**
>
> Automatic alarm will be sounded if this valve is closed.

4-6.1.6 Water Additives. Materials added to water shall not adversely affect the fire-fighting properties of the water and shall be in conformity with any state or local health regulations. Due care and caution shall be given to the use of additives that can remove or suspend scale from older piping systems. Where additives are necessary for proper system operation, due care shall be taken to ensure that additives are replenished after alarm testing or whenever water is removed from the system.

4-6.1.7 Waterflow Detection.

4-6.1.7.1 The supply of water from sprinkler piping through auxiliary devices, circulatory piping, and pumps shall not under any condition or operation, transient or static, cause false sprinkler waterflow signals.

4-6.1.7.2 A sprinkler waterflow signal shall not be impaired when water is discharged through an opened sprinkler or through the system test connection while auxiliary equipment is in any mode of operation (on, off, transient, stable).

4-7 Outside Sprinklers for Protection Against Exposure Fires.

4-7.1 Applications Exposure protection systems shall be permitted on buildings regardless of whether the building's interior is protected by a sprinkler system.

4-7.2 Water Supply and Control.

4-7.2.1* Sprinklers installed for protection against exposure fires shall be supplied from a standard water supply as outlined in Chapter 9.

Exception: Where approved, other supplies, such as manual valves or pumps or fire department connections, shall be acceptable.

4-7.2.2 Where fire department connections are used for water supply, they shall be so located that they will not be affected by the exposing fire.

4-7.3 Control.

4-7.3.1 Each system of outside sprinklers shall have an independent control valve.

4-7.3.2 Manually controlled open sprinklers shall be used only where constant supervision is present.

4-7.3.3 Sprinklers shall be of the open or automatic type. Automatic sprinklers in areas subject to freezing shall be on dry pipe systems conforming to Section 4-2 or antifreeze systems conforming to Section 4-5.

4-7.3.4 Automatic systems of open sprinklers shall be controlled by the operation of fire detection devices designed for the specific application.

4-7.4 System Components.

4-7.4.1 Drain Valves. Each system of outside sprinklers shall have a separate drain valve installed on the system side of each control valve.

Exception: A separate drain valve shall not be required on open sprinkler-top fed systems arranged to facilitate drainage.

4-7.4.2 Check Valves. Where sprinklers are installed on two adjacent sides of a building, protecting against two separate and distinct exposures, with separate control valves for each side, the end lines shall be connected with check valves located so that one sprinkler around the corner will operate *[see Figures 4-7.4.2(a) and (b)]*. The intermediate pipe between the two check valves shall be arranged to drain. As an alternate solution, an additional sprinkler shall be installed on each system located around the corner from the system involved.

Figure 4-7.4.2(a) Typical arrangement of check valves.

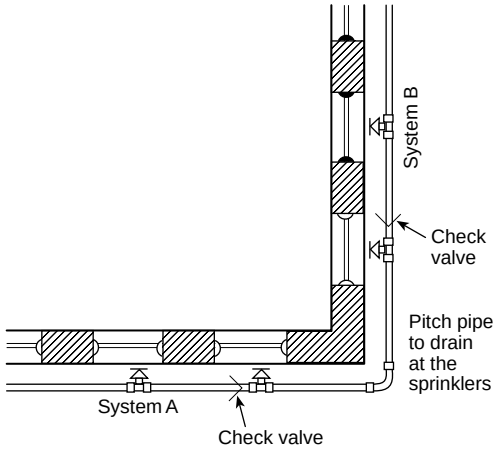
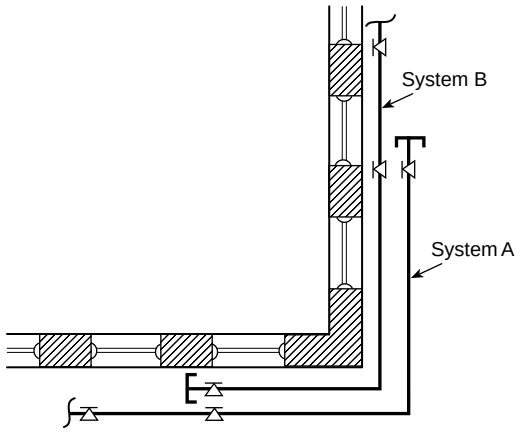


Figure 4-7.4.2(b) Alternate arrangement of check valves.



4-7.4.3 System Arrangement. Where one exposure affects two sides of the protected structure, the system shall not be subdivided between the two sides but rather shall be arranged to operate as a single system.

4-7.5 Pipe and Fittings. Pipe and fittings installed on the exterior of the building shall be corrosion resistant.

4-7.6 Strainers. A listed strainer shall be provided in the riser or feed main that supplies sprinklers having nominal K-factors smaller than 2.8 (4.0).

4-7.7 Gauge Connections. A listed pressure gauge conforming with 5-15.3.2 shall be installed immediately below the control valve of each system.

4-7.8 Sprinklers. Only sprinklers of such type as are listed for window, cornice, sidewall, or ridge pole service shall be installed for such use, except where adequate coverage by use of other types of listed sprinklers and/or nozzles has been demonstrated. Small-orifice or large-orifice sprinklers shall be permitted.

4-8* Refrigerated Spaces.

4-8.1 Spaces Maintained at Temperatures Above 32°F (0°C). Where temperatures are maintained above 32°F (0°C) in refrigerated spaces, the requirements in this section shall not apply.

4-8.2* Spaces Maintained at Temperatures Below 32°F (0°C).

4-8.2.1 Where sprinkler pipe passes through a wall or floor into the refrigerated space, a section of pipe arranged for removal shall be provided immediately inside the space. The removable length of pipe shall be a minimum of 30 in. (762 mm).

4-8.2.2 A low air pressure alarm to a constantly attended location shall be installed.

Exception: Systems equipped with local low pressure alarms and an automatic air maintenance device shall not be required to alarm to a constantly attended location.

4-8.2.3 Piping in refrigerated spaces shall be installed with pitch as outlined in 5-14.2.3.

4-8.2.4* Air supply for systems shall be taken from the room of lowest temperature to reduce the moisture content of the air.

Exception No. 1: This requirement shall not apply where compressed nitrogen gas from cylinders is used in lieu of compressed air.

Exception No. 2: This requirement shall not apply where a compressor/dryer package is listed for the application using an ambient air supply.

4-8.2.5* An indicating-type control valve for operational testing of the system shall be provided on each sprinkler riser outside of the refrigerated space.

4-8.2.6* A check valve with a $^{3}/_{32}$-in. (24-mm) diameter hole in the clapper shall be installed in the system riser below the test valve required in 4-8.2.5.

Exception: When system dry pipe or preaction valves are used, if designed to completely drain all water above the seat and that are listed for installation without priming water remaining and where priming water is not used in the system riser.

4-8.2.7* The air supply piping entering the freezer area shall be equipped with two easily removable supply lines at least 6 ft (1.9 m) long and at least 1 in. (25.4 mm) in diameter as shown in Figure 4-8.2.7. Each supply line shall be equipped with control valves located in the warm area. Only one air supply line shall be open to supply the system air at any one time.

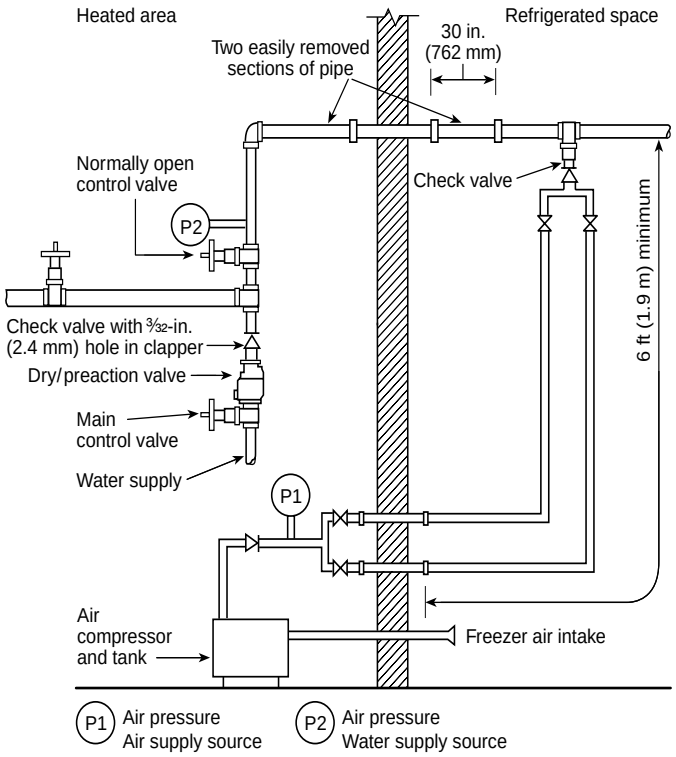
Exception: Two supply lines shall not be required where compressed nitrogen gas from cylinders is used in lieu of compressed air.

4-9 Commercial-Type Cooking Equipment and Ventilation.

4-9.1 In cooking areas protected by automatic sprinklers, additional sprinklers or automatic spray nozzles shall be provided to protect commercial-type cooking equipment and ventilation systems that are designed to carry away grease-laden vapors unless otherwise protected. *(See NFPA 96, Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations.)*

4-9.2* Standard sprinklers or automatic spray nozzles shall be so located as to provide for the protection of exhaust ducts, hood exhaust duct collars, and hood exhaust plenum chambers.

Figure 4-8.2.7 Refrigerator area sprinkler system used to minimize the chances of developing ice plugs.



Notes:
1. Check valve with 3/32-in. (2.4-mm) hole in clapper not required if prime water not used.
2. Supply air to be connection to top or side of system pipe.
3. Each removable air line shall be a minimum of 1 in. (25 mm) diameter and minimum of 6 ft (1.9 m) long.

Exception: Sprinklers or automatic spray nozzles in ducts, duct collars, and plenum chambers shall not be required where all cooking equipment is served by listed grease extractors.

4-9.3 Exhaust ducts shall have one sprinkler or automatic spray nozzle located at the top of each vertical riser and at the midpoint of each offset. The first sprinkler or automatic spray nozzle in a horizontal duct shall be installed at the duct entrance. Horizontal exhaust ducts shall have such devices located on 10-ft (3-m) centers beginning no more than 5 ft (1.5 m) from the duct entrance. A sprinkler(s) or an automatic spray nozzle(s) in exhaust ducts subject to freezing shall be properly protected against freezing by approved means. *(See 5-14.3.1.)*

Exception No. 1: Sprinklers or automatic spray nozzles shall not be required in a vertical riser located outside of a building, provided the riser does not expose combustible material or provided the interior of the building and the horizontal distance between the hood outlet and the vertical riser is at least 25 ft (7.6 m).

Exception No. 2: Sprinklers or automatic spray nozzles shall not be required where the entire exhaust duct is connected to a listed exhaust hood incorporating a specific duct collar and sprinkler (or automatic spray nozzle) assembly that has been investigated and been shown to protect an unlimited length of duct in accordance with UL 300, Standard for Safety Fire Testing of Fire Extinguishing Systems for Protection of Restaurant Cooking Areas.

4-9.4 Each hood exhaust duct collar shall have one sprinkler or automatic spray nozzle located 1 in. minimum to 12 in. maximum (25.4 mm minimum to 305 mm maximum) above the point of duct collar connection in the hood plenum. Hoods that have listed fire dampers located in the duct collar shall be protected with a sprinkler or automatic spray nozzle located on the discharge side of the damper and shall be so positioned as not to interfere with damper operation.

4-9.5 Hood exhaust plenum chambers shall have one sprinkler or automatic spray nozzle centered in each chamber not exceeding 10 ft (3 m) in length. Plenum chambers greater than 10 ft (3 m) in length shall have two sprinklers or automatic spray nozzles evenly spaced, with the maximum distance between the two sprinklers not to exceed 10 ft (3 m).

4-9.6 Sprinklers or automatic spray nozzles being used in duct, duct collar, and plenum areas shall be of the extra-high temperature classification [325°F to 375°F (163°C to 191°C)] and shall have orifice sizes not less than $^1/_4$ in. (6.4 mm) and not more than $^1/_2$ in. (13 mm).

Exception: When use of a temperature-measuring device indicates temperatures above 300°F (149°C), a sprinkler or automatic spray nozzle of higher classification shall be used.

4-9.7 Access must be provided to all sprinklers or automatic spray nozzles for examination and replacement.

4-9.8 Cooking Equipment.

4-9.8.1 Cooking equipment (such as deep fat fryers, ranges, griddles, and broilers) that is considered to be a source of ignition shall be protected in accordance with the provisions of 4-9.1.

4-9.8.2 A sprinkler or automatic spray nozzle used for protection of deep fat fryers shall be listed for that application. The position, arrangement, location, and water supply for each sprinkler or automatic spray nozzle shall be in accordance with its listing.

4-9.8.3 The operation of any cooking equipment sprinkler or automatic spray nozzle shall automatically shut off all sources of fuel and heat to all equipment requiring protection. Any gas appliance not requiring protection but located under ventilating equipment shall also be shut off. All shutdown devices shall be of the type that requires manual resetting prior to fuel or power being restored.

4-9.9 A listed indicating valve shall be installed in the water supply line to the sprinklers and spray nozzles protecting the cooking and ventilating system.

4-9.10 A listed line strainer shall be installed in the main water supply preceding sprinklers or automatic spray nozzles having nominal K-factors smaller than 2.8 (4.0).

4-9.11 A system test connection shall be provided to verify proper operation of equipment specified in 4-9.8.3.

4-9.12 Sprinklers and automatic spray nozzles used for protecting commercial-type cooking equipment and ventilating systems shall be replaced annually.

Exception: Where automatic bulb-type sprinklers or spray nozzles are used and annual examination shows no buildup of grease or other material on the sprinklers or spray nozzles.

Chapter 5 Installation Requirements

5-1* Basic Requirements.

5-1.1* The requirements for spacing, location, and position of sprinklers shall be based on the following principles:

(1) Sprinklers installed throughout the premises
(2) Sprinklers located so as not to exceed maximum protection area per sprinkler
(3) Sprinklers positioned and located so as to provide satisfactory performance with respect to activation time and distribution

Exception No. 1: For locations permitting omission of sprinklers, see 5-13.1, 5-13.2, and 5-13.9.

Exception No. 2: When sprinklers are specifically tested and test results demonstrate that deviations from clearance requirements to structural members do not impair the ability of the sprinkler to control or suppress a fire, their positioning and locating in accordance with the test results shall be permitted.

Exception No. 3: Clearance between sprinklers and ceilings exceeding the maximum specified in 5-6.4.1, 5-7.4.1, 5-8.4.1, 5-9.4.1, 5-10.4.1, and 5-11.4.1 shall be permitted provided that tests or calculations demonstrate comparable sensitivity and performance of the sprinklers to those installed in conformance with these sections.

5-1.2* System valves and gauges shall be accessible for operation, inspection, tests, and maintenance.

5-2 System Protection Area Limitations. The maximum floor area on any one floor to be protected by sprinklers supplied by any one sprinkler system riser or combined system riser shall be as follows:

Light hazard — 52,000 ft^2 (4831 m^2)
Ordinary hazard — 52,000 ft^2 (4831 m^2)
Extra hazard —
Pipe schedule — 25,000 ft^2 (2323 m^2)
Hydraulically calculated — 40,000 ft^2 (3716 m^2)
Storage — High-piled storage (as defined in 1-4.2) and storage covered by other NFPA standards — 40,000 ft^2 (3716 m^2)

Exception No. 1: The floor area occupied by mezzanines shall not be included in the above area.

Exception No. 2: Where single systems protect extra hazard, high-piled storage, or storage covered by other NFPA standards, and ordinary or light hazard areas, the extra hazard or storage area coverage shall not exceed the floor area specified for that hazard and the total area coverage shall not exceed 52,000 ft^2 (4831 m^2).

5-3 Use of Sprinklers.

5-3.1 General.

5-3.1.1* Sprinklers shall be installed in accordance with their listing.

Exception: Where construction features or other special situations require unusual water distribution, listed sprinklers shall be permitted to be installed in positions other than anticipated by their listing to achieve specific results.

5-3.1.2* Upright sprinklers shall be installed with the frame arms parallel to the branch line.

5-3.1.3 Where solvent cement is used as the pipe and fittings bonding agent, sprinklers shall not be installed in the fittings prior to the fittings being cemented in place.

5-3.1.4 Temperature Ratings.

5-3.1.4.1* Ordinary-temperature-rated sprinklers shall be used throughout buildings.

Exception No. 1: Where maximum ceiling temperatures exceed 100°F (38°C), sprinklers with temperature ratings in accordance with the maximum ceiling temperatures of Table 3-2.5.1 shall be used.

Exception No. 2: Intermediate- and high-temperature sprinklers shall be permitted to be used throughout ordinary and extra hazard occupancies.

Exception No. 3: Sprinklers of intermediate- and high-temperature classifications shall be installed in specific locations as required by 5-3.1.4.2.

5-3.1.4.2 The following practices shall be observed to provide sprinklers of other than ordinary temperature classification unless other temperatures are determined or unless high-temperature sprinklers are used throughout *[see Tables 5-3.1.4.2(a) and (b) and Figure 5-3.1.4.2].*

(1) Sprinklers in the high-temperature zone shall be of the high-temperature classification, and sprinklers in the intermediate-temperature zone shall be of the intermediate-temperature classification.
(2) Sprinklers located within 12 in. (305 mm) to one side or 30 in. (762 mm) above an uncovered steam main, heating coil, or radiator shall be of the intermediate-temperature classification.
(3) Sprinklers within 7 ft (2.1 m) of a low-pressure blowoff valve that discharges free in a large room shall be of the high-temperature classification.
(4) Sprinklers under glass or plastic skylights exposed to the direct rays of the sun shall be of the intermediate-temperature classification.
(5) Sprinklers in an unventilated, concealed space, under an uninsulated roof, or in an unventilated attic shall be of the intermediate-temperature classification.
(6) Sprinklers in unventilated show windows having high-powered electric lights near the ceiling shall be of the intermediate-temperature classification.
(7) Sprinklers protecting commercial-type cooking equipment and ventilation systems shall be of the high- or extra-high-temperature classification as determined by use of a temperature-measuring device. *(See 4-9.6.)*

Table 5-3.1.4.2(a) Temperature Ratings of Sprinklers Based on Distance from Heat Sources

Type of Heat Condition	Ordinary Degree Rating	Intermediate Degree Rating	High Degree Rating
(a) Heating ducts			
1. Above	More than 2 ft 6 in.	2 ft 6 in. or less	
2. Side and below	More than 1 ft 0 in.	1 ft 0 in. or less	
3. Diffuser	Any distance except as shown under Intermediate Degree Rating column	*Downward discharge:* Cylinder with 1 ft 0 in. radius from edge extending 1 ft 0 in. below and 2 ft 6 in. above *Horizontal discharge:* Semi-cylinder with 2 ft 6 in. radius in direction of flow extending 1 ft 0 in. below and 2 ft 6 in. above	
(b) Unit heater			
1. Horizontal discharge		*Discharge side:* 7 ft 0 in. to 20 ft 0 in. radius pie-shaped cylinder *[see Figure 5-3.1.4.2]* extending 7 ft 0 in. above and 2 ft 0 in. below heater; also 7 ft 0 in. radius cylinder more than 7 ft 0 in. above unit heater	7 ft 0 in. radius cylinder extending 7 ft 0 in. above and 2 ft 0 in. below unit heater
2. Vertical downward discharge *(For sprinklers below unit heater, see Figure 5-3.1.4.2)*		7 ft 0 in. radius cylinder extending upward from an elevation 7 ft 0 in. above unit heater	7 ft 0 in. radius cylinder extending from the top of the unit heater to an elevation 7 ft 0 in. above unit heater
(c) Steam mains (uncovered)			
1. Above	More than 2 ft 6 in.	2 ft 6 in. or less	
2. Side and below	More than 1 ft 0 in.	1 ft 0 in. or less	
3. Blowoff valve	More than 7 ft 0 in.		7 ft 0 in. or less

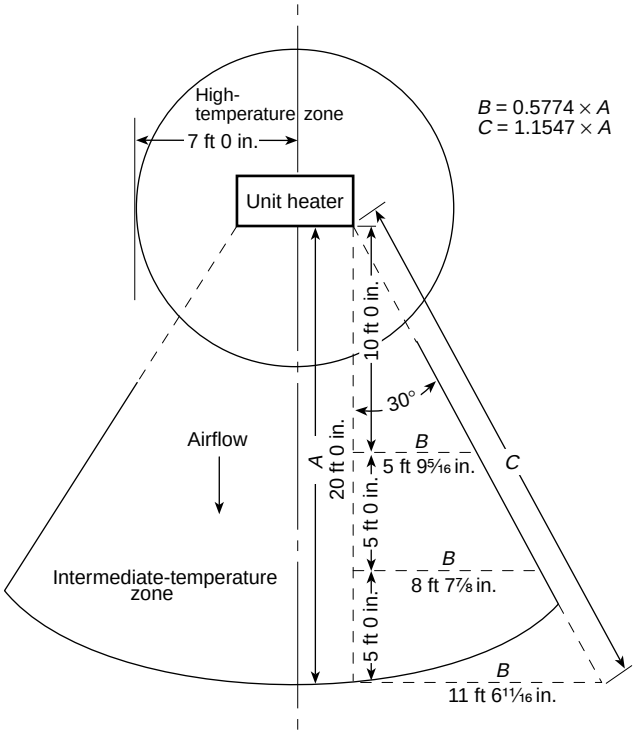
For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m.

Table 5-3.1.4.2(b) Ratings of Sprinklers in Specified Locations

Location	Ordinary Degree Rating	Intermediate Degree Rating	High Degree Rating
Skylights		Glass or plastic	
Attics	Ventilated	Unventilated	
Peaked roof: metal or thin boards, concealed or not concealed, insulated or uninsulated	Ventilated	Unventilated	
Flat roof: metal, not concealed	Ventilated or unventilated	Note: For uninsulated roof, climate and insulated or uninsulated occupancy can necessitate intermediate sprinklers. Check on job.	
Flat roof: metal, concealed, insulated or uninsulated	Ventilated	Unventilated	
Show windows	Ventilated	Unventilated	

Note: A check of job condition by means of thermometers may be necessary.

Figure 5-3.1.4.2 High-temperature and intermediate-temperature zones at unit heaters.



SI units: 1 in. = 25.4 mm; 1 ft = 0.31 m.

5-3.1.4.3 In case of occupancy change involving temperature change, the sprinklers shall be changed accordingly.

5-3.1.4.4* The minimum temperature rating of ceiling sprinklers in general storage, rack storage, rubber tire storage, roll paper storage, and baled cotton storage applications shall be 150°F.

5-3.1.5 Thermal Sensitivity.

5-3.1.5.1* Sprinklers in light hazard occupancies shall be of the quick-response type as defined in 1-4.5.2.

Exception No. 1: Residential sprinklers shall be permitted in accordance with 5-4.5.

Exception No. 2: For modifications or additions to existing systems equipped with standard response sprinklers, standard response sprinklers shall be permitted to be used.

Exception No. 3: When individual standard response sprinklers are replaced in existing systems, standard response sprinklers shall be permitted to be used.

5-3.1.5.2 When existing light hazard systems are converted to use quick-response or residential sprinklers, all sprinklers in a compartmented space shall be changed.

5-4* Application of Sprinkler Types. Sprinklers shall be selected for use as indicated in this section. Sprinklers shall be positioned and spaced as described in Section 5-5.

5-4.1 Standard Upright and Pendent Spray Sprinklers.

5-4.1.1 General Applications. Upright and pendent spray sprinklers shall be permitted in all occupancy hazard classifications and building construction types.

Exception: Quick-response sprinklers shall not be permitted for use in extra hazard occupancies under the area-density design method. (See 7-2.3.2.3, Exception No. 1.)

5-4.1.2 Storage. For general storage, rack storage, rubber tire storage, roll paper storage, and baled cotton storage being protected with spray sprinklers with required densities of 0.34 gpm/ft^2 (13.9 mm/min) or less, standard response sprinklers with a nominal K-factor of 8.0 or larger shall be used. For required densities greater than 0.34 gpm/ft^2 (13.9 mm/min), standard response spray sprinklers with a K-factor of 11.2 or larger that are listed for storage applications shall be used.

Exception No. 1: For densities of 0.20 gpm/ft² (8.2 mm/min) or less, standard response sprinklers with a K-factor of 5.6 shall be permitted.

Exception No. 2: For modifications to existing systems, sprinklers with K-factors of 8.0 or less shall be permitted.

Exception No. 3: The use of quick-response spray sprinklers shall be permitted when listed for such use.

5-4.2 Sidewall Spray Sprinklers. Sidewall sprinklers shall be installed only in light hazard occupancies with smooth, flat ceilings.

Exception No. 1: Sidewall sprinklers shall be permitted to be used in ordinary hazard occupancies with smooth, flat ceilings where specifically listed for such use.

Exception No. 2: Sidewall sprinklers shall be permitted to be used to protect areas below overhead doors.

5-4.3 Extended Coverage Sprinklers. Extended coverage sprinklers shall be limited to a type of unobstructed construction consisting of flat, smooth ceilings with a slope not exceeding a pitch of one in six (a rise of two units in a run of 12 units, a roof slope of 16.7 percent).

Exception No. 1: Where sprinklers are specifically listed for unobstructed or noncombustible obstructed construction, they shall be permitted for such use.

Exception No. 2: Extended coverage upright and pendent spray sprinklers shall be permitted within trusses or bar joists having web members not greater than 1 in. (25.4 mm) maximum dimension or where trusses are spaced greater than $7^1/_2$ ft (2.3 m) on center.

Exception No. 3: Where extended coverage sprinklers are specifically listed for use under smooth, flat ceilings that have slopes not exceeding a pitch of one in three (a rise of four units in a run of 12 units, a roof slope of 33.3 percent) they shall be permitted.

5-4.4 Open Sprinklers. Open sprinklers shall be permitted to be used in deluge systems to protect special hazards or exposures, or in other special locations. Open sprinklers shall be installed in accordance with all applicable requirements of this standard for their automatic counterpart.

5-4.5 Residential Sprinklers.

5-4.5.1* Residential sprinklers shall be permitted in dwelling units and their adjoining corridors provided they are installed in conformance with their listing and the positioning requirements of NFPA 13D, *Standard for the Installation of Sprinkler Systems in One-and Two-Family Dwellings and Manufactured Homes,* or NFPA 13R, *Standard for the Installation of Sprinkler Systems in Residential Occupancies up to and Including Four Stories in Height.*

5-4.5.2 Residential sprinklers shall be used only in wet systems.

Exception: Residential sprinklers shall be permitted for use in dry systems or preaction systems if specifically listed for such service.

5-4.5.3 Where residential sprinklers are installed in a compartment as defined in 1-4.2, all sprinklers within the compartment shall be of the fast-response type that meets the criteria of 1-4.5.1(a)1.

5-4.5.4 Residential sprinklers installed in conformance with this standard shall follow the sprinkler obstruction rules of 5-8.5 or 5-9.5 as appropriate for their installation orientation (upright, pendent, or sidewall and the obstruction criteria specified in the manufacturer's installation instructions).

5-4.6 Early Suppression Fast-Response (ESFR) Sprinklers.

5-4.6.1 ESFR sprinklers shall be used only in wet pipe systems.

Exception: ESFR sprinklers shall be permitted for use in dry systems if specifically listed for such service.

5-4.6.2 ESFR sprinklers shall be installed only in buildings where roof or ceiling slope above the sprinklers does not exceed a pitch of one in six (a rise of two units in a run of 12 units, a roof slope of 16.7 percent).

5-4.6.3* ESFR sprinklers shall be permitted for use only in buildings with the following types of construction:

(1) Smooth ceiling, joists consisting of steel truss-shaped members, or wood truss-shaped members that consist of wood top or bottom chord members not exceeding 4 in. (102 mm) in depth with steel tube or bar web

(2) Wood beams of 4 in. by 4 in. (102 mm by 102 mm) or greater nominal dimension, concrete or steel beams spaced $3^1/_2$ to $7^1/_2$ ft (0.9 m to 2.3 m) on centers and either supported on or framed into girders

[Paragraphs (1) and (2) shall apply to construction with noncombustible or combustible roof or decks.]

(3) Construction with ceiling panels formed by members capable of trapping heat to aid the operation of sprinklers with members spaced greater than $7^1/_2$ ft (2.3 m) and limited to a maximum of 300 ft² (27.9 m²) in area

5-4.6.4 Where ESFR sprinkler systems are installed adjacent to sprinkler systems with standard response sprinklers, a draft curtain of noncombustible construction and at least 2 ft (0.6 m) in depth shall be required to separate the two areas. A clear aisle of at least 4 ft (1.2 m) centered below the draft curtain shall be maintained for separation.

5-4.6.5 Sprinkler temperature ratings for ESFR sprinklers shall be ordinary.

Exception: Sprinklers of intermediate- and high-temperature ratings shall be installed in locations as required by Section 5-3.1.4.1.

5-4.7 Large Drop Sprinklers.

5-4.7.1 Large drop sprinklers shall be permitted to be used in wet, dry, or preaction systems.

5-4.7.2* Where steel pipe is used in preaction and dry pipe systems, piping materials shall be limited to internally galvanized steel.

Exception: Nongalvanized fittings shall be permitted.

5-4.7.3 Sprinkler temperature ratings shall be the same as those indicated in Tables 5-3.1.4.2 (a) and (b) or those used in large-scale fire testing to determine the protection requirements for the hazard involved.

Exception No. 1: Sprinklers of intermediate- and high-temperature ratings shall be installed in specific locations as required by 5-3.1.4.

Exception No. 2: In storage occupancies, ordinary, intermediate, or high temperature–rated sprinklers shall be used for wet pipe systems.

Exception No. 3: In storage occupancies, high temperature–rated sprinklers shall be used for dry pipe systems.

5-4.8 QRES. (Reserved)

5-4.9 Special Sprinklers.

5-4.9.1* Special sprinklers that are intended for the protection of specific hazards or construction features shall be permitted where such devices have been evaluated and listed for performance under the following conditions:

(1) Fire tests related to the intended hazard
(2) Distribution of the spray pattern with respect to wetting of floors and walls
(3) Distribution of the spray pattern with respect to obstructions
(4) Evaluation of the thermal sensitivity of the sprinkler
(5) Performance under horizontal or sloped ceilings
(6) Area of design

5-4.9.2 Special sprinklers shall maintain the following characteristics:

(1) Orifice size shall be in accordance with 3-2.3.
(2) Temperature ratings shall be in accordance with Table 3-2.5.1.
(3) The protection area of coverage shall not exceed 400 ft^2 (36 m^2) for light hazard and ordinary hazard occupancies.
(4) The protection area of coverage shall not exceed 196 ft^2 (17 m^2) for extra hazard and high-pile storage occupancies.

5-5 Position, Location, Spacing, and Use of Sprinklers.

5-5.1 General. Sprinklers shall be located, spaced, and positioned in accordance with the requirements of this section. Sprinklers shall be positioned to provide protection of the area consistent with the overall objectives of this standard by controlling the positioning and allowable area of coverage for each sprinkler. The requirements of 5-5.2 through 5-5.6 shall apply to all sprinkler types unless modified by more restrictive rules in Sections 5-6 through 5-11.

5-5.2 Protection Areas per Sprinkler.

5-5.2.1 Determination of the Protection Area of Coverage. The protection area of coverage per sprinkler *(A_s)* shall be determined as follows:

(a) *Along Branch Lines.* Determine distance between sprinklers (or to wall or obstruction in the case of the end sprinkler on the branch line) upstream and downstream. Choose the larger of either twice the distance to the wall or the distance to the next sprinkler. This dimension will be defined as *S*.

(b) *Between Branch Lines.* Determine perpendicular distance to the sprinkler on the adjacent branch line (or to a wall or obstruction in the case of the last branch line) on each side of the branch line on which the subject sprinkler is positioned. Choose the larger of either twice the distance to the wall or obstruction or the distance to the next sprinkler. This dimension will be defined as *L*.

5-5.2.1.1 The protection area of coverage of the sprinkler shall be established by multiplying the *S* dimension by the *L* dimension, as follows: $A_s = S \times L$

5-5.2.2 Maximum Protection Area of Coverage. The maximum allowable protection area of coverage for a sprinkler *(A_s)* shall be in accordance with the value indicated in the section for each type or style of sprinkler. The maximum area of coverage of any sprinkler shall not exceed 400 ft^2 (36 m^2).

5-5.3 Sprinkler Spacing.

5-5.3.1 Maximum Distance Between Sprinklers. The maximum distance permitted between sprinklers shall be based on the centerline distance between sprinklers on the branch line or on adjacent branch lines. The maximum distance shall be measured along the slope of the ceiling. The maximum distance permitted between sprinklers shall comply with the value indicated in the section for each type or style of sprinkler.

5-5.3.2 Maximum Distance From Walls. The distance from sprinklers to walls shall not exceed one-half of the allowable maximum distance between sprinklers. The distance from the wall to the sprinkler shall be measured perpendicular to the wall.

5-5.3.3 Minimum Distance from Walls. The minimum distance permitted between a sprinkler and the wall shall comply with the value indicated in the section for each type or style of sprinkler. The distance from the wall to the sprinkler shall be measured perpendicular to the wall.

5-5.3.4 Minimum Distance Between Sprinklers. A minimum distance shall be maintained between sprinklers to prevent operating sprinklers from wetting adjacent sprinklers and to prevent skipping of sprinklers. The minimum distance permitted between sprinklers shall comply with the value indicated in the section for each type or style of sprinkler.

5-5.4 Deflector Position.

5-5.4.1* Distance Below Ceilings. The distances between the sprinkler deflector and the ceiling above shall be selected based on the type of sprinkler and the type of construction.

5-5.4.2 Deflector Orientation. Deflectors of sprinklers shall be aligned parallel to ceilings, roofs, or the incline of stairs.

5-5.5 Obstructions to Sprinkler Discharge.

5-5.5.1* Performance Objective. Sprinklers shall be located so as to minimize obstructions to discharge as defined in 5-5.5.2 and 5-5.5.3, or additional sprinklers shall be provided to ensure adequate coverage of the hazard. *(See Figure A-5-5.5.1.)*

5-5.5.2* Obstructions to Sprinkler Discharge Pattern Development.

5-5.5.2.1 Continuous or noncontinuous obstructions less than or equal to 18 in. (457 mm) below the sprinkler deflector that prevent the pattern from fully developing shall comply with 5-5.5.2.

5-5.5.2.2 Sprinklers shall be positioned in accordance with the minimum distances and special exceptions of Sections 5-6 through 5-11 so that they are located sufficiently away from obstructions such as truss webs and chords, pipes, columns, and fixtures.

5-5.5.3* Obstructions that Prevent Sprinkler Discharge from Reaching the Hazard. Continuous or noncontinuous obstructions that interrupt the water discharge in a horizontal plane more than 18 in. (457 mm) below the sprinkler deflector in a manner to limit the distribution from reaching the protected hazard shall comply with 5-5.5.3.

5-5.5.3.1 Sprinklers shall be installed under fixed obstructions over 4 ft (1.2 m) wide such as ducts, decks, open grate flooring, cutting tables, and overhead doors.

Exception: Obstructions that are not fixed in place such as conference tables.

5-5.5.3.2 Sprinklers installed under open gratings shall be of the intermediate level/rack storage type or otherwise shielded from the discharge of overhead sprinklers.

5-5.6* Clearance to Storage. The clearance between the deflector and the top of storage shall be 18 in. (457 mm) or greater.

Exception No. 1: Where other standards specify greater minimums, they shall be followed.

Exception No. 2: A minimum clearance of 36 in. (0.91 m) shall be permitted for special sprinklers.

Exception No. 3: A minimum clearance of less than 18 in. (457 mm) between the top of storage and ceiling sprinkler deflectors shall be permitted where proven by successful large-scale fire tests for the particular hazard.

Exception No. 4: The clearance from the top of storage to sprinkler deflectors shall be not less than 3 ft (0.9 m) where rubber tires are stored.

5-6 Standard Pendent and Upright Spray Sprinklers.

5-6.1 General. All requirements of Section 5-5 shall apply to standard pendent and upright spray sprinklers except as modified below.

5-6.2 Protection Areas per Sprinkler (Standard Pendent and Upright Spray Sprinklers).

5-6.2.1 Determination of the Protection Area of Coverage. The protection area of coverage per sprinkler (A_s) shall be determined in accordance with 5-5.2.1.

Exception: In a small room as defined in 1-4.2, the protection area of coverage for each sprinkler in the small room shall be the area of the room divided by the number of sprinklers in the room.

5-6.2.2 Maximum Protection Area of Coverage. The maximum allowable protection area of coverage for a sprinkler (A_s) shall be in accordance with the value indicated in Tables 5-6.2.2(a) through 5-6.2.2(d). In any case, the maximum area of coverage of a sprinkler shall not exceed 225 ft^2 (21 m^2).

Table 5-6.2.2(a) Protection Areas and Maximum Spacing (Standard Spray Upright/Standard Spray Pendent) for Light Hazard

		Protection Area		Spacing (maximum)	
Construction Type	**System Type**	**ft^2**	**m^2**	**ft**	**m**
Noncombustible obstructed and unobstructed and combustible unobstructed	Pipe schedule	200	18.6	15	4.6
	Hydraulically calculated	225	20.9	15	4.6
Combustible obstructed	All	168	15.6	15	4.6
Combustible with members less than 3 ft on center	All	130	12.1	15	4.6

Table 5-6.2.2(b) Protection Areas and Maximum Spacing (Standard Spray Upright/Standard Spray Pendent) for Ordinary Hazard

		Protection Area		Spacing (maximum)	
Construction Type	**System Type**	**ft^2**	**m^2**	**ft**	**m**
All	All	130	12.1	15	4.6

Table 5-6.2.2(c) Protection Areas and Maximum Spacing (Standard Spray Upright/Standard Spray Pendent) for Extra Hazard

		Protection Area		Spacing (maximum)	
Construction Type	**System Type**	**ft^2**	**m^2**	**ft**	**m**
All	Pipe schedule	90	8.4	12	3.7
				[In buildings with storage bays 25 ft (7.6 m) wide, 12 ft 6 in. (3.8 m) shall be permitted]	
All	Hydraulically calculated with density ≥0.25	100	9.3	12	3.7
				[In buildings with storage bays 25 ft (7.6 m) wide, 12 ft 6 in. (3.8 m) shall be permitted]	
All	Hydraulically calculated with density <0.25	130	12.1	15	4.6

Table 5-6.2.2(d) Protection Areas and Maximum Spacing (Standard Spray Upright/Standard Spray Pendent) for High-Piled Storage

		Protection Area		Spacing (maximum)	
Construction Type	**System Type**	**ft²**	**m²**	**ft**	**m**
All	Hydraulically calculated with density ≥0.25	100	9.3	12	3.7
				[In buildings with storage bays 25 ft (7.6 m) wide, 12 ft 6 in. (3.8 m) shall be permitted]	
All	Hydraulically calculated with density <0.25	130	12.1	15	4.6

5-6.3 Sprinkler Spacing (Standard Pendent and Upright Spray Sprinklers).

5-6.3.1 Maximum Distance Between Sprinklers. The maximum distance permitted between sprinklers shall comply with Tables 5-6.2.2(a) through (d).

5-6.3.2 Maximum Distance from Walls.

5-6.3.2.1* The distance from sprinklers to walls shall not exceed one-half of the allowable distance between sprinklers as indicated in Tables 5-6.2.2(a) through (d). The distance from the wall to the sprinkler shall be measured perpendicular to the wall. Where walls are angled or irregular, the maximum horizontal distance between a sprinkler and any point of floor area protected by that sprinkler shall not exceed 0.75 times the allowable distance permitted between sprinklers, provided the maximum perpendicular distance is not exceeded.

*Exception: *Within small rooms as defined in 1-4.2, sprinklers shall be permitted to be located not more than 9 ft (2.7 m) from any single wall. Sprinkler spacing limitations of 5-6.3 and area limitations of Table 5-6.2.2(a) shall not be exceeded.*

5-6.3.2.2 Under curved surfaces, the horizontal distance shall be measured at the floor level from the wall, or the intersection of the curved surface and the floor to the nearest sprinkler shall not be greater than one-half the allowable distance between sprinklers.

5-6.3.3 Minimum Distance from Walls. Sprinklers shall be located a minimum of 4 in. (102 mm) from a wall.

5-6.3.4 Minimum Distance Between Sprinklers. Sprinklers shall be spaced not less than 6 ft (1.8 m) on center.

Exception No. 1: Sprinklers shall be permitted to be placed less than 6 ft (1.8 m) on center where the following conditions are satisfied:

(a) Baffles shall be installed and located midway between sprinklers and arranged to protect the actuating elements.

(b) Baffles shall be of noncombustible or limited-combustible material that will stay in place before and during sprinkler operation.

(c) Baffles shall be not less than 8 in. (203 mm) wide and 6 in. (152 mm) high. The tops of baffles shall extend between 2 in. and 3 in. (51 mm and 76 mm) above the deflectors of upright sprinklers. The bottoms of baffles shall extend downward to a level at least even with the deflectors of pendent sprinklers.

Exception No. 2: In-rack sprinklers shall be permitted to be placed less than 6 ft (1.8 m) on center.

Exception No. 3: Old-style sprinklers protecting fur storage vaults shall be permitted to be placed less than 6 ft (1.8 m) on center.

5-6.4 Deflector Position (Standard Pendent and Upright Spray Sprinklers).

5-6.4.1 Distance Below Ceilings.

5-6.4.1.1 Under unobstructed construction, the distance between the sprinkler deflector and the ceiling shall be a minimum of 1 in. (25.4 mm) and a maximum of 12 in. (305 mm).

Exception: Ceiling-type sprinklers (concealed, recessed, and flush types) shall be permitted to have the operating element above the ceiling and the deflector located nearer to the ceiling where installed in accordance with their listing.

5-6.4.1.2 Under obstructed construction, the sprinkler deflector shall be located within the horizontal planes of 1 in. to 6 in. (25.4 mm to 152 mm) below the structural members and a maximum distance of 22 in. (559 mm) below the ceiling/roof deck.

Exception No. 1: Sprinklers shall be permitted to be installed with the deflector at or above the bottom of the structural member to a maximum of 22 in. (559 mm) below the ceiling/roof deck where the sprinkler is installed in conformance with 5-6.5.1.2.

Exception No. 2: Where sprinklers are installed in each bay of obstructed construction, deflectors shall be permitted to be a minimum of 1 in. (25.4 mm) and a maximum of 12 in. (305 mm) below the ceiling.

Exception No. 3: Sprinkler deflectors shall be permitted to be 1 in. to 6 in. below composite wood joists to a maximum distance of 22 in. below the ceiling/roof deck only where joist channels are fire-stopped to the full depth of the joists with material equivalent to the web construction so that individual channel areas do not exceed 300 ft² (27.9 m²).

*Exception No. 4: *Deflectors of sprinklers under concrete tee construction with stems spaced less than $7\frac{1}{2}$ ft (2.3 m) but more than 3 ft (0.9 m) on centers shall, regardless of the depth of the tee, be permitted to be located at or above a horizontal plane 1 in. (25.4 mm) below the bottom of the stems of the tees and shall comply with Table 5-6.5.1.2.*

5-6.4.1.3* Sprinklers under or near the peak of a roof or ceiling shall have deflectors located not more than 3 ft (0.9 m) vertically down from the peak. *[See Figures 5-6.4.1.3(a) and 5-6.4.1.3(b).]*

Exception No. 1: Under saw-toothed roofs, sprinklers at the highest elevation shall not exceed a distance of 3 ft (0.9 m) measured down the slope from the peak.

Exception No. 2: Under a steeply pitched surface, the distance from the peak to the deflectors shall be permitted to be increased to maintain a horizontal clearance of not less than 2 ft (0.6 m) from other structural members. [See Figure 5-6.4.1.3(c).]

Figure 5-6.4.1.3(a) Sprinklers under pitched roofs with sprinkler directly under peak; branch lines run up the slope.

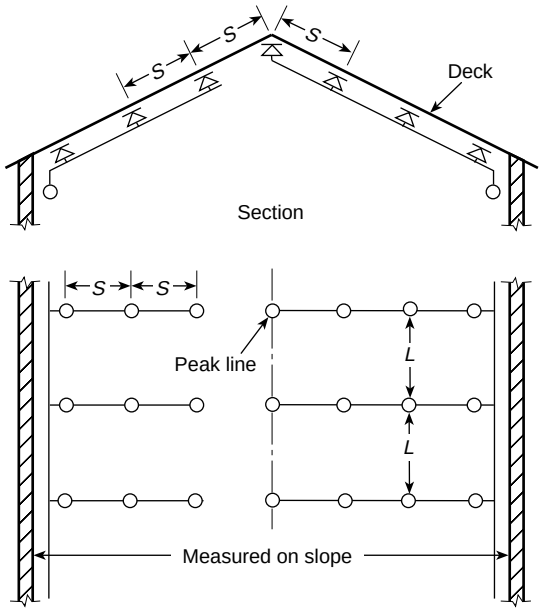


Figure 5-6.4.1.3(b) Sprinklers at pitched roofs; branch lines run up the slope.

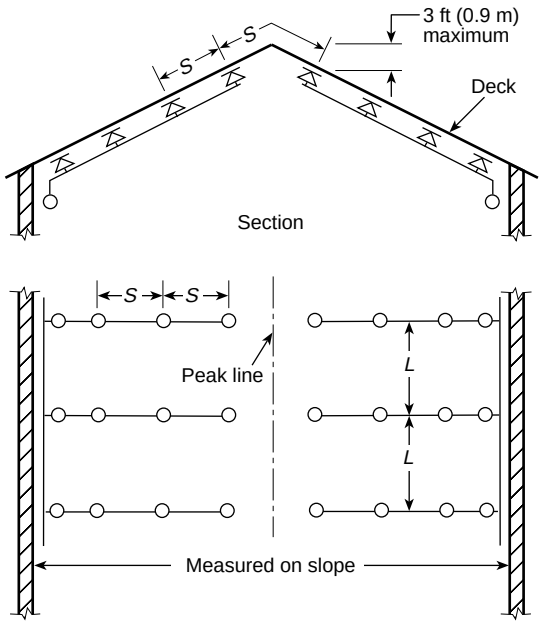
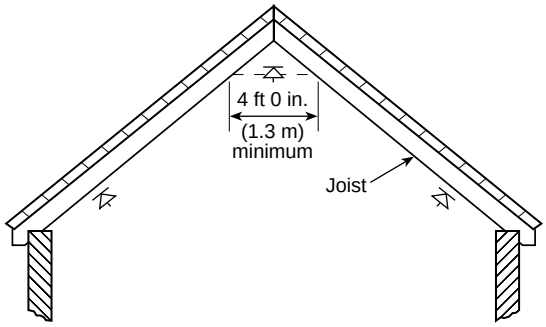


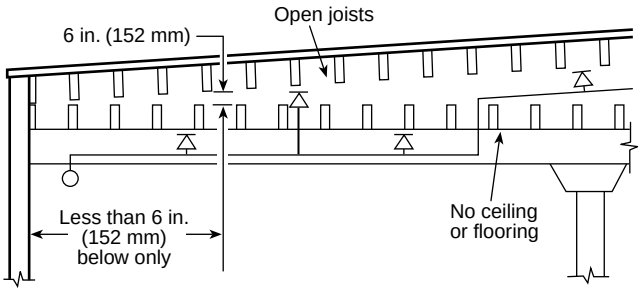
Figure 5-6.4.1.3(c) Horizontal clearance for sprinklers at peak of pitched roof.



5-6.4.1.4 Double Joist Obstructions. Where there are two sets of joists under a roof or ceiling, and there is no flooring over the lower set, sprinklers shall be installed above and below the lower set of joists where there is a clearance of 6 in. (152 mm) or more between the top of the lower joist and the bottom of the upper joist. *(See Figure 5-6.4.1.4.)*

Exception: Sprinklers are permitted to be omitted from below the lower set of joists where at least 18 in. (0.46 m) is maintained between the sprinkler deflector and the top of the lower joist.

Figure 5-6.4.1.4 Arrangement of sprinklers under two sets of open joists — no sheathing on lower joists.



5-6.4.2* Deflector Orientation. Deflectors of sprinklers shall be aligned parallel to ceilings, roofs, or the incline of stairs.

Exception No. 1: Where sprinklers are installed in the peak below a sloped ceiling or roof surface, the sprinkler shall be installed with the deflector horizontal.

Exception No. 2: Pitched roofs having slopes not exceeding a pitch of one in six (a rise of two units in a run of 12 units, a roof slope of 16.7 percent) are considered level in the application of this rule, and sprinklers shall be permitted to be installed with deflectors horizontal.

5-6.5 Obstructions to Sprinkler Discharge (Standard Pendent and Upright Spray Sprinklers).

5-6.5.1 Performance Objective.

5-6.5.1.1 Sprinklers shall be located so as to minimize obstructions to discharge as defined in 5-6.5.2 and 5-6.5.3, or additional sprinklers shall be provided to ensure adequate coverage of the hazard.

5-6.5.1.2 Sprinklers shall be arranged to comply with 5-5.5.2, Table 5-6.5.1.2, and Figure 5-6.5.1.2(a).

Exception No. 1: Sprinklers shall be permitted to be spaced on opposite sides of obstructions not exceeding 4 ft (1.2 m) in width provided the distance from the centerline of the obstruction to the sprinklers does not exceed one-half the allowable distance permitted between sprinklers.

Exception No. 2: Obstructions located against the wall and that are not over 30 in. (762 mm) in width shall be permitted to be protected in accordance with Figure 5-6.5.1.2(b).

Table 5-6.5.1.2 Positioning of Sprinklers to Avoid Obstructions to Discharge (SSU/SSP)

Distance from Sprinklers to Side of Obstruction *(A)*	Maximum Allowable Distance of Deflector above Bottom of Obstruction (in.) *(B)*
Less than 1 ft	0
1 ft to less than 1 ft 6 in.	$2^1/_2$
1 ft 6 in. to less than 2 ft	$3^1/_2$
2 ft to less than 2 ft 6 in.	$5^1/_2$
2 ft 6 in. to less than 3 ft	$7^1/_2$
3 ft to less than 3 ft 6 in.	$9^1/_2$
3 ft 6 in. to less than 4 ft	12
4 ft to less than 4 ft 6 in.	14
4 ft 6 in. to less than 5 ft	$16^1/_2$
5 ft and greater	18

For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m.
Note: For *(A)* and *(B)*, refer to Figure 5-6.5.1.2(a).

Figure 5-6.5.1.2(a) Positioning of sprinklers to avoid obstructions to discharge (SSU/SSP).

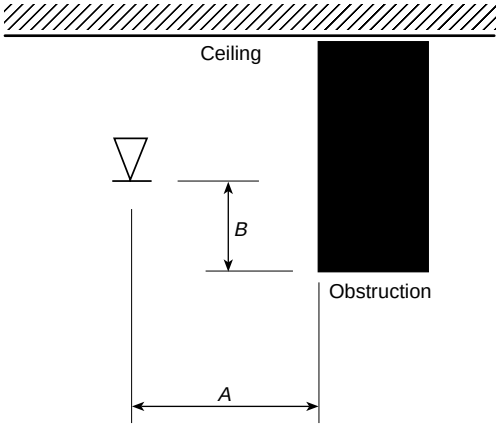
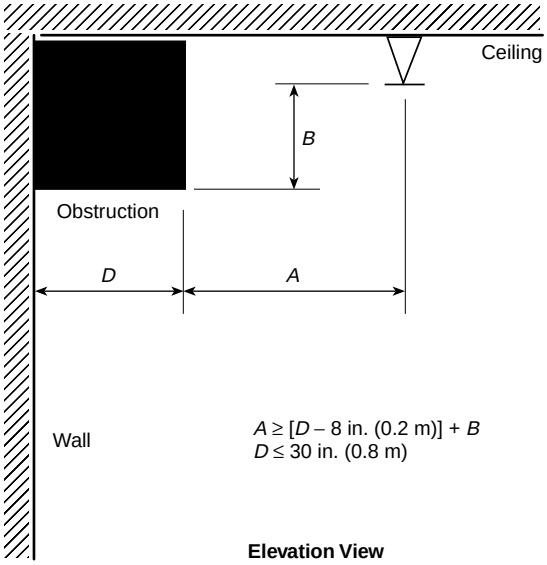


Figure 5-6.5.1.2(b) Obstructions against walls (SSU/SSP).



5-6.5.2 Obstructions to Sprinkler Discharge Pattern Development.

5-6.5.2.1* Continuous or noncontinuous obstructions less than or equal to 18 in. (457 mm) below the sprinkler deflector that prevent the pattern from fully developing shall comply with this section. Regardless of the rules of this section, solid continuous obstructions shall meet the requirements of 5-6.5.1.2.

5-6.5.2.2 Sprinklers shall be positioned such that they are located at a distance three times greater than the maximum dimension of an obstruction up to a maximum of 24 in. (609 mm) (e.g., structural members, pipe, columns, and fixtures). *(See Figure 5-6.5.2.2.)*

Exception No. 1: For light and ordinary hazard occupancies, structural members only shall be considered.

Exception No. 2: Sprinklers shall be permitted to be spaced on opposite sides of the obstruction provided the distance from the centerline of the obstruction to the sprinklers does not exceed one-half the allowable distance between sprinklers.

Exception No. 3: Where the obstruction consists of open trusses 20 in. (0.51 m) or greater apart [24 in. (0.61 m) on center], sprinklers shall be permitted to be located one-half the distance between the obstruction created by the truss provided that all truss members are not greater than 4 in. (102 mm) (nominal) in width.

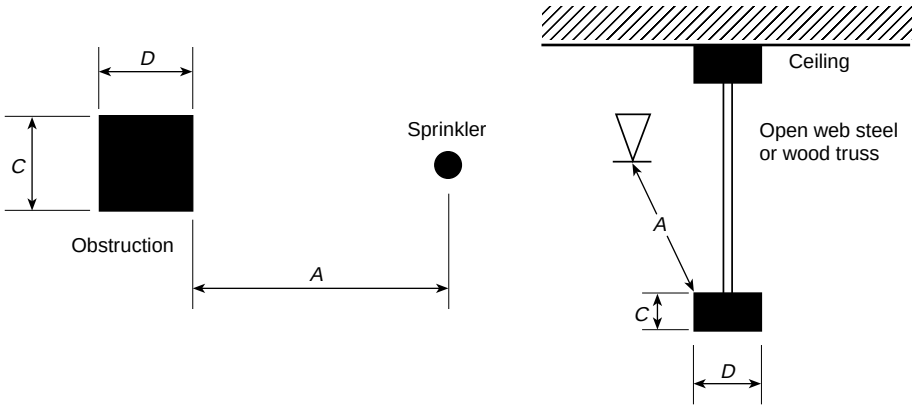
Exception No. 4: Sprinklers shall be permitted to be installed on the centerline of a truss, bar joist, or directly above a beam provided that the truss chord or beam dimension is not more than 8 in. (203 mm) and the sprinkler deflector is located at least 6 in. (152 mm) above the structural member. The sprinkler shall be positioned at a distance three times greater than the maximum dimension of the web members away from the web members.

Exception No. 5: Piping to which an upright sprinkler is directly attached less than 3 in. (76 mm) in diameter.

Exception No. 6: Piping to which pendent sprinklers are directly attached.

Exception No. 7: Sprinklers positioned with respect to obstructions in accordance with 5-6.5.1.2.

Figure 5-6.5.2.2 Minimum distance from obstruction (SSU/SSP).



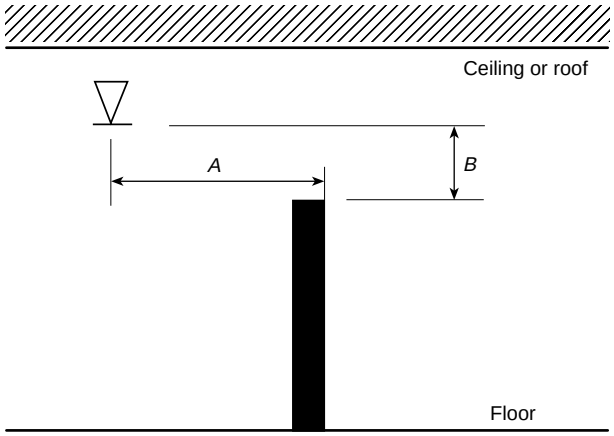
5-6.5.2.3* Suspended or Floor-Mounted Vertical Obstructions. The distance from sprinklers to privacy curtains, free standing partitions, room dividers, and similar obstructions in light hazard occupancies shall be in accordance with Table 5-6.5.2.3 and Figure 5-6.5.2.3.

Table 5-6.5.2.3 Suspended or Floor-Mounted Obstructions (SSU/SSP)

Horizontal Distance *(A)*	Minimum Vertical Distance below Deflector (in.) *(B)*
6 in. or less	3
More than 6 in. to 9 in.	4
More than 9 in. to 12 in.	6
More than 12 in. to 15 in.	8
More than 15 in. to 18 in.	$9^1/_2$
More than 18 in to 24 in.	$12^1/_2$
More than 24 in. to 30 in.	$15^1/_2$
More than 30 in.	18

For SI units, 1 in. = 25.4 mm.
Note: For *(A)* and *(B)*, refer to Figure 5-6.5.2.3.

Figure 5-6.5.2.3 Suspended or floor-mounted obstructions (SSU/SSP).



5-6.5.3* Obstructions that Prevent Sprinkler Discharge from Reaching the Hazard. Continuous or noncontinuous obstructions that interrupt the water discharge in a horizontal plane more than 18 in. (457 mm) below the sprinkler deflector in a manner to limit the distribution from reaching the protected hazard shall comply with this section.

Exception: The requirements of this section shall also apply to obstructions 18 in. or less below the sprinkler for light and ordinary hazard occupancies.

5-6.5.3.1 Sprinklers shall be installed under fixed obstructions over 4 ft (1.2 m) wide such as ducts, decks, open grate flooring, cutting tables, and overhead doors.

Exception: Obstructions that are not fixed in place, such as conference tables.

5-6.5.3.2 Sprinklers installed under open gratings shall be of the intermediate level/rack storage type or otherwise shielded from the discharge of overhead sprinklers.

5-6.6* Clearance to Storage (Standard Pendent and Upright Spray Sprinklers). The clearance between the deflector and the top of storage shall be 18 in. (457 mm) or greater.

Exception: Where other standards specify greater minimums, they shall be followed.

5-7 Sidewall Standard Spray Sprinklers.

5-7.1 General. All requirements of Section 5-5 shall apply to sidewall standard spray sprinklers except as modified below.

5-7.2 Protection Areas per Sprinkler (Standard Sidewall Spray Sprinklers).

5-7.2.1 Determination of the Protection Area of Coverage.

5-7.2.1.1 The protection area of coverage per sprinkler (A_s) shall be determined as follows:

(a) *Along the Wall.* Determine the distance between sprinklers along the wall (or to the end wall or obstruction in the case of the end sprinkler on the branch line) upstream and downstream. Choose the larger of either twice the distance to the end wall or the distance to the next sprinkler. This dimension will be defined as *S*.

(b) *Across the Room.* Determine the distance from the sprinkler to the wall opposite the sprinklers or to the midpoint of the room where sprinklers are installed on two opposite walls *(see 5-7.3.1)*. This dimension will be defined as *L*.

5-7.2.1.2 The protection area of the sprinkler shall be established by multiplying the *S* dimension by the *L* dimension, as follows: $A_s = S \times L$

5-7.2.2 Maximum Protection Area of Coverage. The maximum allowable protection area of coverage for a sprinkler (A_s) shall be in accordance with the value indicated in Table 5-7.2.2. In any case, the maximum area of coverage of a sprinkler shall not exceed 196 ft^2 (59.7 m^2).

5-7.3 Sprinkler Spacing (Standard Sidewall Spray Sprinklers).

5-7.3.1 Maximum Distance Between Sprinklers.

5-7.3.1.1 The maximum distance permitted between sprinklers shall be based on the centerline distance between sprinklers on the branch line. The maximum distance shall be measured along the slope of the ceiling.

5-7.3.1.2 Sidewall spray sprinklers shall be installed along the length of a single wall of rooms or bays in accordance with the maximum spacing provisions of Table 5-7.2.2.

Exception No. 1: Sidewall sprinklers shall not be installed back-to-back without being separated by a continuous lintel or soffit.

Exception No. 2: Where the width of the room or bay exceeds the maximum allowed, up to 24 ft (7.32 m) for light hazard occupancy or 20 ft (6.1 m) for ordinary hazard occupancy sidewall sprinklers shall be provided on two opposite walls or sides of bays with spacing as required by Table 5-7.2.2.

Exception No. 3: Sidewall sprinklers shall be permitted to be installed on opposing or adjacent walls provided no sprinkler is located within the maximum protection area of another sprinkler.

5-7.3.2 Maximum Distance from Walls. The distance from sprinklers to the end walls shall not exceed one-half of the allowable distance permitted between sprinklers as indicated in Table 5-7.2.2.

5-7.3.3 Minimum Distance from Walls. Sprinklers shall be located a minimum of 4 in. (102 mm) from an end wall. The distance from the wall to the sprinkler shall be measured perpendicular to the wall.

5-7.3.4 Minimum Distance Between Sprinklers. Sprinklers shall be spaced not less than 6 ft (1.8 m) on center.

5-7.4 Deflector Position from Ceilings and Walls (Standard Sidewall Spray Sprinklers).

5-7.4.1 Distance Below Ceilings and from Walls.

5-7.4.1.1 Sidewall sprinkler deflectors shall be located not more than 6 in. (152 mm) or less than 4 in. (102 mm) from ceilings.

Exception: Horizontal sidewall sprinklers shall be permitted to be located in a zone 6 in. to 12 in. (152 mm to 305 mm) or 12 in. to 18 in. (305 mm to 457 mm) below noncombustible and limited-combustible ceilings where listed for such use.

5-7.4.1.2 Sidewall sprinkler deflectors shall be located not more than 6 in. (152 mm) or less than 4 in. (102 mm) from walls to which they are mounted.

Exception: Horizontal sidewall sprinklers are permitted to be located with their deflectors less than 4 in. (102 mm) from the wall on which they are mounted.

5-7.4.1.3 Sidewall sprinklers shall only be installed along walls, lintels, or soffits where the distance from the ceiling to the bottom of the lintel or soffit is at least 2 in. (51 mm) greater than the distances from the ceiling to sidewall sprinkler deflectors.

5-7.4.1.4 Where soffits are used for the installation of sidewall sprinklers, they shall not exceed 8 in. (203 mm) in width or projection from the wall.

Exception: Soffits shall be permitted to exceed 8 in. (203 mm) where additional sprinklers are installed below the soffit.

5-7.4.2 Deflector Orientation.

5-7.4.2.1 Deflectors of sprinklers shall be aligned parallel to ceilings or roofs.

5-7.4.2.2 Sidewall sprinklers, where installed under a sloped ceiling, shall be located at the high point of the slope and positioned to discharge downward along the slope.

5-7.5 Obstructions to Sprinkler Discharge (Standard Sidewall Spray Sprinklers).

5-7.5.1 Performance Objective.

5-7.5.1.1 Sprinklers shall be located so as to minimize obstructions to discharge as defined in 5-5.5.2 and 5-5.5.3, or additional sprinklers shall be provided to ensure adequate coverage of the hazard.

Table 5-7.2.2 Protection Areas and Maximum Spacing (Standard Sidewall Spray Sprinkler)

	Light Hazard		Ordinary Hazard	
	Combustible Finish	Noncombustible or Limited-Combustible Finish	Combustible Finish	Noncombustible or Limited-Combustible Finish
Maximum distance along the wall *(S)*	14 ft	14 ft	10 ft	10 ft
Maximum room width *(L)*	12 ft	14 ft	10 ft	10 ft
Maximum protection area	120 ft^2	196 ft^2	80 ft^2	100 ft^2

For SI units, 1 ft = 0.3048 m; 1 ft^2 = 0.0929 m^2.

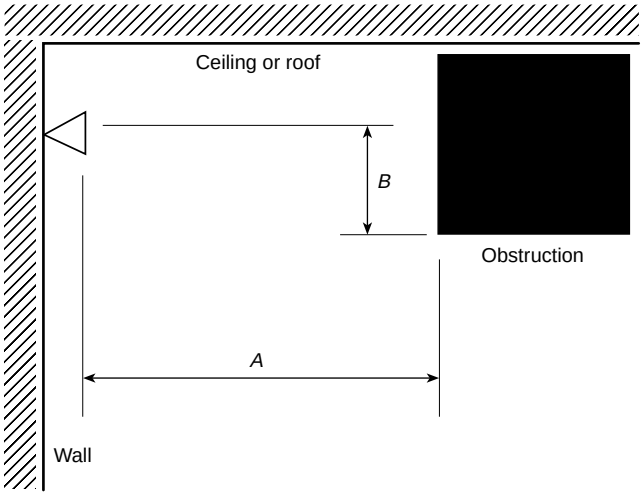
5-7.5.1.2 Sidewall sprinklers shall be installed no closer than 4 ft (1.2 m) from light fixtures or similar obstructions. The distance between light fixtures or similar obstructions located more than 4 ft (1.2 m) from the sprinkler shall be in conformity with Table 5-7.5.1.2 and Figure 5-7.5.1.2.

Table 5-7.5.1.2 Positioning of Sprinklers to Avoid Obstructions (Standard Sidewall Spray Sprinklers)

Distance from Sidewall Sprinkler to Side of Obstruction *(A)*	Maximum Allowable Distance of Deflector above Bottom of Obstruction (in.) *(B)*
Less than 4 ft	0
4 ft to less than 5 ft	1
5 ft to less than 5 ft 6 in.	2
5 ft 6 in. to less than 6 ft	3
6 ft to less than 6 ft 6 in.	4
6 ft 6 in. to less than 7 ft	6
7 ft to less than 7 ft 6 in.	7
7 ft 6 in. to less than 8 ft	9
8 ft to less than 8 ft 6 in.	11
8 ft 6 in. or greater	14

For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m.
Note: For *(A)* and *(B)*, refer to Figure 5-7.5.1.2.

Figure 5-7.5.1.2 Positioning of sprinklers to avoid obstructions (standard sidewall spray sprinklers).



Elevation View

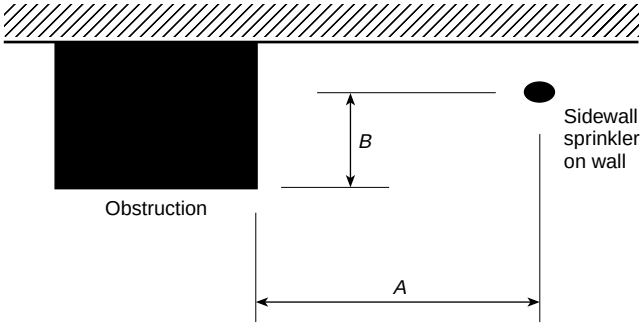
5-7.5.1.3 Obstructions projecting from the same wall as the one on which the sidewall sprinkler is mounted shall be in accordance with Table 5-7.5.1.3 and Figure 5-7.5.1.3.

Table 5-7.5.1.3 Positioning of Sprinklers to Avoid Obstructions Along the Wall (Standard Sidewall Spray Sprinklers)

Distance from Sidewall Sprinkler to Side of Obstruction *(A)*	Maximum Allowable Distance of Deflector above Bottom of Obstruction (in.) *(B)*
Less than 6 in.	1
6 in. to less than 1 ft	2
1 ft to less than 1 ft 6 in.	3
1 ft 6 in. to less than 2 ft	$4^1/_2$
2 ft to less than 2 ft 6 in.	$5^3/_4$
2 ft 6 in. to less than 3 ft	7
3 ft to less than 3 ft 6 in.	8
3 ft 6 in. to less than 4 ft	$9^1/_4$
4 ft to less than 4 ft 6 in.	10
4 ft 6 in. to less than 5 ft	$11^1/_2$
5 ft to less than 5 ft 6 in.	$12^3/_4$
5 ft 6 in. to less than 6 ft	14
6 ft to less than 6 ft 6 in.	15
6 ft 6 in. to less than 7 ft	$16^1/_4$
7 ft to less than 7 ft 6 in.	$17^1/_2$

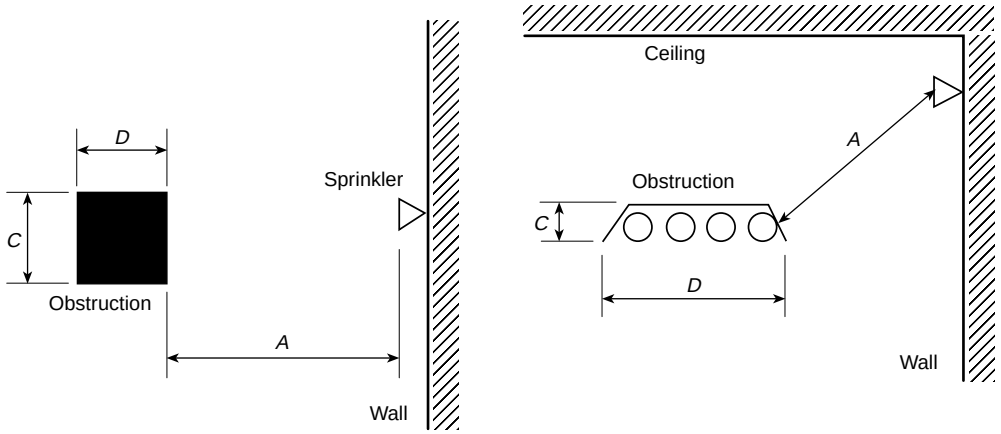
For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m.
Note: For *(A)* and *(B)*, refer to Figure 5-7.5.1.3.

Figure 5-7.5.1.3 Positioning of sprinklers to avoid obstructions along the wall (standard sidewall spray sprinklers).



Elevation View

Figure 5-7.5.2.2 Minimum distance from obstruction (standard sidewall spray sprinkler).



5-7.5.2 Obstructions to Sprinkler Discharge Pattern Development.

5-7.5.2.1* Continuous or noncontinuous obstructions less than or equal to 18 in. (457 mm) below the sprinkler deflector that prevent the pattern from fully developing shall comply with this section. Regardless of the rules of this section, solid continuous obstructions shall meet the requirements of 5-7.5.1.2.

5-7.5.2.2 Sprinklers shall be positioned such that they are located at a distance three times greater than the maximum dimension of an obstruction up to a maximum of 24 in. (609 mm) (e.g., truss webs and chords, pipe, columns, and fixtures). Sidewall sprinklers shall be positioned in accordance with Figure 5-7.5.2.2 where obstructions are present.

Exception No. 1: Piping to which sidewall sprinklers are directly attached.

Exception No. 2: Sprinklers positioned with respect to obstructions in accordance with 5-7.5.1.2 and 5-7.5.1.3.

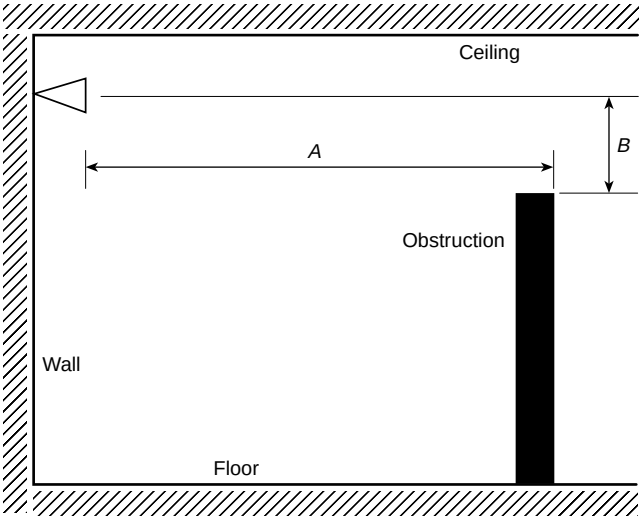
5-7.5.2.3 Suspended or Floor-Mounted Vertical Obstructions. The distance from sprinklers to privacy curtains, freestanding partitions, room dividers, and similar obstructions in light hazard occupancies shall be in accordance with Table 5-7.5.2.3 and Figure 5-7.5.2.3.

Table 5-7.5.2.3 Suspended or Floor-Mounted Obstructions (Standard Sidewall Spray Sprinklers)

Horizontal Distance *(A)*	Minimum Vertical Distance below Deflector (in.) *(B)*
6 in. or less	3
More than 6 in. to 9 in.	4
More than 9 in. to 12 in.	6
More than 12 in. to 15 in.	8
More than 15 in. to 18 in.	$9^1/_2$
More than 18 in. to 24 in.	$12^1/_2$
More than 24 in. to 30 in.	$15^1/_2$
More than 30 in.	18

For SI units, 1 in. = 25.4 mm.
Note: For *(A)* and *(B)*, refer to Figure 5-7.5.2.3.

Figure 5-7.5.2.3 Suspended or floor-mounted obstructions (standard sidewall spray sprinklers).



5-7.5.3* Obstructions that Prevent Sprinkler Discharge from Reaching the Hazard.

5-7.5.3.1 Continuous or noncontinuous obstructions that interrupt the water discharge in a horizontal plane more than 18 in. (457 mm) below the sprinkler deflector in a manner to limit the distribution from reaching the protected hazard shall comply with this section.

5-7.5.3.2 Sprinklers shall be installed under fixed obstructions over 4 ft (1.2 m) wide such as ducts, decks, open grate flooring cutting tables, and overhead doors.

Exception: Obstructions that are not fixed in place such as conference tables.

5-7.6 Clearance to Storage (Standard Sidewall Spray Sprinklers). The clearance between the deflector and the top of storage shall be 18 in. (457 mm) or greater.

5-8 Extended Coverage Upright and Pendent Spray Sprinklers.

5-8.1 General. All requirements of Section 5-5 shall apply to extended coverage upright and pendent sprinklers except as modified below.

5-8.2 Protection Areas per Sprinkler (Extended Coverage Upright and Pendent Spray Sprinklers).

5-8.2.1* Determination of the Protection Area of Coverage. The protection area of coverage *(A_s)* for extended coverage sprinklers shall be not less than that prescribed by the listing. Listing dimensions shall be even-numbered square protection areas as shown in Table 5-8.2.1.

5-8.2.2 Maximum Protection Area of Coverage. The maximum allowable area of coverage for a sprinkler *(A_s)* shall be in accordance with the value indicated in Table 5-8.2.1. In any case, the maximum area of coverage of a sprinkler shall not exceed 400 ft^2 (37.1 m^2).

5-8.3 Sprinkler Spacing (Extended Coverage Upright and Pendent Spray Sprinklers).

5-8.3.1 Maximum Distance Between Sprinklers. The maximum distance permitted between sprinklers shall be based on the centerline distance between sprinklers on the branch line or on adjacent branch lines. The maximum distance shall be measured along the slope of the ceiling. The maximum distance permitted between sprinklers shall comply with Table 5-8.2.1.

5-8.3.2 Maximum Distance from Walls. The distance from sprinklers to walls shall not exceed one-half of the allowable distance permitted between sprinklers as indicated in Table 5-8.2.1. The distance from the wall to the sprinkler shall be measured perpendicular to the wall. Where walls are angled or irregular, the maximum horizontal distance between a sprinkler and any point of floor area protected by that sprinkler shall not exceed 0.75 times the allowable distance permitted between sprinklers.

5-8.3.3 Minimum Distance from Walls. Sprinklers shall be located a minimum of 4 in. (102 mm) from a wall.

Exception: Where sprinklers have been listed for distances less than 4 in. (102 mm) from a wall, they shall be permitted.

5-8.3.4 Minimum Distance Between Sprinklers. Sprinklers shall be spaced not less than 8 ft (2.4 m) on center.

Exception: Sprinklers shall be permitted to be placed less than 8 ft (2.4 m) on center where the following conditions are satisfied:

(a) Baffles shall be installed and located midway between sprinklers and arranged to protect the actuating elements.

(b) Baffles shall be of noncombustible or limited-combustible material that will stay in place before and during sprinkler operation.

(c) Baffles shall be not less than 8 in. (203 mm) wide and 6 in. (152 mm) high. The tops of baffles shall extend between 2 in. and 3 in. (51 mm and 76 mm) above the deflectors of upright sprinklers. The bottoms of baffles shall extend downward to a level at least even with the deflectors of pendent sprinklers. (See A-5-13.4.)

Table 5-8.2.1 Protection Areas and Maximum Spacing (Extended Coverage Upright and Pendent Spray Sprinklers)

	Light Hazard		Ordinary Hazard		Extra Hazard		High-Pile Storage	
Construction Type	Protection Area (ft^2)	Spacing (ft)	Protection Area (ft^2)	Spacing (ft)	Protection Area (ft^2)	Spacing (ft)	Protection Area (ft^2)	Spacing (ft)
Unobstructed	400	20	400	20	—	—	—	—
	324	18	324	18	—	—	—	—
	256	16	256	16	—	—	—	—
	—	—	196	14	196	14	196	14
	—	—	144	12	144	12	144	12
Obstructed noncombustible (when specifically listed for such use)	400	20	400	20	—	—	—	—
	324	18	324	18	—	—	—	—
	256	16	256	16	—	—	—	—
	—	—	196	14	196	14	196	14
	—	—	144	12	144	12	144	12
Obstructed combustible	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

For SI units, 1 ft = 0.3048 m; 1 ft^2 = 0.0929 m^2.

5-8.4 Deflector Position (Extended Coverage Upright and Pendent Spray Sprinklers).

5-8.4.1 Distance Below Ceilings.

5-8.4.1.1 Under unobstructed construction, the distance between the sprinkler deflector and the ceiling shall be a minimum of 1 in. (25.4 mm) and a maximum of 12 in. (305 mm).

Exception No. 1: Ceiling-type sprinklers (concealed, recessed, and flush types) shall be permitted to have the operating element above the ceiling and the deflector located nearer to the ceiling where installed in accordance with their listing.

Exception No. 2: Where sprinklers are listed for use under other ceiling construction features or for different distances, they shall be permitted to be installed in accordance with their listing.

5-8.4.1.2 Under obstructed construction, the sprinkler deflector shall be located 1 in. to 6 in. (25.4 mm to 152 mm) below the structural members and a maximum distance of 22 in. (559 mm) below the ceiling/roof deck.

Exception No. 1: Sprinklers shall be permitted to be installed with the deflector at or above the bottom of the structural member to a maximum of 22 in. (559 mm) below the ceiling/roof deck where the sprinkler is installed in conformance with 5-6.5.1.2.

Exception No. 2: Where sprinklers are installed in each bay of obstructed construction, deflectors shall be a minimum of 1 in. (25.4 mm) and a maximum of 12 in. (305 mm) below the ceiling.

Exception No. 3: Where sprinklers are listed for use under other ceiling construction features or for different distances, they shall be permitted to be installed in accordance with their listing.

5-8.4.1.3* Sprinklers under or near the peak of a roof or ceiling shall have deflectors located not more than 3 ft (0.9 m) vertically down from the peak. *[See Figures 5-6.4.1.3(a) and 5-6.4.1.3(b).]*

5-8.4.2 Deflector Orientation. Deflectors of sprinklers shall be aligned parallel to ceilings or roofs.

5-8.5 Obstructions to Sprinkler Discharge (Extended Coverage Upright and Pendent Spray Sprinklers).

5-8.5.1 Performance Objective.

5-8.5.1.1 Sprinklers shall be located so as to minimize obstructions to discharge as defined in 5-8.5.2 and 5-8.5.3, or additional sprinklers shall be provided to ensure adequate coverage of the hazard.

5-8.5.1.2 Sprinklers shall be arranged to comply with 5-5.5.2, Table 5-8.5.1.2, and Figure 5-8.5.1.2(a).

Exception No. 1: Sprinklers shall be permitted to be spaced on opposite sides of obstructions not exceeding 4 ft (1.2 m) in width provided the distance from the centerline of the obstruction to the sprinklers does not exceed one-half the allowable distance permitted between sprinklers.

Exception No. 2: Obstructions located against the wall and that are not over 30 in. (762 mm) in width shall be permitted to be protected in accordance with Figure 5-8.5.1.2(b).

Table 5-8.5.1.2 Position of Sprinklers to Avoid Obstructions to Discharge (Extended Coverage Upright and Pendent Spray Sprinklers)

Distance from Sprinklers to Side of Obstruction *(A)*	Maximum Allowable Distance of Deflector above Bottom of Obstruction (in.) *(B)*
Less than 1 ft	0
1 ft to less than 1 ft 6 in.	0
1 ft 6 in. to less than 2 ft	1
2 ft to less than 2 ft 6 in.	1
2 ft 6 in. to less than 3 ft	1
3 ft to less than 3 ft 6 in.	3
3 ft 6 in. to less than 4 ft	3
4 ft to less than 4 ft 6 in.	5
4 ft 6 in. to less than 5 ft	7
5 ft to less than 5 ft 6 in.	7
5 ft 6 in. to less than 6 ft	7
6 ft to less than 6 ft 6 in.	9
6 ft 6 in. to less than 7 ft	11
7 ft and greater	14

For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m.
Note: For *(A)* and *(B)*, refer to Figure 5-8.5.1.2(a).

Figure 5-8.5.1.2(a) Position of sprinklers to avoid obstructions to discharge (extended coverage upright and pendent spray sprinklers).

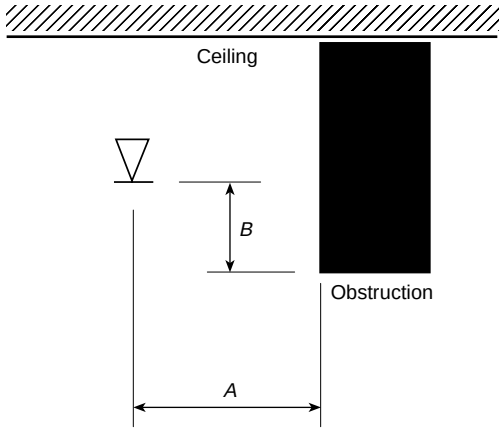
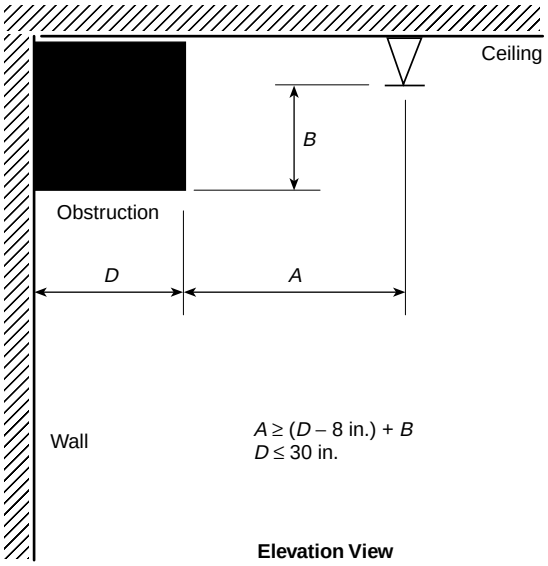


Figure 5-8.5.1.2(b) Obstructions against walls (extended coverage upright and pendent spray sprinklers).



5-8.5.2 Obstructions to Sprinkler Discharge Pattern Development.

5-8.5.2.1* Continuous or noncontinuous obstructions less than or equal to 18 in. (457 mm) below the sprinkler deflector that prevent the pattern from fully developing shall comply with 5-8.5.2. Regardless of the rules of this section, solid continuous obstructions shall meet the requirements of 5-8.5.1.2.

5-8.5.2.2 Sprinklers shall be positioned such that they are located at a distance four times greater than the maximum dimension of an obstruction up to a maximum of 36 in. (.91 m) (e.g., truss webs and chords, pipe, columns, and fixtures). *(See Figure 5-8.5.2.2.)*

Exception No. 1: Sprinklers shall be permitted to be spaced on opposite sides of the obstruction provided the distance from the centerline of the obstruction to the sprinklers does not exceed one-half the allowable distance between sprinklers.

Exception No. 2: Where the obstruction consists of open trusses 20 in. (0.51 m) or greater apart [24 in. (0.61 m) on center], sprinklers shall be permitted to be located one-half the distance between the obstruction created by the truss provided that truss chords do not exceed 4 in. (101 mm) in width and web members do not exceed 1 in. (25.4 mm) in width.

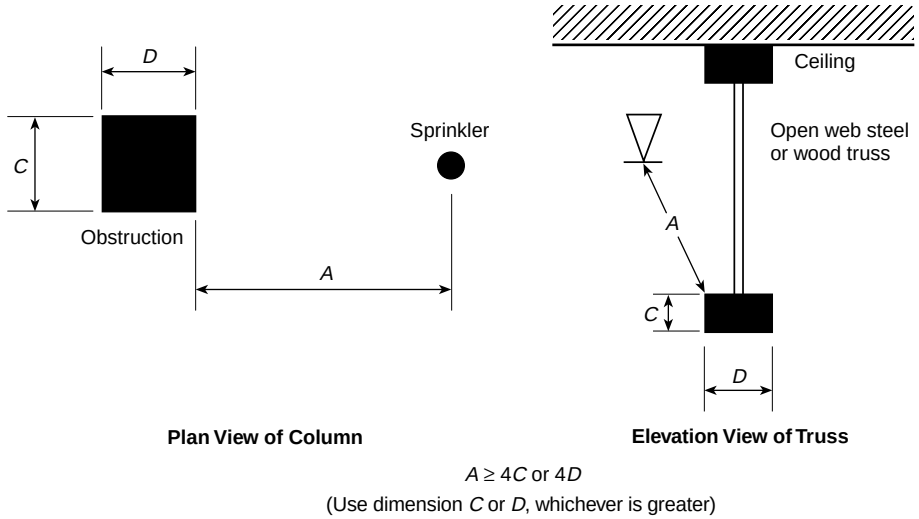
Exception No. 3: Sprinklers shall be permitted to be installed on the centerline of a truss or bar joist or directly above a beam provided that the truss chord or beam dimension is not more than 8 in. (203 mm) and the sprinkler deflector is located at least 6 in. (152 mm) above the structural member. The sprinkler shall be positioned at a distance four times greater than the maximum dimension of the web members away from the web members.

Exception No. 4: Piping to which an upright sprinkler is directly attached less than 3 in. (75 mm) in diameter.

Exception No. 5: Piping to which pendent and sidewall sprinklers are directly attached.

Exception No. 6: Sprinklers positioned with respect to obstructions in accordance with 5-8.5.1.2.

Figure 5-8.5.2.2 Minimum distance from obstruction (extended coverage upright and pendent spray sprinklers).



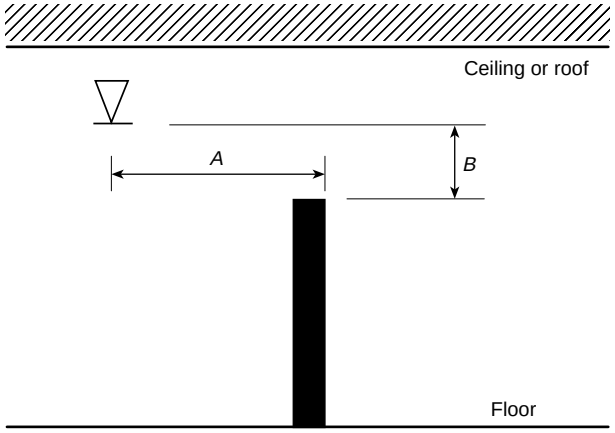
5-8.5.2.3 Suspended or Floor-Mounted Vertical Obstructions. The distance from sprinklers to privacy curtains, freestanding partitions, room dividers, and similar obstructions in light hazard occupancies shall be in accordance with Table 5-8.5.2.3 and Figure 5-8.5.2.3.

Table 5-8.5.2.3 Suspended or Floor-Mounted Obstructions (Extended Coverage Upright and Pendent Spray Sprinklers)

Horizontal Distance *(A)*	Minimum Vertical Distance below Deflector (in.) *(B)*
6 in. or less	3
More than 6 in. to 9 in.	4
More than 9 in. to 12 in.	6
More than 12 in. to 15 in.	8
More than 15 in. to 18 in.	$9^1/_2$
More than 18 in. to 24 in.	$12^1/_2$
More than 24 in. to 30 in.	$15^1/_2$
More than 30 in.	18

For SI units, 1 in. = 25.4 mm.
Note: For *(A)* and *(B)*, refer to Figure 5-8.5.2.3.

Figure 5-8.5.2.3 Suspended or floor-mounted obstructions (extended coverage upright and pendent spray sprinklers).



Elevation View

5-8.5.3* Obstructions that Prevent Sprinkler Discharge from Reaching the Hazard. Continuous or noncontinuous obstructions that interrupt the water discharge in a horizontal plane more than 18 in. (457 mm) below the sprinkler deflector in a manner to limit the distribution from reaching the protected hazard shall comply with 5-8.5.3.

5-8.5.3.1 Sprinklers shall be installed under fixed obstructions over 4 ft (1.2 m) wide such as ducts, decks, open grate flooring, cutting tables, and overhead doors.

Exception: Obstructions that are not fixed in place such as conference tables.

5-8.5.3.2 Sprinklers installed under open gratings shall be of the intermediate level/rack storage type or otherwise shielded from the discharge of overhead sprinklers.

5-8.6 Clearance to Storage (Extended Coverage Upright and Pendent Spray Sprinklers). The clearance between the deflector and the top of storage shall be 18 in. (457 mm) or greater.

Exception: Where other standards specify greater minimums, they shall be followed.

5-9 Extended Coverage Sidewall Spray Sprinklers.

5-9.1 General. All requirements of Section 5-5 shall apply to extended coverage sidewall spray sprinklers except as modified below.

5-9.2 Protection Areas per Sprinkler (Extended Coverage Sidewall Spray Sprinklers).

5-9.2.1* Determination of the Protection Area of Coverage. The protection area of coverage per sprinkler (A_s) for extended coverage sidewall sprinklers shall be not less than that prescribed by the listing. Listing dimensions shall be in 2-ft (0.61-m) increments up to 28 ft (8.5 m).

5-9.2.2 Maximum Protection Area of Coverage. The maximum allowable protection area of coverage for a sprinkler (A_s) shall be in accordance with the value indicated in Table 5-9.2.2. In any case, the maximum area of coverage of a sprinkler shall not exceed 400 ft^2 (37.1 m^2).

5-9.3 Sprinkler Spacing (Extended Coverage Sidewall Spray Sprinklers).

5-9.3.1 Maximum Distance Between Sprinklers.

5-9.3.1.1 The maximum distance permitted between sprinklers shall be based on the centerline distance between sprinklers on the branch line along the wall.

Table 5-9.2.2 Protection Area and Maximum Spacing for Extended Coverage Sidewall Sprinklers

	Light Hazard				Ordinary Hazard			
	Protection Area		Spacing		Protection Area		Spacing	
Construction Type	ft^2	m^2	ft	m	ft^2	m^2	ft	m
Unobstructed, smooth, flat	400	37.2	28	8.5	400	37.2	24	7.3

5-9.3.1.2 Sidewall spray sprinklers shall be installed along the length of a single wall of a room.

Exception No. 1: Sidewall sprinklers shall not be installed back-to-back without being separated by a continuous lintel soffit or baffle.

Exception No. 2: Sidewall sprinklers shall be permitted to be installed on opposing or adjacent walls provided no sprinkler is located within the maximum protection area of another sprinkler.

5-9.3.2 Maximum Distance from Walls. The distance from sprinklers to the end walls shall not exceed one-half of the allowable distance permitted between sprinklers as indicated in Table 5-9.2.2.

5-9.3.3 Minimum Distance from Walls. Sprinklers shall be located a minimum of 4 in. (102 mm) from an end wall. The distance from the wall to the sprinkler shall be measured perpendicular to the wall.

5-9.3.4 Minimum Distance Between Sprinklers. No sprinklers shall be located within the maximum protection area of any other sprinkler.

5-9.4 Deflector Position from Ceilings and Walls (Extended Coverage Sidewall Spray Sprinklers).

5-9.4.1 Distance Below Ceilings and from Walls to Which Sprinklers are Mounted.

5-9.4.1.1 Sidewall sprinkler deflectors shall be located not more than 6 in. (152 mm) nor less than 4 in. (102 mm) from ceilings.

Exception: Horizontal sidewall sprinklers are permitted to be located in a zone 6 in. to 12 in. (152 mm to 305 mm) or 12 in. to 18 in. (305 mm to 457 mm) below noncombustible or limited-combustible ceilings where listed for such use.

5-9.4.1.2 Sidewall sprinkler deflectors shall be located not more than 6 in. (229 mm) or less than 4 in. (102 mm) from walls on which they are mounted.

Exception: Horizontal sidewall sprinklers shall be permitted to be located with their deflectors less than 4 in. (102 mm) from the wall on which they are mounted.

5-9.4.1.3 Sidewall sprinklers shall only be installed along walls, lintels, or soffits where the distance from the ceiling to the bottom of the lintel or soffit is at least 2 in. (51 mm) greater than the distances from the ceiling to sidewall sprinkler deflectors.

5-9.4.1.4 Where soffits are used for the installation of sidewall sprinklers, they shall not exceed 8 in. (203 mm) in width or projection from the wall.

Exception: Soffits shall be permitted to exceed 8 in. (203 mm) where additional sprinklers are installed below the soffit.

5-9.4.2 Deflector Orientation. Deflectors of sprinklers shall be aligned parallel to ceilings or roofs.

5-9.4.2.1 Sidewall sprinklers, where installed under a sloped ceiling, shall be located at the high point of the slope and positioned to discharge downward along the slope.

Exception: Unless specifically listed for other ceiling configurations.

5-9.5 Obstructions to Sprinkler Discharge (Extended Coverage Sidewall Spray Sprinklers).

5-9.5.1 Performance Objective.

5-9.5.1.1 Sprinklers shall be located so as to minimize obstructions to discharge as defined in 5-5.5.2 and 5-5.5.3, or additional sprinklers shall be provided to ensure adequate coverage of the hazard.

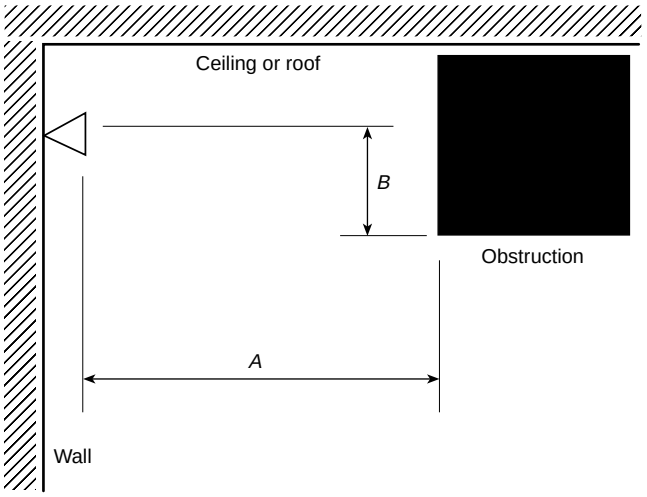
5-9.5.1.2 Sidewall sprinklers shall be installed no closer than 8 ft (2.4 m) from light fixtures or similar obstructions. The distance between light fixtures or similar obstructions located more than 8 ft (2.4 m) from the sprinkler shall be in conformity with Table 5-9.5.1.2 and Figure 5-9.5.1.2.

Table 5-9.5.1.2 Positioning of Sprinklers to Avoid Obstructions (Extended Coverage Sidewall Sprinklers)

Distance from Sidewall Sprinkler to Side of Obstruction *(A)*	Maximum Allowable Distance of Deflector above Bottom of Obstruction (in.) *(B)*
8 ft to less than 10 ft	1
10 ft to less than 11 ft	2
11 ft to less than 12 ft	3
12 ft to less than 13 ft	4
13 ft to less than 14 ft	6
14 ft to less than 15 ft	7
15 ft to less than 16 ft	9
16 ft to less than 17 ft	11
17 ft or greater	14

For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m.
Note: For *(A)* and *(B)*, refer to Figure 5-9.5.1.2.

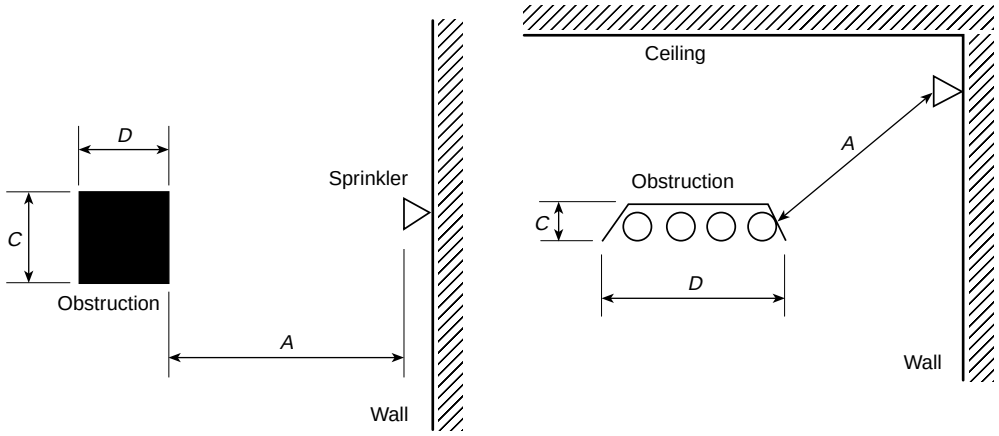
Figure 5-9.5.1.2 Positioning of sprinklers to avoid obstructions (extended coverage sidewall sprinklers).



5-9.5.2 Obstructions to Sprinkler Discharge Pattern Development.

5-9.5.2.1* Continuous or noncontinuous obstructions less than or equal to 18 in. (457 mm) below the sprinkler deflector that prevent the pattern from fully developing shall comply with 5-9.5.2. Regardless of the rules of this section, solid continuous obstructions shall meet the requirements of 5-9.5.1.2.

Figure 5-9.5.2.2 Minimum distance from obstruction (extended coverage sidewall).



$A \geq 4C$ or $4D$
$A \leq 36$ in.
(Use dimension C or D, whichever is greater)

5-9.5.2.2 Sprinklers shall be positioned such that they are located at a distance four times greater than the maximum dimension of the obstruction to a maximum of 36 in. (0.91 m) from the sprinkler (e.g., truss webs and chords, pipe, columns, and fixtures). Sidewall sprinklers shall be positioned in accordance with Figure 5-9.5.2.2 when obstructions are present.

Exception: Sprinklers positioned with respect to obstructions in accordance with 5-9.5.1.2.

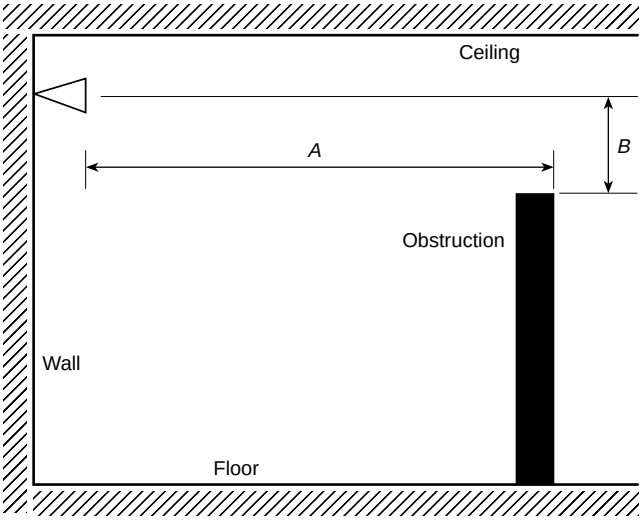
5-9.5.2.3 Suspended or Floor-Mounted Vertical Obstructions. The distance from sprinklers to privacy curtains, freestanding partitions, room dividers, and similar obstructions in light hazard occupancies shall be in accordance with Table 5-9.5.2.3 and Figure 5-9.5.2.3.

Table 5-9.5.2.3 Suspended or Floor-Mounted Obstructions (Extended Coverage Sidewall Sprinklers)

Horizontal Distance *(A)*	Minimum Allowable Distance below Deflector (in.) *(B)*
6 in. or less	3
More than 6 in. to 9 in.	4
More than 9 in. to 12 in.	6
More than 12 in. to 15 in.	8
More than 15 in. to 18 in.	$9^1/_2$
More than 18 in. to 24 in.	$12^1/_2$
More than 24 in. to 30 in.	$15^1/_2$
More than 30 in.	18

For SI units, 1 in. = 25.4 mm.
Note: For *(A)* and *(B)*, refer to Figure 5-9.5.2.3.

Figure 5-9.5.2.3 Suspended or floor-mounted obstructions (extended coverage sidewall sprinklers).



5-9.5.3* Obstructions that Prevent Sprinkler Discharge from Reaching the Hazard. Continuous or noncontinuous obstructions that interrupt the water discharge in a horizontal plane more than 18 in. (457 mm) below the sprinkler deflector in a manner to limit the distribution from reaching the protected hazard shall comply with 5-9.5.3.

5-9.5.3.1 Sprinklers shall be installed under fixed obstructions over 4 ft (1.2 m) wide such as ducts, decks, open grate flooring, cutting tables, and overhead doors.

Exception: Obstructions that are not fixed in place such as conference tables.

5-10 Large Drop Sprinklers.

5-10.1 General. All requirements of Section 5-5 shall apply to large drop sprinklers except as modified below.

5-10.2* Protection Areas per Sprinkler (Large Drop Sprinklers).

5-10.2.1 Determination of the Protection Area of Coverage. The protection area of coverage per sprinkler *(A_s)* shall be determined in accordance with 5-5.2.1.

5-10.2.2 Maximum Protection Area of Coverage. The maximum allowable protection area of coverage for a sprinkler *(A_s)* shall be in accordance with the value indicated in Table 5-10.2.2. In any case, the maximum area of coverage of any sprinkler shall not exceed 130 ft^2 (12.9 m^2).

Table 5-10.2.2 Protection Areas and Maximum Spacing for Large Drop Sprinklers

Construction Type	Protection Area		Maximum Spacing	
	ft^2	m^2	ft	m
Noncombustible unobstructed	130	12.1	12	3.7
Noncombustible obstructed	130	12.1	12	3.7
Combustible unobstructed	130	12.1	12	3.7
Combustible obstructed	100	9.3	10	3.1
Rack storage applications	100	9.3	10	3.1

5-10.2.3 Minimum Protection Area of Coverage. The minimum allowable protection area of coverage for a sprinkler *(A_s)* shall be not less than 80 ft^2 (7.4 m^2).

5-10.3 Sprinkler Spacing (Large Drop Sprinklers).

5-10.3.1* Maximum Distance Between Sprinklers. The distance between sprinklers shall be limited to not more than 12 ft (3.7 m) between sprinklers, as shown in Table 5-10.2.2.

Exception: Under obstructed combustible construction, the maximum distance shall be limited to 10 ft (3 m).

5-10.3.2 Maximum Distance from Walls. The distance from sprinklers to walls shall not exceed one-half of the allowable distance permitted between sprinklers as indicated in Table 5-10.2.2.

5-10.3.3 Minimum Distance from Walls. Sprinklers shall be located a minimum of 4 in. (102 mm) from a wall.

5-10.3.4 Minimum Distance Between Sprinklers. Sprinklers shall be spaced not less than 8 ft (2.4 m) on center.

5-10.4 Deflector Position (Large Drop Sprinklers).

5-10.4.1* Distance Below Ceilings.

5-10.4.1.1 Under unobstructed construction, the distance between the sprinkler deflector and the ceiling shall be a minimum of 6 in. (152 mm) and a maximum of 8 in. (203 mm).

5-10.4.1.2 Under obstructed construction, the distance between the sprinkler deflector and the ceiling shall be a minimum of 6 in. (152 mm) and a maximum of 12 in. (305 mm).

Exception No. 1: Under wood joist or composite wood joist construction, the sprinklers shall be located 1 in. to 6 in. (25.4 mm to 152 mm) below the structural members to a maximum distance of 22 in. (559 mm) below the ceiling/roof or deck.

Exception No. 2: Deflectors of sprinklers under concrete tee construction with stems spaces less than $7^1/_2$ ft (2.3 m) but more than 3 ft (0.9 m) on centers shall, regardless of the depth of the tee, be permitted to be located at or above a horizontal plane 1 in. (25.4 mm) below the bottom of the stems of the tees and shall comply with Table 5-10.5.1.2.

5-10.4.2 Deflector Orientation. Deflectors of sprinklers shall be aligned parallel to ceilings or roofs.

5-10.5* Obstructions to Sprinkler Discharge (Large Drop Sprinklers).

5-10.5.1 Performance Objective.

5-10.5.1.1 Sprinklers shall be located so as to minimize obstructions to discharge as defined in 5-5.5.2 and 5-5.5.3, or additional sprinklers shall be provided to ensure adequate coverage of the hazard.

5-10.5.1.2 Sprinklers shall be arranged to comply with 5-5.5.2, Table 5-10.5.1.2, and Figure 5-10.5.1.2.

Exception: Where positioned on opposite sides of the obstruction.

Table 5-10.5.1.2 Positioning of Sprinklers to Avoid Obstructions to Discharge (Large Drop Sprinkler)

Distance from Sprinkler to Side of Obstruction *(A)*	Maximum Allowable Distance of Deflector above Bottom of Obstruction (in.) *(B)*
Less than 1 ft	0
1 ft to less than 1 ft 6 in.	$1^1/_2$
1 ft 6 in. to less than 2 ft	3
2 ft to less than 2 ft 6 in.	$5^1/_2$
2 ft 6 in. to less than 3 ft	8
3 ft to less than 3 ft 6 in.	10
3 ft 6 in. to less than 4 ft	12
4 ft to less than 4 ft 6 in.	15
4 ft 6 in. to less than 5 ft	18
5 ft to less than 5 ft 6 in.	22
5 ft 6 in. to less than 6 ft	26
6 ft	31

For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m.
Note: For *(A)* and *(B)*, refer to Figure 5-10.5.1.2.

Figure 5-10.5.1.2 Positioning of sprinklers to avoid obstructions to discharge (large drop sprinkler).

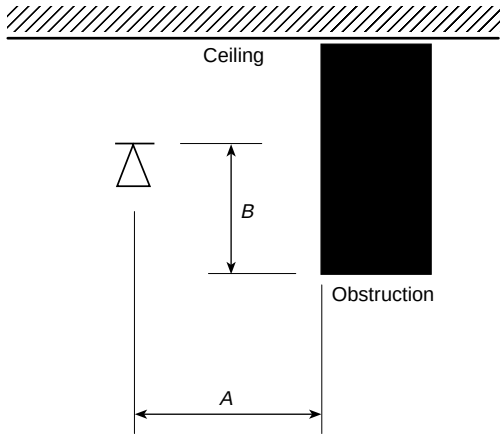
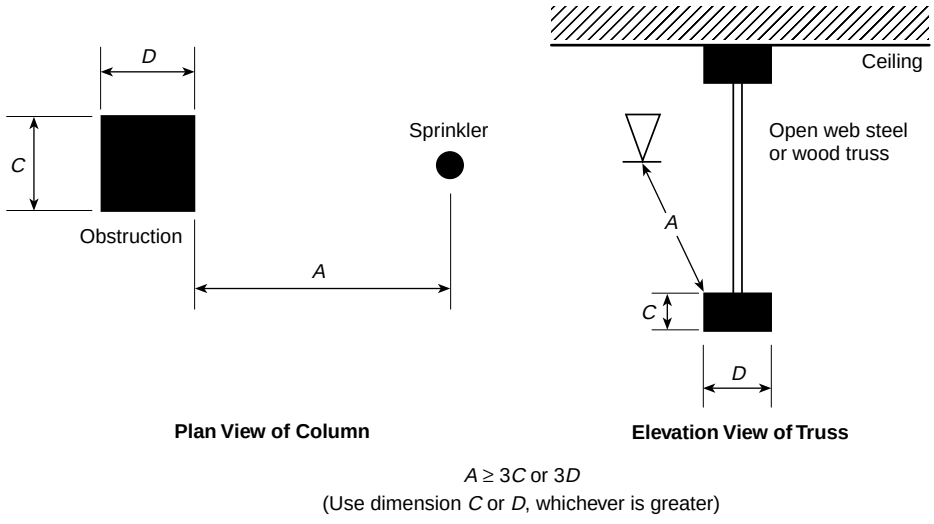


Figure 5-10.5.2.2 Minimum distance from obstruction (large drop sprinkler).



5-10.5.2 Obstructions to Sprinkler Discharge Pattern Development.

5-10.5.2.1* Continuous or noncontinuous obstructions less than or equal to 36 in. (914 mm) below the sprinkler deflector that prevent the pattern from fully developing shall comply with 5-10.5.2. Regardless of the rules of this section, solid continuous obstructions shall meet the requirements of 5-10.5.1.2.

5-10.5.2.2 For obstructions 8 in. (203 mm) or less in width, sprinklers shall be positioned such that they are located at least a distance three times greater than the maximum dimension of the obstruction from the sprinkler (e.g., webs and chord members, pipe, columns, and fixtures). Sprinklers shall be positioned in accordance with Figure 5-10.5.2.2 where obstructions are present.

Exception: Sprinklers positioned with respect to obstructions in accordance with 5-10.5.1.2.

5-10.5.2.3 Where branch lines are larger than 2 in. (51 mm), the sprinkler shall be supplied by a riser nipple to elevate the sprinkler 13 in. (330 mm) for $2^1/_2$ in. (64-mm) pipe and 15 in. (380 mm) for 3-in. (76-mm) pipe. These dimensions shall be measured from the centerline of the pipe to the deflector.

Exception No. 1: This provision shall not apply where the sprinklers are offset horizontally a minimum of 12 in. (305 mm) from the pipe.

Exception No. 2: Piping to which the sprinkler is directly attached less than 2 in. (51 mm) in diameter.

5-10.5.3* Obstructions that Prevent Sprinkler Discharge from Reaching the Hazard. Continuous or noncontinuous obstructions that interrupt the water discharge in a horizontal plane below the sprinkler deflector in a manner to limit the distribution from reaching the protected hazard shall comply with 5-10.5.3.

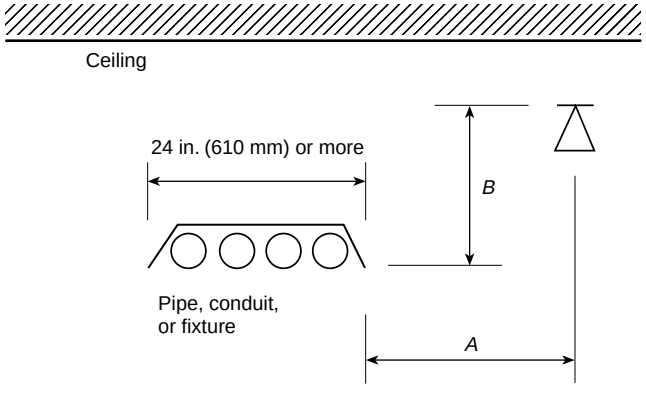
5-10.5.3.1 Sprinklers shall be positioned with respect to fluorescent lighting fixtures, ducts, and obstructions more than 24 in. (610 mm) wide and located entirely below the sprinklers so that the minimum horizontal distance from the near side of the obstruction to the center of the sprinkler is not less than the value specified in Table 5-10.5.3.1. *(See Figure 5-10.5.3.1.)*

Table 5-10.5.3.1 Obstruction Entirely Below the Sprinkler (Large Drop Sprinkler)

Distance of Deflector above Bottom of Obstruction *(B)*	Minimum Distance to Side of Obstruction (ft) *(A)*
Less than 6 in.	$1^1/_2$
6 in. to less than 12 in.	3
12 in. to less than 18 in.	4
18 in. to less than 24 in.	5
24 in. to less than 30 in.	$5^1/_2$
30 in. less than 36 in.	6

For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m.
Note: For *(A)* and *(B)*, refer to Figure 5-10.5.3.1.

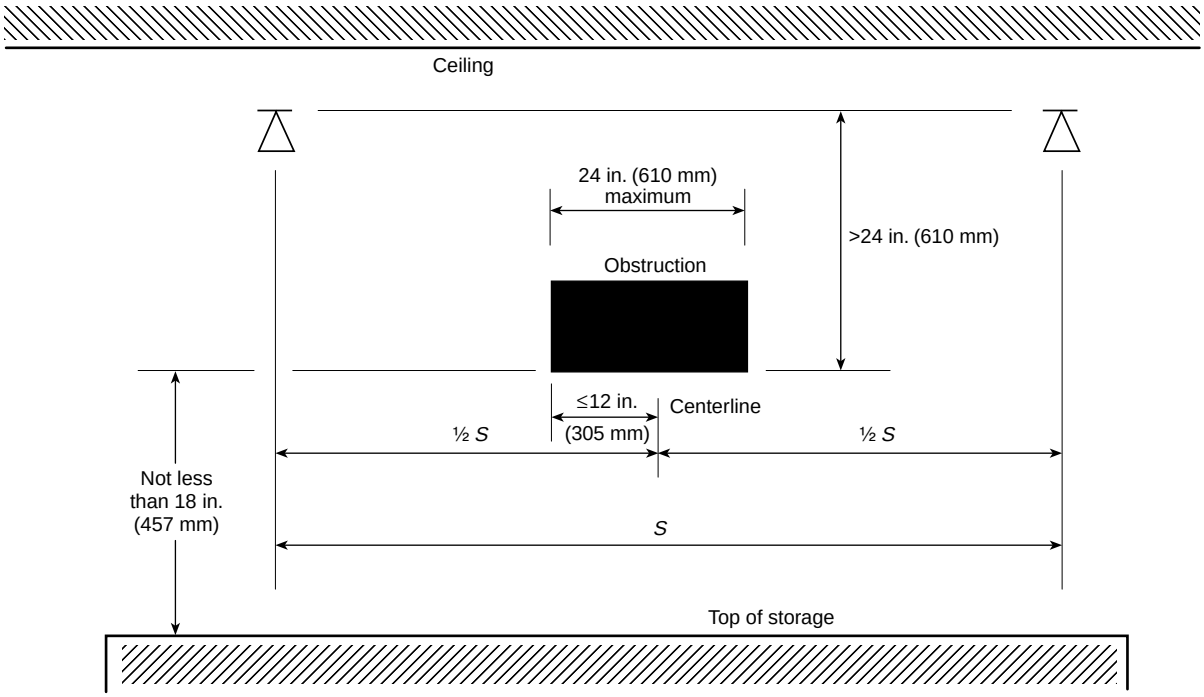
Figure 5-10.5.3.1 Obstruction entirely below the sprinkler (large drop sprinkler).



5-10.5.3.2 Sprinklers installed under open gratings shall be shielded from the discharge of overhead sprinklers.

5-10.5.3.3 Where the bottom of the obstruction is located 24 in. (610 mm) or more below the sprinkler deflectors, the following shall occur:

Figure 5-10.5.3.3 Obstruction more than 24 in. (610 mm) below the sprinkler (large drop sprinkler).



(1) Sprinklers shall be positioned so that the obstruction is centered between adjacent sprinklers. *(See Figure 5-10.5.3.3.)*

(2) The obstruction shall be limited to a maximum width of 24 in. (610 mm). *(See Figure 5-10.5.3.3.)*

Exception: Where the obstruction is greater than 24 in. (610 mm) wide, one or more lines of sprinklers shall be installed below the obstruction.

(3) The obstruction shall not extend more than 12 in. (305 mm) to either side of the midpoint between sprinklers. *(See Figure 5-10.5.3.3.)*

Exception: Where the extensions of the obstruction exceed 12 in. (305 mm), one or more lines of sprinklers shall be installed below the obstruction.

(4) At least 18 in. (457 mm) clearance shall be maintained between the top of storage and the bottom of the obstruction. *(See Figure 5-10.5.3.3.)*

5-10.5.3.4 In the special case of an obstruction running parallel to and directly below a branch line, the following shall occur:

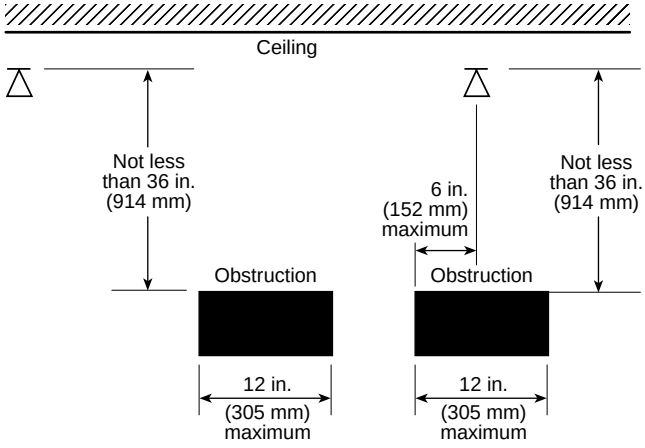
(1) The sprinkler shall be located at least 36 in. (914 mm) above the top of the obstruction. *(See Figure 5-10.5.3.4.)*

(2) The obstruction shall be limited to a maximum width of 12 in. (305 mm). *(See Figure 5-10.5.3.4.)*

(3) The obstruction shall be limited to a maximum extension of 6 in. (152 mm) to either side of the centerline of the branch line. *(See Figure 5-10.5.3.4.)*

5-10.6 Clearance to Storage (Large Drop Sprinklers). The clearance between the deflector and the top of storage shall be 36 in. (914 mm) or greater.

Figure 5-10.5.3.4 Obstruction more than 36 in. (914 mm) below the sprinkler (large drop sprinkler).



5-11 Early Suppression Fast-Response Sprinklers.

5-11.1 General. All requirements of Section 5-5 shall apply except as modified below.

5-11.2 Protection Areas per Sprinkler (Early Suppression Fast-Response Sprinklers).

5-11.2.1 Determination of the Protection Area of Coverage. The protection area of coverage per sprinkler (A_s) shall be determined in accordance with 5-5.2.1.

Table 5-11.2.2 Protection Areas and Maximum Spacing of ESFR Sprinklers

	Ceiling/Roof Heights Up To 30 ft (9.1 m)				Ceiling/Roof Heights Over 30 ft (9.1 m)			
	Protection Area		Spacing		Protection Area		Spacing	
Construction Type	ft^2	m	ft	m	ft^2	m	ft	m
Noncombustible unobstructed	100	9.3	12	3.7	100	9.3	10	3.1
Noncombustible obstructed	100	9.3	12	3.7	100	9.3	10	3.1
Combustible unobstructed	100	9.3	12	3.7	100	9.3	10	3.1
Combustible obstructed	N/A		N/A		N/A		N/A	

5-11.2.2 Maximum Protection Area of Coverage. The maximum allowable protection area of coverage for a sprinkler *(A_s)* shall be in accordance with the value indicated in Table 5-11.2.2. In any case, the maximum area of coverage of any sprinkler shall not exceed 100 ft^2 (9.3 m^2).

*Exception: *It shall be permitted to deviate from the maximum sprinkler spacing to eliminate obstructions created by trusses and bar joists by moving a sprinkler along the branch line a maximum of 1 ft (0.31 m) from its allowable spacing provided coverage for that sprinkler does not exceed 110 ft^2 (10.2 m^2) and the average spacing for the moved sprinkler and the adjacent sprinkler do not exceed 100 ft^2 (9.3 m^2). Adjacent branch lines shall maintain the same pattern. In no case shall the distance between sprinklers exceed 12 ft (3.7 m).*

5-11.2.3 Minimum Protection Area of Coverage. The minimum allowable protection area of coverage for a sprinkler *(A_s)* shall be not less than 80 ft^2 (7.4 m^2).

5-11.3 Sprinkler Spacing (Early Suppression Fast-Response Sprinklers).

5-11.3.1 Maximum Distance Between Sprinklers. The distance between sprinklers shall be limited to not more than 12 ft (3.7 m) between sprinklers as shown in Table 5-11.2.2.

Exception No. 1: ESFR sprinklers used in buildings with storage heights greater than 25 ft (7.6 m) and ceiling heights greater than 30 ft (9.1 m) shall not be spaced more than 10 ft (3 m) between sprinklers.

*Exception No. 2: *It shall be permitted to deviate from the maximum sprinkler spacing to eliminate obstructions created by trusses and bar joists by moving a sprinkler along the branch line a maximum of 1 ft (0.31 m) from its allowable spacing provided coverage for that sprinkler does not exceed 110 ft^2 (10.2 m^2) and the average spacing for the moved sprinkler and the adjacent sprinkler do not exceed 100 ft^2 (9.3 m^2). Adjacent branch lines shall maintain the same pattern. In no case shall the distance between sprinklers exceed 12 ft (3.7 m).*

5-11.3.2 Maximum Distance from Walls. The distance from sprinklers to walls shall not exceed one-half of the allowable distance permitted between sprinklers as indicated in Table 5-11.2.2.

5-11.3.3 Minimum Distance from Walls. Sprinklers shall be located a minimum of 4 in. (102 mm) from a wall.

5-11.3.4 Minimum Distance Between Sprinklers. Sprinklers shall be spaced not less than 8 ft (2.4 m) on center.

5-11.4 Deflector Position (Early Suppression Fast-Response Sprinklers).

5-11.4.1 Distance Below Ceilings. Pendent sprinklers with a nominal K-factor of 14 shall be positioned so that deflectors are a maximum 14 in. (356 mm) and a minimum 6 in. (152 mm) below the ceiling. Pendent sprinklers with a nominal K-factor of 25.2 shall be positioned so that deflectors are a maximum 18 in. (457 mm) and a minimum 6 in. (152 mm) below the ceiling. Upright sprinklers shall be positioned so that the deflector is 3 in. to 5 in. (76 mm to 127 mm) below the ceiling. With obstructed construction, the branch lines shall be permitted to be installed across the beams, but sprinklers shall be located in the bays and not under the beams.

5-11.4.2 Deflector Orientation. Deflectors of sprinklers shall be aligned parallel to ceilings or roofs.

5-11.5 Obstructions to Sprinkler Discharge (Early Suppression Fast-Response Sprinklers).

5-11.5.1 Obstructions at or Near the Ceiling. Sprinklers shall be arranged to comply with Table 5-11.5.1 and Figure 5-11.5.1 for obstructions at the ceiling such as beams, ducts, lights, and top chords of trusses and bar joists.

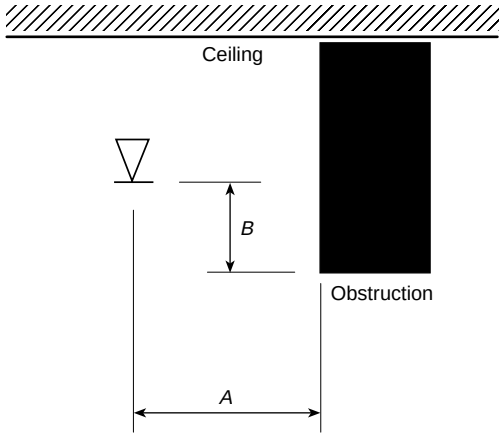
Exception: Sprinklers shall be permitted to be spaced on opposite sides of obstructions provided the distance from the centerline on the obstructions to the sprinklers does not exceed one-half the allowable distance between sprinklers.

Table 5-11.5.1 Positioning of Sprinklers to Avoid Obstructions to Discharge (ESFR Sprinkler)

Distance from Sprinkler to Side of Obstruction *(A)*	Maximum Allowable Distance of Deflector above Bottom of Obstruction (in.) *(B)*
Less than 1 ft	0
1 ft to less than 1 ft 6 in.	$1^1/_2$
1 ft 6 in. to less than 2 ft	3
2 ft to less than 2 ft 6 in.	$5^1/_2$
2 ft 6 in. to less than 3 ft	8
3 ft to less than 3 ft 6 in.	10
3 ft 6 in. to less than 4 ft	12
4 ft to less than 4 ft 6 in.	15
4 ft 6 in. to less than 5 ft	18
5 ft to less than 5 ft 6 in.	22
5 ft 6 in. to less than 6 ft	26
6 ft	31

For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m.
Note: For *(A)* and *(B)*, refer to Figure 5-11.5.1.

Figure 5-11.5.1 Positioning of sprinklers to avoid obstructions to discharge (ESFR sprinkler).



5-11.5.2* Isolated Obstructions Below the Elevation of Sprinklers. Sprinklers shall be installed below isolated noncontinuous obstructions that restrict only one sprinkler and are located below the elevation of sprinklers such as light fixtures and unit heaters.

Exception No. 1: Where the obstruction is 2 ft (0.6 m) or less in width and the sprinkler is located horizontally 1 ft (0.3 m) or greater from the nearest edge of the obstruction.

Exception No. 2: Where sprinklers are positioned with respect to the bottom of obstructions in accordance with 5-11.5.1.

Exception No. 3: If the obstruction is 2 in. (51 mm) or less in width and is located a minimum of 2 ft (0.6 m) below the elevation of the sprinkler deflector or is positioned a minimum of 1 ft (0.3 m) horizontally from the sprinkler.

5-11.5.3 Continuous Obstructions Below the Sprinklers. Sprinklers shall be arranged to comply with Table 5-11.5.1 for horizontal obstructions entirely below the elevation of sprinklers that restrict sprinkler discharge pattern for two or more adjacent sprinklers such as ducts, lights, pipes, and conveyors.

Exception No. 1: If the obstruction is 2 in. (51 mm) or less in width and is located a minimum of 2 ft (0.6 m) below the elevation of the sprinkler deflector or is positioned a minimum of 1 ft (0.3 m) horizontally from the sprinkler.

Exception No. 2: If the obstruction is 1 ft (0.3 m) or less in width and located a minimum of 1 ft (0.3 m) horizontally from the sprinkler.

Exception No. 3: If the obstruction is 2 ft (0.6 m) or less in width and located a minimum of 2 ft (0.6 m) horizontally from the sprinkler.

5-11.5.3.1 Upright sprinklers shall be installed on sprigs arranged so that the deflector is a minimum of 7 in. (178 mm) above the top of the sprinkler pipe.

5-11.5.3.2 ESFR sprinklers shall be positioned a minimum of 1 ft (0.3 m) horizontally from the nearest edge to any bottom chord of a bar joist or open truss.

5-11.5.3.3 Sprinklers installed under open gratings shall be of the intermediate level/rack storage type or otherwise shielded from the discharge of overhead sprinklers.

5-11.6 Clearance to Storage (Early Suppression Fast-Response Sprinklers). The clearance between the deflector and the top of storage shall be 36 in. (914 mm) or greater.

5-12 In-Rack Sprinklers.

5-12.1 System Size. The area protected by a single system of sprinklers in racks shall not exceed 40,000 ft^2 (3716 m^2) of floor area occupied by the racks, including aisles, regardless of the number of levels of in-rack sprinklers.

5-12.2 Type of In-Rack Sprinklers. Sprinklers in racks shall be ordinary temperature standard response classification with a nominal K-factor of 5.6 or 8.0, pendent or upright. Sprinklers with intermediate- and high-temperature ratings shall be used near heat sources as required by 5-3.1.3.

Exception: Quick-response sprinklers shall be permitted to be installed in racks.

5-12.3 In-Rack Sprinkler Water Shields.

5-12.3.1† In-Rack Sprinkler Water Shields for Storage of Class I through IV Commodities. Water shields shall be provided directly above in-rack sprinklers, or listed intermediate level/rack storage sprinklers shall be used where there is more than one level, if not shielded by horizontal barriers.

5-12.3.2 In-Rack Sprinkler Water Shields for Plastic Storage. Where in-rack sprinklers are not shielded by horizontal barriers, water shields shall be provided above the sprinklers or listed intermediate level/rack storage sprinklers shall be used.

5-12.4 Location, Position, and Spacing of In-Rack Sprinklers. *(See Section 7-4).*

5-12.5 Obstructions to In-Rack Sprinkler Discharge. In-rack sprinklers shall not be required to meet the obstruction criteria and clearance from storage requirements of Section 5-5.

5-13 Special Situations.

5-13.1 Concealed Spaces.

5-13.1.1* All concealed spaces enclosed wholly or partly by exposed combustible construction shall be protected by sprinklers.

Exception No. 1: Concealed spaces formed by studs or joists with less than 6 in. (152 mm) between the inside or near edges of the studs or joists. (See Figure 5-6.4.1.4.)

Exception No. 2: Concealed spaces formed by bar joists with less than 6 in. (152 mm) between the roof or floor deck and ceiling.

Exception No. 3: Concealed spaces formed by ceilings attached directly to or within 6 in. (152 mm) of wood joist construction.

Exception No. 4: Concealed spaces formed by ceilings attached directly to the underside of composite wood joist construction, provided the joist channels are firestopped into volumes each not exceeding 160 ft^3 (4.53 m^3) using materials equivalent to the web construction.

Exception No. 5: Concealed spaces entirely filled with noncombustible insulation.

Exception No. 6: Concealed spaces within wood joist construction and composite wood joist construction having noncombustible insulation filling the space from the ceiling up to the bottom edge of the joist of the roof or floor deck, provided that in composite wood joist construction the joist channels are firestopped into volumes each not exceeding 160 ft^3 (4.53 m^3) to the full depth of the joist with material equivalent to the web construction.

Exception No. 7: Concealed spaces over isolated small rooms not exceeding 55 ft^2 (4.6 m^2) in area.

Exception No. 8: Where rigid materials are used and the exposed surfaces have a flame spread rating of 25 or less and the materials have been demonstrated not to propagate fire in the form in which they are installed in the space.

Exception No. 9: Concealed spaces in which the exposed materials are constructed entirely of fire-retardant treated wood as defined by NFPA 703, Standard for Fire Retardant Impregnated Wood and Fire Retardant Coatings for Building Materials.

Exception No. 10: Noncombustible concealed spaces having exposed combustible insulation where the heat content of the facing and substrate of the insulation material does not exceed 1000 Btu/ft² (11,356 kJ/m²).

Exception No. 11: Sprinklers shall not be required in the space below insulation that is laid directly on top of or within the ceiling joists in an otherwise sprinklered attic.

Exception No. 12: Pipe chases under 10 ft² (0.93 m²) formed by studs or wood joists, provided that in multifloor buildings the chases are firestopped at each floor using materials equivalent to the floor construction. Such pipe chases shall contain no sources of ignition, piping shall be noncombustible, and pipe penetrations at each floor shall be properly sealed.

5-13.1.2 Sprinklers in concealed spaces having no access for storage or other use shall be installed in accordance with the requirements for light hazard occupancy.

5-13.1.3 Where heat-producing devices such as furnaces or process equipment are located in the joist channels above a ceiling attached directly to the underside of composite wood joist construction that would not otherwise require sprinkler protection of the spaces, the joist channel containing the heat-producing devices shall be sprinklered by installing sprinklers in each joist channel, on each side, adjacent to the heat-producing device.

5-13.1.4 In concealed spaces having exposed combustible construction, or containing exposed combustibles, in localized areas, the combustibles shall be protected as follows:

(a) If the exposed combustibles are in the vertical partitions or walls around all or a portion of the enclosure, a single row of sprinklers spaced not over 12 ft (3.7 m) apart nor more than 6 ft (1.8 m) from the inside of the partition shall be permitted to protect the surface. The first and last sprinklers in such a row shall not be over 5 ft (1.5 m) from the ends of the partitions.

(b) If the exposed combustibles are in the horizontal plane, the area of the combustibles shall be permitted to be protected with sprinklers on a light hazard spacing. Additional sprinklers shall be installed no more than 6 ft (1.8 m) outside the outline of the area and not more than 12 ft (3.7 m) on center along the outline. When the outline returns to a wall or other obstruction, the last sprinkler shall not be more than 6 ft (1.8 m) from the wall or obstruction.

5-13.2 Vertical Shafts.

5-13.2.1 One sprinkler shall be installed at the top of shafts.

Exception No. 1: Noncombustible or limited-combustible, nonaccessible vertical duct shafts.

Exception No. 2: Noncombustible or limited-combustible, nonaccessible vertical electrical or mechanical shafts.

5-13.2.2* Where vertical shafts have combustible surfaces, one sprinkler shall be installed at each alternate floor level. Where a shaft having combustible surfaces is trapped, an additional sprinkler shall be installed at the top of each trapped section.

5-13.2.3 Where accessible vertical shafts have noncombustible surfaces, one sprinkler shall be installed near the bottom.

5-13.3 Stairways.

5-13.3.1 Sprinklers shall be installed beneath all stairways of combustible construction.

5-13.3.2 In noncombustible stair shafts with noncombustible stairs, sprinklers shall be installed at the top of the shaft and under the first landing above the bottom of the shaft.

Exception: Sprinklers shall be installed beneath landings or stairways where the area beneath is used for storage.

5-13.3.3* Sprinklers shall be installed in the stair shaft at each floor landing where two or more doors open from that landing into separate fire divisions.

5-13.4* Vertical Openings. Where moving stairways, staircases, or similar floor openings are unenclosed, the floor openings involved shall be protected by closely spaced sprinklers in combination with draft stops.

The draft stops shall be located immediately adjacent to the opening, shall be at least 18 in. (457 mm) deep, and shall be of noncombustible or limited-combustible material that will stay in place before and during sprinkler operation. Sprinklers shall be spaced not more than 6 ft (1.8 m) apart and placed 6 in. to 12 in. (152 mm to 305 mm) from the draft stop on the side away from the opening. Where sprinklers are closer than 6 ft (1.8 m), cross baffles shall be provided in accordance with 5-6.3.4.

Exception No. 1: Closely spaced sprinklers and draft stops are not required around large openings such as those found in shopping malls, atrium buildings, and similar structures where all adjoining levels and spaces are protected by automatic sprinklers in accordance with this standard and where the openings have all horizontal dimensions between opposite edges of 20 ft (6 m) or greater and an area of 1000 ft² (93 m²) or greater.

Exception No. 2: Draft stops and closely spaced sprinklers are not required for convenience openings within individual dwelling units that meet all of the following criteria:

(a) Such openings shall connect a maximum of two adjacent stories (pierce one floor only).

(b) Such openings shall be separated from unprotected vertical openings serving other floors by a barrier with a fire resistance rating equal to that required for enclosure of floor openings by NFPA 101®, Life Safety Code®.*

(c) Such openings shall be separate from corridors.

(d) Such openings shall not serve as a required means of egress, although they can serve as a required means of escape.

5-13.5* Building Service Chutes. Building service chutes (e.g., linen, rubbish) shall be protected internally by automatic sprinklers. A sprinkler shall be provided above the top service opening of the chute, above the lowest service opening, and above service openings at alternate levels in buildings over two stories in height. The room or area into which the chute discharges shall also be protected by automatic sprinklers.

5-13.6 Elevator Hoistways and Machine Rooms.

5-13.6.1* Sidewall spray sprinklers shall be installed at the bottom of each elevator hoistway not more than 2 ft (0.61 m) above the floor of the pit.

Exception: For enclosed, noncombustible elevator shafts that do not contain combustible hydraulic fluids, the sprinklers at the bottom of the shaft are not required.

5-13.6.2* Automatic sprinklers in elevator machine rooms or at the tops of hoistways shall be of ordinary- or intermediate-temperature rating.

5-13.6.3* Upright or pendent spray sprinklers shall be installed at the top of elevator hoistways.

Exception: Sprinklers are not required at the tops of noncombustible hoistways of passenger elevators with car enclosure materials that meet the requirements of ASME A17.1, Safety Code for Elevators and Escalators.

5-13.7 Spaces Under Ground Floors, Exterior Docks, and Platforms. Sprinklers shall be installed in spaces under all combustible ground floors, exterior docks, and platforms.

Exception: Sprinklers shall be permitted to be omitted where all of the following conditions prevail:

(a) The space is not accessible for storage purposes and is protected against accumulation of wind-borne debris.

(b) The space contains no equipment such as conveyors or fuel-fired heating units.

(c) The floor over the space is of tight construction.

(d) No combustible or flammable liquids or materials that under fire conditions would convert into combustible or flammable liquids are processed, handled, or stored on the floor above the space.

5-13.8* Exterior Roofs or Canopies.

5-13.8.1 Sprinklers shall be installed under exterior roofs or canopies exceeding 4 ft (1.2 m) in width.

Exception: Sprinklers are permitted to be omitted where the canopy or roof is of noncombustible or limited combustible construction.

5-13.8.2* Sprinklers shall be installed under roofs or canopies over areas where combustibles are stored and handled.

5-13.9 Dwelling Units.

5-13.9.1* Sprinklers are not required in bathrooms that are located within dwelling units, that do not exceed 55 ft^2 (5.1 m^2) in area, and that have walls and ceilings of noncombustible or limited-combustible materials with a 15-minute thermal barrier rating including the walls and ceilings behind fixtures. The area occupied by a noncombustible full height shower/bathtub enclosure shall not be required to be added to the floor area when determining the area of the bathroom.

Exception: Sprinklers are required in bathrooms of nursing homes and in bathrooms opening directly onto public corridors or exitways.

5-13.9.2* Sprinklers are not required in clothes closets, linen closets, and pantries within dwelling units in hotels and motels where the area of the space does not exceed 24 ft^2 (2.2 m^2), the least dimension does not exceed 3 ft (0.9 m), and the walls and ceilings are surfaced with noncombustible or limited-combustible materials.

5-13.10 Library Stack Rooms. Sprinklers shall be installed in every aisle and at every tier of stacks with distance between sprinklers along aisles not to exceed 12 ft (3.7 m). *[See Figure 5-13.10(a).]*

Exception No. 1: Where vertical shelf dividers are incomplete and allow water distribution to adjacent aisles, sprinklers are permitted to be omitted in alternate aisles on each tier. Where ventilation openings are also provided in tier floors, sprinklers shall be staggered vertically. [See Figure 5-13.10(b).]

Exception No. 2: Sprinklers are permitted to be installed without regard to aisles where there is 18 in. (457 mm) or more clearance between sprinkler deflectors and tops of racks.

Figure 5-13.10(a) Sprinklers in multitier library bookstacks with complete vertical dividers.

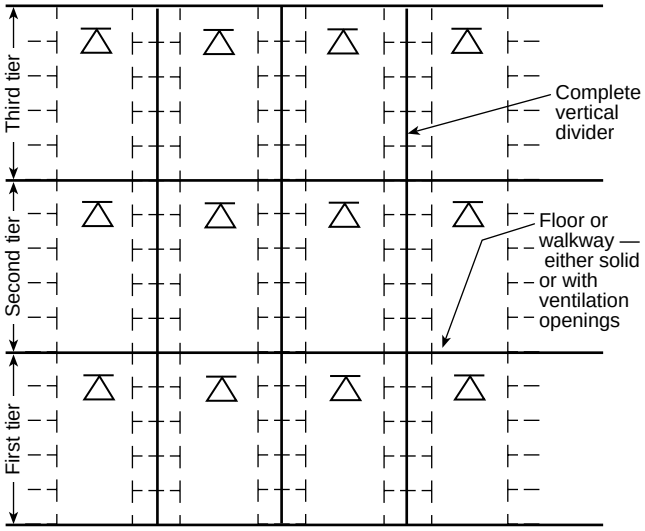
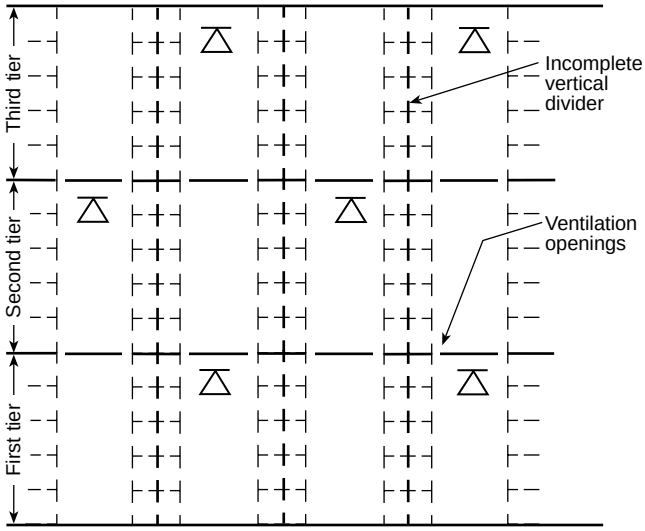


Figure 5-13.10(b) Sprinklers in multitier library bookstacks with incomplete vertical dividers.



5-13.11 Electrical Equipment. Sprinkler protection shall be required in electrical equipment rooms. Hoods or shields installed to protect important electrical equipment from sprinkler discharge shall be noncombustible.

Exception: Sprinklers shall not be required where all of the following conditions are met:

(a) The room is dedicated to electrical equipment only.

(b) Only dry-type electrical equipment is used.

(c) Equipment is installed in a 2-hour fire-rated enclosure including protection for penetrations.

(d) No combustible storage is permitted to be stored in the room.

5-13.12* Industrial Ovens and Furnaces.

5-13.13* Open-Grid Ceilings. Open-grid ceilings shall not be installed beneath sprinklers.

Exception No. 1: Open-grid ceilings in which the openings are $^1/_4$ in. (6.4 mm) or larger in the least dimension, where the thickness or depth of the material does not exceed the least dimension of the opening, and where such openings constitute 70 percent of the area of the ceiling material. The spacing of the sprinklers over the open-grid ceiling shall then comply with the following:

(a) In light hazard occupancies where sprinkler spacing (either spray or old-style sprinklers) is less than 10 ft × 10 ft (3 m × 3 m), a minimum clearance of at least 18 in. (457 mm) shall be provided between the sprinkler deflectors and the upper surface of the open-grid ceiling. Where spacing is greater than 10 ft × 10 ft (3 m × 3 m) but less than 10 ft × 12 ft (3 m × 3.7 m), a clearance of at least 24 in. (610 mm) shall be provided from spray sprinklers and at least 36 in. (914 mm) from old-style sprinklers. Where spacing is greater than 10 ft × 12 ft (3 m × 3.7 m), a clearance of at least 48 in. (1219 mm) shall be provided.

(b) In ordinary hazard occupancies, open-grid ceilings shall be permitted to be installed beneath spray sprinklers only. Where sprinkler spacing is less than 10 ft × 10 ft (3 m × 3 m), a minimum clearance of at least 24 in. (610 mm) shall be provided between the sprinkler deflectors and the upper surface of the open-grid ceiling. Where spacing is greater than 10 ft × 10 ft (3 m × 3 m), a clearance of at least 36 in. (914 mm) shall be provided.

Exception No. 2: Other types of open-grid ceilings shall not be installed beneath sprinklers unless they are listed for such service and are installed in accordance with instructions contained in each package of ceiling material.

5-13.14 Drop-Out Ceilings.

5-13.14.1 Drop-out ceilings shall be permitted to be installed beneath sprinklers where ceilings are listed for that service and are installed in accordance with their listings.

Exception: Special sprinklers shall not be installed above drop-out ceilings unless specifically listed for this purpose.

5-13.14.2 Drop-out ceilings shall not be considered ceilings within the context of this standard.

5-13.14.3* Piping installed above drop-out ceilings shall not be considered concealed piping. *(See 3-6.4, Exception No. 2.)*

5-13.14.4* Sprinklers shall not be installed beneath drop-out ceilings.

5-13.15 Old-Style Sprinklers. Old-style sprinklers shall not be used in a new installation.

*Exception No. 1: *Old-style sprinklers shall be installed in fur storage vaults. (See A-5-13.15, Exception No. 1.)*

Exception No. 2: Use of old-style sprinklers shall be permitted where construction features or other special situations require unique water distribution.

5-13.16 Stages.

5-13.16.1 Sprinklers shall be installed under the roof at the ceiling, in spaces under the stage either containing combustible materials or constructed of combustible materials, and in all adjacent spaces and dressing rooms, storerooms, and workshops.

5-13.16.2 Where proscenium opening protection is required, a deluge system shall be provided with open sprinklers located not more than 3 ft (0.9 m) away from the stage side of the proscenium arch and spaced up to a maximum of 6 ft (1.8 m) on center. *(See Chapter 7 for design criteria.)*

5-13.17 Provision for Flushing Systems. All sprinkler systems shall be arranged for flushing. Readily removable fittings shall be provided at the end of all cross mains. All cross mains shall terminate in $1^1/_4$ in. (31.8 mm) or larger pipe. All branch lines on gridded systems shall be arranged to facilitate flushing.

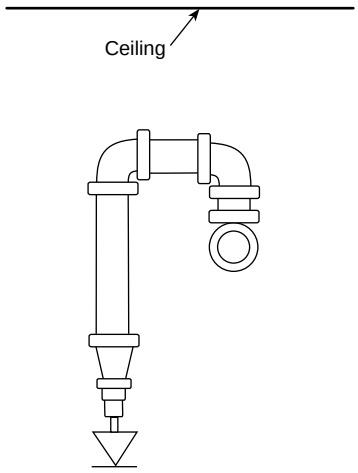
5-13.18 Stair Towers. Stairs, towers, or other construction with incomplete floors, if piped on independent risers, shall be treated as one area with reference to pipe sizes.

5-13.19 Return Bends. Return bends shall be used where pendent sprinklers are supplied from a raw water source, a mill pond, or open-top reservoirs. Return bends shall be connected to the top of branch lines in order to avoid accumulation of sediment in the drop nipples. *(See Figure 5-13.19.)*

Exception No. 1: Return bends shall not be required for deluge systems.

Exception No. 2: Return bends shall not be required where dry-pendent sprinklers are used.

Figure 5-13.19 Return bend arrangement.



5-13.20 Piping to Sprinklers Below Ceilings.

5-13.20.1 In new installations expected to supply sprinklers below a ceiling, minimum 1-in. (25.4-mm) outlets shall be provided.

Exception: Hexagonal bushings shall be permitted to accommodate temporary sprinklers and shall be removed with the temporary sprinklers when the permanent ceiling sprinklers are installed.

5-13.20.2 When pipe schedule systems are revamped, a nipple not exceeding 4 in. (102 mm) in length shall be permitted to be installed in the branch line fitting. All other piping shall be 1 in. (25.4 mm) where it supplies a single sprinkler in an area. *[See Figure 5-13.20.2(a).]*

Exception No. 1: When it is necessary to pipe two new ceiling sprinklers from an existing outlet in an overhead system, the use of a nipple not exceeding 4 in. (102 mm) in length and of the same pipe thread size as the existing outlet shall be permitted, provided that a hydraulic calculation verifies that the design flow rate will be achieved. [See Figure 5-13.20.2(b).]

Exception No. 2: The use of pipe nipples less than 1 in. (25.4 mm) in diameter shall not be permitted in areas subject to earthquakes.

Figure 5-13.20.2(a) Nipple and reducing elbow supplying sprinkler below ceiling.

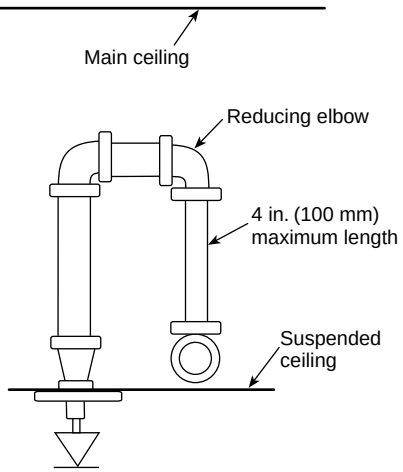
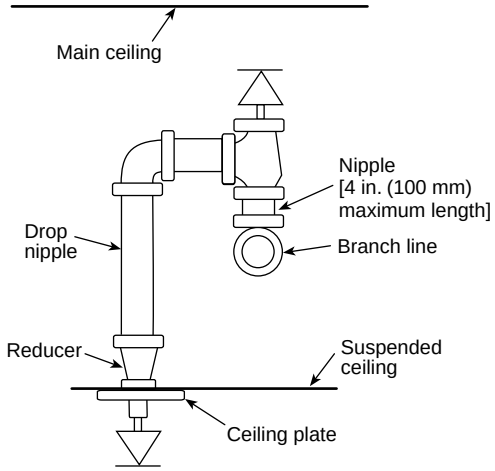


Figure 5-13.20.2(b) Sprinklers in concealed space and below ceiling.



5-13.20.3 When hydraulically designed systems are revamped, any existing bushing shall be removed and a nipple not exceeding 4 in. (102 mm) in length shall be permitted to be installed in the branch line fitting. Calculations shall be provided to verify that the system design flow rate will be achieved.

Exception No. 1: When it is necessary to pipe two new ceiling sprinklers from an existing outlet in an overhead system, any bushings shall be removed and the use of a nipple not exceeding 4 in. (102 mm) in length and of the same pipe thread size as the existing outlet shall be permitted, provided that a hydraulic calculation verifies that the design flow rate will be achieved.

Exception No. 2: The use of pipe nipples less than 1 in. (25.4 mm) in diameter is not permitted in areas subject to earthquakes.

5-13.21 Dry Pipe Underground. Where necessary to place pipe that will be under air pressure underground, the pipe shall be protected against corrosion *(see 5-14.4.2).*

Exception: Unprotected cast-iron or ductile-iron pipe shall be permitted where joined with a gasketed joint listed for air service underground.

5-13.22* System Subdivision. Where individual floor/zone control valves are not provided, a flanged joint or mechanical coupling shall be used at the riser at each floor for connections to piping serving floor areas in excess of 5000 ft^2 (465 m^2).

5-13.23 Spaces Above Nonstorage Areas. Where nonstorage spaces have lower ceilings than the storage portion of the building, the space above this drop ceiling shall be sprinklered unless it complies with the rules of 5-13.1 for allowable unsprinklered concealed spaces. Where the space above a drop ceiling is sprinklered, the sprinkler system shall conform to the rules of 5-4.1.2 or its exceptions.

5-14 Piping Installation.

5-14.1 Valves.

5-14.1.1* Control Valves. *(See 3-8.1.)*

5-14.1.1.1* Each sprinkler system shall be provided with a listed indicating valve in an accessible location, so located as to control all automatic sources of water supply.

5-14.1.1.2 At least one listed indicating valve shall be installed in each source of water supply.

Exception: There shall be no shutoff valve in the fire department connection.

5-14.1.1.3* Valves on connections to water supplies, sectional control and isolation valves, and other valves in supply pipes to sprinklers and other fixed water-based fire suppression systems shall be supervised by one of the following methods:

(1) Central station, proprietary, or remote station signaling service
(2) Local signaling service that will cause the sounding of an audible signal at a constantly attended point
(3) Valves locked in the correct position
(4) Valves located within fenced enclosures under the control of the owner, sealed in the open position, and inspected weekly as part of an approved procedure

Floor control valves in high-rise buildings and valves controlling flow to sprinklers in circulating closed loop systems shall comply with 5-14.1.1.3(1) or (2).

Exception: Supervision of underground gate valves with roadway boxes shall not be required.

5-14.1.1.4 Where control valves are installed overhead, they shall be positioned so that the indicating feature is visible from the floor below.

5-14.1.1.5 Where there is more than one source of water supply, a check valve shall be installed in each connection.

Exception: Where cushion tanks are used with automatic fire pumps, no check valve is required in the cushion tank connection.

5-14.1.1.6 Check valves shall be installed in a vertical or horizontal position in accordance with their listing.

5-14.1.1.7* Where a single wet pipe sprinkler system is equipped with a fire department connection, the alarm valve is considered a check valve, and an additional check valve shall not be required.

5-14.1.1.8* In a connection serving as one source of supply, listed indicating valves or post-indicator valves shall be installed on both sides of all check valves required in 5-14.1.1.5.

Exception No. 1: There shall be no control valves in the fire department connection piping. (See 5-14.1.1.2.)

Exception No. 2: Where the city connection serves as the only automatic source of supply to a wet pipe sprinkler system, a control valve is not required on the system side of the check valve or the alarm check valve.

Exception No. 3: In the discharge pipe from a pressure tank or a gravity tank of less than 15,000 gal (56.78 m^3) capacity, no control valve need be installed on the tank side of the check valve.

5-14.1.1.9* Where a gravity tank is located on a tower in the yard, the control valve on the tank side of the check valve shall be an outside screw and yoke or listed indicating valve; the other shall be either an outside screw and yoke, a listed indicating valve, or a listed valve having a post-type indicator. Where a gravity tank is located on a building, both control valves shall be outside screw and yoke or listed indicating valves and all fittings inside the building, except the drain tee and heater connections, shall be under the control of a listed valve.

5-14.1.1.10* When a pump is located in a combustible pump house or exposed to danger from fire or falling walls, or when a tank discharges into a private fire service main fed by another supply, either the check valve in the connection shall be located in a pit or the control valve shall be of the post-indicator type located a safe distance outside buildings.

5-14.1.1.11* All control valves shall be located where readily accessible and free of obstructions.

5-14.1.1.12 Identification signs shall be provided at each valve to indicate its function and what it controls.

5-14.1.2 Pressure-Reducing Valves.

5-14.1.2.1 In portions of systems where all components are not listed for pressure greater than 175 psi (12.1 bar) and the potential exists for normal (nonfire condition) water pressure in excess of 175 psi (12.1 bar), a listed pressure-reducing valve shall be installed and set for an outlet pressure not exceeding 165 psi (2.4 bar) at the maximum inlet pressure.

5-14.1.2.2 Pressure gauges shall be installed on the inlet and outlet sides of each pressure-reducing valve.

5-14.1.2.3* A relief valve of not less than $^1/_2$ in. (13 mm) in size shall be provided on the discharge side of the pressure-reducing valve set to operate at a pressure not exceeding 175 psi (12.1 bar).

5-14.1.2.4 A listed indicating valve shall be provided on the inlet side of each pressure-reducing valve.

Exception: A listed indicating valve is not required where the pressure-reducing valve meets the listing requirements for use as an indicating valve.

5-14.1.2.5 Means shall be provided downstream of all pressure-reducing valves for flow tests at sprinkler system demand.

5-14.1.3* Post-Indicator Valves.

5-14.1.3.1 Post-indicator valves shall be set so that the top of the post will be 36 in. (0.9 m) above the final grade.

5-14.1.3.2 Post-indicator valves shall be properly protected against mechanical damage where needed.

5-14.1.4 Valves in Pits.

5-14.1.4.1 Where it is impractical to provide a post-indicator valve, valves shall be permitted to be placed in pits with permission of the authority having jurisdiction.

5-14.1.4.2* When used, valve pits shall be of adequate size and readily accessible for inspection, operation, testing, maintenance, and removal of equipment contained therein. They shall be constructed and arranged to properly protect the installed equipment from movement of earth, freezing, and accumulation of water. Poured-in-place or precast concrete, with or without reinforcement, or brick (all depending upon soil conditions and size of pit) are appropriate materials for construction of valve pits. Other approved materials shall be permitted to be used. Where the water table is low and the soil is porous, crushed stone or gravel shall be permitted to be used for the floor of the pit. *[See Figure A-5-15.2(b) for a suggested arrangement.]*

Valve pits located at or near the base of the riser of an elevated tank shall be designed in accordance with Chapter 9 of NFPA 22, *Standard for Water Tanks for Private Fire Protection.*

5-14.1.4.3 The location of the valve shall be clearly marked, and the cover of the pit shall be kept free of obstructions.

5-14.1.5 Sectional Valves.

5-14.1.5.1 Large private fire service main systems shall have sectional controlling valves at appropriate points in order to permit sectionalizing the system in the event of a break or for the making of repairs or extensions.

5-14.1.5.2 A valve shall be provided on each bank where a main crosses water and outside the building foundation(s) where the main or section of main runs under a building. *(See 5-14.4.3.1.)*

5-14.1.6* In-Rack Sprinkler System Control Valves. 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 20 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 the ceiling sprinklers.

5-14.2 Drainage.

5-14.2.1* All sprinkler pipe and fittings shall be so installed that the system can be drained.

5-14.2.2 On wet pipe systems, sprinkler pipes shall be permitted to be installed level. Trapped piping shall be drained in accordance with 5-14.2.5.

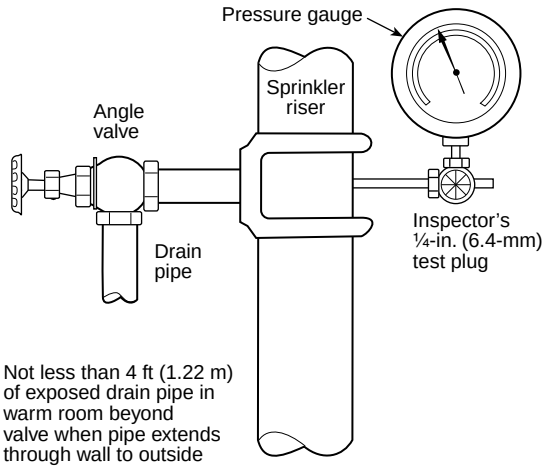
5-14.2.3 In dry pipe systems and preaction systems branch lines shall be pitched at least $^1/_2$ in. per 10 ft (4 mm/m) and mains shall be pitched at least $^1/_4$ in. per 10 ft (2 mm/m).

Exception No. 1: Mains shall be pitched at least $^1/_2$ in. per 10 ft (4 mm/m) in refrigerated areas.

Exception No. 2: Preaction systems located entirely in areas not subject to freezing are not required to be pitched.

5-14.2.4 System, Main Drain, or Sectional Drain Connections. *[See Figures 5-14.2.4 and A-5-15.4.2(b).]*

Figure 5-14.2.4 Drain connection for system riser.



5-14.2.4.1 Provisions shall be made to properly drain all parts of the system.

5-14.2.4.2 Drain connections for systems supply risers and mains shall be sized as shown in Table 5-14.2.4.2.

Table 5-14.2.4.2 Drain Size

Riser or Main Size	Size of Drain Connection
Up to 2 in.	$^3/_4$ in. or larger
$2^1/_2$ in., 3 in., $3^1/_2$ in.	$1^1/_4$ in. or larger
4 in. and larger	2 in. only

For SI units, 1 in. = 25.4 mm.

5-14.2.4.3 Where an interior sectional or floor control valve(s) is provided, it shall be provided with a drain connection sized as shown in Table 5-14.2.4.2 to drain that portion of the system controlled by the sectional valve. Drains shall discharge outside or to a drain connection. *[See Figure A-5-15.4.2(b).]*

Exception: For those drains serving pressure-reducing valves, the drain, drain connection, and all other downstream drain piping shall be sized to permit a flow of at least the greatest system demand supplied by the pressure-reducing valve.

5-14.2.4.4 The test connections required by 5-15.4.1 shall be permitted to be used as main drain connections.

Exception: Where drain connections for floor control valves are tied into a common drain riser, the drain riser shall be one pipe size larger than the largest size drain connection tying into it.

5-14.2.5 Auxiliary Drains.

5-14.2.5.1 Auxiliary drains shall be provided where a change in piping direction prevents drainage of system piping through the main drain valve.

5-14.2.5.2 Auxiliary Drains for Wet Pipe Systems and Preaction Systems in Areas Not Subject to Freezing.

5-14.2.5.2.1 Where the capacity of trapped sections of pipes in wet systems is less than 5 gal (18.9 L), the auxiliary drain shall consist of a nipple and cap or plug not less than $^1/_2$ in. (12 mm) in size.

Exception No. 1: Auxiliary drains are not required for system piping that can be drained by removing a single pendent sprinkler.

Exception No. 2: Where flexible couplings or other easily separated connections are used, the nipple and cap or plug shall be permitted to be omitted.

5-14.2.5.2.2 Where the capacity of isolated trapped sections of pipe is more than 5 gal (18.9 L) and less than 50 gal (189 L), the auxiliary drain shall consist of a valve $^3/_4$ in. (19 mm) or larger and a plug or a nipple and cap.

5-14.2.5.2.3* Where the capacity of isolated trapped sections of pipe is 50 gal (189 L) or more, the auxiliary drain shall consist of a valve not smaller than 1 in. (25.4 mm), piped to an accessible location.

5-14.2.5.2.4 Tie-in drains are not required on wet pipe systems and preaction systems protecting non-freezing environments.

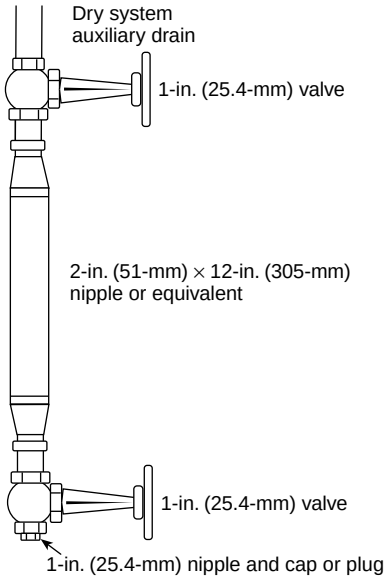
5-14.2.5.3 Auxiliary Drains for Dry Pipe Systems and Preaction Systems in Areas Subject to Freezing.

5-14.2.5.3.1 Where the capacity of trapped sections of pipe is less than 5 gal (18.9 L), the auxiliary drain shall consist of a valve not smaller than $^1/_2$ in. (12 mm) and a plug or a nipple and cap.

Exception: Auxiliary drains are not required for pipe drops supplying dry-pendent sprinklers installed in accordance with 4-2.2.

5-14.2.5.3.2 Where the capacity of isolated trapped sections of system piping is more than 5 gal (18.9 L), the auxiliary drain shall consist of two 1-in. (25.4-mm) valves and one 2-in. × 12-in. (51-mm × 305-mm) condensate nipple or equivalent, accessibly located. *(See Figure 5-14.2.5.3.2.)*

Figure 5-14.2.5.3.2 Dry system auxiliary drain.



5-14.2.5.3.3 Tie-in drains shall be provided for multiple adjacent trapped branch pipes and shall be only 1 in. (25.4 mm). Tie-in drain lines shall be pitched a minimum of $^1/_2$ in. per 10 ft (4 mm/m).

5-14.2.6 Discharge of Drain Valves.

5-14.2.6.1* Direct interconnections shall not be made between sprinkler drains and sewers. The drain discharge shall conform to any health or water department regulations.

5-14.2.6.2 Where drain pipes are buried underground, approved corrosion-resistant pipe shall be used.

5-14.2.6.3 Drain pipes shall not terminate in blind spaces under the building.

5-14.2.6.4 Where exposed to the atmosphere, drain pipes shall be fitted with a turned-down elbow.

5-14.2.6.5 Drain pipes shall be arranged to avoid exposing any part of the sprinkler system to freezing conditions.

5-14.3 Protection of Piping.

5-14.3.1 Protection of Piping Against Freezing.

5-14.3.1.1 Where portions of systems are subject to freezing and temperatures cannot reliably be maintained at or above 40°F (4°C), sprinklers shall be installed as a dry pipe or preaction system.

Exception: Small unheated areas are permitted to be protected by antifreeze systems or by other systems specifically listed for this purpose. (See 4-5.2.)

5-14.3.1.2 Where aboveground water-filled supply pipes, risers, system risers, or feed mains pass through open areas, cold rooms, passageways, or other areas exposed to freezing temperatures, the pipe shall be protected against freezing by insulating coverings, frostproof casings, or other reliable means capable of maintaining a minimum temperature between 40°F (4°C) and 120°F (48.9°C).

5-14.3.2 Protection of Piping Against Corrosion.

5-14.3.2.1* Where corrosive conditions are known to exist due to moisture or fumes from corrosive chemicals or both, special types of fittings, pipes, and hangers that resist corrosion shall be used or a protective coating shall be applied to all unprotected exposed surfaces of the sprinkler system. *(See 3-2.6.)*

5-14.3.2.2 Where water supplies are known to have unusual corrosive properties and threaded or cut-groove steel pipe is to be used, wall thickness shall be in accordance with Schedule 30 [in sizes 8 in. (200 mm) or larger] or Schedule 40 [in sizes less than 8 in. (200 mm)].

5-14.3.2.3 Where corrosive conditions exist or piping is exposed to the weather, corrosion-resistant types of pipe, fittings, and hangers or protective corrosion-resistant coatings shall be used.

5-14.3.2.4 Where steel pipe is used underground, the pipe shall be protected against corrosion.

5-14.3.3 Protection of Piping in Hazardous Areas. Private service main aboveground piping shall not pass through hazardous areas and shall be located so that it is protected from mechanical and fire damage.

Exception: Aboveground piping is permitted to be located in hazardous areas protected by an automatic sprinkler system.

5-14.4* Underground Private Fire Service Mains.

5-14.4.1 Depth of Cover.

5-14.4.1.1* The depth of cover over water pipes shall be determined by the maximum depth of frost penetration in the locality where the pipe is laid. The top of the pipe shall be buried not less than 1 ft (0.3 m) below the frost line for the locality. In those locations where frost is not a factor, the depth of cover shall be not less than $2^1/_2$ ft (0.8 m) to prevent mechanical damage. Pipe under driveways shall be buried a minimum of 3 ft (0.9 m) and under railroad tracks a minimum of 4 ft (1.2 m).

5-14.4.1.2 Depth of covering shall be measured from top of pipe to finished grade, and due consideration shall always be given to future or final grade and nature of soil.

5-14.4.2 Protection Against Freezing.

5-14.4.2.1 Where it is impracticable to bury pipe, it shall be permitted to be laid aboveground, provided the pipe is protected against freezing and mechanical damage.

5-14.4.2.2 Pipes shall not be placed over water raceways or near embankment walls without special attention being given to protection against frost.

5-14.4.2.3 Where pipe is laid in water raceways or shallow streams, care shall be taken that there will be sufficient depth of running water between the pipe and the frost line during all seasons of frost; a safer method is to bury the pipe 1 ft (0.3048 m) or more under the bed of the waterway. Care shall also be taken to keep the pipe back from the banks a sufficient distance to avoid any danger of freezing through the side of the bank above the water line. Pipe shall be buried below the frost line where entering the water.

5-14.4.3 Protection Against Damage.

5-14.4.3.1 Pipe shall not be run under buildings.

Exception No. 1: When absolutely necessary to run pipe under buildings, special precautions shall be taken that include arching the foundation walls over the pipe, running pipe in covered trenches, and providing valves to isolate sections of pipe under buildings. (See 5-14.5.2.)

Exception No. 2: Fire service mains shall be permitted to enter the building adjacent to the foundation.

Exception No. 3: Where adjacent structures or physical conditions make it impractical to locate risers immediately inside an exterior wall, such risers shall be permitted to be located as close as practical to exterior walls to minimize underground piping under the building.

5-14.4.3.2 Where a riser is close to building foundations, underground fittings of proper design and type shall be used to avoid pipe joints being located in or under the foundations.

5-14.4.3.3 Mains running under railroads carrying heavy trucking, under large piles of heavy commodities, or in areas that subject the main to heavy shock and vibrations shall be subjected to an evaluation of the specific loading conditions and suitably protected, if necessary. *(See 3-4.2.)*

5-14.4.3.4* When it is necessary to join metal pipe with pipe of dissimilar metal, the joint shall be insulated, by an approved method, against the passage of an electric current.

5-14.4.3.5 In no case shall the pipe be used for grounding of electrical services.

5-14.4.4 Care in Laying.

5-14.4.4.1 Pipes, valves, hydrants, and fittings shall be inspected for damage when received and shall be inspected prior to installation. Bolted joints shall be checked for proper torquing of bolts. Pipe, valves, hydrants, and fittings shall be clean inside. When work is stopped, open ends shall be plugged to prevent stones and foreign materials from entering.

5-14.4.4.2 All pipe, fittings, valves, and hydrants shall be carefully lowered into the trench with suitable equipment. They shall be carefully examined for cracks or other defects while suspended above the trench immediately before installation. Plain ends shall be inspected with special attention, as these ends are the most susceptible to damage. Under no circumstances shall water main materials be dropped or dumped. Pipe shall not be rolled or skidded against other pipe materials.

5-14.4.4.3 Pipes shall bear throughout their full length and shall not be supported by the bell ends only or by blocks.

Exception: If ground is soft, or of a quicksand nature, special provisions shall be made for supporting pipe. For ordinary conditions of soft ground, longitudinal wooden stringers with cross ties will give good results.

5-14.4.4.4 Valves and fittings used with nonmetallic pipe shall be properly supported and restrained in accordance with the manufacturer's specifications.

5-14.4.5 Pipe Joint Assembly.

5-14.4.5.1 Joints shall be assembled by persons familiar with the particular materials being used and in accordance with the manufacturer's instructions and specifications.

5-14.4.5.2 All bolted joint accessories shall be cleaned and thoroughly coated with asphalt or other corrosion-retarding material after installation.

5-14.4.6 Backfilling.

5-14.4.6.1 Backfill shall be well tamped in layers under and around pipes (and puddled where possible) to prevent settlement or lateral movement and shall contain no ashes, cinders, refuse, organic matter, or other corrosive materials.

5-14.4.6.2 Rocks shall not be placed in trenches. Frozen earth shall not be used for backfilling.

5-14.4.6.3 In trenches cut through rock, tamped backfill shall be used for at least 6 in. (152 mm) under and around the pipe and for at least 2 ft (0.6 m) above the pipe.

5-15 System Attachments.

5-15.1* Sprinkler Alarms/Waterflow Alarms.

5-15.1.1 Local waterflow alarms shall be provided on all sprinkler systems having more than 20 sprinklers.

5-15.1.2 On each alarm check valve used under conditions of variable water pressure, a retarding device shall be installed. Valves shall be provided in the connections to retarding devices to permit repair or removal without shutting off sprinklers; these valves shall be so arranged that they can be locked or sealed in the open position.

5-15.1.3 Alarm, dry pipe, preaction, and deluge valves shall be fitted with an alarm bypass test connection for an electric alarm switch, water motor gong, or both. This pipe connection shall be made on the water supply side of the system and provided with a control valve and drain for the alarm piping. A check valve shall be installed in the pipe connection from the intermediate chamber of a dry pipe valve.

Exception: The alarm test connection at the riser shall be permitted to be made on the system side of an alarm valve.

5-15.1.4 An indicating control valve shall be installed in the connection to pressure-type contactors or water motor–operated alarm devices. Such valves shall be locked or sealed in the open position. The control valve for the retarding chamber on alarm check valves shall be accepted as complying with this paragraph.

5-15.1.5* Attachments — Mechanically Operated. For all types of sprinkler systems employing water motor–operated alarms, a listed $^{3}/_{4}$-in. (19-mm) strainer shall be installed at the alarm outlet of the waterflow detecting device.

Exception: Where a retarding chamber is used in connection with an alarm valve, the strainer shall be located at the outlet of the retarding chamber unless the retarding chamber is provided with an approved integral strainer in its outlet.

5-15.1.6* Alarm Attachments — High-Rise Buildings. When a fire must be fought internally due to the height of a building, the following additional alarm apparatus shall be provided:

(a) Where each sprinkler system on each floor is equipped with a separate waterflow device, it shall be connected to an alarm system in such a manner that operation of one sprinkler will actuate the alarm system and the location of the operated flow device shall be indicated on an annunciator and/or register. The annunciator or register shall be located at grade level at the normal point of fire department access, at a constantly attended building security control center, or at both locations.

Exception: Where the location within the protected buildings where supervisory or alarm signals are received is not under constant supervision by qualified personnel in the employ of the owner, a connection shall be provided to transmit a signal to a remote central station.

(b) A distinct trouble signal shall be provided to indicate a condition that will impair the satisfactory operation of the sprinkler system.

5-15.1.7* Alarm Service. A central station, auxiliary, remote station, or proprietary sprinkler waterflow alarm shall be provided for sprinkler systems protecting storage in accordance with Section 7-3. A local waterflow alarm shall be permitted where recorded guard service is provided.

5-15.1.8† Sprinkler Waterflow Alarm for In-Rack Sprinklers.

5-15.2* Fire Department Connections.

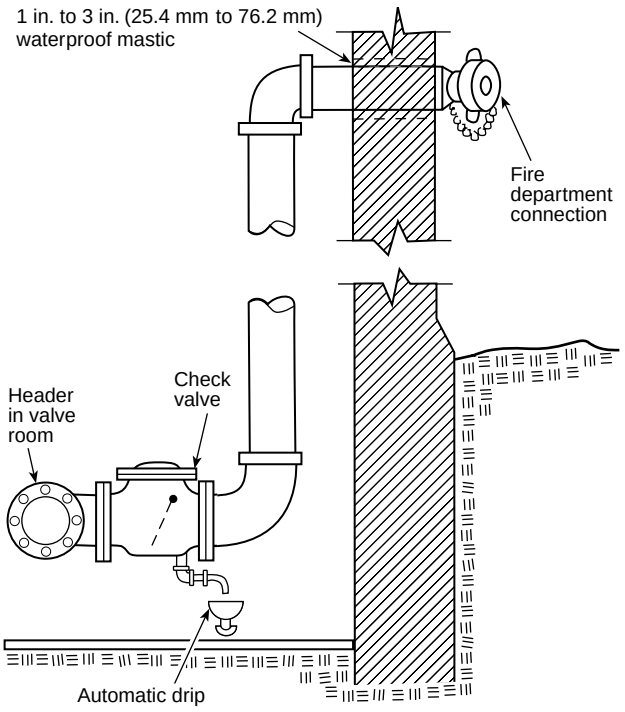
5-15.2.1* A fire department connection shall be provided as described in 5-15.2. *(See Figure 5-15.2.1.)*

Exception No. 1: Buildings located in remote areas that are inaccessible for fire department support.

Exception No. 2: Large-capacity deluge systems exceeding the pumping capacity of the fire department.

Exception No. 3: Single-story buildings not exceeding 2000 ft^2 (186 m^2) in area.

Figure 5-15.2.1 Fire department connections.



5-15.2.2 Size. Pipe size shall be 4 in. (102 mm) for fire engine connections and 6 in. (152 mm) for fire boat connections.

Exception No. 1: For hydraulically calculated systems, fire department connection pipe as small as the system riser shall be permitted where serving one system riser.

Exception No. 2: A single-outlet fire department connection shall be acceptable where piped to a 3-in. (76-mm) or smaller riser.

5-15.2.3* Arrangement. See Figure 5-15.2.1.

5-15.2.3.1 The fire department connection shall be on the system side of the water supply check valve.

5-15.2.3.2 For single systems, the fire department connection shall be installed as follows:

(1) *Wet System.* On the system side of system control, check, and alarm valves *(See Figure A-5-14.1.1.)*
(2) *Dry System.* Between the system control valve and the dry pipe valve
(3) *Preaction System.* Between the preaction valve and the check valve on the system side of the preaction valve
(4) *Deluge System.* On the system side of the deluge valve

Exception: Connection of the fire department connection to underground piping shall be permitted.

5-15.2.3.3 For multiple systems, the fire department connection shall be connected between the supply control valves and the system control valves.

Exception: Connection of the fire department connection to underground piping shall be permitted.

5-15.2.3.4 Where a fire department connection services only a portion of a building, a sign shall be attached indicating the portions of the building served.

5-15.2.3.5 Fire department connections shall be on the street side of buildings and shall be located and arranged so that hose lines can be readily and conveniently attached to the inlets without interference from any nearby objects including buildings, fences, posts, or other fire department connections.

Each fire department connection to sprinkler systems shall be designated by a sign having raised or engraved letters at least 1 in. (25.4 mm) in height on plate or fitting reading service design — for example,

AUTOSPKR., OPEN SPKR. AND STANDPIPE

A sign shall also indicate the pressure required at the inlets to deliver the greatest system demand.

Exception: The sign is not required where the system demand pressure is less than 150 psi (10.3 bar).

5-15.2.3.6 Fire department connections shall not be connected on the suction side of fire pumps.

5-15.2.3.7 Fire department connections shall be properly supported.

5-15.2.4 Valves.

5-15.2.4.1 A listed check valve shall be installed in each fire department connection.

5-15.2.4.2 There shall be no shutoff valve in the fire department connection piping.

5-15.2.5 Drainage. The piping between the check valve and the outside hose coupling shall be equipped with an approved automatic drip.

Exception: An automatic drip is not required in areas not subject to freezing.

5-15.3 Gauges.

5-15.3.1 A pressure gauge with a connection not smaller than $^1/_4$ in. (6.4 mm) shall be installed at the system main drain, at each main drain associated with a floor control valve, and on the inlet and outlet side of each pressure reducing valve. Each gauge connection shall be equipped with a shutoff valve and provisions for draining.

5-15.3.2 The required pressure gauges shall be listed and shall have a maximum limit not less than twice the normal system working pressure at the point where installed. They shall be installed to permit removal and shall be located where they will not be subject to freezing.

5-15.4 System Connections.

5-15.4.1* Main Drain Test Connections Main drain test connections shall be provided at locations that will permit flow tests of water supplies and connections. They shall be so installed that the valve can be opened wide for a sufficient time to assure a proper test without causing water damage. Main drain connections shall be sized in accordance with 5-14.2.4 and 5-14.2.6.

5-15.4.2* Wet Pipe Systems. An alarm test connection not less than 1 in. (25.4 mm) in diameter, terminating in a smooth bore corrosion-resistant orifice, giving a flow equivalent to one sprinkler of a type having the smallest orifice installed on the particular system, shall be provided to test each waterflow alarm device for each system. The test connection valve shall be readily accessible. The discharge shall be to the outside, to a drain connection capable of accepting full flow under system pressure, or to another location where water damage will not result.

5-15.4.3* Dry Pipe Systems. A trip test connection not less than 1 in. (25.4 mm) in diameter, terminating in a smooth bore corrosion-resistant orifice, to provide a flow equivalent to one sprinkler of a type installed on the particular system, shall be installed on the end of the most distant sprinkler pipe in the upper story and shall be equipped with a readily accessible shutoff valve and plug not less than 1 in. (25.4 mm), at least one of which shall be brass. In lieu of a plug, a nipple and cap shall be acceptable.

5-15.4.4 Preaction Systems. A test connection shall be provided on a preaction system using supervisory air. The connection used to control the level of priming water shall be considered adequate to test the operation of the alarms monitoring the supervisory air pressure.

5-15.4.5 Deluge Systems. A test connection is not required on a deluge system.

5-15.4.6 Backflow Devices.

5-15.4.6.1* Backflow Prevention Valves. Means shall be provided downstream of all backflow prevention valves for flow tests at system demand.

5-15.4.6.2 When backflow prevention devices are to be retroactively installed on existing systems, a thorough hydraulic analysis, including revised hydraulic calculations, new fire flow data, and all necessary system modifications to accommodate the additional friction loss, shall be completed as a part of the installation.

5-15.5 Hose Connections.

5-15.5.1† Small ($1^1/_2$-in.) Hose Connections.

5-15.5.1.1* Where required by Sections 7-3, 7-4, 7-6, 7-7, and 7-8, small ($1^1/_2$ in.) hose lines shall be available to reach all portions of the storage area. The hose connections shall not be required to meet the requirements of Class II hose systems defined by NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*. Hose connections shall be supplied from one of the following:

(1) Outside hydrants
(2) A separate piping system for small hose stations
(3) Valved hose connections on sprinkler risers where such connections are made upstream of all sprinkler control valves
(4) Adjacent sprinkler systems
(5) In rack storage areas, the ceiling sprinkler system in the same area (as long as in-rack sprinklers are provided in the same area and are separately controlled)

5-15.5.1.2* Hose used for fire purposes only shall be permitted to be connected to wet sprinkler systems only, subject to the following restrictions:

(1) Hose station's supply pipes shall not be connected to any pipe smaller than $2^1/_2$ in. (64 mm).

Exception: For hydraulically designed loops and grids, the minimum size pipe between the hose station's supply pipe and the source shall be permitted to be 2 in. (51 mm).

(2) For piping serving a single hose station, pipe shall be minimum 1 in. (25.4 mm) for horizontal runs up to 20 ft (6.1 m), minimum $1^1/_4$ in. (33 mm) for the entire run for runs between 20 and 80 ft (6.1 and 24.4 m), and minimum $1^1/_2$ in. (38 mm) for the entire run for runs greater than 80 ft (24.4 m). For piping serving multiple hose stations, runs shall be a minimum of $1^1/_2$ in. (38 mm) throughout.
(3) Piping shall be at least 1 in. (25 mm) for vertical runs.
(4) When the pressure at any hose station outlet exceeds 100 psi (6.9 bar), an approved device shall be installed at the outlet to reduce the pressure at the outlet to 100 psi (6.9 bar).

5-15.5.2* Hose Connections for Fire Department Use. In buildings of light or ordinary hazard occupancy, $2^1/_2$-in. (64-mm) hose valves for fire department use are permitted to be attached to wet pipe sprinkler system risers. *[See 7-2.3.1.3(d).]* The following restrictions shall apply:

(1) Sprinklers shall be under separate floor control valves.
(2) The minimum size of the riser shall be 4 in. (102 mm) unless hydraulic calculations indicate that a smaller size riser will satisfy sprinkler and hose stream demands.
(3) Each combined sprinkler and standpipe riser shall be equipped with a riser control valve to permit isolating a riser without interrupting the supply to other risers from the same source of supply.

(For fire department connections serving standpipe and sprinkler systems, refer to Section 3-9.)

5-16 Spray Application Using Flammable and Combustible Materials.

5-16.1 For applicable terms not defined in Chapter 1, the terms defined in NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials*, shall be used.

5-16.2* The sprinklers for each spray area and mixing room shall be controlled by a separate, accessible, listed indicating valve. Sprinkler systems in stacks or ducts shall be automatic and of a type not subject to freezing. (**33:** 7-2.4)

5-16.3 Sprinklers protecting spray areas and mixing rooms shall be protected against overspray residue so that they will operate quickly in event of fire. If covered, cellophane bags having a thickness of 0.003 in. (0.076 mm) or less, or thin paper bags shall be used. Coverings shall be replaced frequently so that heavy deposits of residue do not accumulate. Sprinklers that have been painted or coated, except by the sprinkler manufacturer, shall be replaced with new listed sprinklers having the same characteristics. (**33:** 7-2.5)

5-17 Storage and Handling of Cellulose Nitrate Motion Picture Film.

5-17.1 For applicable terms not defined in Chapter 1, the terms defined in NFPA 40, *Standard for the Storage and Handling of Cellulose Nitrate Motion Picture Film*, shall be used.

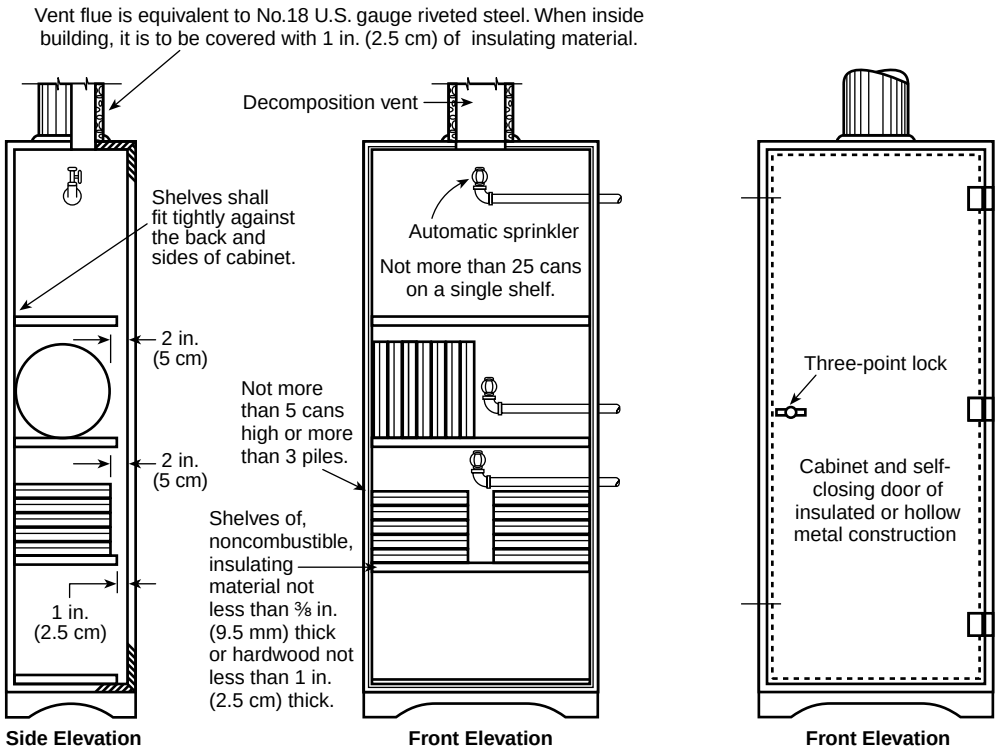
5-17.2 In areas or room where nitrate film is handled, the area that is protected per sprinkler shall not exceed 64 ft^2 (6 m^2) with sprinklers and branch lines not being over 8 ft (2.4 m) apart. (**40:** 3-1.4)

5-17.3 Cabinet Protection. (**40:** 4-2.5)

5-17.3.1 Where cabinets are required to be sprinklered, they shall be provided with at least one automatic sprinkler. (**40:** 4-2.5.1)

5-17.3.2 Where cans are stored on more than one shelf, as shown in Figure 5-17.3.2 and as described in 4-2.6.1 or 4-2.6.2 of NFPA 40, one sprinkler shall be provided for each shelf. (**40:** 4-2.5.2)

Figure 5-17.3.2 Standard film cabinet for other than extended term storage film. (40: Figure 4-2)



5-17.4 Vaults Other than Extended Term Storage Vaults. (**40:** 4-3)

5-17.4.1 Sprinkler protection utilizing regular automatic sprinklers or open sprinklers shall be calculated on the basis of one sprinkler for each 62.5 ft^3 (1.8 m^3) of the interior vault volume. (**40:** 4-3.6.1)

5-17.4.2 The minimum number of sprinklers for a standard 750-ft^3 (21-m^3) vault shall be not less than 12. (**40:** 4-3.6.2)

5-17.5 Extended Term Storage Vaults.

5-17.5.1 Sprinklers shall be provided in a ratio of one sprinkler for each 62.5 ft^3 (1.8 m^3) of vault volume.

Exception: Sprinkler systems in existing extended term storage vaults that were in compliance with the provisions of NFPA 40 at the time of installation shall be permitted to be continued in use.

(**40:** 4-5.5.1)

5-17.5.2 The minimum number of sprinklers for a 1000-ft^3 (28-m^3) vault shall be 15 sprinklers.

Exception: Sprinkler systems in existing extended term storage vaults that were in compliance with the provisions of NFPA 40 at the time of installation shall be permitted to be continued in use.

(**40:** 4-5.5.2)

5-17.5.3 Directional sprinklers that will provide coverage into the face of the shelves shall be provided. (**40:** 4-5.5.3)

5-17.6 Motion Picture Film Laboratories. In all cases, sprinklers shall be arranged so that not more than two machines are protected by any one sprinkler. (**40:** 7-2.5.2)

5-18 Storage of Pyroxylin Plastic.

5-18.1 For applicable terms not defined in Chapter 1 the terms defined in NFPA 42, *Code for the Storage of Pyroxylin Plastic*, shall be used.

5-18.2 Where sprinkler systems are provided for isolated storage buildings per Section 3-4.3 of NFPA 42, sprinklers shall be spaced so that there is one sprinkler per 32 ft^2 (3 m^2). (**42:** 3-4.3)

5-18.3 Sprinklers in buildings used for storage of loose scrap shall be installed in the ratio of one sprinkler for each 1000 lb (454 kg) of storage.

Exception: The ratio in 5-18.3 shall need not apply if the scrap is in tanks or other receptacles kept filled with water.

(**42:** 3-4.4)

5-18.4 Where cabinets are required to be sprinklered, they shall have at least one automatic sprinkler in each compartment. (**42:** 4-2.10)

5-18.5* Vaults Containing Pyroxylin Plastic.

5-18.5.1 Vaults shall be equipped with automatic sprinklers in a ratio of one sprinkler to each 834 lb (378 kg) of pyroxylin plastic or one sprinkler to each 125 ft^3 (3.5 m^3) of total vault space. (**42:** 4-4.1)

5-18.5.2 A vault that is divided into two or more sections shall have at least one automatic sprinkler in each section. (**42:** 4-4.2)

5-18.5.3 Sprinkler systems for vaults shall be equipped with a 1-in. (2.5-cm) drip line with a $^1/_2$-in. (13-mm) outlet valve. (**42:** 4-4.5)

5-18.6* Tote-Box Storeroom for Pyroxylin Plastic. Sprinkler protection provided for the tote box storeroom shall consist of one sprinkler in the center of the aisle immediately in front of the dividing partition between each pair of sections. Proper baffles shall be provided between heads. *[See Figure A-5-18.6(a).]* (**42:** 4-7.9)

5-18.7* Finished Stock Storeroom for Pyroxylin Plastic.

5-18.7.1 Automatic sprinklers shall be installed with proper baffles between sprinklers in the center of the aisle opposite each section. (**42:** 4-8.7)

5-18.7.2 Special Rooms for Stock in Shipping Cases. The special room shall be protected by automatic sprinklers, with at least one sprinkler for each 64 ft^2 (6 m^2). (**42:** 4-9.4)

5-19 Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes.

5-19.1 For applicable terms not defined in Chapter 1, the terms defined in NFPA 51, *Standard for the Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes*, shall be used.

5-19.2 Where sprinkler systems are provided per NFPA 51, 2-3.1, Exception No. 1, sprinklers shall be located not more than 20 ft (6 m) above the floor where the cylinders are stored.

5-20 Electronic Computer Systems. Where sprinkler systems are provided per NFPA 75, *Standard for the Protection of Electronic Computer/Data Processing Equipment*, they shall be valved separately from other sprinkler systems. (**75:** 6-1.3)

5-21 Incinerators, Systems and Equipment.

5-21.1 Where sprinkler systems are provided per NFPA 82, *Standard on Incinerators and Waste and Linen Handling Systems and Equipment*, the following shall apply.

5-21.2 For applicable terms not defined in Chapter 1, NFPA 82 shall be used.

5-21.3 Chute Automatic Sprinklers. (**82:** 3-2.5)

5-21.3.1* Gravity Chute. Gravity chutes shall be protected internally by automatic sprinklers. This requires a sprinkler at or above the top service opening of the chute, and, in addition, a sprinkler shall be installed within the chute at alternate floor levels in buildings over two stories in height with a mandatory sprinkler located at the lowest service level. (**82:** 3-2.5.1)

5-21.3.2 Chute Sprinkler Head Protection. Automatic sprinklers installed in gravity chute service openings shall be recessed out of the chute area through which the material travels. (**82:** 3-2.5.2)

5-21.4 Automatic Sprinklers, Full Pneumatic Systems. Full pneumatic-type risers shall be protected internally by automatic sprinklers. A sprinkler shall be required at or above the top loading station and at alternate floor levels in buildings over two stories in height, with a mandatory sprinkler located at the lowest loading station. Sprinklers shall be recessed out of the station area through which the material travels. (**82:** 3-3.4)

5-21.5 Commercial-Industrial Compactors. All chute-fed compactors shall have an automatic special fine water spray sprinkler with a minimum $^1/_2$-in. (13-mm) orifice installed in the hopper of the compactor. This sprinkler shall be an ordinary temperature–rated sprinkler. The sprinklers shall be supplied by a minimum 1-in. (25.4-mm) ferrous piping or $^3/_4$-in. (19-mm) copper tubing line from the domestic cold water supply.

The sprinkler shall provide a suitable spray into the hopper. A cycling (on-off), self-actuating, snap-action, heat-actuated sprinkler shall be permitted to be used, or the sprinkler shall be permitted to be controlled by a temperature sensor operating a solenoid valve. Sprinkler water piping shall be protected from freezing in outdoor installations. (**82:** 5-3, 5-3.1)

5-22 Industrial Furnaces Using a Special Processing Atmosphere.

5-22.1 For applicable terms not defined in Chapter 1 the terms defined in NFPA 86C, *Standard for Industrial Furnaces Using a Special Processing Atmosphere*, shall be used.

5-22.2 Where sprinkler systems are provided per NFPA 86C, 18-1.2(b), sprinklers shall be of extra high-temperature rating [325°F to 650°F (163°C to 343°C] to avoid premature operation from localized flashing. [**86C:** 18-1.2(b)]

5-23 Water-Cooling Towers.

5-23.1 Where sprinkler systems are provided per NFPA 214, *Standard on Water-Cooling Towers*, the following rules shall apply.

5-23.2 For applicable terms not defined in Chapter 13, NFPA 214 shall be used.

5-23.3* Counterflow Towers. (**214:** 3-2.4.1)

5-23.3.1 The discharge outlets shall be located under the fan deck and fan opening. (**214:** 3-2.4.1.1)

5-23.3.2 Except under the fan opening, all discharge outlets shall have deflector distances installed in accordance with Section 5-5. (**214:** 3-2.4.1.2)

Exception: Under fan openings.

5-23.3.3 Closed-head discharge outlets for dry-pipe and preaction systems shall be installed in the upright position only. (**214:** 3-2.4.1.3)

5-23.4* Crossflow Towers. (**214:** 3-2.4.2)

5-23.4.1 The discharge outlets protecting the plenum area shall be located under the fan deck and in the fan opening. (**214:** 3-2.4.2.1)

5-23.4.2 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. (**214:** 3-2.4.2.2)

5-23.4.3 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. (**214:** 3-2.4.2.3)

5-23.4.4 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.

(**214:** 3-2.4.2.4)

5-23.5* 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. (**214:** 3-2.4.3)

5-23.6 For deluge systems using directional spray nozzles in the pendent position, provisions shall be made to protect the underside of a combustible fan deck. (**214:** 3-2.4.4)

5-23.6.1* 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 5-23.4. (**214:** 3-2.4.5)

5-23.7 Valves. (**214:** 3-2.6)

5-23.7.1 General. Shutoff valves and automatically operated water control valves, if provided, shall be located:

(1) Outside the fire-exposed area;
(2) As close to the cooling tower as possible to minimize the amount of pipe to the discharge device; and
(3) Where they will be accessible during a fire emergency.

(**214:** 3-2.6.1)

5-23.7.2 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. (**214:** 3-2.6.2)

5-23.8 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.)* (**214:** 3-2.7)

5-23.9 Heat Detectors. (**214:** 3-2.8)

5-23.9.1 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®*. (**214:** 3-2.8.1)

5-23.9.2 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 in NFPA 214.)* (**214:** 3-2.8.2)

5-23.9.2.1 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. (**214:** 3-2.8.2.1)

5-23.9.2.2 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. (**214:** 3-2.8.2.2)

5-23.9.3 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.

(**214:** 3-2.8.3)

5-23.9.4 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. (**214:** 3-2.8.4)

5-23.9.5 Where heat detectors are inaccessible during tower operation, an accessible test detector shall be provided for each detection zone. (**214:** 3-2.8.5)

5-23.9.6 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. (**214:** 3-2.8.6)

5-23.10 Protection for Fan Drive Motor. (**214:** 3-2.9)

5-23.10.1 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. (**214:** 3-2.9.1)

5-23.10.2 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. (**214:** 3-2.9.2)

5-23.11 Corrosion Protection. (**214:** 3-3)

5-23.11.1 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. (**214:** 3-3.1)

5-23.11.2 Approved sprinklers 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. (**214:** 3-3.2)

5-23.11.3 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. (**214:** 3-3.3)

5-24 Construction and Fire Protection of Marine Terminals, Piers, and Wharves.

5-24.1 Where sprinkler systems are provided per NFPA 307, *Standard for the Construction and Fire Protection of Marine Terminals, Piers, and Wharves*, the following shall also apply.

5-24.2 For terms not defined in Chapter 1, NFPA 307 shall be used.

5-24.3 Where there is danger of damage to sprinkler equipment by floating objects, physical barriers shall be provided to exclude such objects. (**307:** 3-3.3.2)

5-24.4 The following installation criteria shall also 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 pendent 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 pendent 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 temperature rating of the sprinkler shall not exceed 74°C (165°F).
(6) 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.

(**307:** 3-3.3.3)

5-25 Cleanrooms.

5-25.1 Where sprinkler systems are provided per NFPA 318, *Standard for the Protection of Cleanrooms*, the following shall also apply.

5-25.2 For applicable terms not defined in Chapter 1, NFPA 318 shall be used.

5-25.3 Cleanrooms. Wet pipe automatic sprinkler protection shall be provided throughout facilities containing cleanrooms and clean zones. (**318:** 2-1.1)

5-25.4* Quick response sprinklers shall be utilized for sprinkler installations within down-flow airstreams in cleanrooms and clean zones. (**318:** 2-1.2.2)

5-25.5* Sprinklers installed in ductwork shall be spaced a maximum of 20 ft (6.1 m) apart horizontally and 12 ft (3.7 m) apart vertically. (**318:** 2-1.2.6.1)

5-25.6 A separate indicating control valve shall be provided for sprinklers installed in ductwork. (**318:** 2-1.2.6.2)

5-25.7 The sprinklers shall be accessible for periodic inspection and maintenance. (**318:** 2-1.2.6.5)

5-26 Aircraft Hangars. See NFPA 409, *Standard on Aircraft Hangars*, for sprinkler system installation criteria pertaining to the protection of aircraft hangars.

5-27* Liquid and Solid Oxidizers. See NFPA 430, *Code for the Storage of Liquid and Solid Oxidizers.*

5-28 Organic Peroxide Formulations.

5-28.1 For applicable terms not defined in Chapter 1, NFPA 432, *Code for the Storage of Organic Peroxide Formulations*, shall be used.

5-28.2 Where automatic sprinkler protection is provided for Class I organic peroxide formulations in quantities exceeding 2000 lb (907 kg), it shall be a deluge system. (**432:** 5-5.2)

5-29 Light Water Nuclear Power Plants.

5-29.1 For applicable terms not defined in Chapter 1, NFPA 803, *Standard for Fire Protection for Light Water Nuclear Power Plants*, shall be used.

5-29.2 Each system shall have an independent connection to the plant yard main and be equipped with an approved indicating-type control or shutoff valve. (**803:** 10-2.2)

Multiple sprinkler and standpipe systems shall be supplied by interior headers or fire protection loops. When provided, such headers or loops are considered an extension of the yard main system and shall be provided with at least two connections to the yard main. The arrangement shall be supplied and

valved so that no single impairment can affect sprinkler and hose protection at the same time.

5-29.3 The fire main system piping shall not serve service water system functions. (**803:** 12-3)

5-30 Advanced Light Water Reactor Electric Generating Plants.

5-30.1 For applicable terms not defined in Chapter 1, NFPA 804, *Standard for Fire Protection for Advanced Light Water Reactor Electric Generating Plants*, shall be used.

5-30.2 Yard Mains, Hydrants, and Building Standpipes. (**804:** 7-4)

5-30.2.1 Approved visually indicating sectional control valves such as post-indicator valves shall be provided to isolate portions of the main for maintenance or repair without simultaneously shutting off the supply to both primary and backup fire suppression systems. (**804:** 7-4.2)

5-30.2.2 A common yard fire main loop may serve multi-unit nuclear power plant sites if it is cross-connected between units. Sectional control valves shall permit maintaining independence of the individual loop around each unit. For such installations, common water supplies shall also be permitted to be utilized. For multiple-reactor sites with widely separated plants [approaching 1 mi. (1.6 km) or more], separate yard fire main loops shall be used. (**804:** 7-4.4)

5-30.2.3 Sprinkler systems and manual hose station standpipes shall have connections to the plant underground water main so that a single active failure or a crack in a moderate-energy line can be isolated so as not to impair both the primary and backup fire suppression systems. Alternatively, headers fed from each end are permitted inside buildings to supply both sprinkler and standpipe systems, provided steel piping and fittings meeting the requirements of ANSI B31.1, *Code for Power Piping*, are used for the headers (up to and including the first valve) supplying the sprinkler systems where such headers are part of the seismically analyzed hose standpipe system. Where provided, such headers are considered an extension of the yard main system. Each sprinkler and standpipe system shall be equipped with an outside screw and yoke (OS&Y) gate valve or other approved shutoff valve. (**804:** 7-4.7)

5-30.3 Cable Concentrations. The location of sprinklers or spray nozzles shall consider cable tray arrangements and possible transient combustibles to ensure adequate water coverage for areas that could present exposure fire hazards to the cable raceways. (**804:** 8-4.2.2.2)

5-30.4 Turbine Building. Deluge sprinkler systems or deluge spray systems shall be zoned to limit the area of protection to that which the drainage system can handle with any two adjacent systems actuated. The systems shall be hydraulically designed with each zone calculated with the largest adjacent zone flowing. (**804:** 8-4.2.2.3)

5-31* Electric Generating Plants and High Voltage Direct Current Converter Stations. For applicable terms not defined in Chapter 1, NFPA 850, *Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations*, shall be used.

5-32* Hydroelectric Generating Plants. See NFPA 851, *Recommended Practice for Fire Protection for Hydroelectric Generating Plants*, for applicable terms not defined in Chapter 1.

Chapter 6 Hanging, Bracing, and Restraint of System Piping

6-1 Hangers.

6-1.1* General. Types of hangers shall be in accordance with the requirements of Section 6-1.

Exception No. 1: Hangers certified by a registered professional engineer to include all of the following shall be acceptable:

(a) Hangers shall be designed to support five times the weight of the water-filled pipe plus 250 lb (114 kg) at each point of piping support.

(b) These points of support shall be adequate to support the system.

(c) The spacing between hangers shall not exceed the value given for the type of pipe as indicated in Table 6-2.2.

(d) Hanger components shall be ferrous.

Detailed calculations shall be submitted, when required by the reviewing authority, showing stresses developed in hangers, piping, and fittings and safety factors allowed.

Exception No. 2: In areas subject to earthquake, hangers shall also meet the requirements of 6-4.7.

6-1.1.1 The components of hanger assemblies that directly attach to the pipe or to the building structure shall be listed.

Exception No. 1: Mild steel hangers formed from rods shall be permitted to be not listed.

Exception No. 2: Fasteners as specifically identified in 6-1.5 shall be permitted to be not listed.

6-1.1.2 Hangers and their components shall be ferrous.

Exception No. 1: Nonferrous components that have been proven by fire tests to be adequate for the hazard application, that are listed for this purpose, and that are in compliance with the other requirements of this section shall be acceptable.

Exception No. 2: Holes through solid structural members shall be permitted to serve as hangers for the support of system piping provided such holes are permitted by applicable building codes and the spacing and support provisions for hangers of this standard are satisfied.

6-1.1.3* For trapeze hangers, the minimum size of steel angle or pipe span between purlins or joists shall be such that the available section modulus of the trapeze member from Table 6-1.1.3(b) equals or exceeds the section modulus required in Table 6-1.1.3(a).

Any other sizes or shapes giving equal or greater section modulus shall be acceptable. All angles shall be used with the longer leg vertical. The trapeze member shall be secured to prevent slippage. Where a pipe is suspended from a pipe trapeze of a diameter less than the diameter of the pipe being supported, ring, strap, or clevis hangers of the size corresponding to the suspended pipe shall be used on both ends.

6-1.1.4 The size of hanger rods and fasteners required to support the steel angle iron or pipe indicated in Table 6-1.1.3(b) shall comply with 6-1.4. Holes for bolts shall not exceed $^1/_{16}$ in. greater than the diameter of the bolt. Bolts shall be provided with a flat washer and nut.

6-1.1.5* Sprinkler piping or hangers shall not be used to support nonsystem components.

6-1.2 Concrete Inserts and Expansion Shields.

6-1.2.1 The use of listed inserts set in concrete and listed expansion shields to support hangers shall be permitted for mains and branch lines.

Table 6-1.1.3(a) Section Modulus Required for Trapeze Members (in.^{3})

Span of Trapeze	1 in.	$1^1/_4$ in.	$1^1/_2$ in.	2 in.	$2^1/_2$ in.	3 in.	$3^1/_2$ in.	4 in.	5 in.	6 in.	8 in.	10 in.
1 ft 6 in.	0.08	0.09	0.09	0.09	0.10	0.11	0.12	0.13	0.15	0.18	0.24	0.32
	0.08	0.09	0.09	0.10	0.11	0.12	0.13	0.15	0.18	0.22	0.30	0.41
2 ft 0 in.	0.11	0.12	0.12	0.13	0.13	0.15	0.16	0.17	0.20	0.24	0.32	0.43
	0.11	0.12	0.12	0.13	0.15	0.16	0.18	0.20	0.24	0.29	0.40	0.55
2 ft 6 in.	0.14	0.14	0.15	0.16	0.17	0.18	0.20	0.21	0.25	0.30	0.40	0.54
	0.14	0.15	0.15	0.16	0.18	0.21	0.22	0.25	0.30	0.36	0.50	0.68
3 ft 0 in.	0.17	0.17	0.18	0.19	0.20	0.22	0.24	0.26	0.31	0.36	0.48	0.65
	0.17	0.18	0.18	0.20	0.22	0.25	0.27	0.30	0.36	0.43	0.60	0.82
4 ft 0 in.	0.22	0.23	0.24	0.25	0.27	0.29	0.32	0.34	0.41	0.48	0.64	0.87
	0.22	0.24	0.24	0.26	0.29	0.33	0.36	0.40	0.48	0.58	0.80	1.09
5 ft 0 in.	0.28	0.29	0.30	0.31	0.34	0.37	0.40	0.43	0.51	0.59	0.80	1.08
	0.28	0.29	0.30	0.33	0.37	0.41	0.45	0.49	0.60	0.72	1.00	1.37
6 ft 0 in.	0.33	0.35	0.36	0.38	0.41	0.44	0.48	0.51	0.61	0.71	0.97	1.30
	0.34	0.35	0.36	0.39	0.44	0.49	0.54	0.59	0.72	0.87	1.20	1.64
7 ft 0 in.	0.39	0.40	0.41	0.44	0.47	0.52	0.55	0.60	0.71	0.83	1.13	1.52
	0.39	0.41	0.43	0.46	0.51	0.58	0.63	0.69	0.84	1.01	1.41	1.92
8 ft 0 in.	0.44	0.46	0.47	0.50	0.54	0.59	0.63	0.68	0.81	0.95	1.29	1.73
	0.45	0.47	0.49	0.52	0.59	0.66	0.72	0.79	0.96	1.16	1.61	2.19
9 ft 0 in.	0.50	0.52	0.53	0.56	0.61	0.66	0.71	0.77	0.92	1.07	1.45	1.95
	0.50	0.53	0.55	0.59	0.66	0.74	0.81	0.89	1.08	1.30	1.81	2.46
10 ft 0 in.	0.56	0.58	0.59	0.63	0.68	0.74	0.79	0.85	1.02	1.19	1.61	2.17
	0.56	0.59	0.61	0.65	0.74	0.82	0.90	0.99	1.20	1.44	2.01	2.74

For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m.

Notes:
1. Top values are for Schedule 10 pipe; bottom values are for Schedule 40 pipe.
2. The table is based on a maximum allowable bending stress of 15 ksi and a midspan concentrated load from 15 ft (4.6 m) of water-filled pipe, plus 250 lb (114 kg).

Exception No. 1: Expansion shields shall not be used in cinder concrete, except for branchlines where the expansion shields are alternated with through-bolts or hangers attached to beams.

Exception No. 2: Expansion shields shall not be used in ceilings of gypsum or other similar soft material.

6-1.2.2 Expansion shields shall be installed in a horizontal position in the sides of concrete beams.

Exception: Expansion shields shall be permitted to be installed in the vertical position under the following conditions:

(a) When used in concrete having gravel or crushed stone aggregate to support pipes 4 in. (102 mm) or less in diameter.

(b) When expansion shields are alternated with hangers connected directly to the structural members, such as trusses and girders, or to the sides of concrete beams [to support pipe 5 in. (127 mm) or larger].

(c) When expansion shields are spaced not over 10 ft (3 m) apart [to support pipe 4 in. (102 m) or larger].

6-1.2.3 Holes for expansion shields in the side of beams shall be above the centerline of the beam or above the bottom reinforcement steel rods.

6-1.2.4 Holes for expansion shields used in the vertical position shall be drilled to provide uniform contact with the shield over its entire circumference. The depth of the hole shall not be less than specified for the type of shield used.

6-1.3 Powder-Driven Studs and Welding Studs.

6-1.3.1* Powder-driven studs, welding studs, and the tools used for installing these devices shall be listed. Pipe size, installation position, and construction material into which they are installed shall be in accordance with individual listings.

Table 6-1.1.3(b) Available Section Moduli of Common Trapeze Hangers (in.^{3})

Pipe (in.)	Modulus	Angles	Modulus
Schedule 10			
1	0.12	$1^1/_2 \times 1^1/_2 \times {}^3/_{16}$	0.10
$1^1/_4$	0.19	$2 \times 2 \times {}^1/_8$	0.13
$1^1/_2$	0.26	$2 \times 1^1/_2 \times {}^3/_{16}$	0.18
2	0.42	$2 \times 2 \times {}^3/_{16}$	0.19
$2^1/_2$	0.69	$2 \times 2 \times {}^1/_4$	0.25
3	1.04	$2^1/_2 \times 1^1/_2 \times {}^3/_{16}$	0.28
$3^1/_2$	1.38	$2^1/_2 \times 2 \times {}^3/_{16}$	0.29
4	1.76	$2 \times 2 \times {}^5/_{16}$	0.30
5	3.03	$2^1/_2 \times 2^1/_2 \times {}^3/_{16}$	0.30
6	4.35	$2 \times 2 \times {}^3/_8$	0.35
		$2^1/_2 \times 2^1/_2 \times {}^1/_4$	0.39
		$3 \times 2 \times {}^3/_{16}$	0.41
Schedule 40			
1	0.13	$3 \times 2^1/_2 \times {}^3/_{16}$	0.43
$1^1/_4$	0.23	$3 \times 3 \times {}^3/_{16}$	0.44
$1^1/_2$	0.33	$2^1/_2 \times 2^1/_2 \times {}^5/_{16}$	0.48
2	0.56	$3 \times 2 \times {}^1/_4$	0.54
$2^1/_2$	1.06	$2^1/_2 \times 2 \times {}^3/_8$	0.55
3	1.72	$2^1/_2 \times 2^1/_2 \times {}^3/_8$	0.57
$3^1/_2$	2.39	$3 \times 3 \times {}^1/_4$	0.58
4	3.21	$3 \times 3 \times {}^5/_{16}$	0.71
5	5.45	$2^1/_2 \times 2^1/_2 \times {}^1/_2$	0.72
6	8.50	$3^1/_2 \times 2^1/_2 \times {}^1/_4$	0.75
		$3 \times 2^1/_2 \times {}^3/_8$	0.81
		$3 \times 3 \times {}^3/_8$	0.83
		$3^1/_2 \times 2^1/_2 \times {}^5/_{16}$	0.93
		$3 \times 3 \times {}^7/_{16}$	0.95
		$4 \times 4 \times {}^1/_4$	1.05
		$3 \times 3 \times {}^1/_2$	1.07
		$4 \times 3 \times {}^5/_{16}$	1.23
		$4 \times 4 \times {}^5/_{16}$	1.29
		$4 \times 3 \times {}^3/_8$	1.46
		$4 \times 4 \times {}^3/_8$	1.52
		$5 \times 3^1/_2 \times {}^5/_{16}$	1.94
		$4 \times 4 \times {}^1/_2$	1.97
		$4 \times 4 \times {}^5/_8$	2.40
		$4 \times 4 \times {}^3/_4$	2.81
		$6 \times 4 \times {}^3/_8$	3.32
		$6 \times 4 \times {}^1/_2$	4.33
		$6 \times 4 \times {}^3/_4$	6.25
		$6 \times 6 \times 1$	8.57

Table 6-1.1.3(b) Available Section Moduli of Common Trapeze Hangers (in.^{3})

For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m.

6-1.3.2* Representative samples of concrete into which studs are to be driven shall be tested to determine that the studs will hold a minimum load of 750 lb (341 kg) for 2-in. (51-mm) or smaller pipe, 1000 lb (454 kg) for $2^1/_2$-, 3-, or $3^1/_2$-in. (64-, 76-, or 89-mm) pipe, and 1200 lb (545 kg) for 4- or 5-in. (102- or 127-mm) pipe.

6-1.3.3 Increaser couplings shall be attached directly to the powder-driven studs or welding studs.

6-1.3.4 Welding studs or other hanger parts shall not be attached by welding to steel less than U.S. Standard, 12 gauge.

6-1.4 Rods and U-Hooks.

6-1.4.1 Rods and Coach Screw Rods. Hanger rod size shall be the same as that approved for use with the hanger assembly, and the size of rods shall not be less than that given in Table 6-1.4.1.

Exception: Rods of smaller diameter shall be permitted where the hanger assembly has been tested and listed by a testing laboratory and installed within the limits of pipe sizes expressed in individual listings.

Table 6-1.4.1 Hanger Rod Sizes

Pipe Size	Diameter of Rod	
	in.	mm
Up to and including 4 in.	$^3/_8$	9.5
5, 6, and 8 in.	$^1/_2$	12.7
10 and 12 in.	$^5/_8$	15.9

6-1.4.2 U-Hooks. The size of the rod material of U-hooks shall not be less than that given in Table 6-1.4.2.

Table 6-1.4.2 U-Hook Rod Sizes

Pipe Size	Hook Material Diameter	
	in.	mm
Up to 2 in.	$^5/_{16}$	7.9
$2^1/_2$ to 6 in.	$^3/_8$	9.5
8 in.	$^1/_2$	12.7

6-1.4.3 Eye Rods. The size of the rod material for eye rods shall not be less than specified in Table 6-1.4.3. Eye rods shall be secured with lock washers to prevent lateral motion. Where eye rods are fastened to wood structural members, the eye rod shall be backed with a large flat washer bearing directly against the structural member, in addition to the lock washer.

Table 6-1.4.3 Eye Rod Sizes

Pipe Size	Diameter of Rod			
	With Bent Eye		With Welded Eye	
	in.	mm	in.	mm
Up to 4 in.	$^3/_8$	9.5	$^3/_8$	9.5
5 to 6 in.	$^1/_2$	12.7	$^1/_2$	12.7
8 in.	$^3/_4$	19.1	$^1/_2$	12.7

6-1.4.4 Threaded sections of rods shall not be formed or bent.

6-1.5 Screws and Bolts.

6-1.5.1 Drive screws shall be used only in a horizontal position as in the side of a beam and only for 2-in. pipe or smaller. Drive screws shall only be used in conjunction with hangers that require two points of attachments.

6-1.5.2 For ceiling flanges and U-hooks, screw dimensions shall not be less than those given in Table 6-1.5.2.

Exception: When the thickness of planking and thickness of flange do not permit the use of screws 2 in. (51 mm) long, screws $1^3/_4$ in. (44 mm) long shall be permitted with hangers spaced not over 10 ft (3 m) apart. When the thickness of beams or joists does not permit the use of screws $2^1/_2$ in. (64 mm) long, screws 2 in. (51 mm) long shall be permitted with hangers spaced not over 10 ft (3 m) apart.

6-1.5.3 The size of bolt or lag screw used with a hanger and installed on the side of the beam shall not be less than specified in Table 6-1.5.3. All holes for lag screws shall be predrilled $^1/_8$ in. (3.2 mm) less in diameter than the maximum root diameter of the lag screw thread. Holes for bolts shall not exceed $^1/_{16}$ in. (1.6 mm) greater than the diameter of the bolt. Bolts shall be provided with a flat washer and nut.

Exception: Where the thickness of beams or joists does not permit the use of screws $2^1/_2$ in. (64 mm) long, screws 2 in. (51 mm) long shall be permitted with hangers spaced not over 10 ft (3 m) apart.

Table 6-1.5.2 Screw Dimensions for Ceiling Flanges and U-Hooks

Pipe Size	Two Screw Ceiling Flanges
Up to 2 in.	Wood screw No. 18 × $1^1/_2$ in.
	or
	Lag screw $^5/_{16}$ in. × $1^1/_2$ in.
Pipe Size	**Three Screw Ceiling Flanges**
Up to 2 in.	Wood screw No.18 × $1^1/_2$ in.
$2^1/_2$ in., 3 in., $3^1/_2$ in.	Lag screw $^3/_8$ in. × 2 in.
4 in., 5 in., 6 in.	Lag screw $^1/_2$ in. × 2 in.
8 in.	Lag screw $^5/_8$ in. × 2 in.
Pipe Size	**Four Screw Ceiling Flanges**
Up to 2 in.	Wood screw No. 18 × $1^1/_2$ in.
$2^1/_2$ in., 3 in., $3^1/_2$ in.	Lag screw $^3/_8$ in. × $1^1/_2$ in.
4 in., 5 in., 6 in.	Lag screw $^1/_2$ in. × 2 in.
8 in.	Lag screw $^5/_8$ in. × 2 in.
Pipe Size	**U-Hooks**
Up to 2 in.	Drive screw No. 16 × 2 in.
$2^1/_2$ in., 3 in., $3^1/_2$ in.	Lag screw $^3/_8$ in. × $2^1/_2$ in.
4 in., 5 in., 6 in.	Lag screw $^1/_2$ in. × 3 in.
8 in.	Lag screw $^5/_8$ in. × 3 in.

For SI units, 1 in. = 25.4 mm.

Table 6-1.5.3 Minimum Bolt or Lag Screw Sizes for Side of Beam Installation

Pipe Size	Size of Bolt or Lag Screw		Length of Lag Screw Used with Wood Beams	
	in.	mm	in.	mm
Up to and including 2 in.	$^3/_8$	9.5	$2^1/_2$	64
$2^1/_2$ to 6 in. (inclusive)	$^1/_2$	12.7	3	76
8 in.	$^5/_8$	15.9	3	76

6-1.5.4 Wood screws shall be installed with a screwdriver.

6-1.5.5 Nails are not acceptable for fastening hangers.

6-1.5.6 Screws in the side of a timber or joist shall be not less than $2^1/_2$ in. (64 mm) from the lower edge where supporting branch lines and not less than 3 in. (76 mm) where supporting main lines.

Exception: This requirement shall not apply to 2-in. (51-mm) or thicker nailing strips resting on top of steel beams.

6-1.5.7 The minimum plank thickness and the minimum width of the lower face of beams or joists in which coach screw rods are used shall be not less than that specified in Table 6-1.5.7.

Table 6-1.5.7 Minimum Plank Thicknesses and Beam or Joist Widths

	Nominal Plank Thickness		Nominal Width of Beam or Joist Face	
Pipe Size	in.	mm	in.	mm
Up to 2 in.	3	76	2	51
$2^1/_2$ to $3^1/_2$ in.	4	102	2	51
4 in. and 5 in.	4	102	3	76
6 in.	4	102	4	102

6-1.5.8 Coach screw rods shall not be used for support of pipes larger than 6 in. (152 mm) in diameter. All holes for coach screw rods shall be predrilled $^1/_8$ in. (3.2 mm) less in diameter than the maximum root diameter of the wood screw thread.

6-2 Installation of Pipe Hangers.

6-2.1 General.

6-2.1.1 Sprinkler piping shall be supported independently of the ceiling sheathing.

Exception: Toggle hangers shall be permitted only for the support of pipe $1^1/_2$ in. (38 mm) or smaller in size under ceilings of hollow tile or metal lath and plaster.

6-2.1.2 Where sprinkler piping is installed in storage racks, piping shall be supported from the storage rack structure or building in accordance with all applicable provisions of Sections 6-2 and 6-3.

6-2.1.3* Sprinkler piping shall be substantially supported from the building structure, which must support the added load of the water-filled pipe plus a minimum of 250 lb (114 kg) applied at the point of hanging. Trapeze hangers shall be used where necessary to transfer loads to appropriate structural members.

Exception: Branch line hangers under metal deck shall be permitted only for the support of pipe 1 in. (25.4 mm) or smaller in size, by drilling or punching vertical members and using through bolts. The distance from the bottom of the bolt hole to the bottom of the vertical member shall be not less than $^3/_8$ in. (9.5 mm).

6-2.1.4 Where sprinkler piping is installed below ductwork, piping shall be supported from the building structure or from the ductwork supports, provided such supports are capable of handling both the load of the ductwork and the load specified in 6-2.1.3.

6-2.2* Maximum Distance between Hangers. The maximum distance between hangers shall not exceed that specified in Table 6-2.2.

Exception: The maximum distance between hangers for listed nonmetallic pipe shall be modified as specified in the individual product listings.

6-2.3 Location of Hangers on Branch Lines. This subsection applies to the support of steel pipe or copper tube as specified in 3-3.1 and subject to the provisions of 6-2.2.

6-2.3.1 There shall be not less than one hanger for each section of pipe.

*Exception No. 1: *Where sprinklers are spaced less than 6 ft (1.8 m) apart, hangers spaced up to a maximum of 12 ft (3.7 m) shall be permitted.*

Exception No. 2: Starter lengths less than 6 ft (1.8 m) shall not require a hanger, unless on the end line of a sidefeed system or where an intermediate cross main hanger has been omitted.

Table 6-2.2 Maximum Distance Between Hangers (ft-in.)

Nominal Pipe Size (in.)	$^3/_4$	1	$1^1/_4$	$1^1/_2$	2	$2^1/_2$	3	$3^1/_2$	4	5	6	8
Steel pipe except threaded lightwall	N/A	12-0	12-0	15-0	15-0	15-0	15-0	15-0	15-0	15-0	15-0	15-0
Threaded lightwall steel pipe	N/A	12-0	12-0	12-0	12-0	12-0	12-0	N/A	N/A	N/A	N/A	N/A
Copper tube	8-0	8-0	10-0	10-0	12-0	12-0	12-0	15-0	15-0	15-0	15-0	15-0
CPVC	5-6	6-0	6-6	7-0	8-0	9-0	10-0	N/A	N/A	N/A	N/A	N/A
Polybutylene (IPS)	N/A	3-9	4-7	5-0	5-11	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Polybutylene (CTS)	2-11	3-4	3-11	4-5	5-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ductile Iron Pipe	N/A	N/A	N/A	N/A	N/A	N/A	15-0	N/A	15-0	N/A	15-0	15-0

For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m.
Note: IPS — iron pipe size; CTS — copper tube size

6-2.3.2 The distance between a hanger and the centerline of an upright sprinkler shall not be less than 3 in. (76 mm).

6-2.3.3* The unsupported length between the end sprinkler and the last hanger on the line shall not be greater than 36 in. (0.9 m) for 1-in. pipe, 48 in. (1.2 m) for $1^1/_4$-in. pipe, and 60 in. (1.5 m) for $1^1/_2$-in. or larger pipe. Where any of these limits are exceeded, the pipe shall be extended beyond the end sprinkler and shall be supported by an additional hanger.

*Exception: *When the maximum pressure at the sprinkler exceeds 100 psi (6.9 bar) and a branch line above a ceiling supplies sprinklers in a pendent position below the ceiling, the hanger assembly supporting the pipe supplying an end sprinkler in a pendent position shall be of a type that prevents upward movement of the pipe.*

The unsupported length between the end sprinkler in a pendent position or drop nipple and the last hanger on the branch line shall not be greater than 12 in. (305 mm) for steel pipe or 6 in. (152 mm) for copper pipe. When this limit is exceeded, the pipe shall be extended beyond the end sprinkler and supported by an additional hanger. The hanger closest to the sprinkler shall be of a type that prevents upward movement of the piping.

6-2.3.4* The cumulative horizontal length of an unsupported armover to a sprinkler, sprinkler drop, or sprig-up shall not exceed 24 in. (610 mm) for steel pipe or 12 in. (305 mm) for copper tube.

*Exception: *Where the maximum pressure at the sprinkler exceeds 100 psi (6.9 bar) and a branch line above a ceiling supplies sprinklers in a pendent position below the ceiling, the cumulative horizontal length of an unsupported armover to a sprinkler or sprinkler drop shall not exceed 12 in. (305 mm) for steel pipe and 6 in. (152 mm) for copper tube. The hanger closest to the sprinkler shall be of a type that prevents upward movement of the piping.*

6-2.3.5 Wall-mounted sidewall sprinklers shall be restrained to prevent movement.

6-2.4 Location of Hangers on Mains.

6-2.4.1 Hangers for mains shall be in accordance with 6-2.2 or between each branch line, whichever is the lesser dimension.

Exception No. 1: For cross mains in steel pipe systems in bays having two branch lines, the intermediate hanger shall be permitted to be omitted provided that a hanger attached to a purlin is installed on each branch line located as near to the cross main as the location of the purlin permits. Remaining branch line hangers shall be installed in accordance with 6-2.3.

Exception No. 2: For cross mains in steel pipe systems only in bays having three branch lines, either side or center feed, one (only) intermediate hanger shall be permitted to be omitted provided that a hanger attached to a purlin is installed on each branch line located as near to the cross main as the location of the purlin permits. Remaining branch line hangers shall be installed in accordance with 6-2.3.

Exception No. 3: For cross mains in steel pipe systems only in bays having four or more branch lines, either side or center feed, two intermediate hangers shall be permitted to be omitted provided the maximum distance between hangers does not exceed the distances specified in 6-2.2 and a hanger attached to a purlin on each branch line is located as near to the cross main as the purlin permits.

6-2.4.2 At the end of the main, intermediate trapeze hangers shall be installed unless the main is extended to the next framing member with a hanger installed at this point, in which event an intermediate hanger shall be permitted to be omitted in accordance with 6-2.4.1, Exceptions No. 1, 2, and 3.

6-2.5 Support of Risers.

6-2.5.1 Risers shall be supported by pipe clamps or by hangers located on the horizontal connections within 24 in. of the centerline of the riser.

6-2.5.2 Pipe clamps supporting risers by means of set screws shall not be used.

6-2.5.3 In multistory buildings, riser supports shall be provided at the lowest level, at each alternate level above, above and below offsets, and at the top of the riser. Supports above the lowest level shall also restrain the pipe to prevent movement by an upward thrust where flexible fittings are used. Where risers are supported from the ground, the ground support constitutes the first level of riser support. Where risers are offset or do not rise from the ground, the first ceiling level above the offset constitutes the first level of riser support.

6-2.5.4 Distance between supports for risers in vertical shafts or high bay areas shall not exceed 25 ft (7.6 m).

6-3 Joint Restraint for Fire Mains.

6-3.1 General.

6-3.1.1* All tees, plugs, caps, bends, reducers, valves, and hydrant branches shall be restrained against movement by utilizing thrust blocks in accordance with 6-3.2 or restrained joint systems in accordance with 6-3.3. Piping with fused or welded joints and piping joined in accordance with Section 3-6 shall not require additional restraining.

6-3.1.2 On steep grades, mains shall be properly restrained to prevent slipping. The pipe shall be restrained at the bottom of a hill and at any turns (lateral or vertical). The restraining shall be done either to natural rock or by means of suitable piers built on the downhill side of the bell. Bell ends shall be installed facing uphill. Straight runs on hills shall be restrained as determined by the design engineer.

6-3.2* Thrust Blocks. Thrust blocks shall be considered satisfactory where soil is suitable for their use.

6-3.2.1 The thrust blocks shall be of a concrete mix not leaner than one part cement, two and one-half parts sand, and five parts stone.

6-3.2.2 Thrust blocks shall be placed between undisturbed earth and the fitting to be restrained and shall be of such bearing to ensure adequate resistance to the thrust to be encountered.

6-3.2.3 Whenever possible, thrust blocks shall be placed so that the joints will be accessible for repair.

6-3.3 Restrained Joint Systems. Fire mains utilizing restrained joint systems shall include locking mechanical or push-on joints, mechanical joints utilizing setscrew retainer glands, bolted flange joints, heat-fused or welded joints, pipe clamps and tie rods, or other approved methods or devices.

6-3.3.1 Sizing the Clamps, Rods, Bolts, and Washers.

6-3.3.1.1 Clamps shall be $^1/_2$ in. × 2 in. (12.7 mm × 50.8 mm) for pipe 4 in. to 6 in., $^5/_8$ in. × $2^1/_2$ in. (15.9 mm × 63.5 mm) for pipe 8 in. to 10 in., and $^5/_8$ in. × 3 in. (15.9 mm × 76.2 mm) for pipe 12 in. Bolt holes shall be $^1/_{16}$ in. (1.6 mm) diameter larger than bolts.

6-3.3.1.2 Minimum rod size shall be $^5/_8$ in. (15.9 mm) diameter. Table 6-3.3.1.2 gives numbers of various diameter rods required for a given pipe size. When using bolting rods, the diameter of mechanical joint bolts limits the size of rods to $^3/_4$ in. (19.1 mm).

Threaded sections of rods shall not be formed or bent. When using clamps, rods shall be used in pairs, two to a clamp.

Exception: Assemblies in which a restraint is made by means of two clamps canted on the barrel of the pipe shall be permitted to use one rod per clamp if approved for the specific installation by the authority having jurisdiction.

When using combinations of rods greater in number than two, the rods shall be symmetrically spaced.

Table 6-3.3.1.2 Rod Number — Diameter Combinations

Nominal Pipe Size (in.)	$^5/_8$ in. (15.9 mm)	$^3/_4$ in. (19.1 mm)	$^7/_8$ in. (22.2 mm)	1 in. (25.4 mm)
4	2	—	—	—
6	2	—	—	—
8	3	2	—	—
10	4	3	2	—
12	6	4	3	2
14	8	5	4	3
16	10	7	5	4

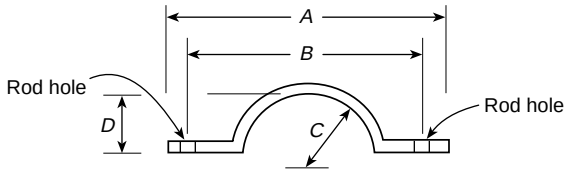
Note: This table has been derived using pressure of 225 psi (15.5 bar) and design stress of 25,000 psi (172.4 MPa).

6-3.3.1.3 Clamp bolts shall be $^5/_8$ in. (15.9 mm) diameter for pipe 4 in., 6 in., and 8 in., $^3/_4$ in. (19.1 mm) diameter for pipe 10 in., and $^7/_8$ in. (22.2 mm) diameter for pipe 12 in.

6-3.3.1.4 Washers can be cast iron or steel, round or square. Dimensions for cast-iron washers shall be $^5/_8$ in. × 3 in. (15.9 mm × 76.2 mm) for pipe 4 in., 6 in., 8 in., and 10 in. and $^3/_4$ in. × $3^1/_2$ in. (19.1 mm × 88.9 mm) for pipe 12 in. Dimensions for steel washers shall be $^1/_2$ in. × 3 in. (12.7 mm × 76.2 mm) for pipe 4 in., 6 in., 8 in., and 10 in. and $^1/_2$ in. × $3^1/_2$ in. (12.7 mm × 88.9 mm) for pipe 12 in. Holes shall be $^1/_8$ in. (3.2 mm) larger than rods.

6-3.3.2 Sizes of Restraint Straps for Tees. Straps shall be $^5/_8$ in. (15.9 mm) thick and $2^1/_2$ in. (63.5 mm) wide for pipe 4 in., 6 in., 8 in., and 10 in. and $^5/_8$ in. (15.9 mm) thick and 3 in. (76.2 mm) wide for pipe 12 in. Rod holes shall be $^1/_{16}$ in. (1.6 mm) larger than rods. Dimensions in inches (mm) for straps are suitable either for mechanical or push-on joint tee fittings. Figure 6-3.3.2 and Table 6-3.3.2 shall be used in sizing the restraint straps.

Figure 6-3.3.2 Restraint straps for tees.



6-3.3.3 Sizes of Plug Strap for Bell End of Pipe. Strap shall be $^3/_4$ in. (19.1 mm) thick, $2^1/_2$ in. (63.5 mm) wide. Strap length is the same as dimension *A* for tee straps given in Figure 6-3.3.2; distance between centers of rod holes is the same as dimension *B* for tee straps.

6-3.3.4 Material used for clamps, rods, rod couplings or turnbuckles, bolts, washers, restraint straps, and plug straps shall be of material having physical and chemical characteristics such that its deterioration under stress can be predicted with reliability.

6-3.3.5* After installation, rods, nuts, bolts, washers, clamps, and other restraining devices shall be cleaned and thoroughly coated with a bituminous or other acceptable corrosion-retarding material.

6-4 Protection of Piping Against Damage Where Subject to Earthquakes.

6-4.1* General. When sprinkler systems or aboveground fire service mains are to be protected against damage from earthquakes, the requirements of Section 6-4 shall apply.

Exception: Alternative methods of providing earthquake protection of sprinkler systems based on a dynamic seismic analysis certified by a registered professional engineer such that system performance will be at least equal to that of the building structure under expected seismic forces shall be permitted.

Table 6-3.3.2 Restraint Straps for Tees

Nominal Pipe Size (in.)	A		B		C		D	
	in.	mm	in.	mm	in.	mm	in.	mm
4	$12^1/_2$	318	$10^1/_8$	257	$2^1/_2$	64	$1^3/_4$	44
6	$14^1/_2$	368	$12^1/_8$	308	$3^9/_{16}$	90	$2^{13}/_{16}$	71
8	$16^3/_4$	425	$14^3/_8$	365	$4^{21}/_{32}$	118	$3^{29}/_{32}$	99
10	$19^1/_{16}$	484	$16^{11}/_{16}$	424	$5^3/_4$	146	5	127
12	$22^5/_{16}$	567	$19^3/_{16}$	487	$6^3/_4$	171	$5^7/_8$	149

6-4.2* Couplings. Listed flexible pipe couplings joining grooved end pipe shall be provided as flexure joints to allow individual sections of piping $2^1/_2$ in. (64 mm) or larger to move differentially with the individual sections of the building to which it is attached. Couplings shall be arranged to coincide with structural separations within a building. Systems having more flexible couplings than required here shall be provided with additional sway bracing as required in 6-4.5.3, Exception No. 4. The flexible couplings shall be installed as follows:

(1) Within 24 in. (610 mm) of the top and bottom of all risers.

Exception No. 1: In risers less than 3 ft (0.9 m) in length, flexible couplings are permitted to be omitted.

Exception No. 2: In risers 3 to 7 ft (0.9 to 2.1 m) in length, one flexible coupling is adequate.

(2) *Within 12 in. (305 mm) above and within 24 in. below the floor in multistory buildings. When the flexible coupling below the floor is above the tie-in main to the main supplying that floor, a flexible coupling shall be provided on the vertical portion of the tie-in piping.

(3) On both sides of concrete or masonry walls within 1 ft of the wall surface.

Exception: Flexible pipe couplings are not required where clearance around the pipe is provided in accordance with 6-4.4.

(4) *Within 24 in. (610 mm) of building expansion joints.

(5) Within 24 in. (610 mm) of the top and bottom of drops to hose lines, rack sprinklers, and mezzanines, regardless of pipe size.

(6) Within 24 in. (610 mm) of the top of drops exceeding 15 ft (4.6 m) in length to portions of systems supplying more than one sprinkler, regardless of pipe size.

(7) Above and below any intermediate points of support for a riser or other vertical pipe.

6-4.3* Seismic Separation Assembly. Seismic separation assemblies with flexible fittings shall be installed where sprinkler piping, regardless of size, crosses building seismic separation joints above ground level.

6-4.4* Clearance. Clearance shall be provided around all piping extending through walls, floors, platforms, and foundations, including drains, fire department connections, and other auxiliary piping.

6-4.4.1 Where pipe passes through holes in platforms, foundations, walls, or floors, the holes shall be sized such that the diameter of the holes is 2 in. (51 mm) larger than the pipe for 1 in. (25.4 mm) nominal to $3^1/_2$ in. (89 mm) nominal and 4 in. (102 mm) larger than the pipe for pipe 4 in. (102 mm) nominal and larger. Clearance from structural members not penetrated or used, collectively or independently, to support the piping shall be at least 2 in. (51 mm).

Exception No. 1: Where clearance is provided by a pipe sleeve, a nominal diameter 2 in. (51 mm) larger than the nominal diameter of the pipe is acceptable for pipe sizes 1 in. (25.4 mm) through $3^1/_2$ in. (89 mm), and the clearance provided by a pipe sleeve of nominal diameter 4 in. (102 mm) larger than the nominal diameter of the pipe is acceptable for pipe sizes 4 in. (102 mm) and larger.

Exception No. 2: No clearance is necessary for piping passing through gypsum board or equally frangible construction that is not required to have a fire resistance rating.

Exception No. 3: No clearance is necessary if flexible couplings are located within 1 ft (0.31 m) of each side of a wall, floor, platform, or foundation.

6-4.4.2 Where required, the clearance shall be filled with a flexible material such as mastic.

6-4.5* Sway Bracing.

6-4.5.1 The system piping shall be braced to resist both lateral and longitudinal horizontal seismic loads and to prevent vertical motion resulting from seismic loads. The structural components to which bracing is attached shall be determined to be capable of carrying the added applied seismic loads.

6-4.5.2 Sway braces shall be designed to withstand forces in tension and compression.

*Exception: *Tension only bracing systems shall be permitted for use where listed for this service and where installed in accordance with their listing limitations, including installation instructions.*

6-4.5.3 Lateral sway bracing spaced at a maximum interval of 40 ft (12.2 m) on center shall be provided on all feed and cross mains regardless of size and all branch lines and other piping with a diameter of $2^1/_2$ in. (63.5 mm) and larger. The last length of pipe at the end of a feed or cross main shall be provided with a lateral brace. Lateral braces shall be allowed to act as longitudinal braces if they are within 24 in. (610 mm) of the centerline of the piping braced longitudinally for lines that are $2^1/_2$ in. (63.5 mm) and greater in diameter. The distance between the last brace and the end of the pipe shall not exceed 20 ft (6.1 m). This requirement shall not preclude the use of a lateral brace serving as a longitudinal brace as described in this paragraph.

Exception No. 1: Where the spacing of lateral braces is permitted to be up to 50 ft (15.2 m), the distance between the last brace and the end of the pipe is permitted to be extended to 25 ft (7.6 m).

Exception No. 2: Lateral sway bracing shall not be required on pipes individually supported by rods less than 6 in. (152 mm) long measured between the top of the pipe and the point of attachment to the building structure.

Exception No. 3: U-type hooks of the wraparound type or those U-type hooks arranged to keep the pipe tight to the underside of the structural element shall be permitted to be used to satisfy the requirements for lateral sway bracing provided the legs are bent out at least 30 degrees from the vertical and the maximum length of each leg and the rod size satisfies the conditions of Table 6-4.5.8.

Exception No. 4: Where flexible couplings are installed on mains other than as required in 6-4.2, a lateral brace shall be provided within 24 in. (610 mm) of every other coupling, but not more than 40 ft (12.2 m) on center.

Exception No. 5: Where building primary structural members exceed 40 ft (12.2 m) on center, lateral braces shall be permitted to be spaced up to 50 ft (15.2 m) on center.

6-4.5.4 Longitudinal sway bracing spaced at a maximum of 80 ft (24.4 m) on center shall be provided for feed and cross mains. Longitudinal braces shall be permitted to serve as lateral braces where they are installed within 24 in. (610 mm) of the piping that is braced laterally. The distance between the last brace and the end of the pipe shall not exceed 40 ft (12.2 m).

6-4.5.5* Tops of risers shall be secured against drifting in any direction, utilizing a four-way sway brace.

6-4.5.6* Horizontal loads for braces shall be determined by analysis based on a horizontal force of $F_p = 0.5\ W_p$, where F_p is the horizontal force factor and W_p is the weight of the water-filled piping. For lateral braces, the load shall include all branch lines and mains, unless the branch lines are provided with longitudinal bracing, within the zone of influence of the

brace. For longitudinal braces, the load shall include all mains within the zone of influence of the brace.

Exception: Where the use of other horizontal force factors is required or permitted by the authority having jurisdiction, they shall take precedence.

6-4.5.7 Where the horizontal force factors used exceed 0.5 W_p and the brace angle is less than 45 degrees from vertical or where the horizontal force factor exceeds 1.0 W_p and the brace angle is less than 60 degrees from vertical, the braces shall be arranged to resist the net vertical reaction produced by the horizontal load.

6-4.5.8* Sway bracing shall be tight. For individual braces, the slenderness ratio (l/r) shall not exceed 300 where l is the length of the brace and r is the least radius of gyration. Where threaded pipe is used as part of a sway brace assembly, it shall not be less than Schedule 30. All parts and fittings of a brace shall lie in a straight line to avoid eccentric loadings on fittings and fasteners. For longitudinal braces only, the brace shall be permitted to be connected to a tab welded to the pipe in conformance with 3-6.2. For individual braces, the slenderness ratio, l/r, shall not exceed 300 where l is the length of the brace and r is the least radius of gyration. For tension-only braces, two tension-only brace components opposing each other must be installed at each lateral or longitudinal brace location. For all braces, whether or not listed, the maximum allowable horizontal load shall be based on the weakest component of the brace with safety factors. The loads determined in 6-4.5.6 shall not exceed the lesser of the maximum allowable loads provided in Table 6-4.5.8 or the manufacturer's certified maximum allowable horizontal loads for 30- to 44-degree, 45- to 59-degree, 60- to 89-degree, and 90-degree brace angles. These certified allowable horizontal loads must include a minimum safety factor of 1.5 against the ultimate break strength of the brace components and then be further reduced according to the brace angles.

Exception: Other pipe schedules and materials not specifically included in Table 6-4.5.8 shall be permitted to be used if certified by a registered professional engineer to support the loads determined in accordance with the above criteria. Calculations shall be submitted where required by the authority having jurisdiction.

Table 6-4.5.8 Maximum Horizontal Loads for Sway Braces

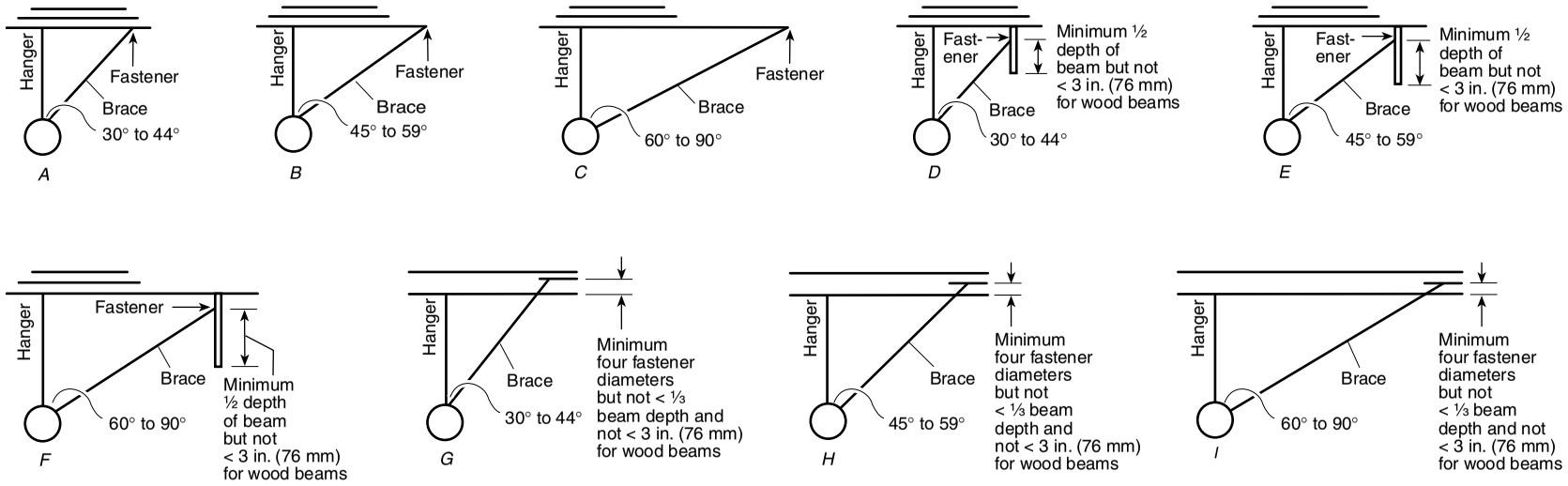
Shape and Size	Least Radius of Gyration	Maximum Length for:	Maximum Horizontal Load (lb)		
			30°–44° Angle from Vertical	45°–59° Angle from Vertical	60°–90° Angle from Vertical
Pipe (Schedule 40)	$= \frac{\sqrt{r_o^2 + r_i^2}}{2}$	$l/r = 100$			
1 in.	0.42	7 ft 0 in.	1,767	2,500	3,061
$1\frac{3}{4}$ in.	0.54	9 ft 0 in.	2,392	3,385	4,145
$1\frac{1}{2}$ in.	0.54	10 ft 4 in.	2,858	4,043	4,955
2 in.	0.787	13 ft 1 in.	3,828	5,414	6,630
Angles		$l/r = 200$			
$1\frac{1}{2} \times 1\frac{1}{2} \times \frac{3}{4}$ in.	0.292	4 ft 10 in.	2,461	3,481	4,263
$2 \times 2 \times \frac{1}{4}$ in.	0.391	6 ft 6 in.	3,356	4,746	5,813
$2\frac{1}{2} \times 2 \times \frac{1}{4}$ in.	0.424	7 ft 0 in.	3,792	5,363	6,569
$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$ in.	0.491	8 ft 2 in.	4,257	6,021	7,374
$3 \times 2\frac{1}{2} \times \frac{1}{4}$ in.	0.528	8 ft 10 in.	4,687	6,628	8,118
$3 \times 3 \times \frac{1}{4}$ in.	0.592	9 ft 10 in.	5,152	7,286	8,923
Rods	$= \frac{r}{2}$	$l/r = 200$			
$\frac{3}{8}$ in.	0.094	1 ft 6 in.	395	559	685
$\frac{1}{2}$ in.	0.125	2 ft 6 in.	702	993	1,217
$\frac{5}{8}$ in.	0.156	2 ft 7 in.	1,087	1,537	1,883
$\frac{3}{4}$ in.	0.188	3 ft 1 in.	1,580	2,235	2,737
$\frac{7}{8}$ in.	0.219	3 ft 7 in.	2,151	3,043	3,726

Table 6-4.5.8 Maximum Horizontal Loads for Sway Braces *(Continued)*

Shape and Size	Least Radius of Gyration	Maximum Length for:	Maximum Horizontal Load (lb)		
			30°–44° Angle from Vertical	45°–59° Angle from Vertical	60°–90° Angle from Vertical
Flats	= 0.29h (where h is smaller of two side dimensions)	l/r = 200			
$1^1/_2 \times {}^1/_4$ in.	0.0725	1 ft 2 in.	1,118	1,581	1,936
$2 \times {}^1/_4$ in.	0.0725	1 ft 2 in.	1,789	2,530	3,098
$2 \times {}^3/_8$ in.	0.109	1 ft 9 in.	2,683	3,795	4,648
Pipe (Schedule 40)	$= \frac{\sqrt{r_0^2 + r_i^2}}{2}$	l/r = 100			
1 in.	0.42	3 ft 6 in.	7,068	9,996	12,242
$1^1/_4$ in.	0.54	4 ft 6 in.	9,567	13,530	16,570
$1^1/_2$ in.	0.623	5 ft 2 in.	11,441	16,181	19,817
2 in.	0.787	6 ft 6 in.	15,377	21,746	26,634
Rods	$= \frac{r}{2}$	l/r = 100			
$^3/_8$ in.	0.094	0 ft 9 in.	1,580	2,234	2,737
$^1/_2$ in.	0.125	1 ft 0 in.	2,809	3,972	4,865
$^5/_8$ in.	0.156	1 ft 3 in.	4,390	6,209	7,605
$^3/_4$ in.	0.188	1 ft 6 in.	6,322	8,941	10,951
$^7/_8$ in.	0.219	1 ft 9 in.	8,675	12,169	14,904
Pipe (Schedule 40)	$= \frac{\sqrt{r_o^2 + r_i^2}}{2}$	l/r = 300			
1 in.	0.42	10 ft 6 in.	786	1,111	1,360
$1^1/_2$ in.	0.54	13 ft 6 in.	1,063	1,503	1,841
$1^1/_2$ in.	0.623	15 ft 7 in.	1,272	1,798	2,202
2 in.	0.787	19 ft 8 in.	1,666	2,355	2,885
Rods	$= \frac{r}{2}$	l/r = 300			
$^3/_8$ in.	0.094	2 ft 4 in.	176	248	304
$^1/_2$ in.	0.125	3 ft 1 in.	312	441	540
$^5/_8$ in.	0.156	3 ft 11 in.	488	690	845
$^3/_4$ in.	0.219	5 ft 6 in.	956	1,352	1,656

Figure 6-4.5.9 Maximum loads for various types of structure and maximum loads for various types of fasteners to structure.

Note: Loads (given in pounds) are keyed to vertical angles of braces and orientation of connecting surface. These values are based on concentric loadings of the fastener. Use figures to determine proper reference within table. For angles between those shown, use most restrictive case. Braces should not be attached to light structure members.



Note: For wooden beams not less than 3 in. (76 mm).

Lag Screws and Lag Bolts in Wood (Load Perpendicular to Grain — Holes Predrilled Using Good Practice)

Shank Diameter of Lag (in.)

		⅜									½									⅝									⅞								
		A	B	C	D	E	F	G	H	I	A	B	C	D	E	F	G	H	I	A	B	C	D	E	F	G	H	I	A	B	C	D	E	F	G	H	I
Length under head (in.)	3	304	325	292	168	325	526	230	324	400	366	—	—	—	—	632	—	—	—	410	—	—	—	—	716	—	—	—	487	—	—	—	—	843	—	—	—
	4	392	354	317	183	354	678	250	352	435	473	509	456	264	509	818	360	507	626	538	—	—	—	—	929	—	—	—	548	—	—	—	—	1122	—	—	—
	5	476	375	336	194	375	824	265	373	461	582	545	488	282	545	1008	385	542	670	687	728	653	277	728	1154	515	725	896	813	—	—	—	—	1407	—	—	—
	6	564	382	342	196	382	976	270	380	470	689	559	501	288	559	1192	395	556	687	791	778	697	403	778	1360	550	775	957	971	—	—	—	—	1630	—	—	—
	8	—	—	—	—	—	—	—	—	—	905	573	513	296	573	1586	405	570	704	1044	806	723	416	806	1807	570	803	991	1297	1365	1223	685	1365	2244	965	1359	1678

For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m; 1 lb = 0.45 kg.

Figure 6-4.5.9 *(Continued)*

Through Bolts in Wood (Load Perpendicular to Grain)

Diameter of Bolt (in.)

		⅜						½						⅝						⅞					
		ABCE	**D**	**F**	**G**	**H**	**I**	**ABCE**	**D**	**F**	**G**	**H**	**I**	**ABCE**	**D**	**F**	**G**	**H**	**I**	**ABCE**	**D**	**F**	**G**	**H**	**I**
Length of Bolt in Timber (in.)	1½	300	173	519	150	211	261	340	197	589	170	239	296	390	225	675	195	275	339	470	272	614	235	331	409
	2	370	214	641	185	261	322	420	243	727	210	296	365	470	272	814	235	331	409	580	335	1004	290	408	504
	2½	460	266	796	230	324	400	550	318	952	275	387	478	620	358	1074	310	437	539	760	439	1316	380	535	661
	3	480	277	831	240	338	417	630	364	1091	315	444	548	710	410	1229	355	500	617	870	503	1506	435	613	757
	3⅝	460	268	797	230	324	400	720	416	1247	360	507	626	850	491	1472	425	599	739	1050	607	1818	525	739	913
	5½	—	—	—	—	—	—	680	393	1177	340	479	591	1020	590	1766	510	718	887	1580	913	2736	790	1113	1374

For SI units, 1 in. = 25.4 mm; 1 lb = 0.45 kg.

Expansion Shields in Concrete

Diameter of Bolt (in.)

		⅜									½									⅝									⅞								
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Min. Depth of Hole (in.)	2½	498	962	1173	678	668	860	925	1303	1609	—	—	—	—	—	—	1638	2306	2848	—	—	—	—	—	—	2080	2930	3617	—	—	—	—	—	—	2470	4113	5078
	3¼	—	—	—	—	—	—	925	1303	1609	923	1782	2076	1200	1782	1597	1638	2306	2848	—	—	—	—	—	—	2080	2930	3617	—	—	—	—	—	—	2970	4113	5078
	3¾	—	—	—	—	—	—	925	1303	1609	—	—	—	—	—	—	1638	2306	2848	1480	2857	2637	1524	2857	2581	2080	2930	3617	—	—	—	—	—	—	2970	4113	5078
	4½	—	—	—	—	—	—	925	1303	1609	—	—	—	—	—	—	1638	2306	2848	—	—	—	—	—	—	2080	2930	3617	3070	4130	3702	2139	4130	5312	2970	4113	5078

For SI units, 1 in. = 25.4 mm; 1 lb = 0.45 kg.

Connections to Steel (Values Assume Bolt Perpendicular to Mounting Surface)

Diameter of Unfinished Steel Bolt (in.)

¼									⅜									½									⅝								
A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
400	500	600	300	500	650	325	458	565	900	1200	1400	800	1200	1550	735	1035	1278	1600	2050	2550	1450	2050	2850	1300	1830	2260	2500	3300	3950	2250	3300	4400	2045	2880	3557

For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m; 1 lb = 0.45 kg.

6-4.5.9* For individual fasteners, the loads determined in 6-4.5.6 shall not exceed the allowable loads provided in Figure 6-4.5.9.

The type of fasteners used to secure the bracing assembly to the structure shall be limited to those shown in Figure 6-4.5.9. For connections to wood, through bolts with washers on each end shall be used. Holes for through bolts shall be $^1/_{16}$ in. (1.6 mm) greater than the diameter of the bolt.

Exception No. 1: Where it is not practical to install through bolts due to the thickness of the member or inaccessibility, lag screws shall be permitted. Holes shall be pre-drilled $^1/_8$ in. (3.2 mm) smaller than the maximum root diameter of the lag screw.

Exception No. 2: Other fastening methods are acceptable for use if certified by a registered professional engineer to support the loads determined in accordance with the criteria in 6-4.5.9. Calculations shall be permitted where required by the authority having jurisdiction.

6-4.5.10 Sway bracing assemblies shall be listed for a maximum load rating. The loads shall be reduced as shown in Table 6-4.5.10 for loads that are less than 90 degrees from vertical.

Exception: Where sway bracing utilizing pipe, angles, flats, or rods as shown in Table 6-4.5.8 is used, the components do not require listing. Bracing fittings and connections used with those specific materials shall be listed.

Table 6-4.5.10 Allowable Horizontal Load on Brace Assemblies Based on the Weakest Component of the Brace Assembly

Brace Angle	Allowable Horizontal Load
30–40 degrees from vertical	Listed load rating divided by 2.000
45–59 degrees from vertical	Listed load rating divided by 1.414
60–89 degrees from vertical	Listed load rating divided by 1.155
90 degrees from vertical	Listed load rating

6-4.5.11 Bracing shall be attached directly to feed and cross mains. Each run of pipe between changes in direction shall be provided with both lateral and longitudinal bracing.

Exception: Pipe runs less than 12 ft (3.6 m) in length shall be permitted to be supported by the braces on adjacent runs of pipe.

6-4.5.12 A length of pipe shall not be braced to sections of the building that will move differentially.

6-4.6 Restraint of Branch Lines.

6-4.6.1* Restraint is considered a lesser degree of resisting loads than bracing and shall be provided by use of one of the following:

(1) A listed sway brace assembly
(2) A wraparound U-hook satisfying the requirements of 6-4.5.3, Exception No. 3
(3) No. 12, 440-lb (200-kg) wire installed at least 45 degrees from the vertical plane and anchored on both sides of the pipe
(4) Other approved means

Wire used for restraint shall be located within 2 ft (610 mm) of a hanger. The hanger closest to a wire restraint shall be of a type that resists upward movement of a branch line.

6-4.6.2 The end sprinkler on a line shall be restrained against excessive vertical and lateral movement.

6-4.6.3* Where upward or lateral movement would result in an impact against the building structure, equipment, or finish materials, branch lines shall be restrained at intervals not exceeding 30 ft (9 m).

6-4.6.4* Sprig-ups 4 ft (1.2 m) or longer shall be restrained against lateral movement.

6-4.7 Hangers and Fasteners Subject to Earthquakes.

6-4.7.1 C-type clamps (including beam and large flange clamps) used to attach hangers to the building structure in areas subject to earthquakes shall be equipped with a restraining strap. The restraining strap shall be listed for use with a C-type clamp or shall be a steel strap of not less than 16 gauge thickness and not less than 1 in. (25.4 mm) wide for pipe diameters 8 in. (203 mm) or less and 14 gauge thickness and not less than $1^1/_4$ in. (31.7 mm) wide for pipe diameters greater than 8 in. (203 mm). The restraining strap shall wrap around the beam flange not less than 1 in. (25.4 mm). A lock nut on a C-type clamp shall not be used as a method of restraint. A lip on a "C" or "Z" purlin shall not be used as a method of restraint.

Where purlins or beams do not provide an adequate lip to be secured by a restraining strap, the strap shall be through-bolted or secured by a self-tapping screw.

6-4.7.2 C-type clamps (including beam and large flange clamps), with or without restraining straps, shall not be used to attach braces to the building structure.

6-4.7.3 Powder-driven fasteners shall not be used to attach braces to the building structure.

Exception: Powder-driven fasteners shall be permitted where they are specifically listed for service in resisting lateral loads in areas subject to earthquakes.

6-4.7.4 Powder-driven fasteners shall not be used to attach hangers to the building structure where the systems are required to be protected against earthquakes using a horizontal force factor exceeding 0.50 W_p, where W_p is the weight of the water-filled pipe.

Exception: Powder-driven fasteners shall be permitted where they are specifically listed for horizontal force factors in excess of 0.50 W_p.

Chapter 7 Design Approaches

7-1 General.

7-1.1 Water demand requirements shall be determined from the occupancy hazard fire control approach of Section 7-2.

Exception: Special design approaches as permitted in Section 7-9.

7-1.2 For buildings with two or more adjacent occupancies that are not physically separated by a barrier or partition capable of delaying heat from a fire in one area from fusing sprinklers in the adjacent area, the required sprinkler protection for the more demanding occupancy shall extend 15 ft (4.6 m) beyond its perimeter.

7-2 Occupancy Hazard Fire Control Approach.

7-2.1 Occupancy Classifications.

7-2.1.1 Occupancy classifications for this standard relate to sprinkler installations and their water supplies only. They shall not be used as a general classification of occupancy hazards.

7-2.1.2 Occupancies or portions of occupancies shall be classified according to the quantity and combustibility of contents, the expected rates of heat release, the total potential for energy release, the heights of stockpiles, and the presence of flammable and combustible liquids, using the definitions contained in Section 1-4. Classifications are as follows:

Light hazard

Ordinary hazard (Groups 1 and 2)

Extra hazard (Groups 1 and 2)

Special occupancy hazard *(see Section 7-10)*

7-2.2 Water Demand Requirements — Pipe Schedule Method.

7-2.2.1 Table 7-2.2.1 shall be used in determining the minimum water supply requirements for light and ordinary hazard occupancies protected by systems with pipe sized according to the pipe schedules of Section 8-5. Pressure and flow requirements for extra hazard occupancies shall be based on the hydraulic calculation methods of 7-2.3. The pipe schedule method shall be permitted only for new installations of 5000 ft^2 (465 m^2) or less or for additions or modifications to existing pipe schedule systems sized according to the pipe schedules of Section 8-5. Table 7-2.2.1 shall be used in determining the minimum water supply requirements.

Exception No. 1: The pipe schedule method shall be permitted for use in systems exceeding 5000 ft^2 (465 m^2) where the flows required in Table 7-2.2.1 are available at a minimum residual pressure of 50 psi (3.4 bar) at the highest elevation of sprinkler.

Exception No. 2: The pipe schedule method shall be permitted for additions or modifications to existing extra hazard pipe schedule systems.

7-2.2.2 The lower duration value of Table 7-2.2.1 shall be acceptable only where remote station or central station waterflow alarm service is provided.

7-2.2.3* The residual pressure requirement of Table 7-2.2.1 shall be met at the elevation of the highest sprinkler. *(See the Exceptions to 7-2.2.1).*

7-2.2.4 The lower flow figure of Table 7-2.2.1 shall be permitted only where the building is of noncombustible construction or the potential areas of fire are limited by building size or compartmentation such that no open areas exceed 3000 ft^2 (279 m^2) for light hazard or 4000 ft^2 (372 m^2) for ordinary hazard.

Table 7-2.2.1 Water Supply Requirements for Pipe Schedule Sprinkler Systems

Occupancy Classification	Minimum Residual Pressure Required (psi)	Acceptable Flow at Base of Riser (Including Hose Stream Allowance) (gpm)	Duration (minutes)
Light hazard	15	500–750	30–60
Ordinary hazard	20	850–1500	60–90

For SI units, 1 gpm = 3.785 L/min; 1 psi = 0.0689 bar.

7-2.3 Water Demand Requirements — Hydraulic Calculation Methods.

7-2.3.1 General.

7-2.3.1.1* The minimum water supply requirements for a hydraulically designed occupancy hazard fire control sprinkler system shall be determined by adding the hose stream demand from Table 7-2.3.1.1 to the water supply for sprinklers determined in 7-2.3.1.2. This supply shall be available for the minimum duration specified in Table 7-2.3.1.1.

Exception No. 1: An allowance for inside and outside hose shall not be required where tanks supply sprinklers only.

Exception No. 2: Where pumps taking suction from a private fire service main supply sprinklers only, the pump need not be sized to accommodate inside and outside hose. Such hose allowance shall be considered in evaluating the available water supplies.

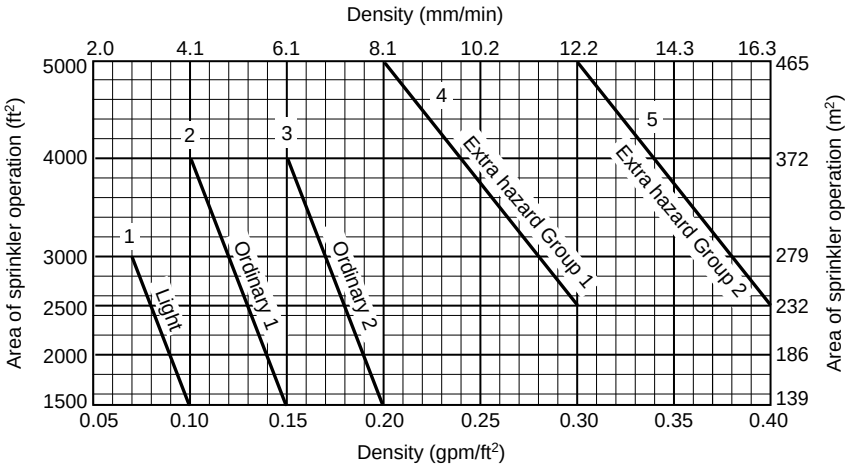
7-2.3.1.2 The water supply for sprinklers only shall be determined either from the area/density curves of Figure 7-2.3.1.2 in accordance with the method of 7-2.3.2 or be based upon the room design method in accordance with 7-2.3.3, at the discretion of the designer. For special areas under consideration, as described in 7-2.3.4, separate hydraulic calculations shall be required in addition to those required by 7-2.3.2 or 7-2.3.3.

Table 7-2.3.1.1† Hose Stream Demand and Water Supply Duration Requirements for Hydraulically Calculated Systems

Occupancy or Commodity Classification	Inside Hose (gpm)	Total Combined Inside and Outside Hose (gpm)	Duration (minutes)
Light hazard	0, 50, or 100	100	30
Ordinary hazard	0, 50, or 100	250	60–90
Extra hazard	0, 50, or 100	500	90–120
Rack storage, Class I, II, and III commodities up to 12 ft (3.7 m) in height	0, 50, or 100	250	90
Rack storage, Class IV commodities up to 10 ft (3.1 m) in height	0, 50, or 100	250	90
Rack storage, Class IV commodities up to 12 ft (3.7 m) in height	0, 50, or 100	500	90
Rack storage, Class I, II, and III commodities over 12 ft (3.7 m) in height	0, 50, or 100	500	90
Rack storage, Class IV commodities over 12 ft (3.7 m) in height and plastic commodities	0, 50, or 100	500	120
General storage, Class I, II, and III commodities over 12 ft (3.7 m) up to 20 ft (6.1 m)	0, 50, or 100	500	90
General storage, Class IV commodities over 12 ft (3.7 m) up to 20 ft (6.1 m)	0, 50, or 100	500	120
General storage, Class I, II, and III commodities over 20 ft (6.1 m) up to 30 ft (9.1 m)	0, 50, or 100	500	120
General storage, Class IV commodities over 20 ft (6.1 m) up to 30 ft (9.1 m)	0, 50, or 100	500	150
General storage, Group A plastics ≤ 5 ft (1.5 m)	0, 50, or 100	250	90
General storage, Group A plastics over 5 ft (1.5 m) up to 20 ft (6.1 m)	0, 50, or 100	500	120
General storage, Group A plastics over 20 ft (6.1 m) up to 25 ft (7.6 m)	0, 50, or 100	500	150

For SI units, 1 gpm = 3.785 L/min.

Figure 7-2.3.1.2 Area/density curves.



7-2.3.1.3 Regardless of which of the two methods is used, the following restrictions shall apply:

(a) For areas of sprinkler operation less than 1500 ft^2 (139 m^2) used for light and ordinary hazard occupancies, the density for 1500 ft^2 (139 m^2) shall be used. For areas of sprinkler operation less than 2500 ft^2 (232 m^2) for extra hazard occupancies, the density for 2500 ft^2 (232 m^2) shall be used.

(b) *For buildings having unsprinklered combustible concealed spaces (as described in 5-13.1.1 and 5-13.7), the minimum area of sprinkler operation shall be 3000 ft^2 (279 m^2).

Exception No. 1: Combustible concealed spaces filled entirely with noncombustible insulation.

*Exception No. 2: *Light or ordinary hazard occupancies where noncombustible or limited combustible ceilings are directly attached to the bottom of solid wood joists so as to create enclosed joist spaces 160 ft^3 (4.8 m^3) or less in volume.*

*Exception No. 3: *Concealed spaces where the exposed surfaces have a flame spread rating of 25 or less and the materials have been demonstrated to not propagate fire in the form in which they are installed in the space.*

(c) Water demand of sprinklers installed in racks or water curtains shall be added to the ceiling sprinkler water demand at the point of connection. Demands shall be balanced to the higher pressure. *(See Chapter 8.)*

(d) Water demand of sprinklers installed in concealed spaces or under obstructions such as ducts and cutting tables need not be added to ceiling demand.

(e) Where inside hose stations are planned or are required, a total water allowance of 50 gpm (189 L/min) for a single hose station installation or 100 gpm (378 L/min) for a multiple hose station installation shall be added to the sprinkler requirements. The water allowance shall be added in 50-gpm (189-L/min) increments beginning at the most remote hose station, with each increment added at the pressure required by the sprinkler system design at that point.

(f) When hose valves for fire department use are attached to wet pipe sprinkler system risers in accordance with 5-15.5.2, the water supply shall not be required to be added to standpipe demand as determined from NFPA 14, *Standard for the Installation of Standpipe and Hose Systems.*

Exception No. 1: Where the combined sprinkler system demand and hose stream allowance of Table 7-2.3.1.1 exceeds the requirements of NFPA 14, Standard for the Installation of Standpipe and Hose Systems, this higher demand shall be used.

Exception No. 2: For partially sprinklered buildings, the sprinkler demand, not including hose stream allowance, as indicated in Table 7-2.3.1.1 shall be added to the requirements given in NFPA 14, Standard for the Installation of Standpipe and Hose Systems.

(g) Water allowance for outside hose shall be added to the sprinkler and inside hose requirement at the connection to the city water main or a yard hydrant, whichever is closer to the system riser.

(h) The lower duration values in Table 7-2.3.1.1 shall be permitted where remote station or central station waterflow alarm service is provided.

(i) Where pumps, gravity tanks, or pressure tanks supply sprinklers only, requirements for inside and outside hose need not be considered in determining the size of such pumps or tanks.

7-2.3.1.4 Total system water supply requirements shall be determined in accordance with the hydraulic calculation procedures of Section 8-4.

7-2.3.2 Area/Density Method.

7-2.3.2.1 The water supply requirement for sprinklers only shall be calculated from the area/density curves in Figure 7-2.3.1.2 or from Section 7-10 where area/density criteria is specified for special occupancy hazards. When using Figure 7-2.3.1.2, the calculations shall satisfy any single point on the appropriate area/density curve as follows:

(1) Light hazard area/density curve 1
(2) Ordinary hazard (Group 1) area/density curve 2
(3) Ordinary hazard (Group 2) area/density curve 3
(4) Extra hazard (Group 1) area/density curve 4
(5) Extra hazard (Group 2) area/density curve 5

It shall not be necessary to meet all points on the selected curve.

Exception: Sprinkler demand for storage occupancies as determined in Sections 7-3 through 7-8.

7-2.3.2.2 For protection of miscellaneous storage, miscellaneous tire storage, and storage up to 12 ft (3.7 m) in height, the discharge criteria in Table 7-2.3.2.2 shall apply.

Table 7-2.3.2.2 Discharge Criteria for Miscellaneous Storage and Storage 12 ft (3.7 m) or Less in Height,[1] Commodity Classes I through IV

Commodity Classification	Palletized and Bin Box	Rack
I	OH-1	OH-1
II up to 8 ft (2.4 m)	OH-1	OH-1
II over 8 ft (2.4 m) up to 12 ft (3.6 m)	OH-2	OH-2
III	OH-2	OH-2
IV up to 10 ft (3 m)	OH-2	OH-2
IV over 10 ft (3 m) to 12 ft (3.6 m)	OH-2	EH-1

Group A Plastics Stored on Racks

Storage Height	Maximum Building Height	Cartoned		Exposed	
		Solid	Expanded	Solid	Expanded
Up to 5 ft	No limit	OH-2	OH-2	OH-2	OH-2
Over 5 ft to 10 ft	15 ft	EH-1	EH-1	EH-2	EH-2
Over 5 ft to 10 ft	20 ft	EH-2	EH-2	EH-2	OH-2 +1 level in-rack[5]
Over 10 ft to 12 ft	17 ft	EH-2[2]	EH-2[2]	EH-2[2]	EH-2[2]
Over 10 ft to 12 ft	No limit	OH-2 +1 level in-rack[5]	OH-2 +1 level in-rack[5]	OH-2 +1 level in-rack[5]	OH-2 +1 level in-rack[5]

Group A Plastics Solid-Piled, Palletized, Bin-Box, or Shelf Storage

Storage Height	Maximum Building Height	Cartoned		Exposed	
		Solid	Expanded	Solid	Expanded
Up to 5 ft	No limit	OH-2	OH-2	OH-2	OH-2
Over 5 ft to 10 ft	15 ft	EH-1	EH-1	EH-2	EH-2
Over 5 ft to 10 ft	20 ft	EH-2	EH-2	EH-2	—
Over 5 ft to 8 ft	No limit	—	—	—	EH-2
Over 10 ft to 12 ft	17 ft	EH-2	EH-2	EH-2	EH-2
Over 10 ft to 12 ft	27 ft	EH-2	EH-2	—	—

Miscellaneous Tire Storage[3]

Piling Methods	Height of Storage	Occupancy Group
On floor, on side	5 ft to 12 ft	EH-1
On floor, on tread or on side	To 5 ft	OH-2
Single-, double-, or multiple-row racks on tread or on side	To 5 ft	OH-2
Single-row rack, portable, on tread or on side	5 ft to 12 ft	EH-1
Single-row rack, fixed, on tread or on side	5 ft to 12 ft	EH-1 or OH-2 plus one level of in-rack sprinklers

Table 7-2.3.2.2 Discharge Criteria for Miscellaneous Storage and Storage 12 ft (3.7 m) or Less in Height,[1] Commodity Classes I through IV *(Continued)*

Rolled Paper Stored on End	Height of Storage	Occupancy Group
Heavy and medium weight	To 8 ft	OH-2
On floor, on tread or on side	Over 8 ft to 12 ft	EH-1
Tissue	To 10 ft	EH-1
Idle Pallet Storage[4]	**Height of Storage**	**Occupancy Group**
Single row rack, fixed	To 6 ft wooden	OH-2
	To 4 ft plastic	OH-2

For SI units, 1 ft = 0.3048 in.
[1]The design of the sprinkler system shall be based on the conditions that will routinely or periodically exist in the building creating the greatest water demand, including pile height and clearance.
[2]For rack storage, OH-2 + 1 level in rack shall also be permitted.
[3]The discharge criteria for the storage in this table shall only apply to miscellaneous tire storage as defined in 1-4.10.
[4]The discharge criteria for pallets shall apply only to the storage of wooden pallets stored up to 6 ft (1.8 m) in height or plastic pallets up to 4 ft (1.2 m) in height with not over four stacks of wooden pallets or two stacks of plastic pallets separated from other stacks by at least an 8-ft (2.7-m) aisle. (For heights or quantities exceeding these limits see Section 7-5).
[5]See Section 7-11 for in-rack sprinkler discharge criteria.

7-2.3.2.3 The densities and areas provided in Figure 7-2.3.1.2 are for use only with spray sprinklers. For use with other types of sprinklers, see Section 7-9.

*Exception No. 1: *Quick-response sprinklers shall not be permitted for use with area/density curves 4 and 5 (extra hazard).*

Exception No. 2: Sidewall spray sprinklers shall be permitted for use with area/density curve 1 (light hazard) and, if specifically listed, with area/density curves 2 or 3 (ordinary hazard).

Exception No. 3: For extended coverage sprinklers, the minimum design area shall be that corresponding to the maximum density for the hazard in Figure 7-2.3.1.2 or the area protected by five sprinklers, whichever is greater. Extended coverage sprinklers shall be listed with and designed for the minimum flow corresponding to the density for the smallest area of operation for the hazard as specified in Figure 7-2.3.1.2.

7-2.3.2.4 Where listed quick-response sprinklers are used throughout a system or portion of a system having the same hydraulic design basis, the system area of operation shall be permitted to be reduced without revising the density as indicated in Figure 7-2.3.2.4 when all of the following conditions are satisfied:

(1) Wet pipe system
(2) Light hazard or ordinary hazard occupancy
(3) 20-ft (6.1-m) maximum ceiling height

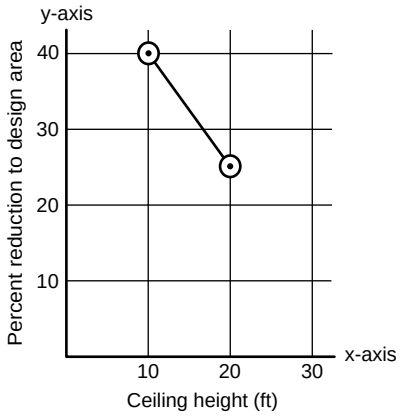
The number of sprinklers in the design area shall never be less than five. Where quick-response sprinklers are used on a sloped ceiling, the maximum ceiling height shall be used for determining the percent reduction in design area. Where quick-response sprinklers are installed, all sprinklers within a compartment shall be of the quick response type.

Exception: Where circumstances require the use of other than ordinary temperature–rated sprinklers, standard response sprinklers shall be permitted to be used.

7-2.3.2.5 The system area of operation shall be increased by 30 percent without revising the density when the following types of sprinklers are used on sloped ceilings with a pitch exceeding one in six (a rise of two units in a run of 12 units, a roof slope of 16.7 percent):

(1) Spray sprinklers, including extended coverage sprinklers listed in accordance with 5-4.3, Exception No. 3, and quick-response sprinklers
(2) Large drop sprinklers

Figure 7-2.3.2.4 Design area reduction for quick-response sprinklers.



Note: $y = \frac{-3x}{2} + 55$

For ceiling height ≥ 10 ft and ≤ 20 ft, $y = \frac{-3x}{2} + 55$

For ceiling height < 10 ft, $y = 40$

For ceiling height > 20, $y = 0$

For SI units, 1 ft = 0.31 m.

7-2.3.2.6 For dry pipe systems and double interlock preaction systems, the area of sprinkler operation shall be increased by 30 percent without revising the density.

7-2.3.2.7 Where high-temperature sprinklers are used for extra hazard occupancies, the area of sprinkler operation shall be permitted to be reduced by 25 percent without revising the density, but not to less than 2000 ft^2 (186 m^2).

7-2.3.2.8* Where multiple adjustments to the area of operation are required to be made in accordance with 7-2.3.2.4, 7-2.3.2.5, 7-2.3.2.6, or 7-2.3.2.7, these adjustments shall be compounded based on the area of operation originally selected from Figure 7-2.3.1.2. If the building has unsprinklered combustible concealed spaces, the rules of 7-2.3.1.3 shall be applied after all other modifications have been made.

7-2.3.3 Room Design Method.

7-2.3.3.1* The water supply requirements for sprinklers only shall be based upon the room that creates the greatest demand. The density selected shall be that from Figure 7-2.3.1.2 corresponding to the room size. To utilize this method, all rooms shall be enclosed with walls having a fire-resistance rating equal to the water supply duration indicated in Table 7-2.3.1.1.

7-2.3.3.2 If the room is smaller than the smallest area shown in the applicable curve in Figure 7-2.3.1.2, the provisions of 7-2.3.1.3(a) shall apply.

7-2.3.3.3 Minimum protection of openings shall be as follows:

(1) Light hazard — automatic or self-closing doors

Exception: Where openings are not protected, calculations shall include the sprinklers in the room plus two sprinklers in the communicating space nearest each such unprotected opening unless the communicating space has only one sprinkler, in which case calculations shall be extended to the operation of that sprinkler. The selection of the room and communicating space sprinklers to be calculated shall be that which produces the greatest hydraulic demand.

(2) Ordinary and extra hazard — automatic or self-closing doors with appropriate fire-resistance ratings for the enclosure

7-2.3.4 Special Design Methods.

7-2.3.4.1 Where the design area consists of a building service chute supplied by a separate riser, the maximum number of sprinklers that needs to be calculated is three.

7-2.3.4.2 Where the room design method is used and the area under consideration is a corridor protected by one row of sprinklers, the maximum number of sprinklers that needs to be calculated is five. *(See 7-2.3.1.)*

Exception: Where the area under consideration is a corridor protected by a single row of sprinklers and the openings are not protected, the design area shall include all sprinklers in the corridor to a maximum of seven.

7-2.3.4.3 Where an area is to be protected by a single line of sprinklers, the design area shall include all sprinklers on the line up to a maximum of seven.

7-3 Fire Control Approach for the Protection of Commodities That Are Stored Palletized, Solid Piled, in Bin Boxes, or in Shelves.

7-3.1 General. This section shall apply to a broad range of combustibles, including plastics that are stored palletized, solid piled, in bin boxes, or in shelves above 12 ft (3.7 m) high and using standard spray sprinklers.

7-3.1.1 For first-aid fire-fighting and mop-up operations, small hose [$1^1/_2$ in. (38 mm)] shall be provided in accordance with 5-15.5.

Exception: Hose connections shall not be required for the protection of Class I, II, III, and IV commodities stored 12 ft (3.7 m) or less in height.

7-3.1.2 Minimum System Discharge Requirements.

7-3.1.2.1 The design density shall not be less than 0.15 gpm/ft^2 (6.1 mm/min), 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.

7-3.1.2.2 The sprinkler design density for any given area of operation for a Class III or Class IV commodity, calculated in accordance with 7-3.2, shall not be less than the density for the corresponding area of operation for ordinary hazard Group 2.

7-3.1.2.3 The water supply requirements for sprinklers only shall be based on the actual calculated demand for the hazard in accordance with 7-3.2, 7-3.3, 7-9.4, or 7-9.5, depending on the type of sprinkler selected and the commodity being protected.

7-3.1.2.4 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.

Exception: This requirement shall not apply where separated by a barrier partition that is capable of preventing heat from a fire in the storage area from fusing sprinklers in the nonstorage area.

7-3.1.3 The sprinkler system criteria specified in Section 7-3 is intended to apply to buildings with ceiling slopes not exceeding two in 12 (16.7 percent).

7-3.2 Water Demand Requirements of Class I through IV Requirements.

7-3.2.1* General.

7-3.2.1.1 Protection for Class I through Class IV commodities in the following configurations shall be provided in accordance with this chapter:

(1) Nonencapsulated commodities that are solid pile, palletized, or bin box storage up to 30 ft (9.1 m) in height
(2) Nonencapsulated commodities on shelf storage up to 15 ft (4.6 m) in height
(3) *Encapsulated commodities that are solid pile, palletized, bin box, or shelf storage up to 15 ft (4.6 m) in height

7-3.2.1.2 Bin box and shelf storage that is over 12 ft (3.7 m) but not in excess of the height limits of 7-3.2.1.1 and that is provided with walkways at vertical intervals of not over 12 ft (3.7 m) shall be protected with automatic sprinklers under the walkway(s). Protection shall be as follows:

(a) Ceiling design density shall be based on the total height of storage within the building.

(b) Automatic sprinklers under walkways shall be designed to maintain a minimum discharge pressure of 15 psi (1 bar) for the most hydraulically demanding six sprinklers on each level. Walkway sprinkler demand shall not be required to be added to the ceiling sprinkler demand. Sprinklers under walkways shall not be spaced more than 8 ft (2.4 m) apart horizontally.

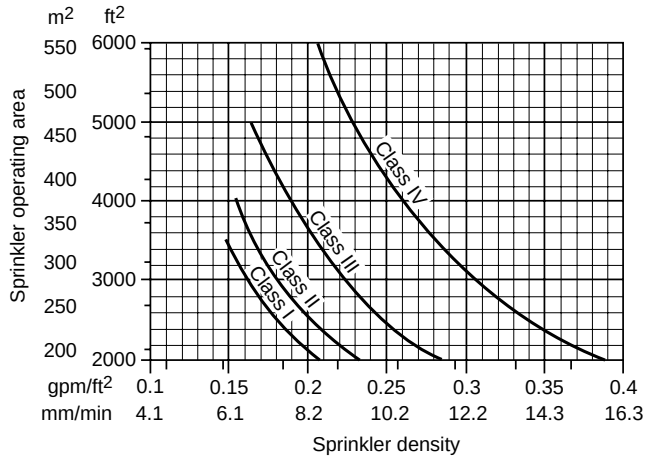
7-3.2.2 Protection Criteria.

7-3.2.2.1 The water supply shall be capable of providing the sprinkler system demand determined in accordance with 7-3.2.2.3, including the hose stream demand and duration requirements of Table 7-2.3.1.1.

7-3.2.2.2 The area and density for the hydraulically remote area shall be determined as specified in 7-2-3.2.2 for storage under 12 ft (3.7 m) and 7-3.2.2.2.1 through 7-3.2.2.2.6 for storage over 12 ft (3.7 m).

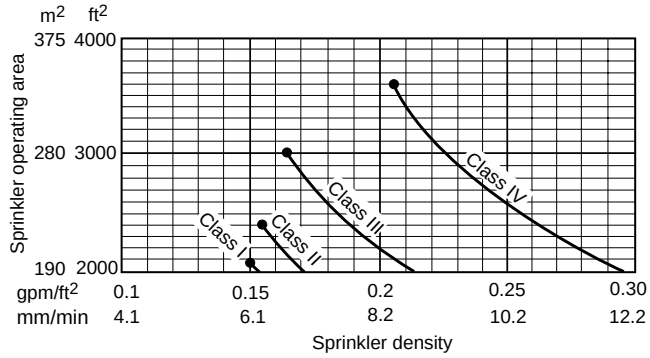
7-3.2.2.2.1 Where using ordinary temperature–rated sprinklers, a single point shall be selected from the appropriate commodity curve on Figure 7-3.2.2.2.1.

Figure 7-3.2.2.2.1 Sprinkler system design curves, 20-ft (6.1-m) high storage — ordinary temperature–rated sprinklers.



7-3.2.2.2.2 Where using high temperature–rated sprinklers, a single point shall be selected from the appropriate commodity curve on Figure 7-3.2.2.2.2.

Figure 7-3.2.2.2.2 Sprinkler system design curves, 20-ft (6.1-m) high storage — high temperature–rated sprinklers.



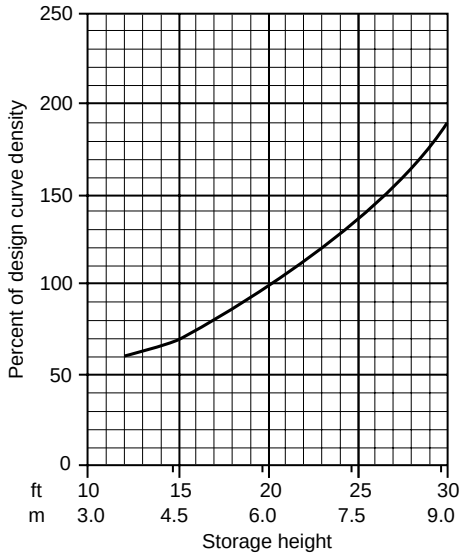
7-3.2.2.2.3 The densities selected in accordance with 7-3.2.2.2.1 or 7-3.2.2.2.2 shall be modified in accordance with Figure 7-3.2.2.2.3 without revising the design area.

7-3.2.2.2.4 Where dry pipe systems are used, the areas of operation indicated in the design curves shall be increased by 30 percent.

7-3.2.2.2.5 In the case of metal bin boxes with face areas not exceeding 16 ft² (1.5 m²) and metal closed shelves with face areas not exceeding 16 ft² (1.5 m²), the area of application shall be permitted to be reduced by 50 percent, provided the minimum requirements of 7-3.1 through 7-3.1.3 are met.

7-3.2.2.2.6 The final area and density shall not be less than the minimum specified in 7-3.1.2.

Figure 7-3.2.2.2.3 Ceiling sprinkler density vs. storage height.



7-3.2.2.3 Given the area and density determined in accordance with 7-3.2.2.2, the fire sprinkler system shall be hydraulically calculated.

7-3.2.2.4 High-Expansion Foam Systems.

7-3.2.2.4.1 High-expansion foam systems that are installed in addition to automatic sprinklers shall be installed in accordance with NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*.

Exception: This requirement shall not apply where modified by this standard.

7-3.2.2.4.2 High-expansion foam used to protect the idle pallet shall have a maximum fill time of 4 minutes.

7-3.2.2.4.3 High-expansion foam systems shall be automatic in operation.

7-3.2.2.4.4 Detectors for high-expansion foam systems shall be listed and shall be installed at no more than one-half the listed spacing.

7-3.2.2.4.5 Detection systems, concentrate pumps, generators, and other system components that are essential to the operation of the system shall have an approved standby power source.

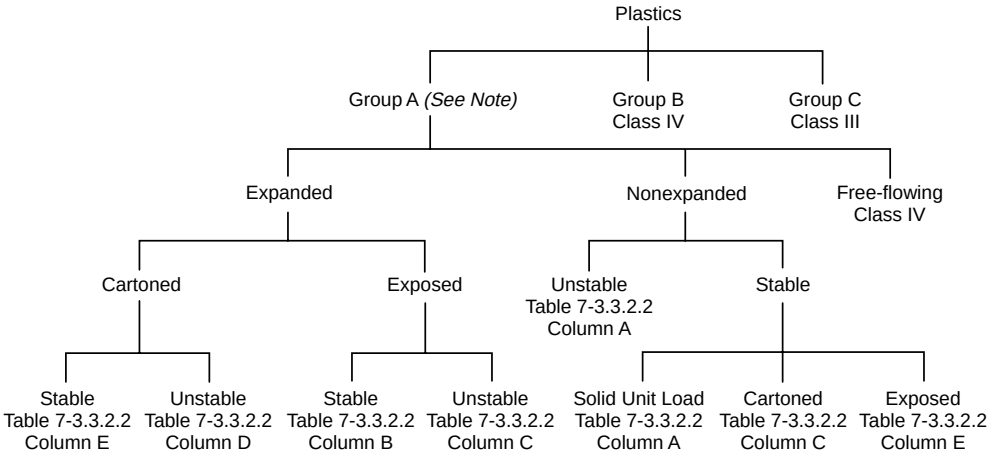
7-3.2.2.4.6 A reduction in ceiling density to one-half that required for Class I through Class IV commodities, idle pallets, or plastics shall be permitted without revising the design area, but the density shall be no less than 0.15 gpm/ft² (6.1 mm/min).

7-3.3 Water Demand Requirements for Plastic and Rubber Commodities.

7-3.3.1* General. See Appendix C.

7-3.3.1.1* Plastics stored up to 25 ft (7.62 m) in height protected by spray sprinklers shall be in accordance with this chapter. The decision tree shown in Figure 7-3.3.1.1 shall be used to determine the protection in each specific situation.

Figure 7-3.3.1.1 Decision tree.



Note: Cartons that contain Group A plastic material shall be permitted to be treated as Class IV commodiites under the following conditions:

(a) There shall be multiple layers of corrugation or equivalent outer material that would significantly delay fire involvement of the Group A plastic

(b) The amount and arrangement of Group A plastic material within an ordinary carton would not be expected to significantly increase the fire hazard

7-3.3.1.2* 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. 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.

7-3.3.1.3 Group B plastics and free-flowing Group A plastics shall be protected in the same manner as a Class IV commodity. See 7-3.2 for protection of these storage commodities with spray sprinklers.

7-3.3.1.4 Group C plastics shall be protected in the same manner as a Class III commodity. See 7-3.2 for protection of these storage commodities with spray sprinklers.

7-3.3.2 Protection Criteria.

7-3.3.2.1* 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 the following:

(1) Pile height
(2) Clearance
(3) Pile stability
(4) Array

Where the distance between roof/ceiling height and top of storage exceeds 20 ft (6.1 m), protection shall be provided for the storage height that would result in a 20-ft (6.1-m) distance between the roof/ceiling height and top of storage.

7-3.3.2.2* Design areas and densities for the appropriate storage configuration shall be selected from Table 7-3.3.2.2. The columns A, B, C, D, and E correspond to the protection required by the decision tree shown in Figure 7-3.3.1.1.

7-3.3.2.2.1 For Table 7-3.3.2.2, the design areas are a minimum of 2500 ft^2 (232 m^2).

Exception No. 1: Where Table 7-3.3.2.2 allows densities and areas to be selected in accordance with 7-2.3, for ordinary hazard Group 2 occupancies, any area/density from that curve shall be acceptable.

Exception No. 2: For closed arrays, the area shall be permitted to be reduced to 2000 ft^2 (186 m^2).

7-3.3.2.2.2 Interpolation of densities between storage heights shall be permitted. Densities shall be based upon the 2500 ft^2 (232 m^2) design area. The "up to" in the table is intended to aid in the interpolation of densities between storage heights. Interpolation of ceiling/roof heights shall not be permitted.

7-3.3.2.3* Where dry pipe systems are used for Group A plastics, the operating area shall be increased by 30 percent without revising the density.

7-3.3.2.4 High-Expansion Foam Systems. Where high-expansion foam is used, a reduction in ceiling density to one-half that required for plastics shall be permitted without revising the design area but shall be not less than 0.15 gpm/ft^2 (6.1 mm/min).

7-4† Fire Control Approach for the Protection of Commodities Stored on Racks.

7-4.1 Protection Criteria — General.

7-4.1.1 This section shall apply to storage of materials representing the broad range of combustibles stored in racks using standard spray sprinklers.

7-4.1.2 The sprinkler system criteria of Section 7-4 is intended to apply to buildings with ceiling slopes not exceeding two in 12 (16.7 percent).

7-4.1.3* Sprinkler protection criteria for the storage of materials on racks shall be in accordance with 7-4.1 and either 7-4.2 for storage up to 25 ft (7.6 m), 7-4.3 for storage over 25 ft (7.6 m), or 7-4.4 for plastics storage as appropriate.

*Exception: *Protection criteria, for Group A plastics as indicated in 7-4.4 shall be permitted for the protection of the same storage height and configuration of Class I, II, III, and IV commodities.*

Table 7-3.3.2.2 Design Densities for Plastic and Rubber Commodities

Storage Height		Roof/Ceiling Height		Density									
				A		B		C		D		E	
ft	m	ft	m	gpm/ft²	mm/min	gpm/ft²	mm/min	gpm/ft²	mm/min	gpm/ft²	mm/min	gpm/ft²	mm/min
≤ 5	1.52	up to 25	up to 7.62	OH-2	OH-2	0.2	8.2	OH-2	OH-2	OH-2	OH-2	OH-2	OH-2
≤ 12	3.66	up to 15	up to 4.57	0.2	8.2	EH-2	EH-2	0.3	12.2	EH-1	EH-1	EH-2	EH-2
		>15 to 20	>4.57 to 6.1	0.3	12.2	0.6	24.5	0.5	20.4	EH-2	EH-2	EH-2	EH-2
		>20 to 32	>6.1 to 9.75	0.4	16.3	0.8	32.6	0.6	24.5	0.45	18.3	0.7	28.5
15	4.5	up to 20	up to 6.1	0.25	10.2	0.5	20.4	0.4	16.3	0.3	12.2	0.45	18.3
		>20 to 25	>6.1 to 7.62	0.4	16.3	0.8	32.6	0.6	24.5	0.45	18.3	0.7	28.5
		>25 to 35	>7.62 to 10.67	0.45	18.3	0.9	36.7	0.7	28.5	0.55	22.4	0.85	34.6
20	6.1	up to 25	up to 7.62	0.3	12.2	0.6	24.5	0.45	18.3	0.35	14.3	0.55	22.4
		>25 to 30	>7.62 to 9.14	0.45	18.3	0.9	36.7	0.7	28.5	0.55	22.4	0.85	34.6
		>30 to 35	>9.14 to 10.67	0.6	24.5	1.2	48.9	0.85	34.6	0.7	28.5	1.1	44.8
25	7.62	up to 30	up to 9.14	0.4	16.3	0.75	30.6	0.55	22.4	0.45	18.3	0.7	28.5
		>30 to 35	>9.14 to 10.67	0.6	24.5	1.2	48.9	0.85	34.6	0.7	28.5	1.1	44.8

Notes:
1. Minimum clearance between sprinkler deflector and top of storage shall be maintained as required.
2. 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
3. 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
4. Hose streams shall be provided in accordance with Table 7-2.3.1.1.

7-4.1.3.1† Sprinkler protection criteria is based on the assumption that roof vents and draft curtains are not being used.

7-4.1.4 Flue Space.

7-4.1.4.1† Storage Up to and Including 25 ft (7.6 m). In double-row and multiple-row racks without solid shelves, a longitudinal (back-to-back clearance between loads) flue space shall not be required. Nominal 6-in. (152.4-mm) transverse flue spaces between loads and at-rack uprights shall be maintained in single-row, double-row, and multiple-row racks. Random variations in the width of flue spaces or in their vertical alignment shall be permitted. *(See Figure 7-4.1.4.1)*

7-4.1.4.2 Storage Height Over 25 ft (7.6 m). Nominal 6-in. (152.4-mm) transverse flue spaces between loads and at-rack uprights shall be maintained in single-row, double-row, and multiple-row racks. Nominal 6-in. (152.4-mm) longitudinal flue spaces shall be provided in double-row racks. Random variations in the width of the flue spaces or in their vertical alignment shall be permitted.

7-4.1.5 Protection Systems.

7-4.1.5.1* Sprinkler systems shall be wet pipe systems.

Exception: In areas that are subject to freezing or where special conditions exist, dry-pipe systems and preaction systems shall be permitted.

7-4.1.5.2 Where dry pipe systems are used, the ceiling sprinkler areas of operation shall be increased 30 percent over the areas specified by 7-4.2, 7-4.3, and 7-4.4. Densities and areas shall be selected so that the final area of operation after the 30 percent increase is not greater than 6000 ft² (557.4 m²).

7-4.1.5.3 Where preaction systems are used, preaction systems shall be treated as dry pipe systems.

Exception: This requirement shall not apply where it can be demonstrated that the detection system that activates the preaction system

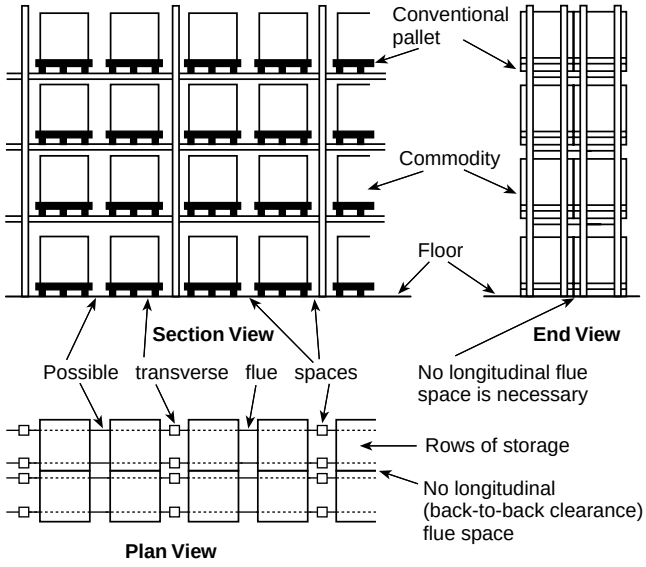
causes water to be discharged from sprinklers as quickly as the discharge from a wet pipe system.

7-4.1.5.4 Detectors for preaction systems shall be installed in accordance with 7-4.1.12.3.

7-4.1.5.5* In buildings that are used in part for rack storage of commodities, the design of the ceiling sprinkler system that is within 15 ft (4.6 m) of the racks shall be the same as that provided for the rack storage area.

Exception: Where separated by a barrier partition that is capable of preventing heat from a fire in the rack storage area from fusing sprinklers in the nonrack storage area.

Figure 7-4.1.4.1 Typical double-row rack with back-to-back loads.



7-4.1.6 Hose Connections. For first-aid fire-fighting and mop-up operations, small hose [$1^1/_2$ in. (38 mm)] shall be provided in accordance with 5-15.5.

Exception: Hose connections shall not be required for the protection of Class I, II, III, and IV commodities stored 12 ft (3.7 m) or less in height.

7-4.1.7 Solid and Slatted Shelves.

7-4.1.7.1*† Slatted shelves shall be considered equivalent to solid shelves.

Exception: A wet pipe system that is designed to provide a minimum of 0.6 gpm/ft^2 (24.5 mm/min) density over a minimum area of 2000 ft^2 (186 m^2) or K-14 ESFR sprinklers operating at a minimum of 50 psi (3.5 bar) shall be permitted to protect single-row and double-row slatted-shelf racks where all of the following conditions are met:

(a) Sprinklers shall be K-11.2 orifice spray sprinklers with a temperature rating of ordinary, intermediate, or high and shall be listed for storage occupancies or shall be K-14 ESFR.

(b) The protected commodities shall be limited to Class I–IV, Group B plastics, Group C plastics, cartoned (expanded and unexpanded) Group A plastics, and exposed (unexpanded) Group A plastics.

(c) Shelves shall be slatted using a minimum nominal 2-in. (51-mm) thick by maximum nominal 6-in. (152-mm) wide slat held in place by spacers that maintain a minimum 2-in. (51-mm) opening between each slat.

(d) Where K-11.2 orifice sprinklers are used, there shall be no slatted shelf levels in the rack above 12 ft (3.7 m). Wire mesh (greater than 50 percent opening) shall be permitted for shelf levels above 12 ft (3.7 m).

(e) Transverse flue spaces at least 3 in. (76 mm) wide shall be provided at least every 10 ft (3.1 m) horizontally.

(f) Longitudinal flue spaces at least 6 in. (152 mm) wide shall be provided for double-row racks.

(g) The aisle widths shall be at least $7^1/_2$ ft (2.3 m).

(h) The maximum roof height shall be 27 ft (8.2 m).

(i) The maximum storage height shall be 20 ft (6.1 m).

(j) Solid plywood or similar materials shall not be placed on the slatted shelves so that they block the 2-in. (51-mm) spaces between slats, nor shall they be placed on the wire mesh shelves.

7-4.1.7.2† Sprinklers shall be installed at the ceiling and beneath each shelf in single-, double-, or multiple-row racks with solid shelves that obstruct both longitudinal and transverse flue spaces. Design criteria for combined ceiling and in-rack sprinklers shall be used with this storage configuration.

7-4.1.8† Open-Top Combustible Containers.

7-4.1.9 Movable Racks. Rack storage in movable racks shall be protected in the same manner as multiple-row racks.

7-4.1.10 In-Rack Sprinklers. 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.

7-4.1.11* Horizontal Barriers and In-Rack Sprinklers. 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. (51 mm) horizontally around rack uprights. *[See Table 7-4.3.1.5.1, Figures 7-4.3.1.5.1(a), (g), and (j), and Figures 7-4.3.1.5.3(c) and (e).]*

7-4.1.12 High-Expansion Foam.

7-4.1.12.1* 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: This requirement shall not apply where modified by this standard.

7-4.1.12.2 In-rack sprinklers shall not be required where high-expansion foam systems are used in combination with ceiling sprinklers.

7-4.1.12.3 Detectors for High-Expansion Foam Systems. Detectors shall be listed and shall be installed in one of the following configurations:

(1) At the ceiling only where installed at one-half the 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 the ceiling/roof clearance from the top of the storage exceeds 10 ft (3.1 m) or the height of the storage exceeds 25 ft (7.6 m).

(2) At the ceiling at the listed spacing and in racks at alternate levels

(3) Where listed for rack storage installation and installed in accordance with the listing to provide response within 1 minute after ignition using an ignition source that is equivalent to that used in a rack storage testing program

7-4.1.12.4 High-Expansion Foam Submergence.

7-4.1.12.4.1 Storage of Classes I, II, III, and IV Commodities Up to and Including 25 ft (7.6 m) in Height.

7-4.1.12.4.1.1* Where high-expansion foam systems are used without sprinklers, the maximum submergence time shall be 5 minutes for Class I, Class II, or Class III commodities and 4 minutes for Class IV commodities.

7-4.1.12.4.1.2 Where high-expansion foam systems are used in combination with ceiling sprinklers, the maximum submergence time shall be 7 minutes for Class I, Class II, or Class III commodities and 5 minutes for Class IV commodities.

7-4.1.12.4.1.3 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 (8.2 mm/min) for Class I, Class II, or Class III commodities or 0.25 gpm/ft^2 (10.2 mm/min) for Class IV commodities for the most hydraulically remote 2000-ft^2 (186-m^2) operating area.

7-4.1.12.4.2 Storage of Classes I, II, III, and IV Commodities Over 25 ft (7.6 m) in Height.

7-4.1.12.4.2.1 Where high-expansion foam systems are used for storage over 25 ft (7.6 m) high up to and including 35 ft (10.7 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, Class II, or Class III commodities and 4 minutes for Class IV commodities.

7-4.1.12.4.2.2 Where high-expansion foam is used in combination with ceiling sprinklers, the minimum ceiling sprinkler design density shall be 0.2 gpm/ft^2 (8.2 mm/min) for Class I, Class II, or Class III commodities and 0.25 gpm/ft^2 (10.2 mm/min) for Class IV commodities for the most hydraulically remote 2000-ft^2 (186-m^2) operating area.

7-4.2 Spray Sprinkler Protection Criteria for Class I through Class IV Commodities Stored Up to and Including 25 ft (7.6 m) in Height.

7-4.2.1 In-Rack Sprinklers.

7-4.2.1.1 In-Rack Sprinkler Location.

7-4.2.1.1.1*† 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.

7-4.2.1.1.2* 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 in-rack sprinkler deflectors and the top of a tier of storage. Sprinkler discharge shall not be obstructed by horizontal rack members.

7-4.2.1.1.3 In-rack sprinklers at one level 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-half of the storage height.

7-4.2.1.1.4 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.

7-4.2.1.2 In-Rack Sprinkler Spacing.

7-4.2.1.2.1* Maximum horizontal spacing of in-rack 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 7-4.2.1.2.1.

For encapsulated storage, maximum horizontal spacing shall be 8 ft (2.44 m).

Table 7-4.2.1.2.1 In-Rack Sprinkler Spacing for Class I, II, III, and IV Commodities Stored up to 25 ft in Height

Aisle Widths		Commodity Class					
		I and II		III		IV	
ft	m	ft	m	ft	m	ft	m
8	2.4	12	3.7	12	3.7	8	2.4
4	1.2	12	3.7	8	2.4	8	2.4

7-4.2.1.2.2† Sprinklers installed in racks shall be spaced without regard to rack uprights.

7-4.2.1.3† In-Rack Sprinkler Discharge Pressure. Sprinklers in racks shall discharge at not less than 15 psi (1 bar) for all classes of commodities.

7-4.2.1.4† 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:

(1) Six sprinklers where only one level is installed in racks with Class I, Class II, or Class III commodities

(2) Eight sprinklers where only one level is installed in racks with Class IV commodities

(3) Ten sprinklers (five on each two top levels) where more than one level is installed in racks with Class I, Class II, or Class III commodities

(4) Fourteen sprinklers (seven on each two top levels) where more than one level is installed in racks with Class IV commodities

Exception: Where a storage rack, due to its length, requires less than the number of in-rack sprinklers specified, only those in-rack sprinklers in a single rack need to be included in the calculation.

7-4.2.1.5 In-Rack Sprinkler Location — Single- and Double-Row Racks. In single- or double-row racks without solid shelves, in-rack sprinklers shall be installed in accordance with Table 7-4.2.1.5.

7-4.2.1.6† In-Rack Sprinkler Location — Multiple-Row Racks.

7-4.2.1.6.1 For encapsulated or nonencapsulated storage in multiple-row racks no deeper than 16 ft (4.9 m) with aisles 8 ft (2.4 m) or wider, in-rack sprinklers shall be installed in accordance with Table 7-4.2.1.6.1.

Table 7-4.2.1.5 Single- or Double-Row Racks — Storage Height Up to and Including 25 ft (7.6 m) Without Solid Shelves

Height	Commodity Class	Encapsulated	Aisles* ft	Aisles* m	Sprinklers Mandatory In-Racks	Ceiling Sprinkler Water Demand: With In-Rack Sprinklers: Figure	Curves	Apply Figure 7-4.2.2.1.3	Without In-Rack Sprinklers: Figure	Curves	Apply Figure 7-4.2.2.1.3
Over 12 ft (3.7 m), up to and including 20 ft (6.1 m)	I	No	4	1.2	No	7-4.2.2.1.1(a)	C and D	Yes	7-4.2.2.1.1(a)	F and H	Yes
			8	2.4			A and B			E and G	
		Yes	4	1.2	No	7-4.2.2.1.1(e)	C and D		7-4.2.2.1.1(e)	G and H	Yes
			8	2.4			A and B			E and F	
	II	No	4	1.2	No	7-4.2.2.1.1(b)	C and D		7-4.2.2.1.1(b)	G and H	Yes
			8	2.4			A and B			E and F	
		Yes	4	1.2	No	7-4.2.2.1.1(e)	C and D		7-4.2.2.1.1(e)	G and H	Yes
			8	2.4			A and B			E and F	
	III	No	4	1.2	No	7-4.2.2.1.1(c)	C and D		7-4.2.2.1.1(c)	G and H	Yes
			8	2.4			A and B			E and F	
		Yes	4	1.2	1 level	7-4.2.2.1.1(f)	C and D		—	—	—
			8	2.4			A and B				
	IV	No	4	1.2	No	7-4.2.2.1.1(d)	C and D		7-4.2.2.1.1(d)	G and H	Yes
			8	2.4			A and B			E and F	
		Yes	4	1.2	1 level	7-4.2.2.1.1(g)	C and D		—	—	—
			8	2.4			A and B				
Over 20 ft (6.1 m), up to and including 22 ft (6.7 m)	I	No	4	1.2	No	7-4.2.2.1.1(a)	C and D	No	7-4.2.2.1.1(a)	F and H	Yes
			8	2.4			A and B			E and G	
		Yes	4	1.2	1 level	7-4.2.2.1.1(e)	C and D		—	—	—
			8	2.4			A and B				
	II	No	4	1.2	No	7-4.2.2.1.1(b)	C and D		7-4.2.2.1.1(b)	G and H	Yes
			8	2.4			A and B			E and F	
		Yes	4	1.2	1 level	7-4.2.2.1.1(e)	C and D		—	—	—
			8	2.4			A and B				
	III	No	4	1.2	No	7-4.2.2.1.1(c)	C and D		7-4.2.2.1.1(c)	G and H	Yes
			8	2.4			A and B			E and F	
		Yes	4	1.2	1 level	7-4.2.2.1.1(f)	C and D		—	—	—
			8	2.4			A and B				
	IV	No	4	1.2	No	7-4.2.2.1.1(d)	C and D		7-4.2.2.1.1(d)	G and H	Yes
			8	2.4			A and B			E and F	
		Yes	4	1.2	1 level	7-4.2.2.1.1(g)	C and D		—	—	—
			8	2.4			A and B				

Table 7-4.2.1.5 Single- or Double-Row Racks — Storage Height Up to and Including 25 ft (7.6 m) Without Solid Shelves *(Continued)*

Height	Commodity Class	Encapsulated	Aisles* ft	Aisles* m	Sprinklers Mandatory In-Racks	Ceiling Sprinkler Water Demand: With In-Rack Sprinklers: Figure	Curves	Apply Figure 7-4.2.2.1.3	Without In-Rack Sprinklers: Figure	Curves	Apply Figure 7-4.2.2.1.3
Over 22 ft (6.7 m), up to and including 25 ft (7.6 m)	I	No	4	1.2	No	7-4.2.2.1.1(a)	C and D	No	7-4.2.2.1.1(a)	F and H	Yes
			8	2.4			A and B			E and G	
		Yes	4	1.2	1 level	7-4.2.2.1.1(e)	C and D		—	—	—
			8	2.4			A and B				
	II	No	4	1.2	No	7-4.2.2.1.1(b)	C and D		7-4.2.2.1.1(b)	G and H	Yes
			8	2.4			A and B			E and F	
		Yes	4	1.2	1 level	7-4.2.2.1.1(e)	C and D		—	—	—
			8	2.4			A and B				
	III	No	4	1.2	No	7-4.2.2.1.1(c)	C and D		7-4.2.2.1.1(c)	G and H	Yes
			8	2.4			A and B			E and F	
		Yes	4	1.2	1 level	7-4.2.2.1.1(f)	C and D		—	—	—
			8	2.4			A and B				
	IV	No	4	1.2	1 level	7-4.2.2.1.1(d)	C and D		—	—	—
			8	2.4			A and B				
		Yes	4	1.2		7-4.2.2.1.1(g)	C and D		—	—	—
			8	2.4			A and B				

*See 7-4.2.2.2.2 for interpolation of aisle widths.

Table 7-4.2.1.6.1 Multiple-Row Racks — Rack Depth Up to and Including 16 ft (4.9 m), Aisles 8 ft (2.4 m) or Wider, Storage Height Up to 25 ft (7.6 m)

Height	Commodity Class	Encapsulated	Sprinklers Mandatory In-Racks	Ceiling Sprinkler Water Demand: With In-Rack Sprinklers: Figure	Curves	Apply Figure 7-4.2.2.1.3	1.25 × Density	Without In-Rack Sprinklers: Figure	Curves	Apply Figure 7-4.2.2.1.3	1.25 × Density
Over 12 ft (3.7 m), up to and including 15 ft (4.6 m)	I	No	No	7-4.2.2.1.1(a)	C and D	Yes	No	7-4.2.2.1.1(a)	I and J	Yes	No
		Yes		7-4.2.2.1.1(a)			Yes	7-4.2.2.1.1(a)	I and J		Yes
	II	No		7-4.2.2.1.1(b)			No	7-4.2.2.1.1(b)	I and J	Yes	No
		Yes		7-4.2.2.1.1(b)			Yes	7-4.2.2.1.1(b)	I and J		Yes
	III	No	No	7-4.2.2.1.1(c)			No	7-4.2.2.1.1(c)	I and J	Yes	No
		Yes	1 level	7-4.2.2.1.1(c)			Yes		NA	NA	NA
	IV	No	No	7-4.2.2.1.1(d)			No	7-4.2.2.1.1(d)	C and D	No	No
		Yes	1 level	7-4.2.2.1.1(d)	A and B		1.50 × density		NA	NA	NA
Over 15 ft (4.6 m), up to and including 20 ft (6.1 m)	I	No	No	7-4.2.2.1.1(a)	C and D	Yes	No	7-4.2.2.1.1(a)	I and J	Yes	No
		Yes		7-4.2.2.1.1(a)			Yes	7-4.2.2.1.1(a)	I and J		Yes
	II	No		7-4.2.2.1.1(b)			No	7-4.2.2.1.1(b)	I and J	Yes	No
		Yes		7-4.2.2.1.1(b)			Yes	7-4.2.2.1.1(b)	I and J		Yes
	III	No	No	7-4.2.2.1.1(c)			No	7-4.2.2.1.1(c)	I and J	Yes	No
		Yes	1 level	7-4.2.2.1.1(c)			Yes	NA	NA	NA	NA
	IV	No	1 level	7-4.2.2.1.1(d)			No				
		Yes		7-4.2.2.1.1(d)	A and B		1.50 × density				

(continues)

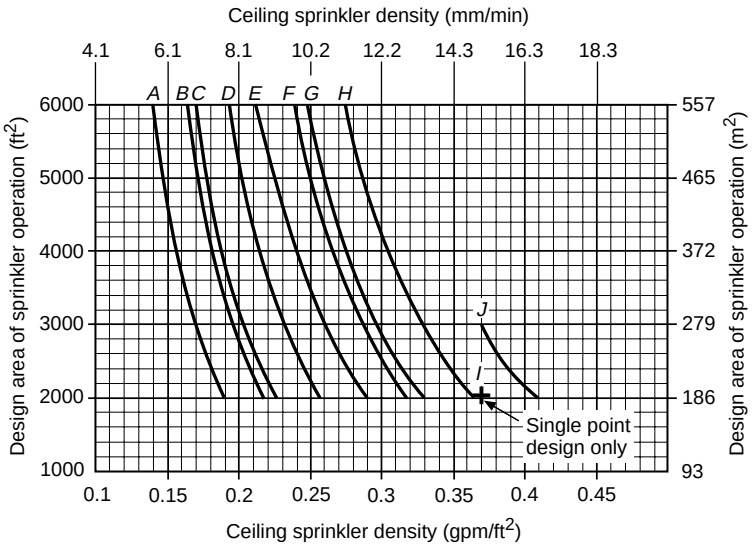
Table 7-4.2.1.6.1 Multiple-Row Racks — Rack Depth Up to and Including 16 ft (4.9 m), Aisles 8 ft (2.4 m) or Wider, Storage Height Up to 25 ft (7.6 m) ***(Continued)***

Height	Commodity Class	Encapsulated	Sprinklers Mandatory In-Racks	Ceiling Sprinkler Water Demand							
				With In-Rack Sprinklers				Without In-Rack Sprinklers			
				Figure	Curves	Apply Figure 7-4.2.2.1.3	1.25 × Density	Figure	Curves	Apply Figure 7-4.2.2.1.3	1.25 × Density
Over 20 ft (6.1 m), up to and including 25 ft (7.6 m)	I	No	No	7-4.2.2.1.1(a)	C and D	No	No	7-4.2.2.1.1(a)	I and J	Yes	No
		Yes	1 level	7-4.2.2.1.1(a)			Yes	NA	NA	NA	NA
	II	No	1 level	7-4.2.2.1.1(b)			No				
		Yes		7-4.2.2.1.1(b)			Yes				
	III	No		7-4.2.2.1.1(c)			No				
		Yes		7-4.2.2.1.1(c)			Yes				
	IV	No	2 levels	7-4.2.2.1.1(d)			No				
		Yes		7-4.2.2.1.1(d)	A and B		1.50 × density				

Table 7-4.2.1.6.2 Multiple-Row Racks — Rack Depth Over 16 ft (4.9 m) or Aisles Narrower than 8 ft (2.4 m), Storage Height Up to and Including 25 ft (7.6 m)

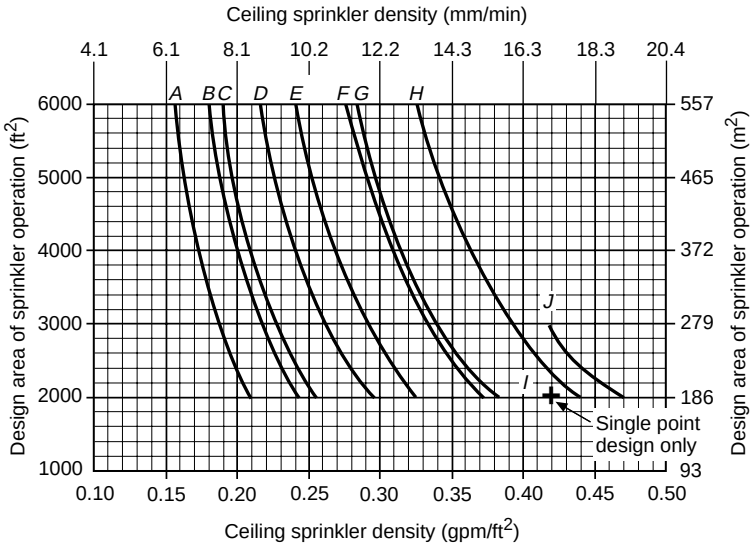
Height	Commodity Class	Encapsulated	Sprinklers Mandatory In-Racks	Ceiling Sprinkler Water Demand							
				With In-Rack Sprinklers				Without In-Rack Sprinklers			
				Figure	Curves	Apply Figure 7-4.2.2.1.3	1.25 × Density	Figure	Curves	Apply Figure 7-4.2.2.1.3	1.25 × Density
Over 12 ft (3.7 m), up to and including 15 ft (4.6 m)	I	No	No	7-4.2.2.1.1(a)	C and D	Yes	No	7-4.2.2.1.1(a)	I and J	Yes	No
		Yes		7-4.2.2.1.1(a)			Yes	7-4.2.2.1.1(a)	I and J		Yes
	II	No		7-4.2.2.1.1(b)			No	7-4.2.2.1.1(b)	I and J	Yes	No
		Yes		7-4.2.2.1.1(b)			Yes	7-4.2.2.1.1(b)	I and J		Yes
	III	No		7-4.2.2.1.1(c)			No	7-4.2.2.1.1(c)	I and J	Yes	No
		Yes	1 level	7-4.2.2.1.1(c)			Yes				
	IV	No	No	7-4.2.2.1.1(d)			No	7-4.2.2.1.1(d)	C and D	No	No
		Yes	1 level	7-4.2.2.1.1(d)			1.50 × density				
Over 15 ft (4.6 m), up to and including 20 ft (6.1 m)	I	No	1 level	7-4.2.2.1.1(a)	C and D	Yes	No	NA	NA	NA	NA
		Yes		7-4.2.2.1.1(a)			Yes				
	II	No		7-4.2.2.1.1(b)			No				
		Yes		7-4.2.2.1.1(b)			Yes				
	III	No		7-4.2.2.1.1(c)			No				
		Yes		7-4.2.2.1.1(c)			Yes				
	IV	No		7-4.2.1.1(d)			No				
		Yes		7-4.2.2.1.1(d)			1.50 × density				
Over 20 ft (6.1 m), up to and including 25 ft (7.6 m)	I	No	1 level	7-4.2.2.1.1(a)	C and D	No	No	NA	NA	NA	NA
		Yes		7-4.2.2.1.1(a)			Yes				
	II	No		7-4.2.2.1.1(b)			No				
		Yes		7-4.2.2.1.1(b)			Yes				
	III	No		7-4.2.2.1.1(c)			No				
		Yes		7-4.2.2.1.1(c)			Yes				
	IV	No	2 levels	7-4.2.2.1.1(d)			No				
		Yes		7-4.2.2.1.1(d)			1.50 × density				

Figure 7-4.2.2.1.1(a) Sprinkler system design curves — 20-ft (6.1-m) high rack storage — Class I nonencapsulated commodities — conventional pallets.



Curve	Legend	Curve	Legend
A	Single-or double-row racks with 8-ft (2.44-m) aisles with 286°F (141°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers	*E*	Single-or double-row racks with 8-ft (2.44-m) aisles and 286°F (141°C) ceiling sprinklers
B	Single-or double-row racks with 8-ft (2.44-m) aisles with 165°F (74°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers	*F*	Single-or double-row racks with 8-ft (2.44-m) aisles and 165°F (74°C) ceiling sprinklers
C	Single-or double-row racks with 4-ft (1.22-m) aisles or multiple-row racks with 286°F (141°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers	*G*	Single-or double-row racks with 4-ft (1.22-m) aisles and 286°F (141°C) ceiling sprinklers
D	Single-or double-row racks with 4-ft (1.22-m) aisles or multiple-row racks with 165°F (74°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers	*H*	Single-or double-row racks with 4-ft (1.22-m) aisles and 165°F (74°C) ceiling sprinklers
		I	Multiple-row racks with 8-ft (2.44-m) or wider aisles and 286°F (141°C) ceiling sprinklers
		J	Multiple-row racks with 8-ft (2.44-m) or wider aisles and 165°F (74°C) ceiling sprinklers

Figure 7-4.2.2.1.1(b) Sprinkler system design curves — 20-ft (6.1-m) high rack storage — Class II nonencapsulated commodities — conventional pallets.



Curve	Legend	Curve	Legend
A	Single-or double-row racks with 8-ft (2.44-m) aisles with 286°F (141°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers	*E*	Single-or double-row racks with 8-ft (2.44-m) aisles and 286°F (141°C) ceiling sprinklers
B	Single-or double-row racks with 8-ft (2.44-m) aisles with 165°F (74°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers	*F*	Single-or double-row racks with 8-ft (2.44-m) aisles and 165°F (74°C) ceiling sprinklers
C	Single-or double-row racks with 4-ft (1.22-m) aisles or multiple-row racks with 286°F (141°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers	*G*	Single-or double-row racks with 4-ft (1.22-m) aisles and 286°F (141°C) ceiling sprinklers
D	Single-or double-row racks with 4-ft (1.22-m) aisles or multiple-row racks with 165°F (74°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers	*H*	Single-or double-row racks with 4-ft (1.22-m) aisles and 165°F (74°C) ceiling sprinklers
		I	Multiple-row racks with 8-ft (2.44-m) or wider aisles and 286°F (141°C) ceiling sprinklers
		J	Multiple-row racks with 8-ft (2.44-m) or wider aisles and 165°F (74°C) ceiling sprinklers

7-4.2.1.6.2 For encapsulated or nonencapsulated storage in multiple-row racks deeper than 16 ft (4.9 m) or with aisles less than 8 ft (2.4 m) wide, in-rack sprinklers shall be installed in accordance with Table 7-4.2.1.6.2.

7-4.2.1.6.3* Maximum horizontal spacing of in-rack 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 (2.4 m) for Class IV commodities, with area limitations of 100 ft^2 (9.3 m^2) per sprinkler for Class I, II, or III commodities and 80 ft^2 (7.4 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.

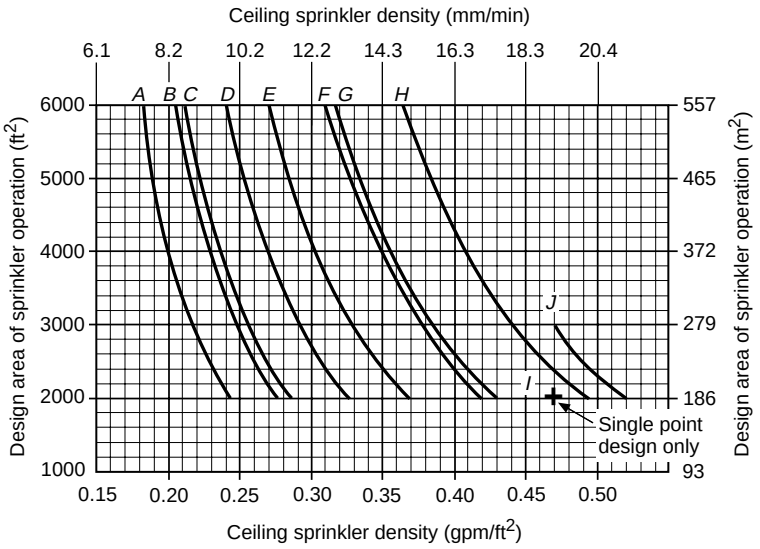
7-4.2.1.6.4 A minimum of 6 in. (152.4 mm) shall be maintained between the in-rack sprinkler deflector and the top of a tier of storage.

7-4.2.2† Ceiling Sprinkler Discharge Criteria — Area Density Method.

7-4.2.2.1 General.

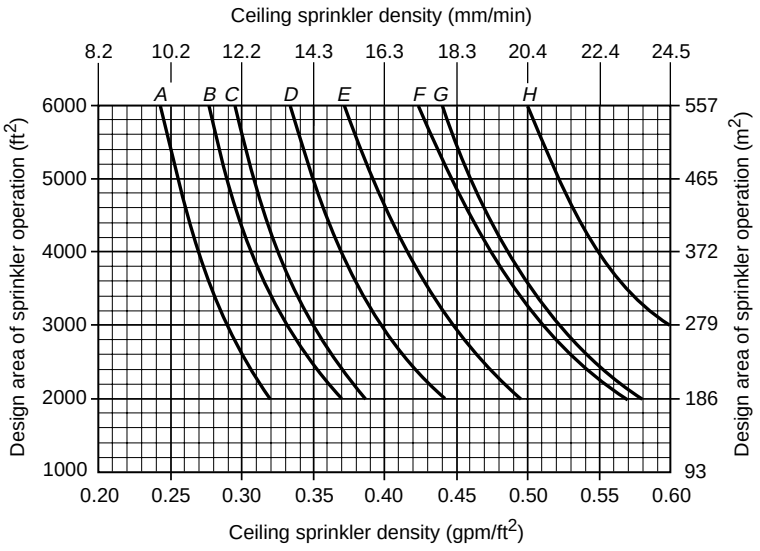
7-4.2.2.1.1*† Ceiling Sprinkler Water Demand. Ceiling sprinkler water demand shall be determined in accordance with 7-4.2.2.2 for single- and double-row racks or 7-4.2.3 for multiple-row racks. The design curves in Figures 7-4.2.2.1.1(a) through (g) shall apply to nominal 20 ft (6.1 m) height of storage.

Figure 7-4.2.2.1.1(c) Sprinkler system design curves — 20-ft (6.1-m) high rack storage — Class III nonencapsulated commodities — conventional pallets.



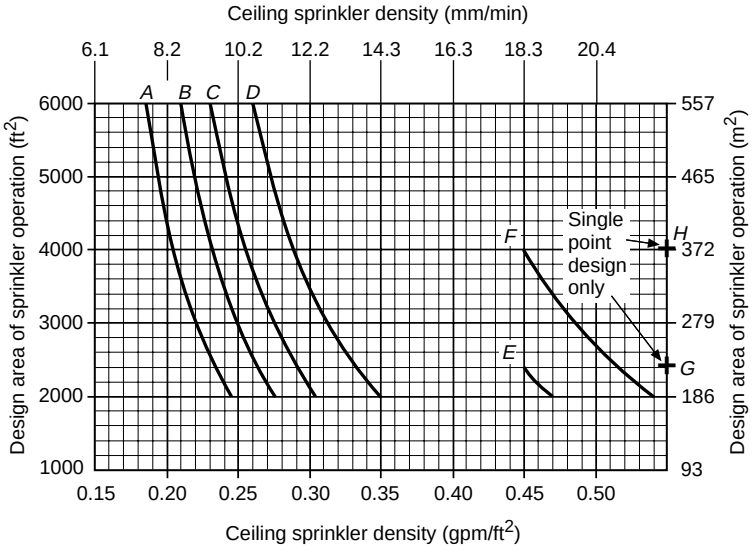
Curve	Legend
A	Single-or double-row racks with 8-ft (2.44-m) aisles with 286°F (141°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers
B	Single-or double-row racks with 8-ft (2.44-m) aisles with 165°F (74°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers
C	Single-or double-row racks with 4-ft (1.22-m) aisles or multiple-row racks with 286°F (141°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers
D	Single-or double-row racks with 4-ft (1.22-m) aisles or multiple-row racks with 165°F (74°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers
E	Single-or double-row racks with 8-ft (2.44-m) aisles and 286°F (141°C) ceiling sprinklers
F	Single-or double-row racks with 8-ft (2.44-m) aisles and 165°F (74°C) ceiling sprinklers
G	Single-or double-row racks with 4-ft (1.22-m) aisles and 286°F (141°C) ceiling sprinklers
H	Single-or double-row racks with 4-ft (1.22-m) aisles and 165°F (74°C) ceiling sprinklers
I	Multiple-row racks with 8-ft (2.44-m) or wider aisles and 286°F (141°C) ceiling sprinklers
J	Multiple-row racks with 8-ft (2.44-m) or wider aisles and 165°F (74°C) ceiling sprinklers

Figure 7-4.2.2.1.1(d) Sprinkler system design curves — 20-ft (6.1-m) high rack storage — Class IV nonencapsulated commodities — conventional pallets.



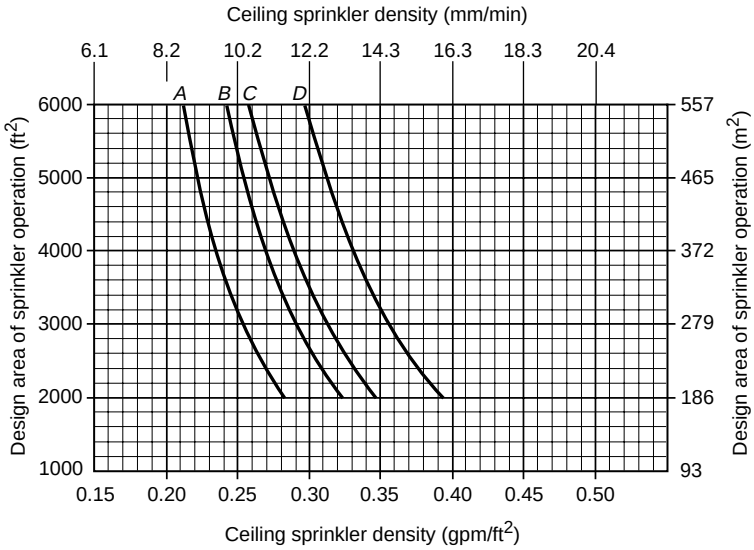
Curve	Legend
A	Single-or double-row racks with 8-ft (2.44-m) aisles with 286°F (141°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers
B	Single-or double-row racks with 8-ft (2.44-m) aisles with 165°F (74°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers
C	Single-or double-row racks with 4-ft (1.22-m) aisles or multiple-row racks with 286°F (141°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers
D	Single-or double-row racks with 4-ft (1.22-m) aisles or multiple-row racks with 165°F (74°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers
E	Single-or double-row racks with 8-ft (2.44-m) aisles and 286°F (141°C) ceiling sprinklers
F	Single-or double-row racks with 8-ft (2.44-m) aisles and 165°F (74°C) ceiling sprinklers
G	Single-or double-row racks with 4-ft (1.22-m) aisles and 286°F (141°C) ceiling sprinklers
H	Single-or double-row racks with 4-ft (1.22-m) aisles and 165°F (74°C) ceiling sprinklers

Figure 7-4.2.2.1.1(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.



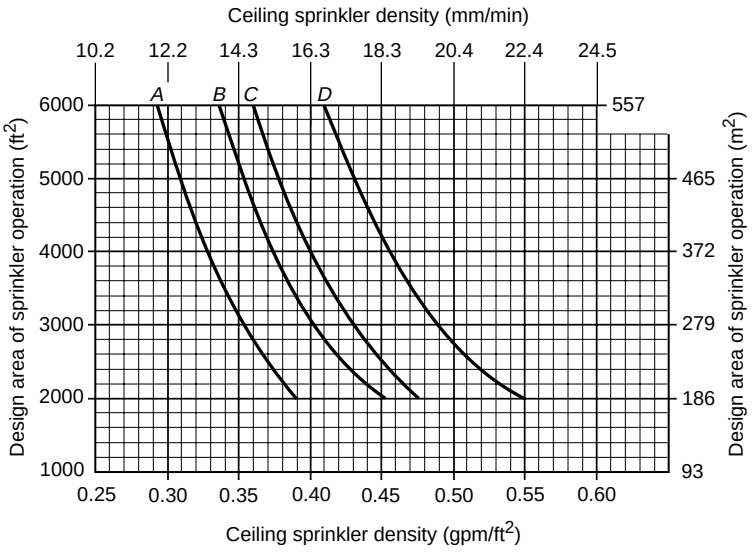
Curve	Legend
A	8-ft (2.44-m) aisles with 286°F (141°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers
B	8-ft (2.44-m) aisles with 165°F (74°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers
C	4-ft (1.22-m) aisles with 286°F (141°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers
D	4-ft (1.22-m) aisles with 165°F (74°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers
E	8-ft (2.44-m) aisles with 288°F (141°C) ceiling sprinklers
F	8-ft (2.44-m) aisles with 165°F (74°C) ceiling sprinklers
G	4-ft (1.22-m) aisles with 286°F (141°C) ceiling sprinklers
H	4-ft (1.22-m) aisles with 165°F (74°C) ceiling sprinklers

Figure 7-4.2.2.1.1(f) Single- or double-row racks — 20-ft (6.1-m) high rack storage — sprinkler system design curves — Class III encapsulated commodities — conventional pallets.



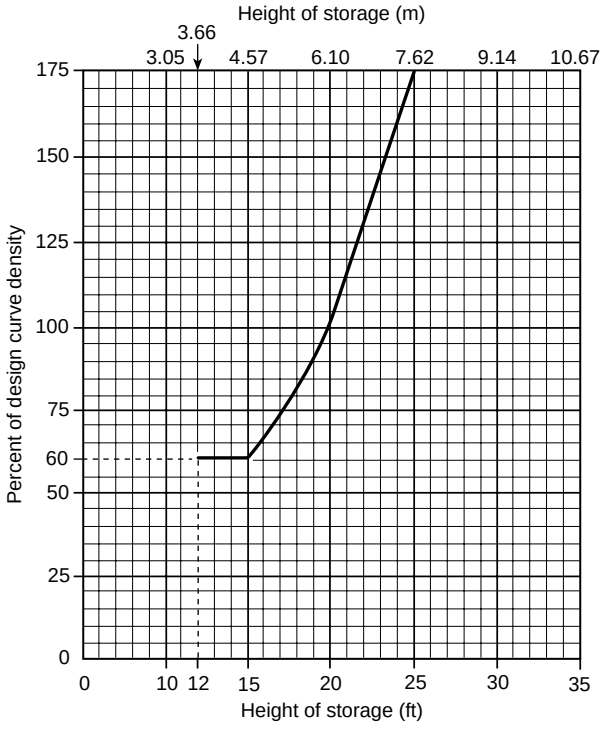
Curve	Legend
A	8-ft (2.44-m) aisles with 286°F (141°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers
B	8-ft (2.44-m) aisles with 165°F (74°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers
C	4-ft (1.22-m) aisles with 288°F (141°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers
D	4-ft (1.22-m) aisles with 165°F (74°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers

Figure 7-4.2.2.1.1(g) Single- or double-row racks — 20-ft (6.1-m) high rack storage — sprinkler system design curves — Class IV encapsulated commodities — conventional pallets.



Curve	Legend
A	8-ft (2.44-m) aisles with 286°F (141°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers
B	8-ft (2.44-m) aisles with 165°F (74°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers
C	4-ft (1.22-m) aisles with 288°F (141°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers
D	4-ft (1.22-m) aisles with 165°F (74°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers

Figure 7-4.2.2.1.3 Ceiling sprinkler density vs. storage height.



7-4.2.2.1.2 The design curves indicate water demands for ordinary temperature–rated and nominal high temperature–rated sprinklers at the ceiling. The ordinary-temperature design curves corresponding to ordinary temperature–rated sprinklers shall be used for sprinklers with ordinary- and intermediate-temperature classification. The high-temperature design curve corresponding to high temperature–rated sprinklers shall be used for sprinklers having a high-temperature rating.

7-4.2.2.1.3 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 7-4.2.2.1.3.

7-4.2.2.1.4 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 7-4.2.2.1.3.

7-4.2.2.1.5 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 7-4.2.2.1.3 shall be permitted to be reduced an additional 20 percent, as indicated in Table 7-4.2.2.1.5.

7-4.2.2.1.6 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 as indicated in Table 7-4.2.2.1.5. Densities shall not be adjusted in accordance with Figure 7-4.2.2.1.3 for storage height.

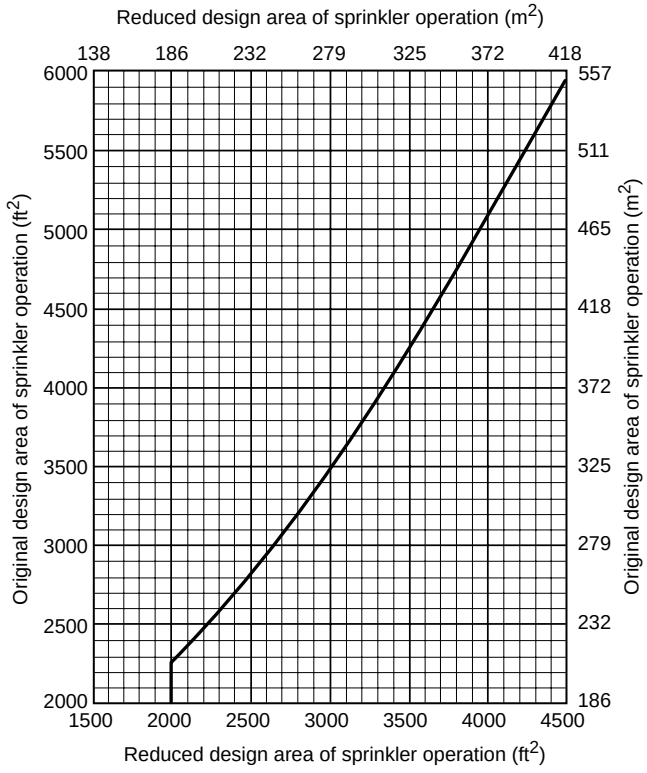
7-4.2.2.1.7 For storage height up to and including 20 ft (6.1 m) protected with ceiling sprinklers and in-rack sprinklers at each tier, densities obtained from design curves and adjusted in accordance with Figure 7-4.2.2.1.3 shall be permitted to be reduced an additional 40 percent, as indicated in Table 7-4.2.2.1.5.

7-4.2.2.1.8 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, as indicated in Table 7-4.2.2.1.5. Densities shall not be adjusted in accordance with Figure 7-4.2.2.1.3 for storage height.

Table 7-4.2.2.1.5 Adjustment to Ceiling Sprinkler Density for Storage Height and In-Rack Sprinklers

Storage Height	In-Rack Sprinklers	Apply Figure 7-4.2.2.1.3 for Storage Height Adjustment	Permitted Ceiling Sprinklers Density Adjustments Where In-rack Sprinklers Are Installed
Over 12 ft (3.7 m) through 25 ft (7.6 m)	None	Yes	None
Over 12 ft (3.7 m) through 20 ft (6.1 m)	Minimum required	Yes	None
	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
Over 20 ft (6.1 m) through 25 ft (7.6 m)	Minimum required	No	None
	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

Figure 7-4.2.2.1.9 Adjustment of design area of sprinkler operation for clearance from top of storage to ceiling.



7-4.2.2.1.9† Where clearance from ceiling to top of storage is less than $4^1/_2$ ft (1.37 m), the sprinkler operating area indicated in curves E, F, G, and H in Figures 7-4.2.2.1.1(a) through (e) shall be permitted to be reduced as indicated in Figure 7-4.2.2.1.9 but shall not be reduced to less than 2000 ft² (185.8 m²). *(See 7-4.2.2.1.10.)*

7-4.2.2.1.10 Where clearance from ceiling to top of Class I or Class 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 7-4.2.2.1.1(e) shall be permitted to be reduced by 50 percent but shall not be reduced to less than 2000 ft² (186 m²).

7-4.2.2.1.11 Where solid, flat-bottom, combustible pallets are used with storage height up to and including 25 ft (7.6 m), the densities that are indicated in the design curves shown in Figures 7-4.2.2.1.1(a) through (g), based on conventional pallets, shall be increased 20 percent for the given area. The percentage shall be applied to the density determined in accordance with Figure 7-4.2.2.1.3. The increase in density shall not apply where in-rack sprinklers are installed.

7-4.2.2.2* Ceiling Sprinkler Water Demand — Double- and Single-Row Racks.

7-4.2.2.2.1 For Class I, Class II, Class III, or Class IV commodities, encapsulated or nonencapsulated in single- or double-row racks, ceiling sprinkler water demand in terms of density (gpm/ft²) (mm/min) and area of sprinkler operation [ft² (m²) of ceiling or roof] shall be selected from the curves in Figures 7-4.2.2.1.1-1.6(a) through (g) as directed by Table 7-4.2.1.5. The curves in Figures 7-4.2.2.1.1(a) through (g) 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 7-4.2.2.1.3 shall be used to adjust the density for storage height unless otherwise specified.

7-4.2.2.2.2*† Design curves for single- and double-row racks shall be selected to correspond to aisle width. For aisle widths between 4 ft (1.2 m) and 8 ft (2.4 m), a direct linear interpolation between curves shall be made. The density given for 8-ft (2.4-m) wide aisles shall be applied to aisles wider than 8 ft (2.4 m). The density given for 4-ft (1.2-m) wide aisles shall be applied to aisles narrower than 4 ft (1.2 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.

7-4.2.3 Ceiling Sprinkler Water Demand — Multiple-Row Racks.

7-4.2.3.1 For nonencapsulated Class I, Class II, Class III, or Class IV commodities, ceiling sprinkler water demand in terms of density (gpm/ft^2) (mm/min) and area of sprinkler operation [ft^2 (m^2) of ceiling or roof] shall be selected from the curves in Figures 7-4.2.2.1.1(a) through (d). The curves in Figures 7-4.2.2.1.1(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 7-4.2.2.1.3 shall be used to adjust density for storage height unless otherwise specified. *(See A-7-4.2.1.2.1.)*

7-4.2.3.2 For encapsulated Class I, Class II, or Class 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.

7-4.2.3.3 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.

7-4.3 Spray Sprinkler Protection Criteria for Class I through Class IV Commodities Stored Over 25 ft (7.6 m) in Height.

7-4.3.1 General.

7-4.3.1.1 In-Rack Sprinkler Spacing. In-rack sprinklers shall be staggered horizontally and vertically where installed in accordance with Table 7-4.3.1.5.1, Figures 7-4.3.1.5.1(a) through (j), and Figures 7-4.3.1.5.3(a) through (e).

7-4.3.1.2 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 mm) from rack uprights and no more than 18 in. (460 mm) from the aisle face of storage. Longitudinal flue in-rack sprinklers shall be located at the intersection with the transverse flue space and with the deflector located at or below the bottom of horizontal load beams or above or below other adjacent horizontal rack members. Such in-rack sprinklers shall be a minimum of 3 in. (76 mm) radially from the side of the rack uprights.

7-4.3.1.3 In-Rack Sprinkler Discharge. Sprinklers in racks shall discharge at a rate not less than 30 gpm (113.6 L/min) for all classes of commodities. *(See C-7-4.2.1.4.)*

7-4.3.1.4 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:

(1) Six sprinklers where only one level is installed in racks with Class I, Class II, or Class III commodities

(2) Eight sprinklers where only one level is installed in racks with Class IV commodities

(3) Ten sprinklers (five on each two top levels) where more than one level is installed in racks with Class I, Class II, or Class III commodities

(4) Fourteen sprinklers (seven on each two top levels) where more than one level is installed in racks with Class IV commodities

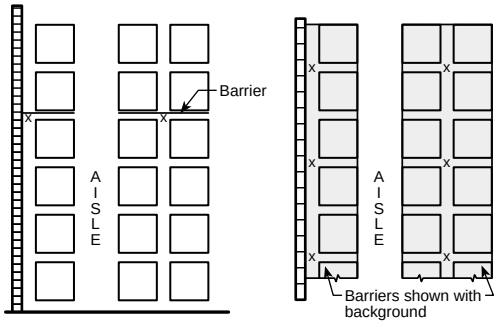
7-4.3.1.5 In-Rack Sprinkler Location — Double- and Single-Row Racks.

7-4.3.1.5.1* 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 7-4.3.1.5.1 and Figures 7-4.3.1.5.1(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 7-4.1.9.)*

Where a single-row rack is mixed with double-row racks, Table 7-4.3.1.5.1 and Figures 7-4.3.1.5.1(a) through 7-4.3.1.5.1(j) shall be used.

Exception: Figures 7-4.3.1.5.3(a) through (c) shall be permitted to be used for the protection of the single-row racks.

Figure 7-4.3.1.5.1(a) In-rack sprinkler arrangement, Class I commodities, storage height 25 ft to maximum 30 ft (7.6 m to maximum 9.1 m).



Note: Symbol x indicates in-rack sprinklers.

Table 7-4.3.1.5.1 Double-Row Racks without Solid Shelves — Storage Higher than 25 ft (7.6 m), Aisles 4 ft (1.2 m) or Wider

Commodity Class	In-Rack Sprinklers — Approximate Vertical Spacing at Tier Nearest the Vertical Distance and Maximum Horizontal Spacing[1,2,3]		Figure	Maximum Storage Height	Stagger	Ceiling Sprinkler Operating Area		Ceiling Sprinkler Density Clearance up to 10 ft (3.1 m)[4,5,6]			
								Ordinary Temperature		High Temperature	
	Longitudinal Flue[7]	Face[8,9]				ft^2	m^2	gpm/ft^2	mm/min	gpm/ft^2	mm/min
I	Vertical 20 ft (6.1 m) Horizontal 10 ft (3.1 m) under horizontal barriers	None	7-4.3.1.5.1(a)	30 ft (9.1 m)	No			0.25	10.2	0.35	14.3
	Vertical 20 ft (6.1 m) Horizontal 10 ft (3.1 m)	Vertical 20 ft (6.1 m) Horizontal 10 ft (3.1 m)	7-4.3.1.5.1(b)	Higher than 25 ft (7.6 m)	Yes			0.25	10.2	0.35	14.3
I, II, III	Vertical 10 ft (3.1 m) or at 15 ft (4.6 m) and 25 ft (7.6 m) Horizontal 10 ft (3.1 m)	None	7-4.3.1.5.1(c)	30 ft (9.1 m)	Yes	2000	186	0.3	12.2	0.4	16.3
	Vertical 10 ft (3.1 m) Horizontal 10 ft (3.1 m)	Vertical 30 ft (9.1 m) Horizontal 10 ft (3.1 m)	7-4.3.1.5.1(d)	Higher than 25 ft (7.6 m)	Yes			0.3	12.2	0.4	16.3
	Vertical 20 ft (6.1 m) Horizontal 10 ft (3.1 m)	Vertical 20 ft (6.1 m) Horizontal 5 ft (1.5 m)	7-4.3.1.5.1(e)		Yes			0.3	12.2	0.4	16.3
	Vertical 25 ft (7.6 m) Horizontal 5 ft (1.5 m)	Vertical 25 ft (7.6 m) Horizontal 5 ft (1.5 m)	7-4.3.1.5.1(f)		No			0.3	12.2	0.4	16.3
	Horizontal barriers at 20 ft (6.1 m) Vertical intervals — two lines of sprinklers under barriers — maximum horizontal spacing 10 ft (3.1 m), staggered		7-4.3.1.5.1(g)		Yes			0.3	12.2	0.4	16.3

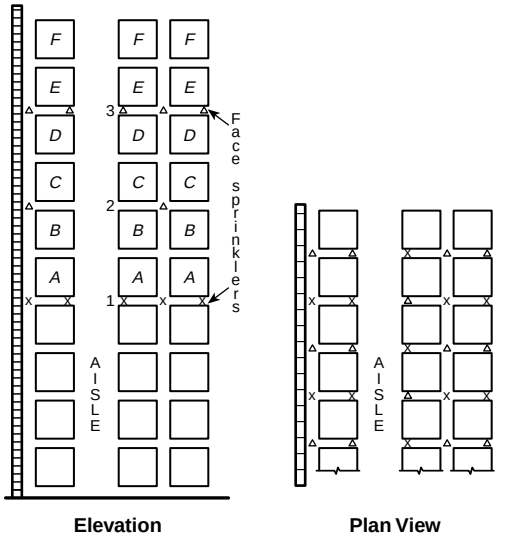
(continues)

Table 7-4.3.1.5.1 Double-Row Racks without Solid Shelves — Storage Higher than 25 ft (7.6 m), Aisles 4 ft (1.2 m) or Wider *(Continued)*

Commodity Class	In-Rack Sprinklers — Approximate Vertical Spacing at Tier Nearest the Vertical Distance and Maximum Horizontal Spacing[1,2,3]		Figure	Maximum Storage Height	Stagger	Ceiling Sprinkler Operating Area		Ceiling Sprinkler Density Clearance up to 10 ft (3.1 m)[4,5,6]			
								Ordinary Temperature		High Temperature	
	Longitudinal Flue[7]	Face[8,9]				ft^2	m^2	gpm/ft^2	mm/min	gpm/ft^2	mm/min
I, II, III, IV	Vertical 15 ft (4.6 m) Horizontal 10 ft (3.1 m)	Vertical 20 ft (6.1 m) Horizontal 10 ft (3.1 m)	7-4.3.1.5.1(h)	Higher than 25 ft (7.6 m)	Yes	2000	186	0.35	14.3	0.45	18.3
	Vertical 20 ft (6.1 m) Horizontal 5 ft (1.5 m)	Vertical 20 ft (6.1 m) Horizontal 5 ft (1.5 m)	7-4.3.1.5.1(i)		No			0.35	14.3	0.45	18.3
	Horizontal barriers at 15 ft (4.6 m) Vertical intervals — two lines of sprinklers under barriers — maximum horizontal spacing 10 ft (3.1 m), staggered		7-4.3.1.5.1(j)		Yes			0.35	14.3	0.45	18.3

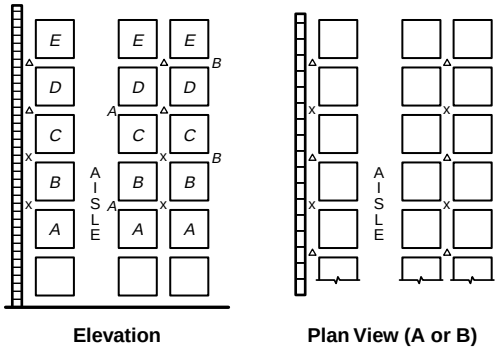
[1]Minimum in-rack sprinkler discharge, 30 gpm (114 L/min) *(see 7-4.3.1.3).*
[2]Water shields required *(see 5-12.3.1).*
[3]All in-rack sprinkler spacing dimensions start from the floor.
[4]For encapsulated commodity, increase density 25 percent *(see 7-4.3.2.2).*
[5]Clearance is distance between top of storage and ceiling.
[6]See A-7-4.3.1.5.3, A-7-4.1.11, and A-7-4.3.2.1 for protection recommendations where clearance is greater than 10 ft (3.1 m).
[7]Install sprinklers at least 3 in. (76.2 mm) from uprights *(see 7-4.3.1.2).*
[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 Figures 7-4.3.1.5.1(g) and 7-4.3.1.5.1(j).
[9]In Figures 7-4.3.1.5.1(a) through 7-4.3.1.5.1(j), each square represents a storage cube that measures 4 ft to 5 ft (1.2 m to 1.5 m) on a side. Actual load heights can vary from approximately 18 in. to 10 ft (0.46 m to 3.1 m). Therefore, there can be one load to six or seven loads between in-rack sprinklers that are spaced 10 ft (3.1 m) apart vertically.

Figure 7-4.3.1.5.1(b) In-rack sprinkler arrangement, Class I commodities, storage height over 25 ft (7.6 m).



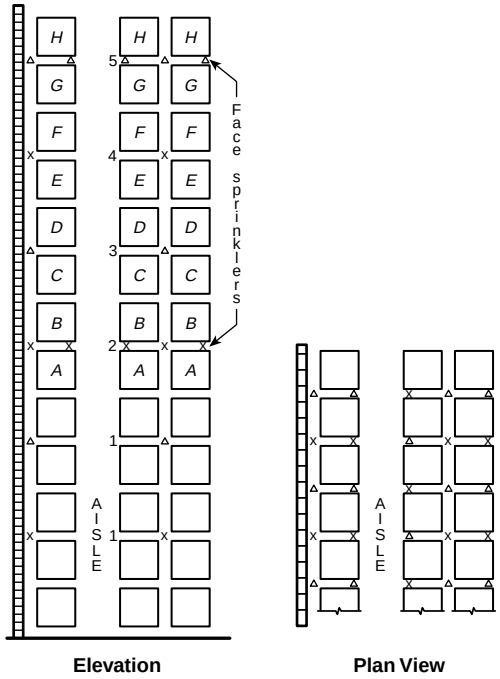
Notes:
1. Sprinklers labeled 1 (the selected array from Table 7-4.3.1.5.1) shall be required where loads labeled *A* or *B* represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled *C* or *D* represent top of storage.
3. Sprinklers labeled 1 and 3 shall be required 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.

Figure 7-4.3.1.5.1(c) In-rack sprinkler arrangement, Class I, Class II, or Class III commodities, storage height 25 ft to maximum 30 ft (7.6 m to maximum 9.1 m).



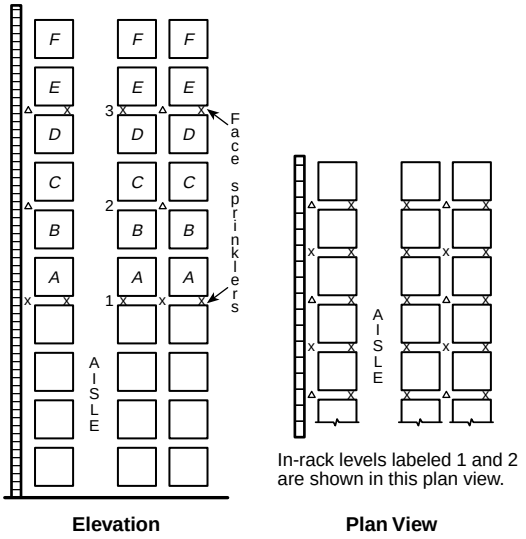
Notes:
1. Alternate location of in-rack sprinklers. Sprinklers shall be permitted to be installed above loads *A* and *C* or above loads *B* and *D*.
2. Symbol Δ or x indicates sprinklers on vertical or horizontal stagger.

Figure 7-4.3.1.5.1(d) In-rack sprinkler arrangement, Class I, Class II, or Class III commodities, storage height over 25 ft (7.6 m) — option 1.



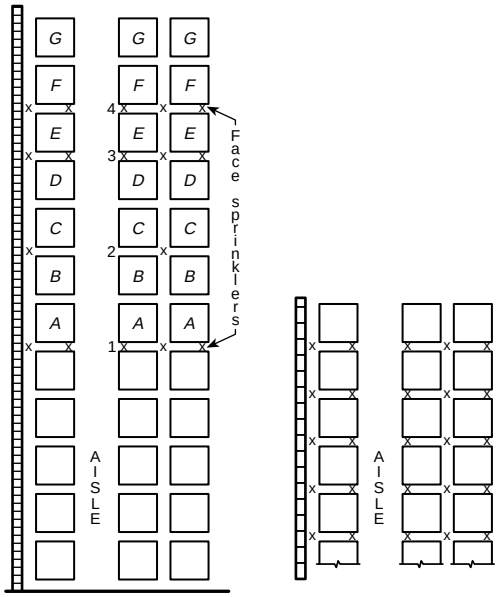
Notes:
1. Sprinklers labeled 1 shall be required where loads labeled *A* represent the top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled *B* or *C* represent top of storage.
3. Sprinklers labeled 1, 2, and 3 shall be required where loads labeled *D* or *E* represent 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.

Figure 7-4.3.1.5.1(e) In-rack sprinkler arrangement, Class I, Class II, or Class III commodities, storage height over 25 ft (7.6 m) — option 2.



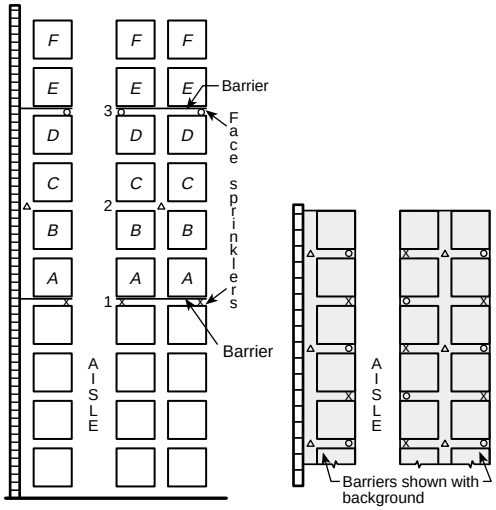
Notes:
1. Sprinklers labeled 1 (the selected array from Table 7-4.3.1.5.1) shall be required where loads labeled *A* or *B* represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled *C* or *D* represent top of storage.
3. Sprinklers labeled 1 and 3 shall be required 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.

Figure 7-4.3.1.5.1(f) In-rack sprinkler arrangement, Class I, Class II, or Class III commodities, storage height over 25 ft (7.6 m) — option 3.



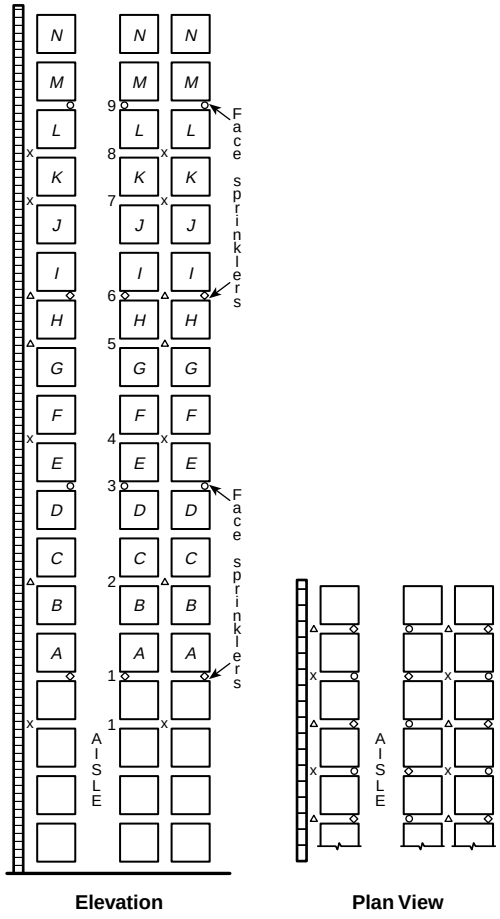
Notes:
1. Sprinklers labeled 1 (the selected array from Table 7-4.3.1.5.1) shall be required where loads labeled *A* or *B* represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled *C* or *D* represent top of storage.
3. Sprinklers labeled 1 and 3 shall be required 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.

Figure 7-4.3.1.5.1(g) In-rack sprinkler arrangement, Class I, Class II, or Class III commodities, storage height over 25 ft (7.6 m) — option 4.



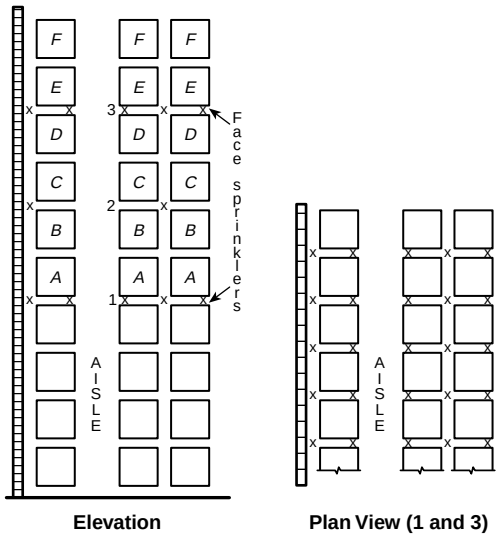
Notes:
1. Sprinklers labeled 1 (the selected array from Table 7-4.3.1.5.1) shall be required where loads labeled *A* or *B* represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled *C* or *D* represent top of storage.
3. Sprinklers labeled 1 and 3 shall be required 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.

Figure 7-4.3.1.5.1(h) In-rack sprinkler arrangement, Class I, Class II, Class III, or Class IV commodities, storage height over 25 ft (7.6 m) — option 1.



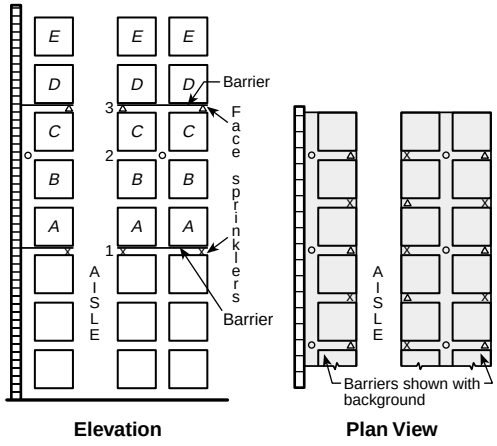
Notes:
1. Sprinklers labeled 1 (the selected array from Table 7-4.3.1.5.1) shall be required where loads labeled *A* or *B* represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled *C* or *D* represent top of storage.
3. Sprinklers labeled 1, 2, and 3 shall be required 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 labeled *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.

Figure 7-4.3.1.5.1(i) In-rack sprinkler arrangement, Class I, Class II, Class III, or Class IV commodities, storage height over 25 ft (7.6 m) — option 2.



Notes:
1. Sprinklers labeled 1 (the selected array from Table 7-4.3.1.5.1) 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.

Figure 7-4.3.1.5.1(j) In-rack sprinkler arrangement, Class I, Class II, Class III, or Class IV commodities, storage height over 25 ft (7.6 m) — option 3.



Notes:
1. Sprinklers labeled 1 (the selected array from Table 7-4.3.1.5.1) 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.

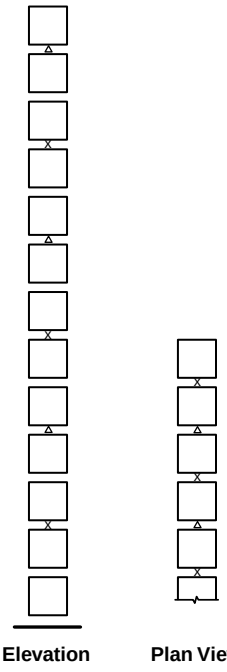
7-4.3.1.5.2 In-rack sprinklers for storage higher than 25 ft (7.6 m) in double-row racks shall be spaced horizontally and located in the horizontal space nearest the vertical intervals specified in Table 7-4.3.1.5.1 and Figures 7-4.3.1.5.1(a) through (j).

7-4.3.1.5.3* 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 7-4-3.1.5.3(a) through (e).

In single-row racks, where figures show in-rack sprinklers in transverse flue spaces centered between the rack faces, it shall be permitted to position these in-rack sprinklers in the transverse flue at any point between the load faces.

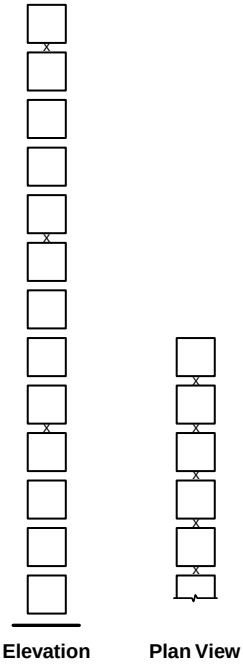
7-4.3.1.5.4* In-Rack Sprinkler Location — Multiple-Row Racks. In multiple-row racks with a maximum of 10 ft (3.1 m) between the top of storage and the ceiling, protection shall be in accordance with Table 7-4.3.1.5.4 and in-rack sprinklers shall be installed as indicated in Figures 7-4.3.1.5.4(a), (b), 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, Class II, or Class III commodities or 5 ft (1.5 m) below the top of storage for Class IV commodities.

Figure 7-4.3.1.5.3(a) Class I, Class II, Class III, or Class IV commodities, in-rack sprinkler arrangement, single-row racks, storage height over 25 ft (7.6 m) — option 1.



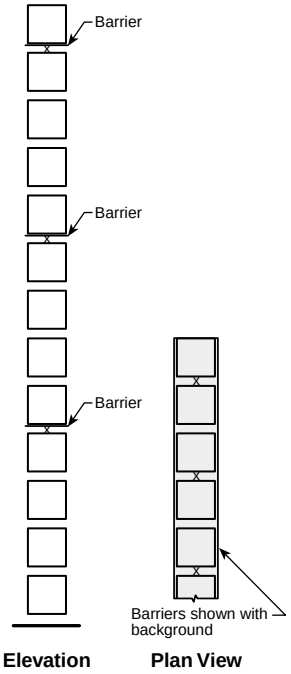
Notes:
1. For all storage heights, sprinklers shall be installed in every other tier and staggered as indicated.
2. Symbol Δ or x indicates sprinklers on vertical or horizontal stagger.
3. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-4.3.1.5.3(b) Class I, Class II, or Class III commodities, in-rack sprinkler arrangement, single-row racks, storage height over 25 ft (7.6 m) — option 1.



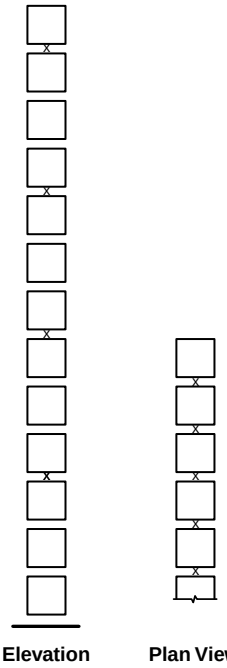
Note: Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-4.3.1.5.3(c) Class I, Class II, or Class III commodities, in-rack sprinkler arrangement, single-row racks, storage height over 25 ft (7.6 m) — option 2.



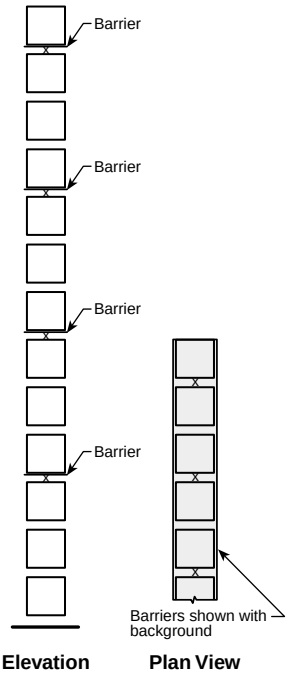
Note: Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-4.3.1.5.3(d) Class I, Class II, Class III, or Class IV commodities, in-rack sprinkler arrangement, single-row racks, storage height over 25 ft (7.6 m) — option 2.



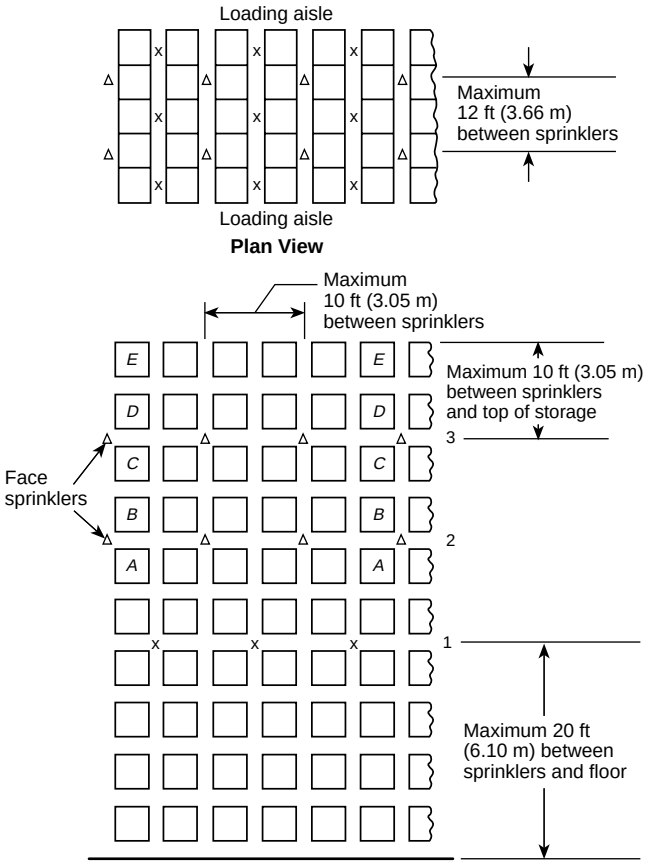
Note: Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-4.3.1.5.3(e) Class I, Class II, Class III, or Class IV commodities, in-rack sprinkler arrangement, single-row racks, storage height over 25 ft (7.6 m) — option 3.



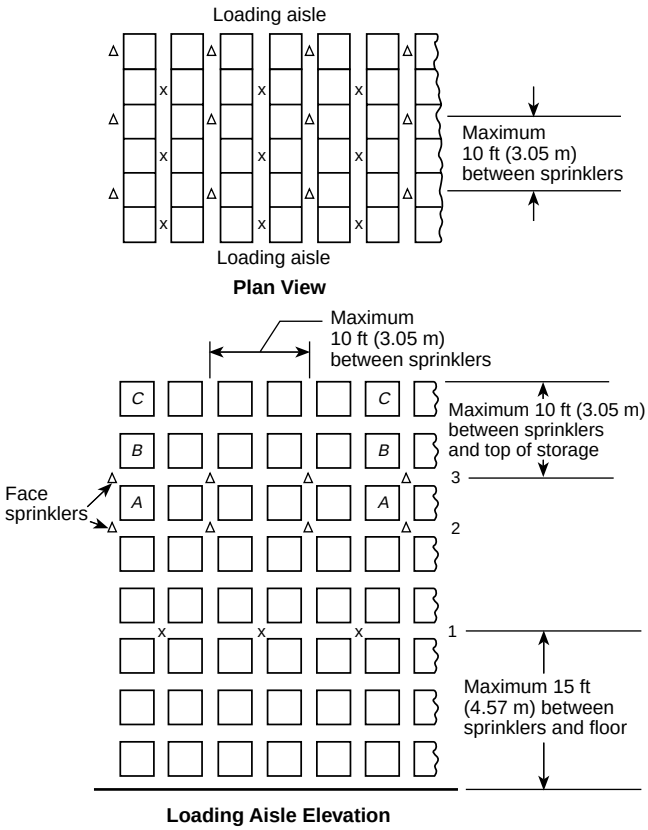
Note: Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-4.3.1.5.4(a) In-rack sprinkler arrangement — multiple-row racks, Class I commodities, storage height over 25 ft (7.6 m).



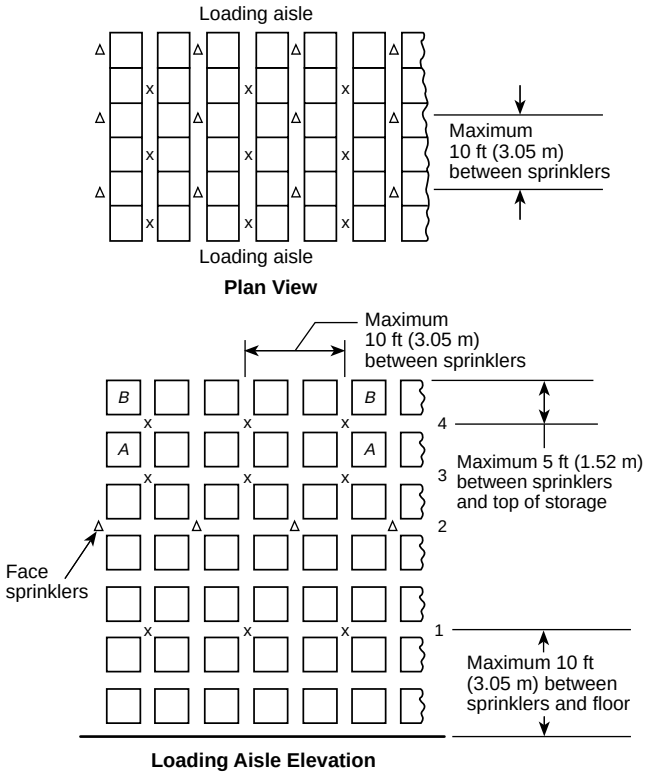
Notes:
1. Sprinklers labeled 1 shall be required if loads labeled *A* represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required if loads labeled *B* or *C* represent top of storage.
3. Sprinklers labeled 1 and 3 shall be required if loads labeled *D* or *E* represent top of storage.
4. 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.

Figure 7-4.3.1.5.4(b) In-rack sprinkler arrangement — multiple-row racks, Class I, Class II, or Class III 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.

Figure 7-4.3.1.5.4(c) In-rack sprinkler arrangement, Class I, Class II, Class III, or Class IV commodities — multiple-row racks, storage height over 25 ft (7.6 m).



Notes:
1. Sprinklers labeled 1, 2, and 3 shall be required if loads labeled *A* represent top of storage.
2. Sprinklers labeled 1, 2, and 4 shall be required if loads labeled *B* represent top of storage.
3. For storage higher than represented by loads labeled *B*, the cycle defined by Notes 1 and 2 is repeated, with stagger as indicated.
4. Symbol Δ or x indicates sprinklers on vertical or horizontal stagger.

7-4.3.1.5.5 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 7-4.3.1.5.4(a), (b), and (c).

7-4.3.2 Ceiling Sprinklers for Single- and Double-Row Racks — Area Density Method.

7-4.3.2.1*† The water demand for nonencapsulated storage on racks without solid shelves separated by aisles at least 4 ft (1.2 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 (186-m^2) operating area, discharging a minimum of 0.25 gpm/ft^2 (10.2 mm/min) for Class I commodities, 0.3 gpm/ft^2 (12.2 mm/min) for Classes II and III commodities, and 0.35 gpm/ft^2 (14.3 mm/min) for Class IV commodities for ordinary temperature–rated sprinklers or a minimum of 0.35 gpm/ft^2 (14.3 mm/min) for Class I commodities, 0.4 gpm/ft^2 (16.3 mm/min) for Classes II and III commodities, and 0.45 gpm/ft^2 (18.3 mm/min)] for Class IV commodities for high temperature–rated sprinklers. *(See Table 7-4.3.1.5.1.)*

7-4.3.2.2 Where storage as described in 7-4.3.2.1 is encapsulated, ceiling sprinkler density shall be 25 percent greater than for nonencapsulated storage.

7-4.3.3 Ceiling Sprinklers for Multiple-Row Racks — Area Density Method.

7-4.3.3.1 The water demand for nonencapsulated storage on racks without solid shelves separated by aisles at least 4 ft (1.2 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 (186-m^2) operating area for multiple-row racks, discharging a minimum of 0.25 gpm/ft^2 (10.2 mm/min) for Class I commodities, 0.3 gpm/ft^2 (12.2 mm/min) for Classes II and III commodities, and 0.35 gpm/ft^2 (14.3 mm/min) for Class IV commodities for ordinary temperature–rated sprinklers or a minimum of 0.35 gpm/ft^2 (14.3 mm/min) for Class I commodities, 0.4 gpm/ft^2 (16.3 mm/min) for Classes II and III commodities, and 0.45 gpm/ft^2 (18.3 mm/min) for Class IV commodities for high temperature–rated sprinklers. *(See Table 7-4.3.1.5.4.)*

7-4.3.3.2 Where such storage is encapsulated, ceiling sprinkler density shall be 25 percent greater than for nonencapsulated storage.

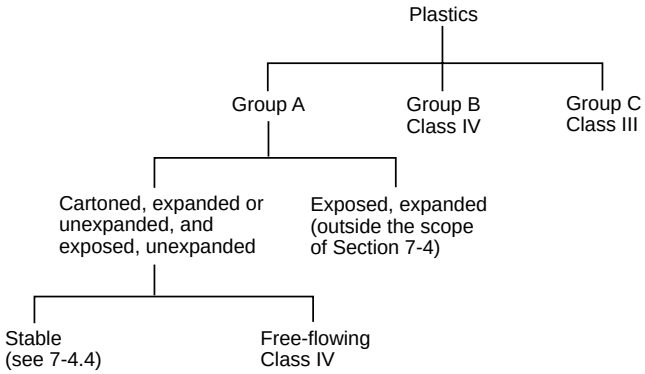
7-4.3.4 High-Expansion Foam Systems. Where high-expansion foam is used in combination with ceiling sprinklers, the minimum ceiling sprinkler design density shall be 0.2 gpm/ft^2 (8.2 mm/min) for Class I, Class II, or Class III commodities and 0.25 gpm/ft^2 (10.2 mm/min) for Class IV commodities for the most hydraulically remote 2000-ft^2 (186-m^2) area.

7-4.4 Spray Sprinkler Protection Criteria for Plastics Commodities.

7-4.4.1* 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 7-2.3.2.2 shall be used.

7-4.4.1.1† Plastic commodities shall be protected in accordance with Figure 7-4.4.1.1. This decision tree also shall be used to determine protection for commodities that are not entirely Group A plastics but contain such quantities and arrangements of Group A plastics that they are deemed more hazardous than Class IV commodities.

Figure 7-4.4.1.1 Decision tree.



7-4.4.1.2 Group B plastics and free-flowing Group A plastics shall be protected the same as Class IV commodities.

7-4.4.1.3 Group C plastics shall be protected the same as Class III commodities.

Table 7-4.3.1.5.4 Multiple-Row Racks, Storage Heights over 25 ft (7.6 m)

		In-Rack Sprinklers[1,2,3]													Ceiling Sprinklers Density			
		Approximate Vertical Spacing		Maximum Horizontal Spacing in a Flue		Maximum Horizontal Spacing across Flue					Maximum Spacing from Top of Storage to Highest In-Rack Sprinklers		Ceiling Sprinkler Operating Area		165° Rating		286° Rating	
Commodity Class	Encapsulated	ft	m	ft	m	ft	m	Height Limit ft	Stagger	Figure	ft	m	ft^2	m^2	gpm/ft^2	mm/min	gpm/ft^2	mm/min
I	No	20	6.1	12	3.7	10	3.1	None	Between adjacent flues	7-4.3.1.5.4(a)	10	3.1	2000	186	0.25	10.2	0.35	14.3
	Yes														0.31		0.44	
I, II, and III	No	15	4.6	10	3.1	10	3.1			7-4.3.1.5.4(b)	10	3.1			0.30	12.2	0.40	16.3
	Yes														0.37		0.50	20.4
I, II, III, and IV	No	10	3.1	10	3.1	10	3.1			7-4.3.1.5.4(c)	5	1.5			0.35	14.3	0.45	18.3
	Yes														0.44		0.56	

For SI units, °C = $^5/_9$(°F – 32); 1 gpm/ft^2 = 40.746 mm/min.
[1]All four rack faces shall be protected by sprinklers located within 18 in. (0.46 m) of the faces, as indicated in Figures 7-4.3.1.5.4(a), (b), and (c). It shall not be required for each sprinkler level to protect all faces. *(See A-7-4.3.1.5.4.)*
[2]All in-rack sprinkler spacing dimensions start from the floor.
[3]In Figures 7-4.3.1.5.4(a) through 7-4.3.1.5.4(c), each square represents a storage cube measuring 4 ft to 5 ft (1.2 m to 1.5 m) on a side. Actual load heights can vary from approximately 18 in. to 10 ft (0.46 m to 1 m). Therefore, there could be as few as one load or as many as six or seven loads between in-rack sprinklers that are spaced 10 ft (3.1 m) apart vertically.

7-4.4.1.4† Ceiling sprinklers shall have a temperature rating of ordinary, intermediate, or high temperature.

Exception: High temperature–rated sprinklers shall be used where required by 5-3.1.3.

7-4.4.2 In-Rack Sprinklers.

7-4.4.2.1 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.

7-4.4.2.2 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:

(1) Eight sprinklers where only one level is installed in racks
(2) Fourteen sprinklers (seven on each top two levels) where more than one level is installed in racks

7-4.4.2.3† In-Rack Sprinklers — Storage Up to and Including 25 ft (7.6 m). In-rack sprinklers shall be installed in accordance with Figures 7-4.4.2.3(a) through (g).

Figure 7-4.4.2.3(a) 5-ft to 10-ft (1.5-m to 3-m) storage.

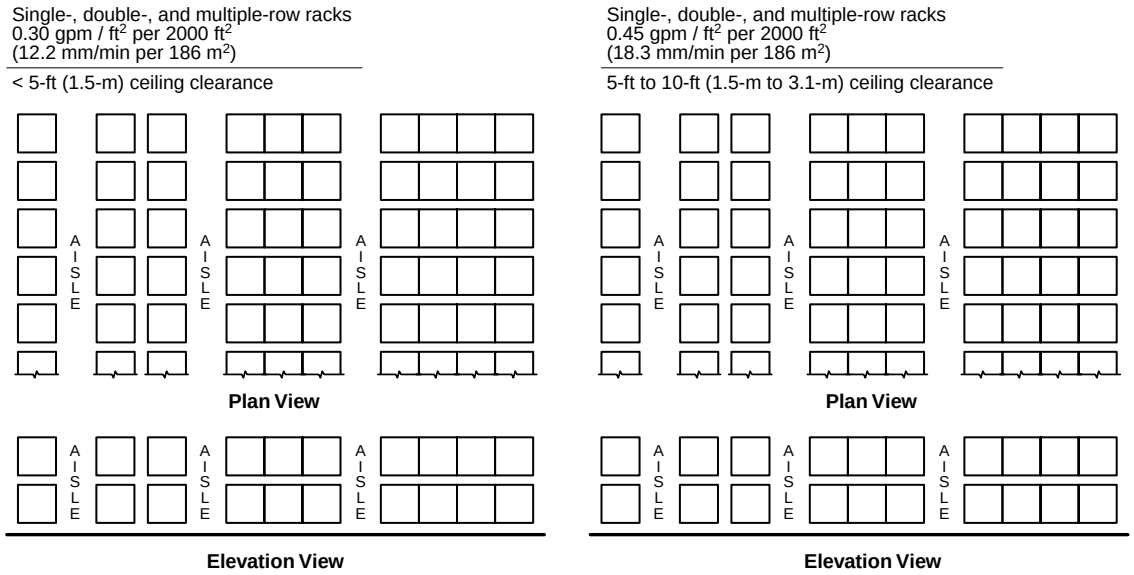
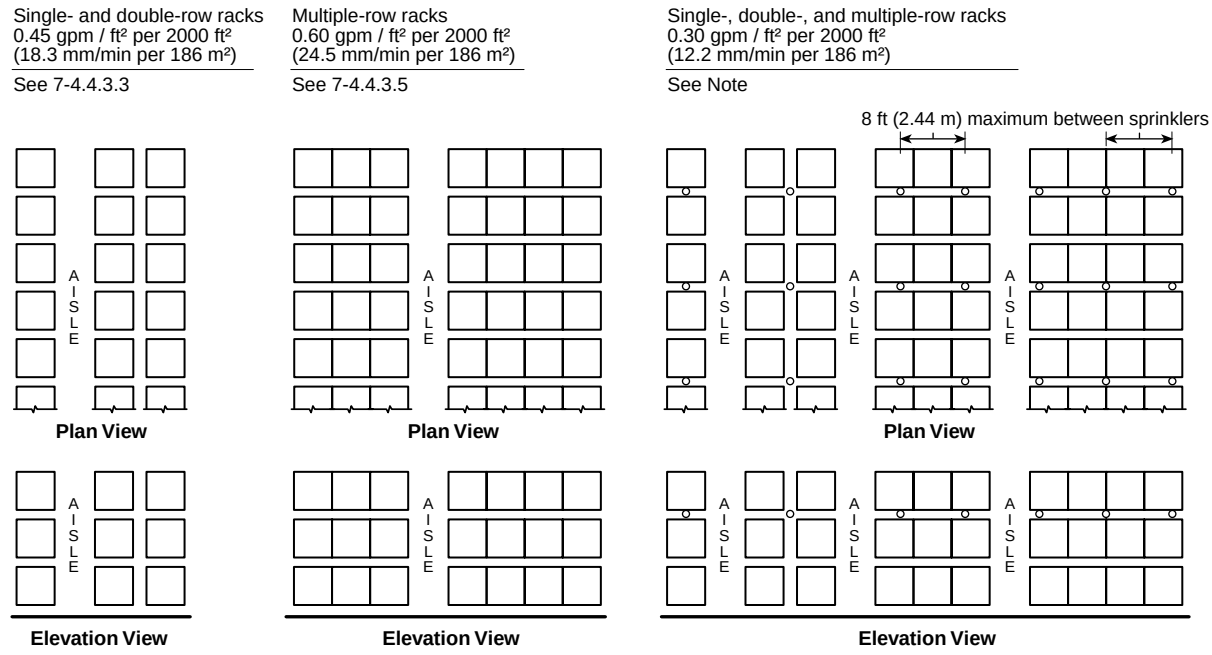
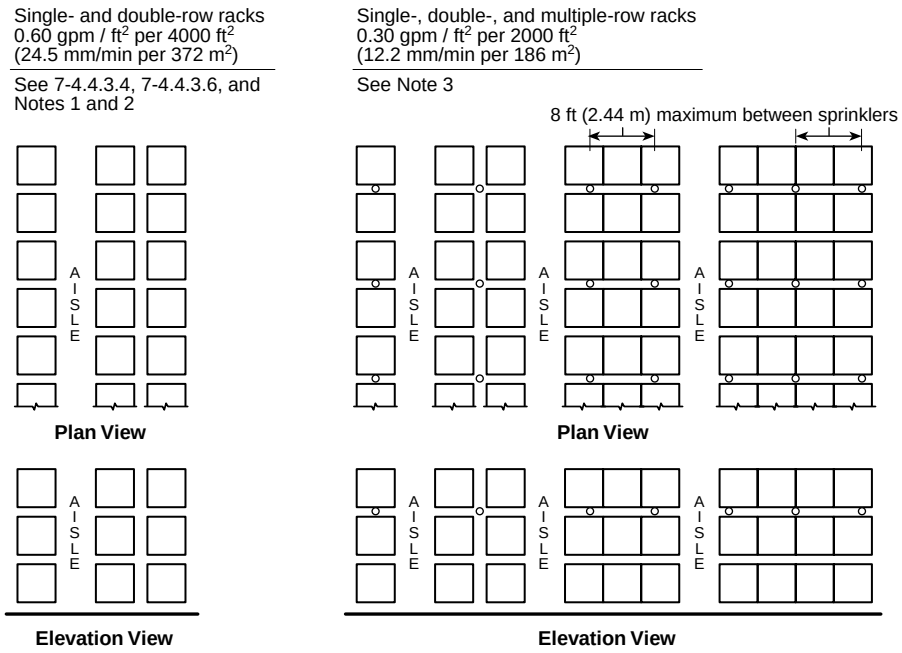


Figure 7-4.4.2.3(b) 15-ft (4.6-m) storage; <5-ft (1.5-m) clearance.



Note: Single level of in-rack sprinklers [½ in. or 17⁄32 in. (12.7 mm or 13.5 mm) 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.

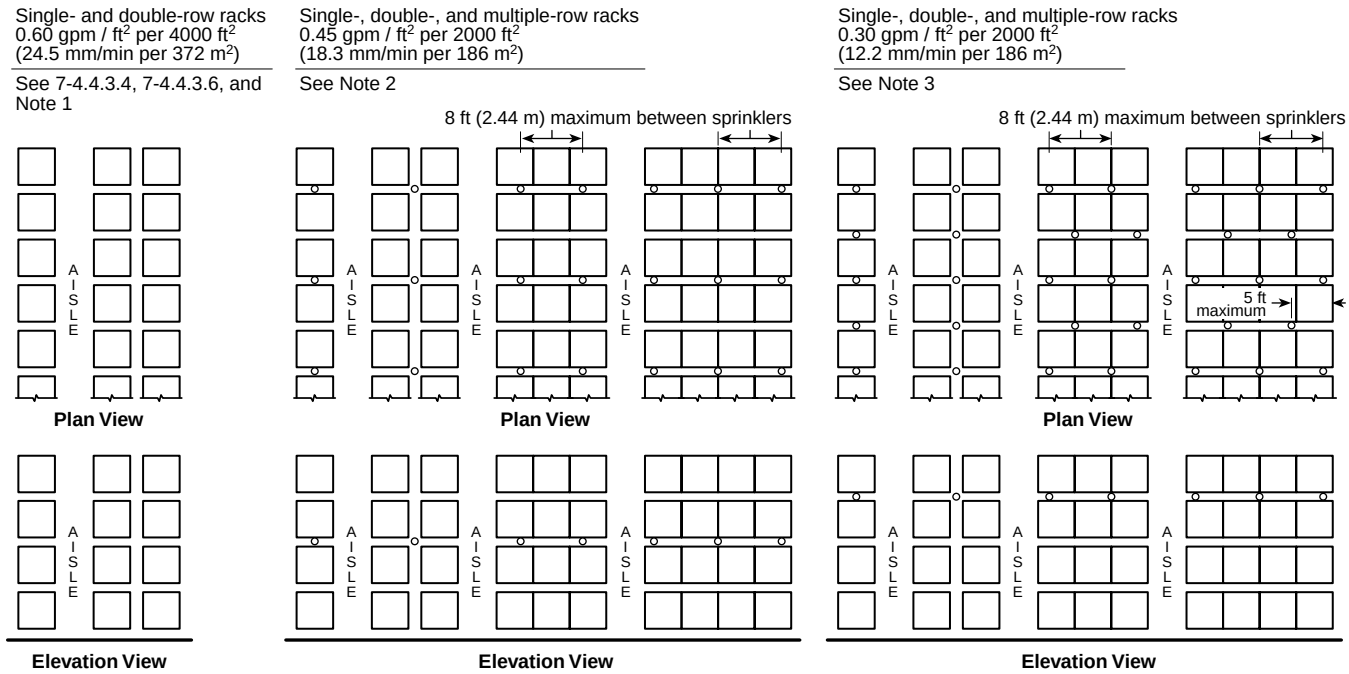
Figure 7-4.4.2.3(c) 15-ft (4.6-m) storage; 5-ft to 10-ft (1.5-m to 3.1-m) ceiling clearance.



Notes:

1. † Where ⅝-in. (15.9-mm) orifice sprinklers listed for storage use are installed at the ceiling only, the ceiling sprinkler discharge criteria shall be permitted to be reduced to 0.6 gpm / ft² per 2000 ft² (24.5 mm/min per 186 m²).
2. † Where ⅝-in. (15.9-mm) orifice sprinklers listed for storage use are installed at the ceiling only and the ceiling height in the protected area does not exceed 22 ft (6.7 m), the ceiling sprinkler discharge criteria shall be permitted to be reduced 0.45 gpm / ft² per 2000 ft² (18.3 mm/min per 186 m²).
3. Single level of in-rack sprinklers [½ in. or 17/32 in. (12.7 mm or 13.5 mm) 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.

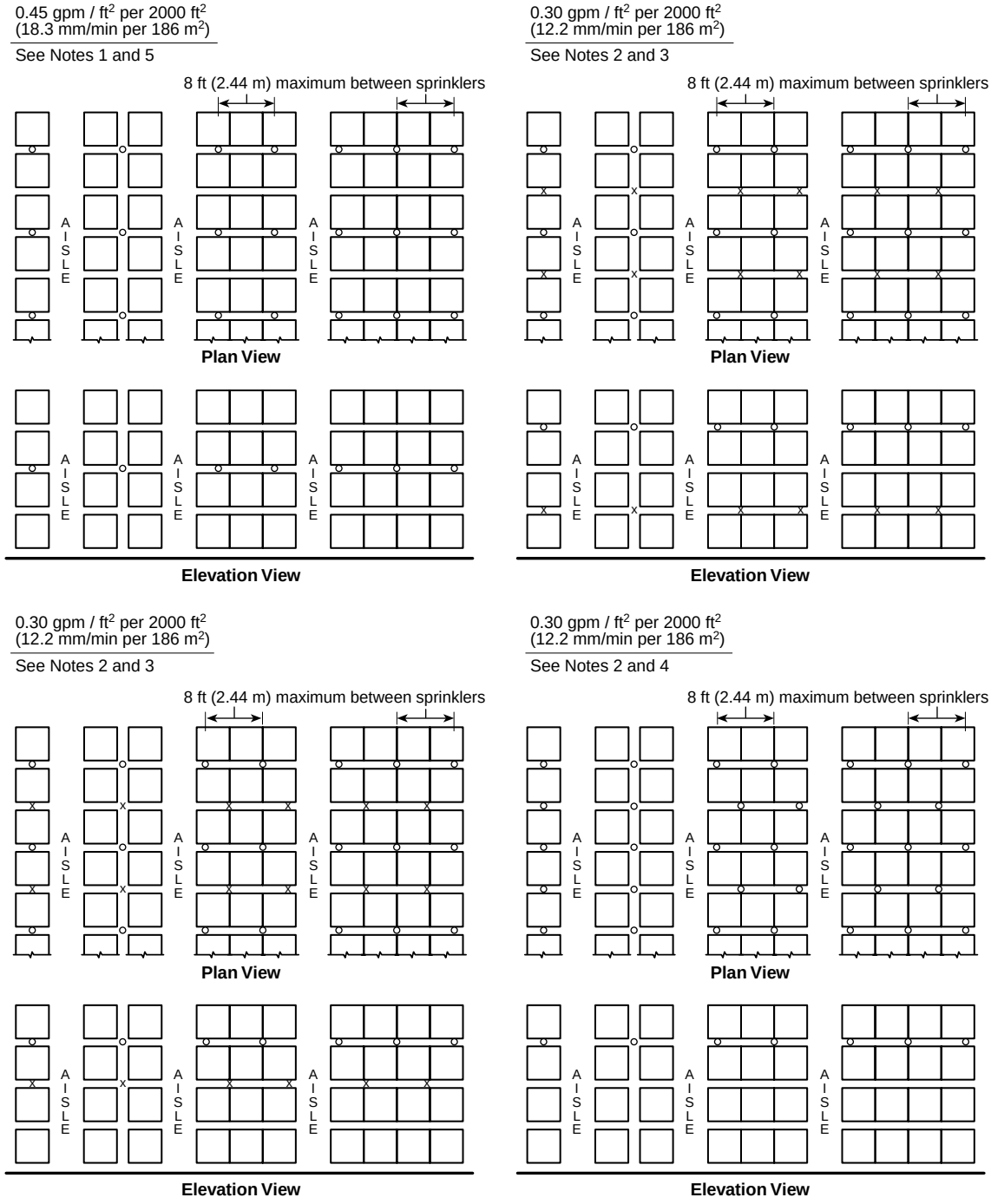
Figure 7-4.4.2.3(d) 20-ft (6.1-m) storage; <5-ft (1.5-m) ceiling clearance.



Notes:

1. † Where ⅝-in. (15.9-mm) orifice sprinklers listed for storage use are installed at the ceiling only, the ceiling sprinkler discharge criteria shall be permitted to be reduced to 0.6 gpm / ft² per 2000 ft² (24.5 mm/min per 186 m²).
2. Single level of in-rack sprinklers [½ in. or 17/32 in. (12.7 mm or 13.5 mm) 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. (13.5 mm) operating at 15 psi (1.03 bar) minimum or ½ in. (12.7 mm) 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.

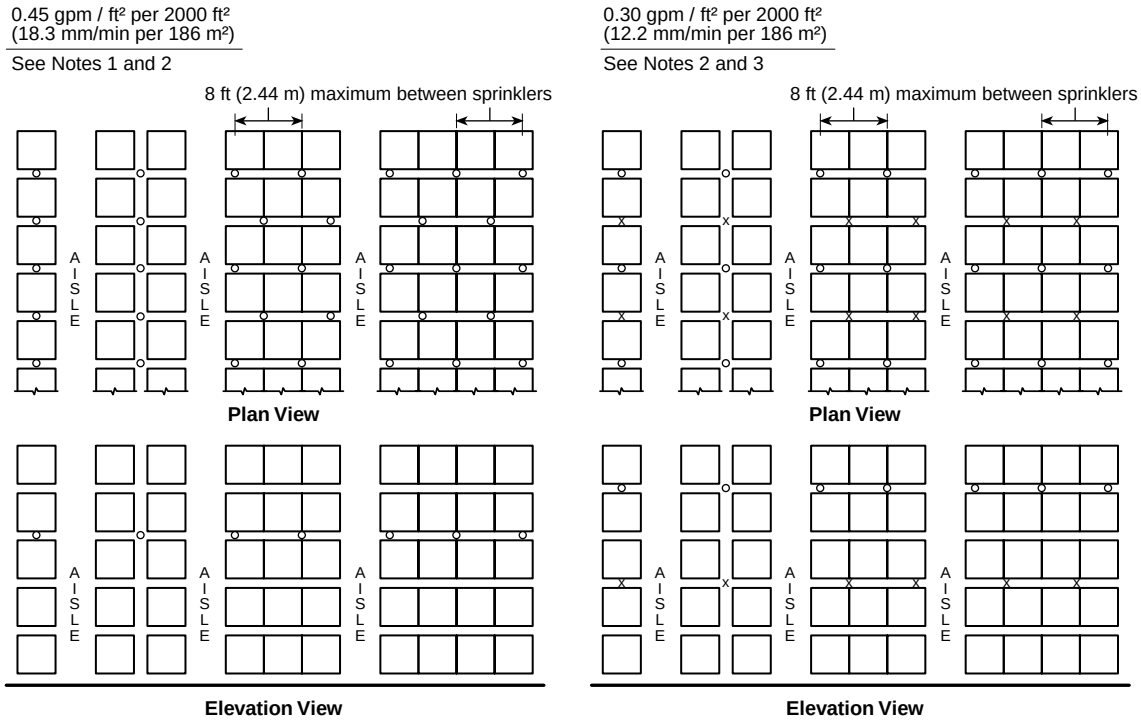
Figure 7-4.4.2.3(e) 20-ft (6.1-m) storage; 5-ft to 10-ft (1.5-m to 3.1-m) ceiling clearance.)



Notes:

1. Single level of in-rack sprinklers [½ in. or 17⁄32 in. (12.7 mm or 13.5 mm) 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.
2. Ceiling-only protection shall not be permitted for this storage configuration.
3. Two levels of in-rack sprinklers [½ in. or 17⁄32 in. (12.7 mm or 13.5 mm) 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 space.
4. Single level of in-rack sprinklers [17⁄32 in. (13.5 mm) operating at 15 psi (1.03 bar) minimum or ½ in. (12.7 mm) 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.
5. Where 5⁄8-in. (15.9-mm) orifice sprinklers listed for storage use are installed at the ceiling, the in-rack sprinklers shall not be required, provided the ceiling sprinkler discharge criteria is increased to 0.6 gpm per ft² /2000 ft² (24 L/ min per m ² /186m ²) and the ceiling height in the protected area does not exceed 27 ft (8.2 m).

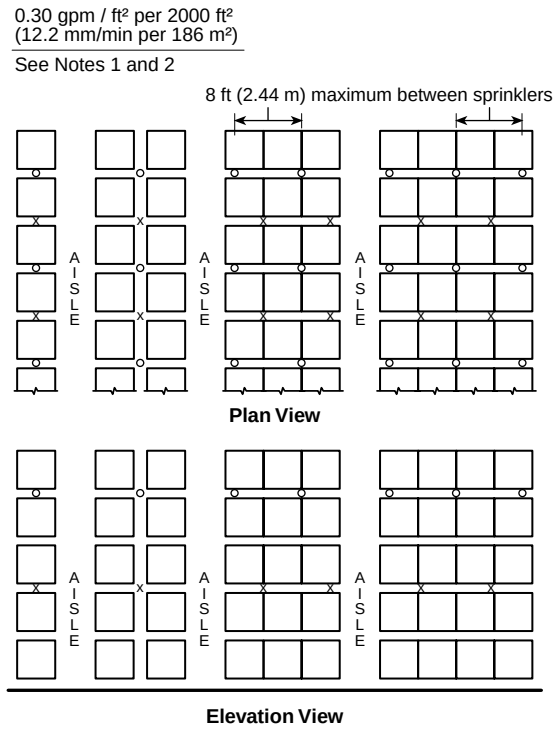
Figure 7-4.4.2.3(f) 25-ft (7.6-m) storage; <5-ft (1.5-m) ceiling clearance. *(See Note 2.)*



Notes:

1. Single level of in-rack sprinklers [17⁄32 in. (13.5 mm) operating at 15 psi (1.03 bar) minimum or ½ in. (12.7 mm) 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.
2. Ceiling-only protection shall not be permitted for this storage configuration.
3. Two levels of in-rack sprinklers [½ in. or 17⁄32 in. (12.7 mm or 13.5 mm) 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 space.

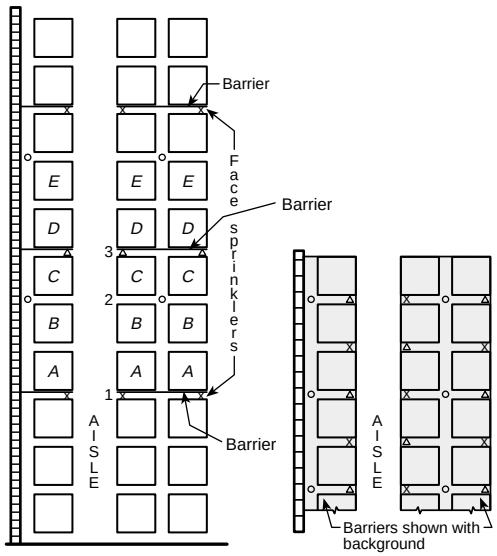
Figure 7-4.4.2.3(g) 25-ft (7.6-m) storage; 5-ft to 10-ft (1.5-m to 3.1-m) ceiling clearance. ***(See Note 2.)***



Notes:

1. Two levels of in-rack sprinklers [½ in. or 17⁄32 in. (12.7 mm or 13.5 mm) 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 space.
2. Ceiling-only protection shall not be permitted for this storage configuration.

Figure 7-4.4.2.4.1(a) In-rack sprinkler arrangement, Group A plastic commodities, storage height over 25 ft (7.6 m) — option 1.



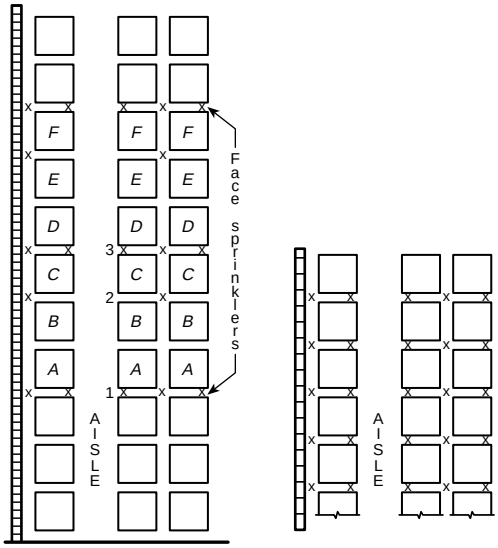
Notes:

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 represents a storage cube measuring 4 ft to 5 ft (1.22 m to 1.53 m) on a side. Actual load heights can vary from approximately 18 in. (0.46 m) up to 10 ft (3.05 m). Therefore, there could be as few as one load to as many as six or seven loads between in-rack sprinklers that are spaced 10 ft (3.05 m) apart vertically.

7-4.4.2.4 In-Rack Sprinkler Location — Storage Over 25 ft (7.6 m) in Height.

7-4.4.2.4.1 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 Figure 7-4.4.2.4.1(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.

Figure 7-4.4.2.4.1(b) In-rack sprinkler arrangement, Group A plastic commodities, storage height over 25 ft (7.6 m) — option 2.



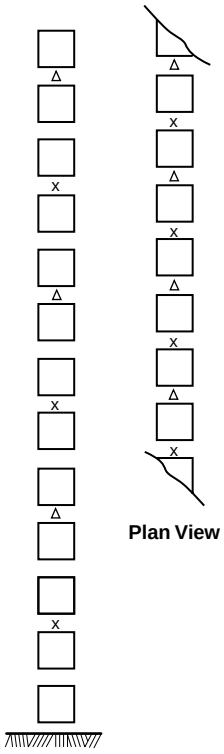
Notes:
1. Sprinklers labeled 1 shall be required where loads labeled *A* or *B* represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled *C* represent top of storage.
3. Sprinklers labeled 1 and 3 shall be required where loads labeled *D* or *E* represent top of storage.
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 represents a storage cube measuring 4 ft to 5 ft (1.22 m to 1.53 m) on a side. Actual load heights can vary from approximately 18 in. (0.46 m) up to 10 ft (3.05 m). Therefore, there could be as few as one load to as many as six or seven loads between in-rack sprinklers that are spaced 10 ft (3.05 m) apart vertically.

7-4.4.2.4.2 In-rack sprinklers for storage higher than 25 ft (7.6 m) in double-row racks shall be spaced horizontally and shall be located in the horizontal space nearest the vertical intervals specified in Figure 7-4.4.2.4.1(a) or (b).

7-4.4.2.4.3 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 Figure 7-4.4.2.4.3(a), (b), or (c).

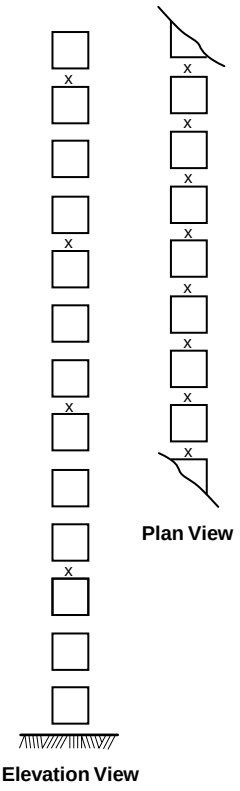
7-4.4.2.4.4 In multiple-row racks without solid shelves with storage height over 25 ft (7.6 m) and a maximum of 10 ft (3.1 m) between the top of storage and the roof/ceiling, in-rack sprinklers shall be installed as indicated in Figures 7-4.4.2.4.4(a) through 7-4.4.2.4.4(f).

Figure 7-4.4.2.4.3(a) In-rack sprinkler arrangement, Group A plastic commodities, single-row racks, storage height over 25 ft (7.6 m) — option 1.



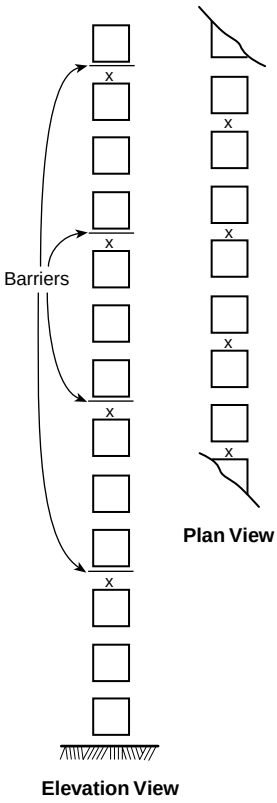
Note: Each square represents a storage cube measuring 4 ft to 5 ft (1.22 m to 1.53 m) on a side. Actual load heights can vary from approximately 18 in. (0.46 m) up to 10 ft (3.05 m). Therefore, there could be as few as one load to as many as six or seven loads between in-rack sprinklers that are spaced 10 ft (3.05 m) apart vertically.

Figure 7-4.4.2.4.3(b) In-rack sprinkler arrangement, Group A plastic commodities, single-row racks, storage height over 25 ft (7.6 m) — option 2.



Note: Each square represents a storage cube measuring 4 ft to 5 ft (1.22 m to 1.53 m) on a side. Actual load heights can vary from approximately 18 in. (0.46 m) up to 10 ft (3.05 m). Therefore, there could be as few as one load to as many as six or seven loads between in-rack sprinklers that are spaced 10 ft (3.05 m) apart vertically.

Figure 7-4.4.2.4.3(c) In-rack sprinkler arrangement, Group A plastic commodities, single-row racks, storage height over 25 ft (7.6 m) — option 3.



Note: Each square represents a storage cube measuring 4 ft to 5 ft (1.22 m to 1.53 m) on a side. Actual load heights can vary from approximately 18 in. (0.46 m) up to 10 ft (3.05 m). Therefore, there could be as few as one load to as many as six or seven loads between in-rack sprinklers that are spaced 10 ft (3.05 m) apart vertically.

Figure 7-4.4.2.4.4(a)* In-rack sprinkler arrangement, cartoned plastic and uncartoned unexpanded plastic, multiple-row racks, storage height over 25 ft (7.6 m) — option 1.

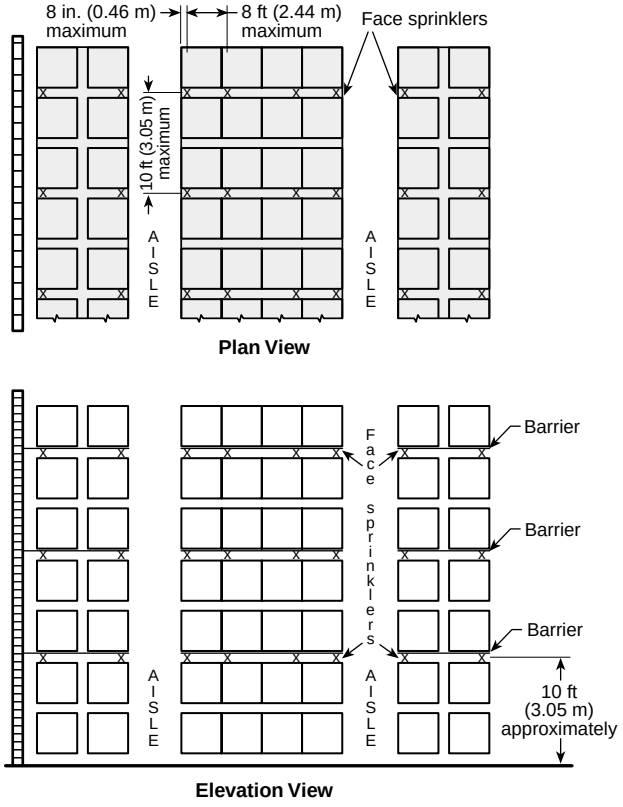


Figure 7-4.4.2.4.4(b)* In-rack sprinkler arrangement, cartoned plastic and uncartoned unexpanded plastic, multiple-row racks, storage height over 25 ft (7.6 m) — option 2.

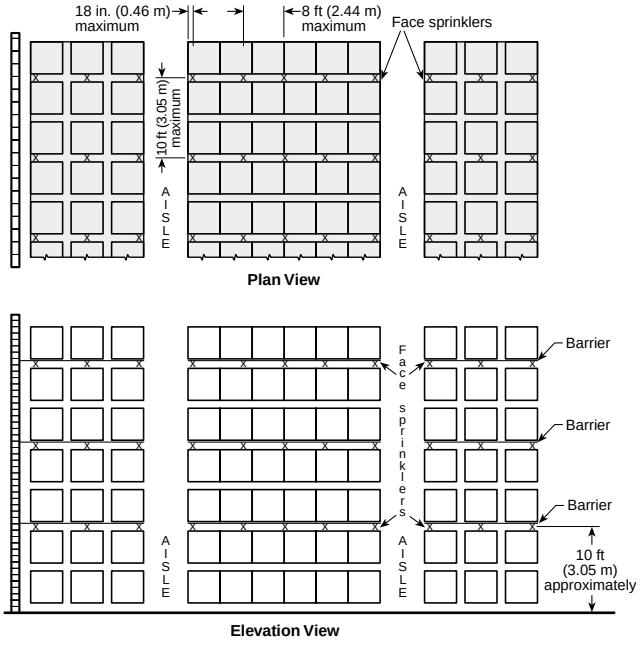


Figure 7-4.4.2.4.4(c)* In-rack sprinkler arrangement, cartoned plastic and uncartoned unexpanded plastic, multiple-row racks, storage height over 25 ft (7.6 m) — option 1.

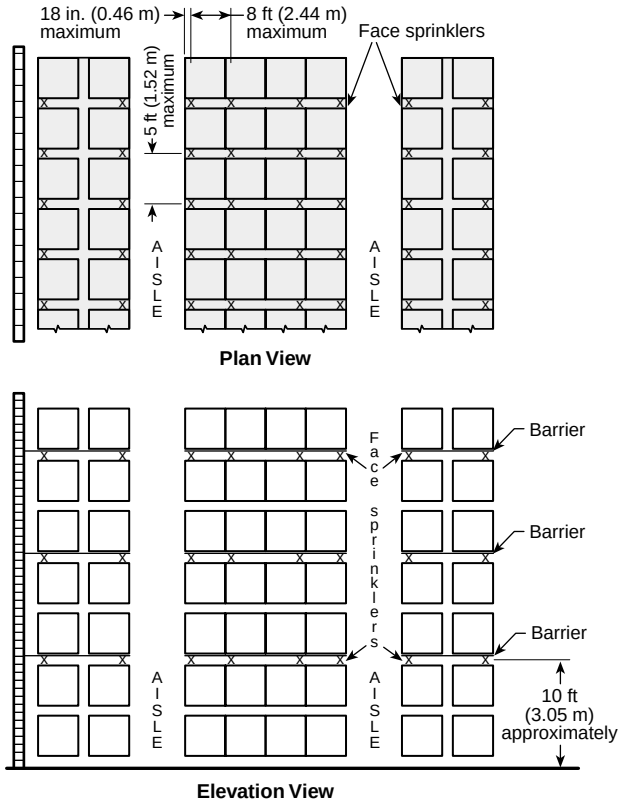


Figure 7-4.4.2.4.4(d)* In-rack sprinkler arrangement, cartoned plastic and uncartoned unexpanded plastic, multiple-row racks, storage height over 25 ft (7.6 m) — option 2.

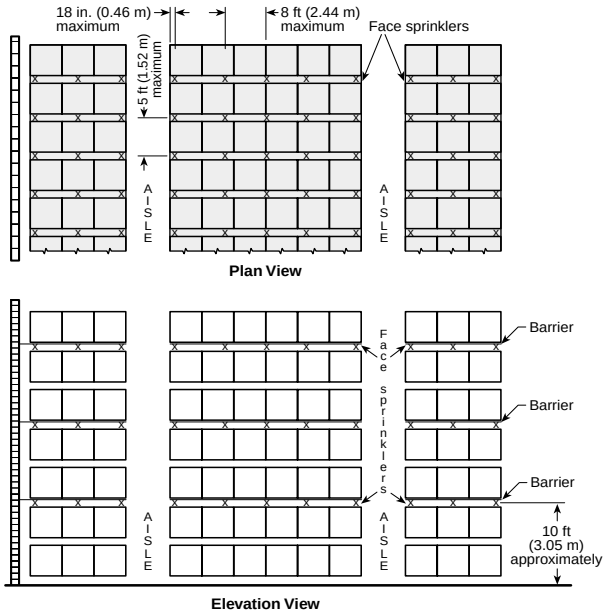
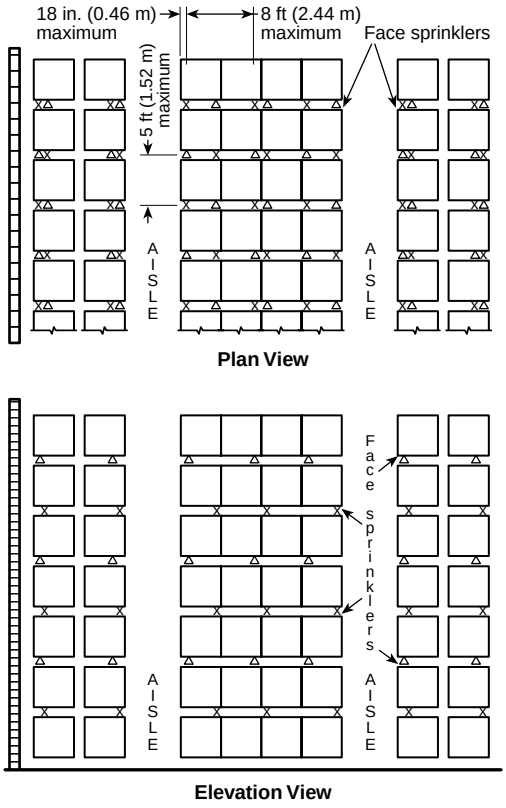


Figure 7-4.4.2.4.4(e)* In-rack sprinkler arrangement, cartoned plastic and uncartoned unexpanded plastic, multiple-row racks, storage height over 25 ft (7.6 m) — option 3.



7-4.4.2.4.5 In-Rack Sprinkler Discharge Pressure. Sprinklers in racks shall discharge at not less than 30 gpm (113.6 L/min).

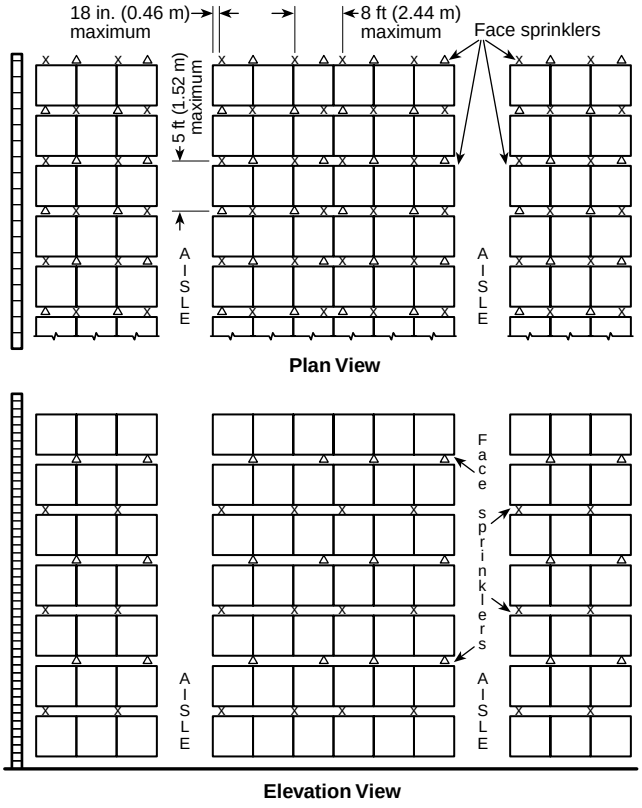
7-4.4.3 Ceiling Sprinklers for Single-, Double-, and Multiple-Row Racks — Storage Height Up to 25 ft (7.6 m) — Clearances Up to and Including 10 ft (3.1 m) — Area Density Method.

7-4.4.3.1 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 (mm/min)] and area of operation [ft^2 (m^2)] shall be selected from Figures 7-4.4.2.3(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.

7-4.4.3.2 Single-, Double-, and Multiple-Row Racks Up to 10-ft (3.1-m) Storage with Up to 10-ft (3.1-m) Clearance. The protection strategies utilizing only ceiling sprinklers, as shown in Figure 7-4.4.2.3(a), shall be acceptable for single-, double-, and multiple-row rack storage.

7-4.4.3.3 Single- and Double-Row Rack Storage Greater than 10 ft (3.1 m) Up to 15 ft (4.6 m) with Less than 5-ft (1.25-m) Clearance. The protection strategy utilizing only ceiling sprinklers, as shown in Figure 7-4.4.2.3(b), shall be acceptable only for single- and double-row rack storage.

Figure 7-4.4.2.4.4(f)* In-rack sprinkler arrangement, cartoned plastic and uncartoned unexpanded plastic, multiple-row racks, storage height over 25 ft (7.6 m) — option 4.



7-4.4.3.4 Single- and Double-Row Rack Storage Greater than 10 ft (3.1 m) Up to 15 ft (4.6 m) with Clearance from 5 ft to 10 ft (1.5 m to 3.1 m), and Single- and Double-Row Rack Storage Up to 20 ft (6.1 m) with Less than 5-ft (1.5-m) Clearance. The protection strategies utilizing only ceiling sprinklers, as shown in Figures 7-4.4.2.3(c) and (d), shall be acceptable only for single- and double-row rack storage.

7-4.4.3.5 Multiple-Row Racks — 15-ft (4.6-m) Storage with Less than 5-ft (1.5-m) Clearance. Where using the protection strategy utilizing only ceiling sprinklers, as shown in Figure 7-4.4.2.3(b), for multiple-row rack storage, the density to be used shall be 0.6 gpm/ft^2 (24.5 mm/min) over 2000 ft^2 (186 m^2). The combination of ceiling and in-rack sprinklers specified in Figure 7-4.4.2.3(b) shall be permitted as an alternative.

7-4.4.3.6 Multiple-Row Racks — 15-ft (4.6-m) Storage with 10-ft (3.1-m) Clearance, and 20-ft (6.1-m) Storage with Less than 5-ft (1.5-m) Clearance. The protection strategies utilizing only ceiling sprinklers, as shown in Figures 7-4.4.2.3(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.

7-4.4.4 Ceiling Sprinklers for Single-, Double-, and Multiple-Row Racks — Storage Over 25 ft (7.1 m) in Height — Area Density Method.

7-4.4.4.1 Ceiling Sprinkler Water Demand. For Group A plastic commodities in cartons, encapsulated or nonencapsulated, ceiling sprinkler water demand in terms of density [gpm/ft^2 (mm/min)] and area of operation [ft^2 (m^2)] shall be selected from Table 7-4.4.4.1.

Table 7-4.4.4.1 Ceiling Sprinkler Discharge Criteria for Single-, Double-, and Multiple-Row Racks with Storage Over 25 ft (7.6 m) in Height

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/ft^2 = 40.746 mm/min; 1 ft^2 = 0.0929 m^2.
Note: Provide in-rack sprinkler protection per Figures 7-4.4.2.4.1(a) and (b) and Figures 7-4.4.2.4.3(a) through (c).

7-4.4.4.2 Where a single-row rack is mixed with double-row racks, either Figures 7-4.4.2.3(a) through (g) or Figures 7-4.4.2.4.1(a) and (b) shall be used in accordance with the corresponding storage height.

Exception: Figures 7-4.4.2.4.3(a) through 7-4.4.2.4.3(c) shall be permitted to be used for the protection of the single-row racks.

7-5* Protection of Idle Pallets.

7-5.1 General.

7-5.1.1 The following criteria is intended to apply to buildings with ceiling slopes not exceeding 2 in 12 (16.7 percent).

7-5.1.2 Where dry pipe systems are used, the sprinkler system design area shall be increased by 30 percent.

7-5.2 Wood Pallets.

7-5.2.1* Pallets shall be stored outside or in a detached structure.

Exception: Indoor pallet storage shall be permitted in accordance with 7-5.2.2.

7-5.2.2* Pallets, where stored indoors, shall be protected as indicated in Table 7-5.2.2 using standard spray sprinklers, Tables 7-9.4.1.1 and 7-9.4.1.2 using large drop sprinklers, or Tables 7-9.5.1.1 and 7-9.5.1.2 using ESFR sprinklers, unless the following conditions are met:

(1) Pallets shall be stored no higher than 6 ft (1.8 m).

(2) 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.

7-5.2.3† Idle wood pallets shall not be stored in racks.

Exception: Idle wooden pallets shall be permitted to be stored in racks when protected in accordance with the appropriate provisions of 7-9.5.1.2.

7-5.3 Plastic Pallets.

7-5.3.1 Plastic pallets shall be stored outside or in a detached structure.

Exception No. 1: Indoor plastic pallet storage shall be permitted in accordance with 7-5.3.2.

Exception No. 2: Indoor storage of nonexpanded polyethylene solid deck pallets shall be permitted to be protected in accordance with 7-5.2.2.

Exception No. 3: Indoor storage of plastic pallets shall be permitted to be protected in accordance with Table 7-9.5.1.1 or Table 7-9.5.1.2.

Exception No. 4: Indoor storage of non-wood pallets having a demonstrated fire hazard that is equal to or less than idle wood pallets and is listed for such equivalency shall be permitted to be protected in accordance with 7-5.2.2.

7-5.3.2 Plastic pallets where stored indoors shall be protected as specified in 7-5.3.2(1) and (2):

(1) Where stored in cutoff rooms the following shall apply:
   a. The cutoff rooms shall have at least one exterior wall.
   b. The plastic pallet storage shall be separated from the remainder of the building by 3-hour-rated fire walls.
   c. The storage shall be protected by sprinklers designed to deliver 0.6 gpm/ft^2 (24.5 mm/min) for the entire room or by high-expansion foam and sprinklers as indicated in 7-3.2.2.4.
   d. The storage shall be piled no higher than 12 ft (3.7 m).
   e. 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. Flow from these sprinklers shall be permitted to be omitted from the sprinkler system demand for hydraulic calculations.

(2) Where stored without cutoffs from other storage the following shall apply:
   a. Plastic pallet storage shall be piled no higher than 4 ft (1.2 m).
   b. Sprinkler protection shall employ high temperature–rated sprinklers.
   c. 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.

7-5.3.3 Idle plastic pallets shall not be stored in racks.

Exception: Idle plastic pallets shall be permitted to be stored in racks when protected in accordance with the appropriate provisions of 7-9.5.1.2.

7-6 Protection of Rubber Tire Storage.

7-6.1 General. The sprinkler system criteria of Section 7-6 shall apply to buildings with ceiling slopes not exceeding 2 in 12 (16.7 percent).

7-6.2 Ceiling Systems.

7-6.2.1* Sprinkler discharge and area of application shall be in accordance with Table 7-6.2.1(a) and Figure 7-6.2.1 for standard spray sprinklers. See 5-4.1.2 for appropriate orifice sizes. Large drop and ESFR sprinklers shall be in accordance with Tables 7-6.2.1(b) and (c), respectively.

Table 7-5.2.2 Protection for Indoor Storage of Idle Wood Pallets

Height of Pallet Storage		Sprinkler Density Requirements		Area of Sprinkler Demand			
				High Temperature		Ordinary Temperature	
ft	m	gpm/ft²	mm/min	ft²	m²	ft²	m²
Up to 6	Up to 1.8	0.2	8.2	2000	186	3000	279
6–8	1.8–2.4	0.3	12.2	2500	232	4000	372
8–12	2.4–3.7	0.6	24.5	3500	325	6000	557
12–20	3.7–6.1	0.6	24.5	4500	418	—	—

Table 7-6.2.1(a) Protection Criteria for Rubber Tire Storage Using Standard Spray Sprinklers

Piling Method	Piling Height (ft)	Sprinkler Discharge Density *(See Note 1.)* (gpm/ft²)	Areas of Application (ft²) *(See Note 1.)*	
			Ordinary Temperature	High Temperature
(1) On-floor storage	Up to 5	0.19	2000	2000
a. Pyramid piles, on-side	Over 5 to 12	0.30	2500	2500
b. Other arrangements such that no horizontal channels are formed (*See Note 2.*)	Over 12 to 18	0.60	Not allowed	2500
(2) On-floor storage	Up to 5	0.19	2000	2000
Tires on-tread	Over 5 to 12	0.30	2500	2500
(3) Palletized portable rack storage	Up to 5	0.19	2000	2000
On-side or on-tread	Over 5 to 20	See Figure 7-6.2.1	—	—
	Over 20 to 30	0.30 plus high-expansion foam	3000	3000
(4) Palletized portable rack storage	Up to 5	0.19	2000	2000
On-side	Over 5 to 20	See Figure 7-6.2.1	—	—
	20 to 25	0.60 and	Not allowed	5000
		0.90 *(see Note 3)*;	Not allowed	3000
		or		
		0.75 with 1-hour fire-resistive rating of roof and ceiling assembly	Not allowed	4000
(5) Open portable rack storage, on-side or on-tread	Up to 5	0.19	2000	2000
	Over 5 to 12	0.60	5000	3000
	Over 12 to 20	0.60 and	Not allowed	5000
		0.90 *(see Note 3)*;	Not allowed	3000
		or		
		0.30 plus high-expansion foam	3000	3000
(6) Single-, double-, and multiple-row fixed rack storage on pallets, on-side or on-tread	Up to 5	0.19	2000	2000
	Over 5 to 20	See Figure 7-6.2.1;		
		or		
		0.40 plus one level in-rack sprinklers;	3000	3000
		or		
		0.30 plus high-expansion foam	3000	3000
	Over 20 to 30	0.30 plus high-expansion foam	Not allowed	3000

(continues)

Table 7-6.2.1(a) Protection Criteria for Rubber Tire Storage Using Standard Spray Sprinklers *(Continued)*

Piling Method	Piling Height (ft)	Sprinkler Discharge Density *(See Note 1.)* (gpm/ft²)	Areas of Application (ft²) *(See Note 1.)* Ordinary Temperature	Areas of Application (ft²) *(See Note 1.)* High Temperature
(7) Single-, double-, and multiple-row fixed rack storage without pallets or shelves, on-side or on-tread	Up to 5	0.19	2000	2000
	Over 5 to 12	0.60	5000	3000
	Over 12 to 20	0.60 and	Not allowed	5000
		0.90 *(see Note 3)*;	Not allowed	3000
		or		
		0.40 plus one level in-rack sprinklers;	3000	3000
		or		
		0.30 plus high-expansion foam	3000	3000
	Over 20 to 30	0.30 plus high-expansion foam	Not allowed	3000

For SI units, 1 ft = 0.3048 m; 1 ft² = 0.0929 m²; 1 gpm/ft² = 40.746 mm/min.
Notes:
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 is not a definitive measurement.
2.* Laced tires on-floor, vertical stacking on-side (typical truck tires), and off-road tires.
3. Water supply shall fulfill both requirements.

Figure 7-6.2.1 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 6.1 m) in height.

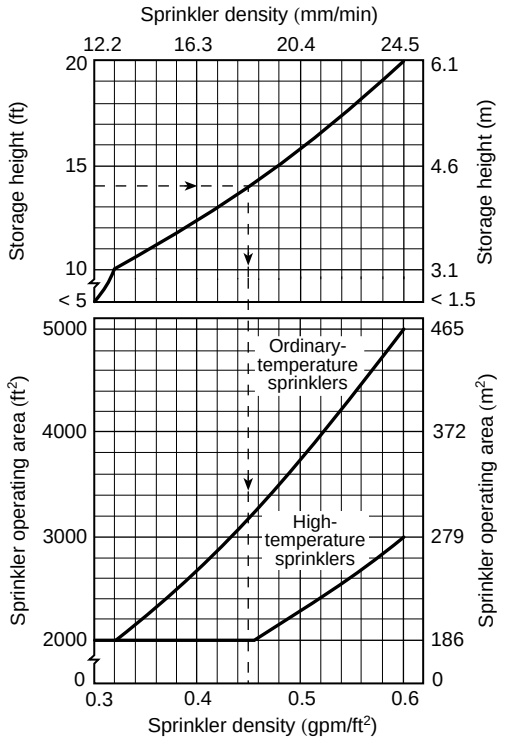


Figure 7-6.2.1 shall be used as follows.

(1) Note the example indicated by the broken line.

(2) Read across the graph to the 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/ft² (18.3 mm/min).

(3) Read down until the sprinkler density intersects the sprinkler operating area curves at 3200 ft² (397 m²) for ordinary-temperature sprinklers and 2000 ft² (186 m²) for high-temperature sprinklers.

7-6.2.2 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.

7-6.2.3 Where high-expansion foam systems are installed in accordance with NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*, a reduction in sprinkler discharge density to one-half the density specified in Table 7-6.2.1(a) or 0.24 gpm/ft² (9.78 mm/min), whichever is higher, shall be permitted.

7-6.3 In-Rack Sprinkler System Requirements.

7-6.3.1 In-rack sprinklers, where provided, shall be installed in accordance with 7-4, except as modified by 7-6.3.2 through 7-6.3.4.

7-6.3.2 The maximum horizontal spacing of sprinklers in rack shall be 8 ft (2.4 m).

7-6.3.3 Sprinklers in racks shall discharge at not less than 30 psi (2.1 bar).

7-6.3.4 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.

7-6.4 Water Supplies.

7-6.4.1 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.

Table 7-6.2.1(b) Large Drop Sprinkler Protection for Rubber Tires *(See Note 1.)*

Piling Method	Pile Height	Number of Sprinklers and Minimum Operating Pressures *(See Note 2.)*	Maximum Building Height	Duration (hr)	Hose Demand
Rubber tire storage, on-side or on-tread, in palletized portable racks, or open portable racks, or fixed racks without solid shelves	Up to 25 ft (7.6 m)	15 sprinklers @ 75 psi (5.2 bar) *(See Note 3.)*	32 ft (9.8 m)	3	500 gpm (1893 L/min)

Notes:
1. Wet systems only.
2. Sprinkler operating pressures and number of sprinklers in the design are based on tests in which the clearance was 5 ft to 7 ft (1.5 m to 2.1 m) between the sprinkler deflector and the maximum height of storage.
3. The design area shall consist of the most hydraulically demanding area of 15 sprinklers, consisting of five sprinklers on each of three branch lines. The design shall include a minimum operating area of 1200 ft^2 (112 m^2) and a maximum operating area of 1500 ft^2 (139 m^2) and shall utilize a high temperature–rated sprinkler.

Table 7-6.2.1(c) ESFR Sprinklers for Protection of Rubber Tires *(See Note 1.)*

Piling Method	Pile Height	Maximum Building Height		Nominal K-factor	Number of Sprinklers *(See Note 2.)*	Minimum Operating Pressure *(See Note 2.)*		Duration (hours)	Hose Demand	
		ft	m			psi	bar		gpm	L/min
Rubber tire storage, on-side or on-tread, in palletized portable racks, open portable racks, or fixed racks without solid shelves	Up to 25 ft (7.6 m)	30	9.1	13.5–14.5	12 *(See Note 3.)*	50	3.5	1	250	946
				23.9–26.5	12 *(See Note 3.)*	20	1.4	1	250	946
Rubber tire storage, on-side, in palletized portable racks, open portable racks, or fixed racks without solid shelves	Up to 25 ft (7.6 m)	35	10.7	13.5–14.5	12 *(See Note 3.)*	75	5.2	1	250	946
				23.9–26.5	12 *(See Note 3.)*	30	2.1	1	250	946
Laced tires in open portable steel racks. *[See Figure A-1-4.10.1(g).]*	Up to 25 ft (7.6 m)	30	9.1	13.5–14.5	20 *(See Notes 4 and 5.)*	75	5.2	3	500	1892

Notes:
1. Wet systems only.
2. Sprinkler operating pressures and number of sprinklers in the design are based on tests in which the clearance was 5 ft to 7 ft (1.5 m to 2.1 m) between the sprinkler deflector and the maximum height of storage.
3. The shape of the design area shall be in accordance with 7-9.5.2.2.
4. Where used in this application, ESFR protection is expected to control rather than to suppress the fire.
5. The design area shall consist of the most hydraulically demanding area of 20 sprinklers, consisting of 5 sprinklers on each of 4 branch lines. The design shall include a minimum operating area of 1600 ft^2 (149 m^2).

7-6.4.2 Total water supplies shall include provision for not less than 750 gpm (2835 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 No. 1: 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.

Exception No. 2: For ESFR and large drop sprinkler systems approved for rubber tire storage, duration and hose demand shall be in accordance with Tables 7-6.2.1(b) and 7-6.2.1(c).

7-6.4.3* Where dry pipe systems are used, the area of sprinkler application shall be increased by not less than 30 percent.

7-6.5 Miscellaneous Tire Storage. Miscellaneous tire storage shall be protected in accordance with 7-2.3.2.2.

7-6.6 Small Hose. For first-aid fire-fighting and mop-up operations, small hose [$1^1/_2$ in. (38 mm)] shall be provided in accordance with 5-15.5.

7-7 Protection of Baled Cotton Storage.

7-7.1 General. The sprinkler system criteria in Section 7-7 shall apply to buildings with ceiling slopes not exceeding 2 in 12 (16.7 percent).

7-7.2 Sprinkler Systems.

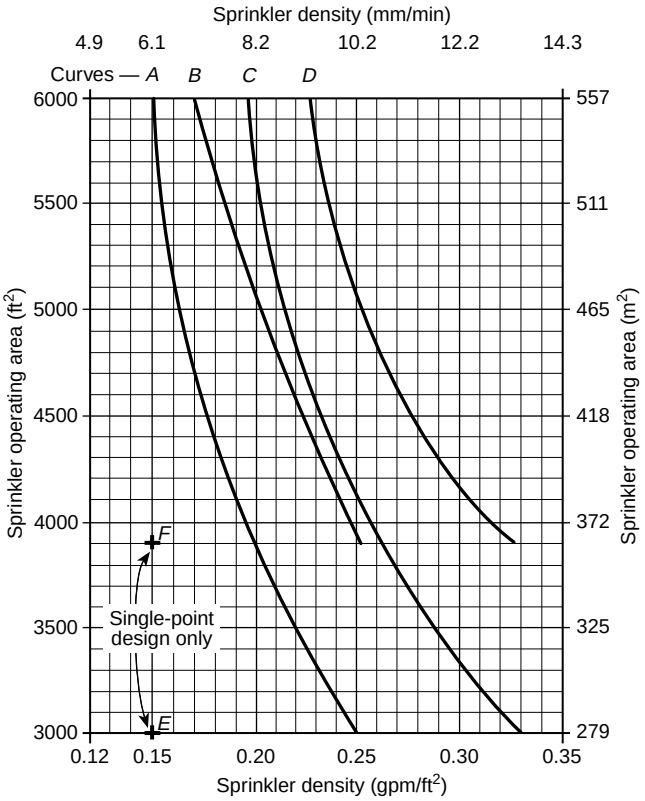
7-7.2.1 For tiered or rack storage up to a nominal 15 ft (4.6 m) in height, sprinkler discharge densities and areas of application shall be in accordance with Figure 7-7.2.1. The density provided for the area of operation can be taken from any point on the selected curve. It is not necessary to meet more than one point on the selected curve.

7-7.2.2 Where roof or ceiling heights would prohibit storage above a nominal 10 ft (3.1 m), the sprinkler discharge density shall be permitted to be reduced by 20 percent of that indicated in Figure 7-7.2.1 but shall not be reduced to less than 0.15 gpm/ft^2 (6.1 mm/min).

7-7.2.3* 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.

7-7.2.4 In warehouses that have mixed rack storage, tiered or untiered storage, or a combination of these, the curve applicable to the storage configuration shall apply and the highest density recommendation shall extend at least 15 ft (4.6 m) beyond the recommended operating area.

Figure 7-7.2.1 Sprinkler system design curves.



Curve	Legend
A	— Wet pipe system for tiered storage to 15 ft (4.6 m)
B	— Dry pipe system for tiered storage to 15 ft (4.6 m)
C	— Wet pipe system for rack storage to 15 ft (4.6 m)
D	— Dry pipe system for rack storage to 15 ft (4.6 m)
E	— Wet pipe system for untiered storage
F	— Dry pipe system for untiered storage

7-7.2.5 Minimum sprinkler operating areas shall 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 shall not exceed 6000 ft^2 (557 m^2). No area credit is recommended for the use of high-temperature sprinklers.

7-7.3 Water Supplies.

7-7.3.1 The total water supply available shall be sufficient to provide the recommended sprinkler discharge density over the area to be protected, plus a minimum of 500 gpm (1893 L/min) for hose streams.

7-7.3.2 Water supplies shall be capable of supplying the total demand for sprinklers and hose streams for not less than 2 hours.

7-7.4 Small Hose. For first-aid fire-fighting and mop-up operations, small hose [$1^1/_2$ in. (38 mm)] shall be provided in accordance with 5-15.5.

7-8* Protection of Roll Paper Storage.

7-8.1 General.

7-8.1.1 The sprinkler system criteria in Section 7-8 is intended to apply to buildings with ceiling slopes not exceeding 2 in 12 (16.7 percent).

7-8.1.2 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.

7-8.1.3 Wet pipe systems shall be used in tissue storage areas.

7-8.1.4 Horizontal storage of heavyweight or mediumweight paper shall be protected as a closed array.

7-8.1.5 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).

7-8.1.6 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).

7-8.1.7 For purposes of sprinkler system design criteria, lightweight class paper shall be protected as tissue.

7-8.2* Protection Criteria.

7-8.2.1 Roll paper storage shall be protected by spray sprinklers in accordance with 7-8.2.2, large drop sprinklers in accordance with 7-8.2.3, or ESFR sprinklers in accordance with 7-8.2.4.

7-8.2.2 Spray Sprinklers.

7-8.2.2.1 Storage of heavyweight or mediumweight classes of rolled paper up to 10 ft (3.1 m) in height shall be protected by sprinklers designed for Ordinary Hazard, Group 2 densities.

7-8.2.2.2 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 Extra Hazard, Group 1 densities.

7-8.2.2.3 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 7-8.2.2.3(a) and (b).

Table 7-8.2.2.3(a) Automatic Sprinkler System Design Criteria — Spray Sprinklers for Buildings or Structures with Roof or Ceilings up to 30 ft (Discharge densities are gpm/ft^2 over ft^2.)

		Heavyweight					Mediumweight				
			Standard Array		Open Array			Standard Array		Open Array	Tissues
Storage Height (ft)	Clearance (ft)	Closed Array Banded or Unbanded	Banded	Unbanded	Banded	Unbanded	Closed Array Banded or Unbanded	Banded	Unbanded	Banded or Unbanded	All Storage Array
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	See Note 1

Notes:
1. Sprinkler protection requirements for tissue stored above 20 ft have not been determined.
2. Densities or areas, or both, shall be permitted to be interpolated between any 5-ft storage height increment.

Table 7-8.2.2.3(b) Automatic Sprinkler System Design Criteria — Spray Sprinklers for Buildings or Structures with Roof or Ceilings Up to 9.1 m (Discharge densities are mm/min over m^2.)

		Heavyweight					Mediumweight				
			Standard Array		Open Array			Standard Array			Tissue
Storage Height (m)	Clearance (m)	Closed Array Banded or Unbanded	Banded	Unbanded	Banded	Unbanded	Closed Array Banded or Unbanded	Banded	Unbanded	Open Array Banded or Unbanded	All Storage Arrays
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	See Note 1

Notes:
1. Sprinkler protection requirements for tissue stored above 6.1 m have not been determined.
2. Densities or areas, or both, shall be permitted to be interpolated between any 1.5-m storage height increment.

Table 7-8.2.3 Automatic Sprinkler System Design Criteria — Large Drop Sprinklers (number of sprinklers to be calculated)

					Heavyweight					Mediumweight					
Storage Height		Clearance			Closed Array	Standard Array		Open Array		Closed Array	Standard Array		Open Array		Tissue All Storage Arrays
ft	m	ft	m	System Type	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	NA	15	15	15	NA	NA	See Note 3
20	6.1	<10	<3.1	D	25	25	25	NA	NA	25	25	25	NA	NA	NA
26	7.9	<34	<10.4	W	15	15	15	15	NA	NA	NA	NA	NA	NA	NA
26	7.9	< 34	<10.4	D	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes:
1. W = wet; D = dry; NA = not applicable.
2. For definition of storage height, see Section 1-4.
3. Twenty-five large drop sprinklers @ 75 psi (5.2 bar) for closed or standard array; other arrays NA.

Table 7-8.2.4 Rolled Paper Storage — Automatic Sprinkler Design Criteria — ESFR Sprinklers (maximum height of storage permitted)

						Heavyweight						Mediumweight						
		Pressure		Building Height		Closed		Standard		Open		Closed		Standard		Open		Tissue All Arrays
ESFR K-factor	System Type	psi	bar	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m	
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	NA
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	NA
13.5–14.5	Wet	75	5.2	40	12.2	30	9.1	30	9.1	30	9.1	NA		NA		NA		NA
24.2–26.2	Wet	20	1.4	30	9.1	25	7.6	25	7.6	25	7.6	25	7.6	25	7.6	25	7.6	NA
24.2–26.2	Wet	40	2.8	40	12.2	30	9.1	30	9.1	30	9.1	NA		NA		NA		NA

Note: NA = not applicable.

7-8.2.2.4* Where dry pipe systems are used in heavyweight class or mediumweight class storage areas, the areas of operation indicated by Tables 7-8.2.2.3(a) and (b) shall be increased by 30 percent.

7-8.2.2.5* High-temperature sprinklers shall be used for installations protecting roll paper stored 15 ft (4.6 m) or higher.

7-8.2.2.6 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).

7-8.2.2.7 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 (9.8 mm/min) with a minimum operating area of 2000 ft^2 (186 m^2).

7-8.2.2.8 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 7-8.2.2.3(a) and (b).

7-8.2.3 Large Drop Sprinklers. Where automatic sprinkler system protection utilizes large drop sprinklers, hydraulic design criteria shall be as specified in Table 7-8.2.3. Design discharge pressure shall be 50 psi (3.4 bar). The number of sprinklers to be calculated is indicated based on storage height, clearance, and system type.

7-8.2.4 ESFR Sprinklers. Where automatic sprinkler system protection utilizes ESFR sprinklers, hydraulic design criteria shall be as specified in Table 7-8.2.4. Design discharge pressure shall be applied to 12 operating sprinklers.

7-8.3 Water Supplies.

7-8.3.1 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.

7-8.3.2 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).

7-8.3.3 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.

7-8.4 Small Hose. For first-aid fire-fighting and mop-up operations, small hose [$1^1/_2$ in. (38 mm)] shall be provided in accordance with Section 5-15.5.

7-9 Special Design Approaches.

7-9.1 General. All special design approaches utilize the hydraulic calculation procedures of Section 8-4, except as specified.

7-9.2 Residential Sprinklers.

7-9.2.1* Sprinkler discharge rates shall be provided in accordance with minimum flow rates indicated in individual residential sprinkler listings, both for the single sprinkler discharge and the multiple sprinkler discharge of the design sprinklers.

7-9.2.2* The design area shall be that area that includes the four hydraulically most demanding sprinklers. Calculations shall be provided to verify the single (one) operating sprinkler criteria and the multiple (four) operating sprinkler criteria.

7-9.2.3 Where areas such as attics, basements, or other types of occupancies are outside of dwelling units but within the same structure, these areas shall be protected in accordance with the provisions of this standard, including appropriate design criteria of 7-2.3.

7-9.2.4 Hose stream demand and water supply duration requirements shall be in accordance with those for light hazard occupancies in Table 7-2.3.1.1.

7-9.3 Quick-Response Early Suppression (QRES) Sprinklers. (Reserved) *(See 1-4.5.2 and A-1-4.5.2.)*

7-9.4 Large Drop Sprinklers.

7-9.4.1 Large drop sprinklers shall be permitted to protect ordinary hazard, storage of Class I through Class IV commodities, plastic commodities, miscellaneous storage, and other storage as specified in Sections 7-5, 7-6, and 7-8 or by other NFPA standards.

7-9.4.1.1 Protection of palletized and solid-piled storage of Class I through Class IV, unexpanded plastic and expanded plastic commodities shall be in accordance with Table 7-9.4.1.1.

Table 7-9.4.1.1 Large Drop Sprinkler Design Criteria for Palletized and Solid-Piled Storage

Configuration	Commodity Class	Maximum Storage Height ft	Maximum Storage Height m	Maximum Building Height ft	Maximum Building Height m	Type of System	Number of Design Sprinklers by Minimum Operating Pressure 25 psi (1.7 bar)	50 psi (3.4 bar)	75 psi (5.2 bar)	Hose Stream Demand gpm	Hose Stream Demand L/min	Water Supply Duration (hours)
Palletized	I, II, or III	25	7.6	35	10.7	Wet	15	15	15	500	1900	2
						Dry	25	25	25	—	—	—
Palletized	IV	20	6.1	30	9.1	Wet	20	15	15	500	1900	2
						Dry	NA	NA	NA	—	—	—
Palletized	Cartoned or exposed unexpanded plastics	20	6.1	30	9.1	Wet	25	15	15	500	1900	2
						Dry	NA	NA	NA	—	—	—
Palletized	Cartoned or exposed expanded plastics	18	5.5	26	7.9	Wet	NA	15	15	500	1900	2
						Dry	NA	NA	NA	—	—	—

(continues)

Table 7-9.4.1.1 Large Drop Sprinkler Design Criteria for Palletized and Solid-Piled Storage *(Continued)*

Configuration	Commodity Class	Maximum Storage Height ft	Maximum Storage Height m	Maximum Building Height ft	Maximum Building Height m	Type of System	Number of Design Sprinklers by Minimum Operating Pressure 25 psi (1.7 bar)	50 psi (3.4 bar)	75 psi (5.2 bar)	Hose Stream Demand gpm	Hose Stream Demand L/min	Water Supply Duration (hours)
Palletized	Idle wood pallets	20	6.1	30	9.1	Wet	15	15	15	500	1900	$1^1/_2$
						Dry	25	25	25	—	—	—
Solid pile	I, II, or III	20	6.1	30	9.1	Wet	15	15	15	500	1900	$1^1/_2$
						Dry	25	25	25	—	—	—
Solid pile	IV	20	6.1	30	9.1	Wet	NA	15	15	500	1900	$1^1/_2$
						Dry	NA	NA	NA	—	—	
Solid pile	Cartoned or exposed unexpanded plastics	20	6.1	30	9.1	Wet	NA	15	15	500	1900	$1^1/_2$
						Dry	NA	NA	NA	—	—	—

Note: NA = not allowed.

Table 7-9.4.1.2 Large Drop Sprinkler Design Criteria for Single-, Double-, and Multiple-Row Racks without Solid Shelves

Commodity Class	Maximum Storage Height ft	Maximum Storage Height m	Maximum Ceiling/ Roof Height ft	Maximum Ceiling/ Roof Height m	Type of System	Number of Design Sprinklers by Minimum Operating Pressure 25 psi (1.7 bar)	50 psi (3.4 bar)	75 psi (5.2 bar)	Hose Stream Demand gpm	Hose Stream Demand L/min	Water Supply Duration (hours)
I, II	25	7.6	30	9.1	Wet	20	20	20	500	1900	$1^1/_2$
					Dry	30	30	30	—	—	—
I, II	30	9.1	35	10.7	Wet	20 plus one level of in-rack sprinklers	20 plus one level of in-rack sprinklers	20 plus one level of in-rack sprinklers	500 —	1900 —	$1^1/_2$ —
					Dry	30 plus one level of in-rack sprinklers	30 plus one level of in-rack sprinklers	30 plus one level of in-rack sprinklers	500 —	1900 —	$1^1/_2$ —
I, II, III	20	6.1	30	9.1	Wet	15	15	15	500	1900	$1^1/_2$
					Dry	25	25	25	—	—	—
I, II, III	25	7.6	35	10.7	Wet	15 plus one level of in-rack sprinklers	15 plus one level of in-rack sprinklers	15 plus one level of in-rack sprinklers	500 —	1900 —	$1^1/_2$ —
					Dry	25 plus one level of in-rack sprinklers	25 plus one level of in-rack sprinklers	25 plus one level of in-rack sprinklers	500 —	1900 —	$1^1/_2$ —
IV	20	6.1	30	9.1	Wet	NA	20	15	500	1900	2
					Dry	NA	NA	NA			
IV	25	7.6	35	10.7	Wet	NA	20 plus one level of in-rack sprinklers	15 plus one level of in-rack sprinklers	500	1900	2
					Dry	NA	NA	NA			
Cartoned or exposed unexpanded plastics	20	6.1	30	9.1	Wet	NA	30	20	500	1900	2
					Dry	NA	NA	NA	—	—	—

Table 7-9.4.1.2 Large Drop Sprinkler Design Criteria for Single-, Double-, and Multiple-Row Racks without Solid Shelves *(Continued)*

Commodity Class	Maximum Storage Height ft	Maximum Storage Height m	Maximum Ceiling/ Roof Height ft	Maximum Ceiling/ Roof Height m	Type of System	Number of Design Sprinklers by Minimum Operating Pressure 25 psi (1.7 bar)	50 psi (3.4 bar)	75 psi (5.2 bar)	Hose Stream Demand gpm	Hose Stream Demand L/min	Water Supply Duration (hours)
IV	20	6.1	25	7.6	Wet	NA	15	15	500	1900	2
					Dry	NA	NA	NA	—	—	—
Cartoned or exposed unexpanded plastics	25	7.6	35	10.7	Wet	NA	30 plus one level of in-rack sprinklers	20 plus one level of in-rack sprinklers	500	1900	2
IV	25	7.6	30	9.1	Wet	NA	15 plus one level of in-rack sprinklers	15 plus one level of in-rack sprinklers	500	1900	2
					Dry	NA	NA	NA	—	—	—
Cartoned or exposed unexpanded plastics	20	6.1	25	7.6	Wet	NA	15	15	500	1900	2
					Dry	NA	NA	NA	—	—	—
Cartoned or exposed unexpanded plastics	25	7.6	30	9.1	Wet	NA	15 plus one level of in-rack sprinklers	15 plus one level of in-rack sprinklers	500	1900	2
	25	7.6	36	9.1	Dry	NA	NA	NA	—	—	—

Note: NA = not allowed.

7-9.4.1.2 Protection of single-, double-, and multiple-row rack storage without solid shelves for Classes I through IV unexpanded plastic commodities shall be in accordance with Table 7-9.4.1.2.

7-9.4.1.2.1 For rack storage, a minimum of 6-in. (152.4-mm) longitudinal flue spaces shall be maintained in addition to transverse flue spaces.

7-9.4.1.2.2 Where in-rack sprinklers are required by Table 7-9.4.1.2, in-rack sprinkler spacing, design pressure, and hydraulic calculation criteria shall be in accordance with the requirements of Section 7-4 as applicable for the commodity.

7-9.4.2 Protection Criteria.

7-9.4.2.1 Protection shall be provided as specified in Tables 7-9.4.1.1 and 7-9.4.1.2, Section 7-6, Section 7-8, or appropriate NFPA standards in terms of minimum operating pressure and the number of sprinklers to be included in the design area.

7-9.4.2.2 The minimum number of design sprinklers for ordinary hazard and miscellaneous storage in accordance with this standard shall be 15 for wet pipe and preaction systems and 25 for double interlock preaction systems and dry pipe systems. For other storage configurations, the number of design sprinklers shall be in accordance with Section 7-6, Section 7-8, or other NFPA standards.

7-9.4.3 Large drop sprinkler systems shall be designed such that the minimum operating pressure is not less than 25 psi (1.7 bar).

7-9.4.4 For design purposes, 95 psi (6.6 bar) shall be the maximum discharge pressure at the hydraulically most remote sprinkler.

7-9.4.5 The design area shall be a rectangular area having a dimension parallel to the branch lines at least 1.2 times the square root of the area protected by the number of sprinklers to be included in the design area. Any fractional sprinkler shall be included in the design area.

7-9.4.6 The nominal diameter of branch line pipes (including riser nipples) shall be not less than $1^1/_4$ in. (33 mm) nor greater than 2 in. (51 mm).

Exception No. 1: Starter pieces shall be permitted to be $2^1/_2$-in. (64 mm).

Exception No. 2: Where branch lines are larger than 2 in. (51 mm), the sprinkler shall be supplied by a riser nipple to elevate the sprinkler 13 in. (330 mm) for $2^1/_2$-in. (64-mm) pipe and 15 in. (380 mm) for 3-in. (76-mm) pipe. These dimensions are measured from the centerline of the pipe to the deflector. In lieu of this, sprinklers shall be permitted to be offset horizontally a minimum of 12 in. (305 mm).

7-9.4.7 Hose stream demand and water supply duration requirements shall be in accordance with those for extra hazard occupancies in Table 7-2.3.1.1 or Table 7-9.4.1.1 and Table 7-9.4.1.2, whichever applies.

7-9.4.8 Where large drop sprinklers are installed under open wood joist construction, their minimum operating pressure shall be 50 psi (3.4 bar).

Exception: Where each joist channel of open, wood joist construction is fully fire stopped to its full depth at intervals not exceeding 20 ft (6.1 m), the lower pressures specified in Table 7-9.4.1.2 shall be permitted to be used.

7-9.4.9 For the purpose of using Table 7-9.4.1.1 and Table 7-9.4.1.2, preaction systems shall be classified as dry pipe systems.

Exception: Where it can be demonstrated that the detection system activating the preaction system will cause water to be at the sprinklers when they operate, preaction systems shall be permitted to be treated as wet pipe systems.

7-9.4.10 Building steel shall not require special protection where Table 7-9.4.1.1 or Table 7-9.4.1.2 is applied as appropriate for the storage configuration.

7-9.5* Early Suppression Fast-Response (ESFR) Sprinklers.

7-9.5.1 ESFR sprinklers shall be permitted to protect ordinary hazard, storage of Class I through Class IV commodities, plastic commodities, miscellaneous storage, and other storage as specified in Sections 7-5, 7-6, and 7-8 or by other NFPA standards.

7-9.5.1.1* Protection of palletized and solid pile storage of Classes I through IV, cartoned or uncartoned unexpanded plastic, cartoned expanded plastic, and idle wood or plastic pallets shall be in accordance with Table 7-9.5.1.1.

7-9.5.1.2 Protection of single-, double-, and multiple-row rack storage of Classes I through IV, cartoned or uncartoned unexpanded plastic, cartoned expanded plastic, and idle wood or plastic pallets shall be in accordance with Table 7-9.5.1.2.

Exception: ESFR protection as defined shall not apply to the following:

(a) Rack storage involving solid shelves

(b) Rack storage involving combustible, open-top cartons or containers

7-9.5.1.2.1 Where required by Table 7-9.5.1.2, one level of K-8.0 quick-response, ordinary-temperature in-rack sprinklers shall be installed at the tier level closest to but not exceeding $^1/_2$ of the maximum storage height. In-rack sprinkler hydraulic design criteria shall be the most hydraulically remote eight sprinklers at 50 psi (3.4 bar). In-rack sprinklers shall be located at the intersection of the longitudinal and transverse flue space. Horizontal spacing shall not be permitted to exceed 5-ft (1.5-m) intervals.

7-9.5.1.2.2 Where ESFR sprinklers are installed, see 7-4.1.4 for special requirements for longitudinal flue spaces in double-row racks.

7-9.5.1.3 ESFR sprinklers shall be permitted to be used in other specific hazard classifications and configurations only when proven by large-scale or other suitable fire testing.

7-9.5.2* General Protection Criteria.

7-9.5.2.1 ESFR sprinkler systems shall be designed such that the minimum operating pressure is not less than that indicated in Table 7-9.5.1.1, Table 7-9.5.1.2, Section 7-6, or Section 7-8 for type of storage, commodity, storage height, and building height involved.

7-9.5.2.2 The design area shall consist of the most hydraulically demanding area of 12 sprinklers, consisting of four sprinklers on each of three branch lines. The design shall include a minimum of 960 ft^2 (89 m^2).

7-9.5.2.3 The maximum building height shall be measured to the underside of the roof deck or ceiling.

Table 7-9.5.1.1 ESFR Protection of Palletized and Solid-Pile Storage

		Maximum Height of Storage		Maximum Ceiling/ Roof Height of Building			Sprinkler Design Pressure		Hose Stream Demand		
Type of Storage	Commodity	ft	m	ft	m	Nominal K-factor	psi	bar	gpm	L/ min	Duration (hours)
Palletized and solid-pile storage (no open-top containers or solid shelves)	1. Cartoned unexpanded plastic 2. Cartoned expanded plastic 3. Uncartoned unexpanded plastic 4. Class I, Class II, Class III, or Class IV commodities, encapsulated or unencapsulated 5. Idle wood or plastic pallets	25	7.6	30	9.1	14	50	3.4	250	946	1
	1. Cartoned or uncartoned unexpanded plastic 2. Class I, Class II, Class III, or Class IV commodities, encapsulated or unencapsulated 3. Idle wood or plastic pallets	35	10.7	40	12.2	14	75	5.2	250	946	1
	1. Cartoned or uncartoned unexpanded plastic 2. Class I, Class II, Class III, or Class IV commodities, encapsulated or unencapsulated	35	10.7	45	13.7	14	90	6.2	250	946	1
	1. Cartoned unexpanded plastic 2. Class I, Class II, Class III, or Class IV commodities, encapsulated or unencapsulated	20	6.1	25	7.6	11.2	50	3.4	250	946	1
		25	7.6	30	9.1	25.2	20	1.4	250	946	1
		30	9.1	35	10.7	25.2	30	2.1	250	946	1
		35	10.7	40	12.2	25.2	40	2.8	250	946	1
		40	12.2	45	13.7	25.2	50	3.4	250	946	1

Table 7-9.5.1.2 ESFR Protection of Rack Storage without Solid Shelves

Type of Storage*	Commodity	Maximum Height of Storage ft	Maximum Height of Storage m	Maximum Ceiling/ Roof Height of Building ft	Maximum Ceiling/ Roof Height of Building m	Nominal K-factor	Sprinkler Design Pressure psi	Sprinkler Design Pressure bar	In-Rack Sprinkler Requirements	Hose Stream Demand gpm	Hose Stream Demand L/min	Duration (hours)
Single-row rack storage, double-row rack storage, multiple-row rack storage	1. Cartoned unexpanded plastic 2. Cartoned expanded plastic 3. Exposed unexpanded plastic 4. Classes I, II, III, and IV commodities, encapsulated or unencapsulated 5. Idle wood and plastic pallets	25	7.6	30	9.1	14	50	3.4	No	250	946	1
	1. Cartoned or exposed unexpanded plastic 2. Classes I, II, III, and IV commodities, encapsulated or unencapsulated 3. Idle wood and plastic pallets	35	10.7	40	12.2	14	75	5.2	No	250	946	1
	1. Cartoned or exposed unexpanded plastic 2. Classes I, II, III, and IV commodities, encapsulated or unencapsulated	35	10.7	45	13.7	14	90	6.2	No	250	946	1
		40	12.2	45	13.7	14	90	6.2	Yes	250	946	1
	1. Cartoned unexpanded plastic 2. Classes I, II, III, and IV commodities, encapsulated or unencapsulated	20	6.1	25	7.6	11.2	50	3.4	No	250	946	1
		25	7.6	30	9.1	25.2	20	1.4	No	250	946	1
		30	9.1	35	10.7	25.2	30	2.1	No	250	946	1
		35	10.7	40	12.2	25.2	40	2.8	No	250	946	1
		40	12.2	45	13.7	25.2	50	3.4	No	250	946	1

*No open-top containers

7-9.5.2.4 ESFR sprinklers shall be limited to wet pipe systems.

7-9.5.2.5 Early suppression fast-response (ESFR) sprinklers shall be used only in buildings equal to, or less than, the height of the building for which they have been listed.

7-9.6 Exposure Protection.

7-9.6.1* Piping shall be hydraulically calculated in accordance with Section 8-4 to furnish a minimum of 7 psi (0.5 bar) at any sprinkler with all sprinklers facing the exposure operating.

7-9.6.2 Where the water supply feeds other fire protection systems, it shall be capable of furnishing total demand for such systems as well as the exposure system demand.

7-9.7 Water Curtains. Sprinklers in a water curtain such as described in 5-13.4 shall be hydraulically designed to provide a discharge of 3 gpm per lineal foot (37 L/min per lineal meter) of water curtain, with no sprinklers discharging less than 15 gpm (56.8 L/min). For water curtains employing automatic sprinklers, the number of sprinklers calculated in this water curtain shall be the number in the length corresponding to the length parallel to the branch lines in the area determined by 8-4.4.1(a). If a single fire can be expected to operate sprinklers within the water curtain and within the design area of a hydraulically calculated system, the water supply to the water curtain shall be added to the water demand of the hydraulic calculations and shall be balanced to the calculated area demand. Hydraulic design calculations shall include a design area selected to include ceiling sprinklers adjacent to the water curtain. *(See 5-13.4.)*

7-9.8 Fire Protection of Steel Columns.

7-9.8.1† Columns within Storage Racks of Class I through Class IV and Plastic Commodities. Where sprinkler protection of building columns within the rack structure or vertical rack members supporting the building are required in lieu of fireproofing, sprinkler protection in accordance with one of the following shall be provided:

(1) Sidewall sprinklers at the 15-ft (4.6-m) elevation, pointed toward one side of the steel column

(2) Provision of ceiling sprinkler density for a minimum of 2000 ft^2 (186 m^2) with 165°F (74°C) or 286°F (141°C) rated sprinklers as shown in Table 7-9.8.1 for storage heights above 15 ft (4.6 m), up to and including 20 ft (6.1 m)

(3) Provision of large drop or ESFR ceiling sprinkler protection in accordance with 7-9.4 and 7-9.5, respectively.

7-9.8.2 Columns within Rubber Tire Storage. Where fireproofing is not provided, steel columns shall be protected as follows:

(1) Storage exceeding 15 ft through 20 ft (4.6 m through 6 m) in height — one sidewall sprinkler directed to one side of the column at a 15-ft (4.6-m) level
(2) Storage exceeding 20 ft (6.1 m) in height — 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 protection specified in 7-9.8.1(1) and (2) shall not be required where storage in fixed racks is protected by in-rack sprinklers.

Table 7-9.8.1 Ceiling Sprinkler Densities for Protection of Steel Building Columns

Commodity Class	Aisle Width			
	4 ft (1.2 m)		8 ft (2.4 m)	
	gpm/ft^2	mm/min	gpm/ft^2	mm/min
I	0.37	15.1	0.33	13.5
II	0.44	17.9	0.37	15.1
III	0.49	20.0	0.42	17.1
IV and plastics	0.68	27.7	0.57	23.2

Note: For aisle widths of 4 ft to 8 ft (1.2 m to 2.4 m), a direct linear interpolation between densities shall be permitted to be made.
For SI units, 1 gpm/ft^2 = 40.746 mm/min.

7-10 Sprinkler System Discharge Criteria for Special Occupancy Hazards.

7-10.1 Flammable and Combustible Liquids. See NFPA 30, *Flammable and Combustible Liquids Code*, for sprinkler system discharge criteria pertaining to the protection of flammable and combustible liquids.

7-10.2 Aerosol Products. See NFPA 30B, *Code for the Manufacture and Storage of Aerosol Products*, for sprinkler system discharge criteria pertaining to the protection of aerosol products.

7-10.3 Spray Application Using Flammable or Combustible Materials.

7-10.3.1 See NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials*, for applicable terms not defined in Chapter 1.

7-10.3.2* Spray Areas and Mixing Rooms. The automatic sprinkler system in spray areas and mixing rooms shall be designed for Extra Hazard (Group 2) occupancies. (**33:** 7-2.1)

7-10.3.3 Water supply for sprinklers shall be sufficient to supply all sprinklers likely to open in any one fire incident without depleting the available water for use in hose streams. Where sprinklers are installed to protect spray areas and mixing rooms only, water shall be permitted to be furnished from the domestic supply, subject to the approval of the authority having jurisdiction and provided the domestic supply can meet the design criteria for extra hazard, Group 2 occupancies. (**33:** 7-2.3)

7-10.3.4 For spray application areas using styrene cross-linked thermoset resins (commonly known as glass fiber reinforced plastics), automatic sprinkler systems shall be designed and installed for at least ordinary hazard, Group 2 occupancies. (**33:** 15-3)

7-10.4 Solvent Extraction Plants.

7-10.4.1 See NFPA 36, *Standard for Solvent Extraction Plants*, for applicable terms not defined in Chapter 1.

7-10.4.2* Sprinkler Systems. (**36:** 2-9)

7-10.5 Nitrate Film.

7-10.5.1 See NFPA 40, *Standard for the Storage and Handling of Cellulose Nitrate Motion Picture Film*, for applicable terms not defined in Chapter 1.

7-10.5.2 Where rooms containing nitrate film are required to be sprinklered per NFPA 40, the sprinkler system shall be installed in accordance with the requirements for extra hazard occupancies. (**40:** 3-1.2)

7-10.5.3 Sprinkler System Water Supply. Water supplies for automatic sprinklers shall be based on 20 gpm (1.26 L/sec) per sprinkler for 20 minutes for the total number of sprinklers in one vault, plus 25 percent of the sprinklers in the communicating fire area. (**40:** 3-2.2)

7-10.6 Storage of Pyroxylin Plastic.

7-10.6.1 See NFPA 42, *Code for the Storage of Pyroxylin Plastic*, for applicable terms not defined in Chapter 1.

7-10.6.2 Sprinkler System Water Supply.

7-10.6.2.1 The water supply for automatic sprinklers shall be based on the number of sprinklers liable to be affected in any fire section between fire walls or fire-resistive partitions. It shall be assumed that any one of the following numbers of sprinklers can be affected and the condition giving maximum flow used as a basis:

(1) All sprinklers in a vault
(2) All sprinklers in a tote box storeroom
(3) Three-fourths of the sprinklers in a finished-stock storeroom
(4) All sprinklers in a section of an isolated storage building (**42:** 2-4.3.1)

7-10.6.2.2 The water supply for an automatic sprinkler system shall be based on a flow of 20 gpm (76 Lpm) per sprinkler for 20 minutes, with a minimum rate of flow of 500 gpm (1900 Lpm). Such flow shall be with an effective pressure at the top line of sprinklers of not less than 40 psi (2.8 bar). (**42:** 2-4.3.2)

7-10.7 Laboratories Using Chemicals.

7-10.7.1 See NFPA 45, *Standard for Fire Protection for Laboratories Using Chemicals*, for applicable terms not defined in Chapter 1.

7-10.7.2 An automatic sprinkler system, where required by Table 3-1(a) of NFPA 45, depending on the construction of the building, the hazard class of the laboratory unit, the construction of the laboratory unit enclosure, and the area of the laboratory unit shall be in accordance with the following:

(1) Automatic sprinkler system protection for Class A and Class B laboratories shall be in accordance with ordinary hazard, Group 2 occupancies.
(2) Automatic sprinkler system protection for Class C and Class D laboratories shall be in accordance with ordinary hazard, Group 1 occupancies. (**45:** 4-2.1.1)

7-10.8 Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes.

7-10.8.1 See NFPA 51, *Standard for the Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes*, for applicable terms not defined in Chapter 1.

7-10.8.2 Where sprinkler systems are required per 2-3.1 of NFPA 51, they shall provide a sprinkler discharge density of at least 0.25 gpm/ft^2 (10.2 mm/min) over a minimum operating area of at least 3000 ft^2 (88 m^2). (**51:** 2-3.1, Exception No. 1)

7-10.9 Acetylene Cylinder Charging Plants.

7-10.9.1 See NFPA 51A, *Standard for Acetylene Cylinder Charging Plants*, for applicable terms not defined in Chapter 1.

7-10.9.2 Where an automatic sprinkler system is required per NFPA 51A, *Standard for Acetylene Cylinder Charging Plants*, it shall be an extra hazard open or closed head sprinkler system. (**51A:** 9-2.2)

7-10.10 Storage, Use, and Handling of Compressed and Liquefied Gases in Portable Cylinders.

7-10.10.1 See NFPA 55, *Standard for the Storage, Use, and Handling of Compressed and Liquefied Gases in Portable Cylinders*, for applicable terms not defined in Chapter 1.

7-10.10.2 Where an automatic sprinkler system is required per NFPA 55, the sprinkler system protecting the gas cylinder storage, and for a distance of 25 ft (7.6 m) beyond in all directions, shall be capable of providing a sprinkler density of at least 0.3 gpm/ft^2 (12.2 mm/min) over the most hydraulically remote 2500 ft^2 (232.25 m^2). (**55:** 2-2.2.1)

7-10.10.3 Where sprinkler systems are provided per NFPA 55, 2-2.2.2, Exception No. 1, they shall be designed for ordinary hazard, Group 1 occupancies. (**55:** 2-2.2.2)

7-10.10.4 Where sprinkler systems are provided per NFPA 55, 2-2.2.2, Exception No. 2, they shall be designed for ordinary hazard, Group 1 occupancies. (**55:** 2-2.2.2)

7-10.10.5 Where sprinkler systems are required for gas cylinder storage rooms per NFPA 55, they shall be capable of providing a minimum density of 0.3 gpm/ft^2 (12.2 mm/min) over the most hydraulically remote 2500 ft^2 (232.25 m^2) or the entire room area, whichever is smaller. (**55:** 2-2.3.2)

7-10.11 Storage and Handling of Liquefied Petroleum Gases at Utility Gas Plants.

7-10.11.1 See NFPA 59, *Standard for the Storage and Handling of Liquefied Petroleum Gases at Utility Gas Plants*, for applicable terms not defined in Chapter 1.

7-10.11.2 Sprinkler System Water Supply. The design of fire water supply and distribution systems, if required by NFPA 59, shall provide for the simultaneous supply of those fixed fire protection systems, including monitor nozzles, at their design flow and pressure, involved in the maximum single incident expected in the plant. An additional supply of 1000 gpm (3785 L/min) shall be available for hand hose streams for a period of not less than 2 hours. Manually actuated monitors shall be permitted to be used to augment hand hose streams. (**59:** 10-5.2)

7-10.12 Production, Storage, and Handling of Liquefied Natural Gas (LNG).

7-10.12.1 See NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*, for applicable terms not defined in Chapter 1.

7-10.12.2 The design of fire water supply and distribution systems, if required by NFPA 59A, shall provide for the simultaneous supply of those fixed fire protection systems, including monitor nozzles, at their design flow and pressure, involved in the maximum single incident expected in the plant plus an allowance of 1000 gpm (3785 L/min) for hand hose streams for not less than 2 hours. (**59A:** 9-5.2)

7-10.13 Ventilation Control and Fire Protection of Commercial Cooking Operations.

7-10.13.1 See NFPA 96, *Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations*, for applicable terms not defined in Chapter 1.

7-10.13.2 Sprinkler System Water Supply. Solid fuel appliances with fire boxes exceeding 5 ft^3 (0.14 m^3) shall be provided with a fixed water pipe system with a hose in the immediate vicinity of the appliance. The system shall have a minimum operating pressure of 40 psi (2.8 bar) and shall provide a minimum of 5 gpm per cu ft (18.9 L/min per 0.03 m^3) of fire box volume. (**96:** 11-7.5)

7-10.14 Class A Hyperbaric Chambers.

7-10.14.1 See NFPA 99, *Standard for Health Care Facilities*, for applicable terms not defined in Chapter 1.

7-10.14.2 In chambers that consist of more than one chamber compartment (lock), the design of the deluge system shall ensure adequate operation when the chamber compartments are at different depths (pressures). The design shall also ensure the independent or simultaneous operation of deluge systems. (**99:** 19-2.5.2)

7-10.14.3 Water shall be delivered from the sprinklers as specified in 7-10.14.5 within 3 seconds of activation of any affiliated deluge control. (**99:** 19-2.5.2.2)

7-10.14.4* Where an automatic sprinkler system is provided per NFPA 99, the average spray density at floor level shall be not less than 2 gpm/ft^2 (81.5 mm/min) with no floor area larger than 1 m^2 receiving less than 1 gpm/ft^2 (40.8 mm/min). (**99:** 19-2.5.2.3)

7-10.14.5 There shall be sufficient water available in the deluge system to maintain the flow specified in NFPA 99, 19-2.5.2.3 simultaneously in each chamber compartment (lock) containing the deluge system for 1 minute. The limit on maximum extinguishment duration shall be governed by the chamber capacity (bilge capacity also, if so equipped) and/or its drainage system. (**99:** 19-2.5.2.4)

7-10.14.6 The deluge system shall have stored pressure to operate for at least 15 seconds without electrical branch power. (**99:** 19-2.5.2.5)

7-10.15 Fixed Guideway Transit Systems.

7-10.15.1 See NFPA 130, *Standard for Fixed Guideway Transit Systems*, for applicable terms not defined in Chapter 1.

7-10.15.2 Where an automatic sprinkler system is installed per NFPA 130, Section 6-4, it shall be of a closed-head type for ordinary hazard classification. (**130:** 6-4.1)

7-10.16 Race Track Stables.

7-10.16.1 See NFPA 150, *Standard on Fire Safety in Racetrack Stables*, for applicable terms not defined in Chapter 1.

7-10.16.2 Automatic sprinkler systems shall be designed in accordance with ordinary hazard, Group 2 classification. (**150:** 4-1.2)

7-10.17 Water-Cooling Towers.

7-10.17.1 See NFPA 214, *Standard on Water-Cooling Towers*, for applicable terms not defined in Chapter 1.

7-10.17.2 Types of Systems.

7-10.17.2.1 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. (**214:** 3-2.2.1)

7-10.17.2.2 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. (**214:** 3-2.2.2)

7-10.17.3 Minimum Rate of Application.

7-10.17.3.1 Under the fan decks of counterflow towers, the rate of application of water shall be 0.5 gpm/ft^2 (20.4 mm/min) (including fan opening). (**214:** 3-2.3.1)

7-10.17.3.2 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. (**214:** 3-2.4.2.3)

7-10.17.3.3 Under the fan decks of crossflow towers, the rate of application of water shall be 0.33 gpm/ft^2 (13.5 mm/min) (including fan opening). (**214:** 3-2.3.2)

7-10.17.3.4 Over the fill areas of crossflow towers, the rate of application of water shall be 0.5 gpm/ft^2 (20.4 mm/min). (**214:** 3-2.3.3)

7-10.17.4 Discharge outlets [in crossflow towers] shall be open directional spray nozzles or other approved spray devices arranged to discharge 0.35 gpm/ft^2 (14.3 mm/min) directly on the distribution basin and 0.15 gpm/ft^2 (6.1 mm/min) 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 NFPA 214. (**214:** 3-2.4.3)

7-10.17.5 For deluge systems [in crossflow towers] using directional spray nozzles in the pendent position, provisions shall be made to protect the underside of a combustible fan deck at a minimum of 0.15 gpm/ft^2 (6.1 mm/min), which shall be included as part of the application rate specified in 7-10.17.3 of NFPA 13. (**214:** 3-2.4.4)

7-10.17.6 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 (14.3 mm/min) directly on the distribution basin, and 0.15 gpm/ft^2 (6.1 mm/min) on the underside of the water basin covers. (**214:** 3-2.4.5)

7-10.17.7 Exposure Protection. Systems for exterior protection shall be designed with the same attention and care as interior systems. Pipe sizing shall be based on hydraulic calculations. The water supply and discharge rate shall be based on a minimum 0.15 gpm/ft^2 (6.1 mm/min) for all surfaces being protected. (**214:** 3-2.10.2)

7-10.17.8 Sprinkler System Water Supply.

7-10.17.8.1 Deluge Systems.

7-10.17.8.1.1* 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. (**214:** 3-6.1.1)

7-10.17.8.1.2 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. (**214:** 3-6.1.2)

7-10.17.8.1.3* 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. (**214:** 3-6.1.3)

7-10.17.8.2* Wet, Dry, and Preaction Systems.

7-10.17.8.2.1 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. (**214:** 3-6.2.1)

7-10.17.8.2.2* 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. (**214:** 3-6.2.2)

7-10.17.8.3 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. (**214:** 3-6.3)

7-10.17.8.4 Duration. An adequate water supply of at least 2-hour duration shall be provided for the combination of the water supply specified in 7-10.17.8.1 or 7-10.17.8.2 of NFPA 13, plus the hose stream demand specified in 7-10.17.8.3 of NFPA 13. (**214:** 3-6.4)

7-10.18 Piers, Terminals, and Wharves.

7-10.18.1 See NFPA 307, *Standard for the Construction and Fire Protection of Marine Terminals, Piers, and Wharves*, for applicable terms not defined in Chapter 1.

7-10.18.2* Piers and Wharves. Where sprinkler systems are required per NFPA 307, the sprinklers shall be K-5.6 and shall discharge at a minimum pressure of 12.5 psi (0.9 bar). The design area shall be based upon the largest area between firestops plus an additional area embracing at least two branch lines on opposite sides of the firestop. The minimum design area shall be not less than 5000 ft^2 (465 m^2). [**307:** 3-3.3.3(a)5]

7-10.18.3 Terminals. 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. (**307:** 4-4.2)

7-10.18.4 If the maximum storage height that the building will permit exceeds 12 ft (3.7 m), [the sprinkler system shall be designed for the requirements for] Class IV commodities piled to the maximum height permitted by building construction. *(See Sections 7-3 and 7-4 of NFPA 13.)* (**307:** 4-4.3)

7-10.18.5 If racks or shelving are present or likely to be present, [the sprinkler system shall be designed for the requirements for] Class IV commodities. Protection in warehouses for the long-term storage of specific commodities shall be designed for the specific use. *(See Sections 7-3 and 7-4 of NFPA 13.)*

Exception: Buildings not exceeding 5000 ft² (465 m²) total floor area.

(**307:** 4-4.4)

7-10.19 Cleanrooms.

7-10.19.1 See NFPA 318, *Standard for the Protection of Cleanrooms*, for applicable terms not defined in Chapter 1.

7-10.19.2* Automatic sprinklers for cleanrooms or clean zones shall be hydraulically designed for a density of 0.2 gpm/ft² (8.2 mm/min) over a design area of 3000 ft² (278.8 m²). (**318:** 2-1.2.2)

7-10.19.3 Automatic sprinkler protection shall be designed and installed in the plenum and interstitial space above cleanrooms for a density of 0.2 gpm/ft² (8.2 mm/min) over a design area of 3000 ft² (278.8 m²). (**318:** 2-1.2.6)

7-10.19.4* 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. (**318:** 2-1.2.7.1)

7-10.20 Aircraft Hangars. See NFPA 409, *Standard on Aircraft Hangars*, for sprinkler system discharge criteria pertaining to the protection of aircraft hangars.

7-10.21 Airport Terminal Buildings, Fueling Ramp Drainage, and Loading.

7-10.21.1 See NFPA 415, *Standard on Airport Terminal Buildings, Fueling Ramp Drainage, and Loading Walkways*, for applicable terms not defined in Chapter 1.

7-10.21.2 Sprinkler System Design.

7-10.21.2.1 Passenger handling areas [in airport terminal buildings] shall be classified as ordinary hazard, Group 1 occupancy for the purpose of sprinkler system design. (**415:** 2-5.1.1)

7-10.21.2.2* Other areas of the airport terminal building shall be classified in accordance with Chapter 2 of NFPA 13, based on the occupancy of the area. (**415:** 2-5.1.2)

7-10.21.3 Sprinkler System Water Supply. Water supply from public or private sources shall be adequate to supply maximum calculated sprinkler demand plus a minimum of 500 gpm (1893 L/min) for hose streams. The supply shall be available at the rate specified for a period of at least 1 hour. (**415:** 2-5.5)

7-10.22 Aircraft Engine Test Facilities.

7-10.22.1 See NFPA 423, *Standard for Construction and Protection of Aircraft Engine Test Facilities*, for applicable terms not defined in Chapter 1.

7-10.22.2* In engine test cells, the minimum design discharge density shall be 0.5 gpm/ft² (20.4 mm/min) of protected area. (**423:** 5-6.3)

7-10.22.3 In engine test cells, water supplies shall be capable of meeting the largest demand at the design rate plus hose stream demand for a period of 30 minutes. Hose stream demand shall be a minimum of 250 gpm (946 L/min). The hydraulic calculation and the water supply shall be based on the assumption that all sprinklers in the test cell are operating simultaneously. (**423:** 5-6.4)

7-10.23 Liquid and Solid Oxidizers.

7-10.23.1 See NFPA 430, *Code for the Storage of Liquid and Solid Oxidizers*, for applicable terms not defined in Chapter 1.

Table 7-10.23.5.1 Sprinkler Protection for Class 2 Oxidizers

	Ceiling Sprinklers						
	Storage Height		Density		Area of Application		
Type of Storage	ft	m	gpm/ft²	mm/min	ft²	m²	In-Rack Sprinklers
Palletized	8	2.4	0.20	8.2	3750	348	—
Bulk	12	3.7	0.35	14.3	3750	348	—
Rack	12	3.7	0.20	8.2	3750	348	One line above each level of
	16	4.9	0.30	12.2	2000	186	storage except the top level

(**430:** Table 4-4.1)

Table 7-10.23.6.1 Sprinkler Protection for Class 3 Oxidizers

Type of Storage	Storage Height		Density		Area of Application		In-Rack Sprinklers
	ft	m	gpm/ft²	mm/min	ft²	m²	
Palletized	5	1.5	0.35	14.3	5000	465	—
Bulk	10	3	0.65	26.5	5000	465	—
Rack	10	3	0.35	14.3	5000	465	1 level at midpoint of rack

(**430:** Table 5-4.1)

7-10.23.2 Only wet pipe sprinkler systems shall be employed for protection of buildings or areas containing Class 2 or Class 3 oxidizers. (**430:** 2-11.3)

7-10.23.3 Sprinkler System Water Supplies.

7-10.23.3.1 Water supplies shall be adequate for the protection of the oxidizer storage by hose streams and automatic sprinklers. The water system shall be capable of providing not less than 750 gpm (2840 L/min) where protection is by means of hose streams, or 500 gpm (1890 L/min) for hose streams in excess of the automatic sprinkler water demand. (**430:** 2-11.4.1)

7-10.23.3.2 Duration of the water supply shall be a minimum of 2 hours. (**430:** 2-11.4.2)

7-10.23.4 Class 1 Oxidizers. Class I oxidizers in noncombustible or combustible containers (paper bags or noncombustible containers with removable combustible liners) shall be designated as a Class 1 commodity; as a Class 2 commodity where contained in fiber packs or noncombustible containers in combustible packaging; and as a Class 3 commodity where contained in plastic containers. (**430:** 3-3.2)

7-10.23.5 Class 2 Oxidizers.

7-10.23.5.1* Sprinkler protection for Class 2 oxidizers shall be designed in accordance with Table 7-10.23.5.1. (**430:** 4-4.1)

7-10.23.5.2 Storage Protection with In-Rack Sprinklers. In-rack sprinklers shall be designed to provide 30 psi (2.1 bar) on the hydraulically most remote six sprinklers on each level. (**430:** 4-4.4, 4-4.4.1)

7-10.23.6 Class 3 Oxidizers.

7-10.23.6.1* Sprinkler protection for Class 3 oxidizers shall be designed in accordance with Table 7-10.23.6.1. (**430:** 5-4.1)

7-10.23.6.2 Storage Protection with In-Rack Sprinklers. In-rack sprinklers shall be designed to provide 30 psi (2.1 bar) on the hydraulically most remote six sprinklers on each level. (**430:** 5-4.4, 5-4.4.1)

7-10.23.7 Class 4 Oxidizers. Sprinkler protection for Class 4 oxidizers shall be installed on a deluge sprinkler system to provide water density of 0.35 gpm (14.3 mm/min) over the entire storage area. (**430:** 6-4.1)

7-10.24 Storage of Organic Peroxide Formulations.

7-10.24.1 See NFPA 432, *Code for the Storage of Organic Peroxide Formulations*, for applicable terms not defined in Chapter 1.

7-10.24.2 Where [automatic sprinkler systems are required per NFPA 432, *Code for the Storage of Organic Peroxide Formulations*, they] shall provide the following discharge densities:

Class I [organic peroxides] — 0.5 gpm/ft² (20. 4 mm/min)

Class II [organic peroxides] — 0.4 gpm/ft² (16.3 mm/min)

Class III [organic peroxides] — 0.3 gpm/ft (12.2 mm/min)

Class IV [organic peroxides] — 0.25 gpm/ft² (10.2 mm/min) (**432:** 2-8.2)

7-10.24.2.1 The system shall be designed to provide the required density over a 3000-ft² (279-m²) area for areas protected by a wet pipe sprinkler system or 3900 ft² (363 m²) for areas protected by a dry pipe sprinkler system. The entire area of any building of less than 3000 ft² (279 m²) shall be used as the area of application. (**432:** 2-8.2.1)

7-10.24.3 Sprinkler System Water Supply. Water supplies for automatic sprinkler systems, fire hydrants, and so forth, shall be capable of supplying the anticipated demand for at least 90 minutes. (**432:** 2-8.3)

7-10.24.4 Where automatic sprinkler systems are required for Class I organic peroxide formulations in quantities exceeding 2000 lb (908 kg) in detached storage, per NFPA 432, *Code for the Storage of Organic Peroxide Formulations*, automatic sprinkler protection shall be of the deluge type. (**432:** 5-5.2)

7-10.25 Organic Peroxide Formulations.

7-10.25.1 See NFPA 432, *Code for the Storage of Organic Peroxide Formulations*, for applicable terms not defined in Chapter 1.

7-10.25.2 Automatic sprinkler systems for the protection of storage of organic peroxide formulations shall provide the following discharge densities:

Class I — 0.5 gpm/ft² (20.4 mm/min)

Class II — 0.4 gpm/ft² (16.3 mm/min)

Class III — 0.3 gpm/ft² (12.2 mm/min)

Class IV — 0.25 gpm/ft² (10.2 mm/min)

7-10.25.3 The system shall be designed to provide the required density over a 3000 ft² (280 m²) area for areas protected by a wet pipe sprinkler system or 3900 ft² (360 m²) for areas protected by a dry pipe sprinkler system. The entire area of any building of less than 3000 ft² (280 m²) shall be used as the area of application.

7-10.26 Light Water Nuclear Power Plants.

7-10.26.1 See NFPA 803, *Standard for Fire Protection for Light Water Nuclear Power Plants*, for applicable terms not defined in Chapter 1.

7-10.26.2* The yard mains shall be looped and shall be of sufficient size to meet the flow requirements specified in Section 7-10.26.3 of NFPA 13. (**803:** 11-2)

7-10.26.3 The water supply for the permanent fire protection installation shall be based on the maximum automatic sprinkler system demand, with simultaneous flow of 750 gpm at grade (2835 L/min) for hose streams and the shortest portion of the fire loop main out of service. (**803:** 12-4)

7-10.27 Advanced Light Water Reactor Electric Generating Plants.

7-10.27.1 See NFPA 804, *Standard for Fire Protection for Advanced Light Water Reactor Electric Generating Plants*, for applicable terms not defined in Chapter 1.

7-10.27.2* Sprinkler System Water Supply. The fire water supply shall be calculated on the basis of the largest expected flow rate for a period of 2 hours, but shall not be less than 300,000 gal (1,135,500 L). This flow rate shall be based on 500 gpm (1892.5 L/min) for manual hose streams plus the largest design demand of any sprinkler system. The fire water supply shall be capable of delivering this design demand with the hydraulically least demanding portion of fire main loop out of service. (**804:** 7-2.1)

7-10.27.3 Yard Mains. The underground yard fire main loop shall be installed to furnish anticipated water requirements. The type of pipe and water treatment shall be design considerations, with tuberculation as one of the parameters. Means for inspecting and flushing the systems shall be provided. (**804:** 7-4.1)

7-10.27.4 Cable Tunnels. (**804:** 8-4.2)

7-10.27.4.1 Automatic sprinkler systems shall be designed for a density of 0.3 gpm/ft^2 (12.2 mm/min) for the most remote 100 linear feet (30.5 linear meters) of cable tunnel up to the most remote 2500 ft^2 (232.2 m^2). (**804:** 8-4.2.2.1)

7-10.27.4.2 Deluge sprinkler systems or deluge spray systems shall be zoned to limit the area of protection to that which the drainage system can handle with any two adjacent systems actuated. The systems shall be hydraulically designed with each zone calculated with the largest adjacent zone flowing. (**804:** 8-4.2.2.3)

7-10.27.5* Beneath Turbine Generator Operating Floor. [When automatic sprinkler systems are provided per NFPA 804] all areas beneath the turbine generator operating floor shall be protected by an automatic sprinkler or foam-water sprinkler system. The sprinkler system beneath the turbine generator shall take into consideration obstructions from structural members and piping and shall be designed to a minimum density of 0.3 gpm/ft^2 (12.2 mm/min) over a minimum application of 5000 ft^2 (464.5 m^2). (**804:** 8-8.2, 8-8.2.1)

7-10.27.6* Turbine Generator Bearings. (**804:** 8-8.3)

7-10.27.6.1 Lubricating oil lines above the turbine operating floor shall be protected with an automatic sprinkler system covering those areas subject to oil accumulation, including the area within the turbine lagging (skirt). The automatic sprinkler system shall be designed to a minimum density of 0.30 gpm/ft^2 (12.2 mm/min). (**804:** 8-8.4)

7-10.27.6.2 If shaft-driven ventilation systems are used, an automatic preaction sprinkler system providing a density of 0.3 gpm/ft^2 (12.2 mm/min) over the entire area shall be provided. (**804:** 8-8.6)

7-10.27.7 Standby Emergency Diesel Generators and Combustion Turbines. Sprinkler and water spray protection systems shall be designed for a 0.25-gpm/ft^2 (10.2-mm/min) density over the entire area. (**804:** 8-9.2)

7-10.27.8 Fire Pump Room/House. If sprinkler and water spray systems are provided for fire pump houses, they shall be designed for a minimum density of 0.25 gpm/ft^2 (10.2 mm/min) over the entire fire area. (**804:** 8-22)

7-10.27.9 Oil-Fired Boilers. Sprinkler and water spray systems shall be designed for a minimum density of 0.25 gpm/ft^2 (10.2 mm/min) over the entire area. (**804:** 8-24.2)

7-10.28* Electric Generating Plants and High-Voltage Direct Current Converter Stations.

7-10.29* Hydroelectric Generating Plants.

7-10.30* Fire Protection in Places of Worship.

7-11 In-Rack Sprinklers. In-rack sprinklers mandated by this standard shall meet the requirements of this section.

7-11.1 In-rack sprinklers shall operate at a minimum of 15 psi (1 bar).

7-11.2 Water Demand. Where one level of in-rack sprinklers is installed for miscellaneous storage, water demand shall be based on simultaneous operation of the hydraulically most demanding four adjacent sprinklers.

Chapter 8 Plans and Calculations

8-1* Working Plans.

8-1.1* Working plans shall be submitted for approval to the authority having jurisdiction before any equipment is installed or remodeled. Deviation from approved plans shall require permission of the authority having jurisdiction.

8-1.1.1 Working plans shall be drawn to an indicated scale, on sheets of uniform size, with a plan of each floor, and shall show those items from the following list that pertain to the design of the system.

(1) Name of owner and occupant.
(2) Location, including street address.
(3) Point of compass.
(4) Full height cross section, or schematic diagram, including structural member information if required for clarity and including ceiling construction and method of protection for nonmetallic piping.
(5) Location of partitions.
(6) Location of fire walls.
(7) Occupancy class of each area or room.
(8) Location and size of concealed spaces, closets, attics, and bathrooms.
(9) Any small enclosures in which no sprinklers are to be installed.
(10) Size of city main in street and whether dead end or circulating; if dead end, direction and distance to nearest circulating main; and city main test results and system elevation relative to test hydrant *(see A-9-2.1)*.
(11) Other sources of water supply, with pressure or elevation.
(12) Make, type, model, and nominal K-factor of sprinklers.
(13) Temperature rating and location of high-temperature sprinklers.
(14) Total area protected by each system on each floor.

(15) Number of sprinklers on each riser per floor.
(16) Total number of sprinklers on each dry pipe system, preaction system, combined dry pipe-preaction system, or deluge system.
(17) Approximate capacity in gallons of each dry pipe system.
(18) Pipe type and schedule of wall thickness.
(19) Nominal pipe size and cutting lengths of pipe (or center-to-center dimensions). Where typical branch lines prevail, it shall be necessary to size only one typical line.
(20) Location and size of riser nipples.
(21) Type of fittings and joints and location of all welds and bends. The contractor shall specify on drawing any sections to be shop welded and the type of fittings or formations to be used.
(22) Type and locations of hangers, sleeves, braces, and methods of securing sprinklers when applicable.
(23) All control valves, check valves, drain pipes, and test connections.
(24) Make, type, model, and size of alarm or dry pipe valve.
(25) Make, type, model, and size of preaction or deluge valve.
(26) Kind and location of alarm bells.
(27) Size and location of standpipe risers, hose outlets, hand hose, monitor nozzles, and related equipment.
(28) Private fire service main sizes, lengths, locations, weights, materials, point of connection to city main; the sizes, types and locations of valves, valve indicators, regulators, meters, and valve pits; and the depth that the top of the pipe is laid below grade.
(29) Piping provisions for flushing.
(30) Where the equipment is to be installed as an addition to an existing system, enough of the existing system indicated on the plans to make all conditions clear.
(31) For hydraulically designed systems, the information on the hydraulic data nameplate.
(32) A graphic representation of the scale used on all plans.
(33) Name and address of contractor.
(34) Hydraulic reference points shown on the plan that correspond with comparable reference points on the hydraulic calculation sheets.
(35) The minimum rate of water application (density), the design area of water application, in-rack sprinkler demand, and the water required for hose streams both inside and outside.
(36) The total quantity of water and the pressure required noted at a common reference point for each system.
(37) Relative elevations of sprinklers, junction points, and supply or reference points.
(38) If room design method is used, all unprotected wall openings throughout the floor protected.
(39) Calculation of loads for sizing and details of sway bracing.
(40) The setting for pressure-reducing valves.
(41) Information about backflow preventers (manufacturer, size, type).
(42) Information about antifreeze solution used (type and amount).
(43) Size and location of hydrants, showing size and number of outlets and if outlets are to be equipped with independent gate valves. Whether hose houses and equipment are to be provided, and by whom, shall be indicated. Static and residual hydrants that were used in flow tests shall be shown.
(44) Size, location, and piping arrangement of fire department connections.

8-1.1.2 The working plan submittal shall include the manufacturer's installation instructions for any specially listed equipment, including descriptions, applications, and limitations for any sprinklers, devices, piping, or fittings.

8-1.1.3* Working Plans for Automatic Sprinkler Systems with Non-Fire Protection Connections. Special symbols shall be used and explained for auxiliary piping, pumps, heat exchangers, valves, strainers, and the like, clearly distinguishing these devices and piping runs from those of the sprinkler system. Model number, type, and manufacturer's name shall be identified for each piece of auxiliary equipment.

8-2 Water Supply Information.

8-2.1 Water Supply Capacity Information. The following information shall be included:

(1) Location and elevation of static and residual test gauge with relation to the riser reference point
(2) Flow location
(3) Static pressure, psi (bar)
(4) Residual pressure, psi (bar)
(5) Flow, gpm (L/min)
(6) Date
(7) Time
(8) Test conducted by or information supplied by
(9) Other sources of water supply, with pressure or elevation

8-2.2 Water Supply Treatment Information. The following information shall be included where required by 9-1.5:

(1) Type of condition that requires treatment
(2) Type of treatment needed to address the problem
(3) Details of treatment plan

8-3 Hydraulic Calculation Forms.

8-3.1 General. Hydraulic calculations shall be prepared on form sheets that include a summary sheet, detailed worksheets, and a graph sheet. *[See copies of typical forms in Figures A-8-3.2(a), A-8-3.3, and A-8-3.4.]*

8-3.2* Summary Sheet. The summary sheet shall contain the following information, where applicable:

(1) Date
(2) Location
(3) Name of owner and occupant
(4) Building number or other identification
(5) Description of hazard
(6) Name and address of contractor or designer
(7) Name of approving agency
(8) System design requirements, as follows:
    a. Design area of water application, ft^2 (m^2)
    b. Minimum rate of water application (density), gpm/ft^2 (mm/min)
    c. Area per sprinkler, ft^2 (m^2)
(9) Total water requirements as calculated, including allowance for inside hose, outside hydrants, and water curtain and exposure sprinklers
(10) Allowance for in-rack sprinklers, gpm (L/min)
(11) Limitations (dimension, flow, and pressure) on extended coverage or other listed special sprinklers

8-3.3* Detailed Worksheets. Detailed worksheets or computer printout sheets shall contain the following information:

(1) Sheet number
(2) Sprinkler description and discharge constant *(K)*
(3) Hydraulic reference points
(4) Flow in gpm (L/min)
(5) Pipe size
(6) Pipe lengths, center-to-center of fittings
(7) Equivalent pipe lengths for fittings and devices
(8) Friction loss in psi/ft (bar/m) of pipe
(9) Total friction loss between reference points
(10) In-rack sprinkler demand balanced to ceiling demand
(11) Elevation head in psi (bar) between reference points
(12) Required pressure in psi (bar) at each reference point
(13) Velocity pressure and normal pressure if included in calculations
(14) Notes to indicate starting points or reference to other sheets or to clarify data shown
(15) *Diagram to accompany gridded system calculations to indicate flow quantities and directions for lines with sprinklers operating in the remote area
(16) Combined K-factor calculations for sprinklers on drops, armovers, or sprigs where calculations do not begin at the sprinkler

8-3.4* Graph Sheet. A graphic representation of the complete hydraulic calculation shall be plotted on semiexponential graph paper ($Q^{1.85}$) and shall include the following:

(1) Water supply curve
(2) Sprinkler system demand
(3) Hose demand (where applicable)
(4) In-rack sprinkler demand (where applicable)

8-4 Hydraulic Calculation Procedures.

8-4.1* General. A calculated system for a building, or a calculated addition to a system in an existing sprinklered building, shall supersede the rules in this standard governing pipe schedules, except that all systems shall continue to be limited by area and pipe sizes shall be no less than 1 in. (25.4 mm) nominal for ferrous piping and $^3/_4$ in. (19 mm) nominal for copper tubing or nonmetallic piping listed for fire sprinkler service. The size of pipe, number of sprinklers per branch line, and number of branch lines per cross main shall otherwise be limited only by the available water supply. However, sprinkler spacing and all other rules covered in this and other applicable standards shall be observed.

8-4.2 Formulas.

8-4.2.1 Friction Loss Formula. Pipe friction losses shall be determined on the basis of the Hazen-Williams formula, as follows:

$$p = \frac{4.52\,Q^{1.85}}{C^{1.85}\,d^{4.87}}$$

where:

p = frictional resistance in psi per foot of pipe
Q = flow in gpm
C = friction loss coefficient
d = actual internal diameter of pipe in inches

For SI units, the following equation shall be used:

$$p_m = 6.05\left(\frac{Q_m^{1.85}}{C^{1.85}\,d_m^{4.87}}\right)10^5$$

where:

p_m = frictional resistance in bar per meter of pipe
Q_m = flow in L/min
C = friction loss coefficient
d_m = actual internal diameter in mm

8-4.2.2 Velocity Pressure Formula. Velocity pressure shall be determined on the basis of the following formula:

$$P_v = \frac{0.001123\,Q^2}{D^4}$$

where:

P_v = velocity pressure in psi
Q = flow in gpm
D = inside diameter in inches

For SI units, 1 in. = 25.4 mm; 1 gal = 3.785 L; 1 psi = 0.0689 bar.

8-4.2.3 Normal Pressure Formula. Normal pressure *(P_n)* shall be determined on the basis of the following formula:

$$P_n = P_t - P_v$$

where:

P_n = normal pressure
P_t = total pressure in psi (bar)
P_v = velocity pressure in psi (bar)

8-4.2.4 Hydraulic Junction Points. Pressures at hydraulic junction points shall balance within 0.5 psi (0.03 bar). The highest pressure at the junction point, and the total flows as adjusted, shall be carried into the calculations.

8-4.3 Equivalent Pipe Lengths of Valves and Fittings.

8-4.3.1 Table 8-4.3.1 shall be used to determine the equivalent length of pipe for fittings and devices unless manufacturer's test data indicate that other factors are appropriate. For saddle-type fittings having friction loss greater than that shown in Table 8-4.3.1, the increased friction loss shall be included in hydraulic calculations. For internal pipe diameters different from Schedule 40 steel pipe, the equivalent feet shown in Table 8-4.3.1 shall be multiplied by a factor derived from the following formula:

$$\left(\frac{\text{Actual inside diameter}}{\text{Schedule 40 steel pipe inside diameter}}\right)^{4.87} = \text{Factor}$$

The factor thus obtained shall be further modified as required by Table 8-4.3.1.

This table shall apply to other types of pipe listed in Table 8-4.3.1 only where modified by factors from 8-4.3.1 and 8-4.3.2.

Table 8-4.3.1 Equivalent Schedule 40 Steel Pipe Length Chart

Fittings and Valves	Fittings and Valves Expressed in Equivalent Feet of Pipe														
	1/2 in.	3/4 in.	1 in.	1 1/4 in.	1 1/2 in.	2 in.	2 1/2 in.	3 in.	3 1/2 in.	4 in.	5 in.	6 in.	8 in.	10 in.	12 in.
45° elbow	—	1	1	1	2	2	3	3	3	4	5	7	9	11	13
90° standard elbow	1	2	2	3	4	5	6	7	8	10	12	14	18	22	27
90° long-turn elbow	0.5	1	2	2	2	3	4	5	5	6	8	9	13	16	18
Tee or cross (flow turned 90°)	3	4	5	6	8	10	12	15	17	20	25	30	35	50	60
Butterfly valve	—	—	—	—	—	6	7	10	—	12	9	10	12	19	21
Gate valve	—	—	—	—	—	1	1	1	1	2	2	3	4	5	6
Swing check*	—	—	5	7	9	11	14	16	19	22	27	32	45	55	65

For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m.
Notes:
1. This table applies to all types of pipe listed in Table 8-4.4.5.
2. Information on 1/2-in. pipe is included in this table only because it is allowed under 5-13.20.2 and 5-13.20.3.
*Due to the variations in design of swing check valves, the pipe equivalents indicated in this table are considered average.

8-4.3.2 Table 8-4.3.1 shall be used with a Hazen-Williams *C* factor of 120 only. For other values of *C*, the values in Table 8-4.3.1 shall be multiplied by the factors indicated in Table 8-4.3.2.

Table 8-4.3.2 *C* Value Multiplier

Value of *C*	100	130	140	150
Multiplying factor	0.713	1.16	1.33	1.51

Note: These factors are based upon the friction loss through the fitting being independent of the *C* factor available to the piping.

8-4.3.3 Specific friction loss values or equivalent pipe lengths for alarm valves, dry pipe valves, deluge valves, strainers, and other devices shall be made available to the authority having jurisdiction.

8-4.3.4 Specific friction loss values or equivalent pipe lengths for listed fittings not in Table 3-5.1 *(see 3-5.2)* shall be used in hydraulic calculations where these losses or equivalent pipe lengths are different from those shown in Table 8-4.3.1.

8-4.4* Calculation Procedure.

8-4.4.1* For all systems the design area shall be the hydraulically most demanding based on the criteria of 7-2.3.

Exception: Special design approaches in accordance with Section 7-9.

8-4.4.1.1 Where the design is based on area/density method, the design area shall be a rectangular area having a dimension parallel to the branch lines at least 1.2 times the square root of the area of sprinkler operation *(A)* used, which shall permit the inclusion of sprinklers on both sides of the cross main. Any fractional sprinkler shall be carried to the next higher whole sprinkler.

Exception: In systems having branch lines with an insufficient number of sprinklers to fulfill the 1.2 $\sqrt{A}$ requirement, the design area shall be extended to include sprinklers on adjacent branch lines supplied by the same cross main.

8-4.4.1.2 Where the design is based on the room design method, the calculation shall be based on the room and communicating space, if any, that is hydraulically the most demanding. *(See 7-2.3.3.)*

8-4.4.2* For gridded systems, the designer shall verify that the hydraulically most demanding area is being used. A minimum of two additional sets of calculations shall be submitted to demonstrate peaking of demand area friction loss when compared to areas immediately adjacent on either side along the same branch lines.

Exception: Computer programs that show the peaking of the demand area friction loss shall be acceptable based on a single set of calculations.

8-4.4.3 System piping shall be hydraulically designed using design densities and areas of operation in accordance with 7-2.3.2.1 or 7-2.3.2.2 as required for the occupancies or hazards involved.

8-4.4.3.1* The density shall be calculated on the basis of floor area of sprinkler operation. The area covered by any sprinkler used in hydraulic design and calculations shall be the horizontal distances measured between the sprinklers on the branch line and between the branch lines in accordance with 5-5.2.1.

8-4.4.3.2* Where sprinklers are installed above and below a ceiling or in a case where more than two areas are supplied from a common set of branch lines, the branch lines and supplies shall be calculated to supply the largest water demand.

8-4.4.4* Each sprinkler in the design area and the remainder of the hydraulically designed system shall discharge at a flow rate at least equal to the stipulated minimum water application rate (density) multiplied by the area of sprinkler operation. Calculations shall begin at the hydraulically most remote sprinkler. Discharge at each sprinkler shall be based on the calculated pressure at that sprinkler.

Exception No. 1: Where the area of application is equal to or greater than the minimum allowable area of Figure 7-2.3.1.2 for the appropriate hazard classification (including a 30 percent increase for dry pipe systems), sprinkler discharge in closets, washrooms, and similar small compartments requiring only one sprinkler shall be permitted to be omitted from hydraulic calculations within the area of application. Sprinklers in these small compartments shall, however, be capable of discharging minimum densities in accordance with Figure 7-2.3.1.2.

Exception No. 2: Where spray sprinklers and large drop sprinklers are provided above and below obstructions such as wide ducts or tables, the water supply for one of the levels of sprinklers shall be permitted to be omitted from the hydraulic ceiling design calculations within the area of application. Where ESFR sprinklers are installed above and below obstructions, the discharge for up to two sprinklers from one of the levels shall be included with those of the other level in the hydraulic calculation.

8-4.4.5 Pipe friction loss shall be calculated in accordance with the Hazen-Williams formula with *C* values from Table 8-4.4.5.

(a) Include pipe, fittings, and devices such as valves, meters, and strainers, and calculate elevation changes that affect the sprinkler discharge.

Exception: Tie-in drain piping shall not be included in the hydraulic calculations.

(b) Calculate the loss for a tee or a cross where flow direction change occurs based on the equivalent pipe length of the piping segment in which the fitting is included. The tee at the top of a riser nipple shall be included in the branch line, the tee at the base of a riser nipple shall be included in the riser nipple, and the tee or cross at a cross main-feed main junction shall be included in the cross main. Do not include fitting loss for straight-through flow in a tee or cross.

(c) Calculate the loss of reducing elbows based on the equivalent feet value of the smallest outlet. Use the equivalent feet value for the standard elbow on any abrupt 90-degree turn, such as the screw-type pattern. Use the equivalent feet value for the long-turn elbow on any sweeping 90-degree turn, such as a flanged, welded, or mechanical joint-elbow type. *(See Table 8-4.3.1.)*

(d) Friction loss shall be excluded for the fitting directly connected to a sprinkler.

(e) Losses through a pressure-reducing valve shall be included based on the normal inlet pressure condition. Pressure loss data from the manufacturer's literature shall be used.

Table 8-4.4.5 Hazen-Williams *C* Values

Pipe or Tube	*C* Value*
Unlined cast or ductile iron	100
Black steel (dry systems including preaction)	100
Black steel (wet systems including deluge)	120
Galvanized (all)	120
Plastic (listed) all	150
Cement-lined cast or ductile iron	140
Copper tube or stainless steel	150
Asbestos cement	140
Concrete	140

*The authority having jurisdiction is permitted to consider other *C* values.

8-4.4.6* Orifice plates or sprinklers of different orifice sizes shall not be used for balancing the system.

Exception No. 1: Sprinklers with different orifice sizes shall be acceptable for special use such as exposure protection, small rooms or enclosures, or directional discharge. (See 1-4.2 for definition of small rooms.)

Exception No. 2: Extended coverage sprinklers with a different orifice size shall be acceptable for part of the protection area where installed in accordance with their listing.

8-4.4.7* When calculating flow from an orifice, the total pressure (P_t) shall be used. Flow from a sprinkler shall be calculated using the nominal K-factor.

Exception: Use of the normal pressure (P_n) calculated by subtracting the velocity pressure from the total pressure shall be permitted. Where the normal pressure is used, it shall be used on all branch lines and cross mains where applicable.

8-4.4.8 Minimum operating pressure of any sprinkler shall be 7 psi (0.5 bar).

Exception: Where higher minimum operating pressure for the desired application is specified in the listing of the sprinkler.

8-5 Pipe Schedules. Pipe schedules shall not be used, except in existing systems and in new systems or extensions to existing systems described in Chapter 7. Water supplies shall conform to 7-2.2.

8-5.1* General. The pipe schedule sizing provisions shall not apply to hydraulically calculated systems. Sprinkler systems having sprinklers with orifices other than $^1/_2$ in. (13 mm) nominal, listed piping material other than that covered in Table 3-3.1, extra hazard, Groups 1 and 2 systems, and exposure protection systems shall be hydraulically calculated.

8-5.1.1 The number of automatic sprinklers on a given pipe size on one floor shall not exceed the number given in 8-5.2, 8-5.3, or 8-5.4 for a given occupancy.

8-5.1.2* Size of Risers. Each system riser shall be sized to supply all sprinklers on the riser on any one floor as determined by the standard schedules of pipe sizes in 8-5.2, 8-5.3, or 8-5.4.

8-5.1.3 Slatted Floors, Large Floor Openings, Mezzanines, and Large Platforms. Buildings having slatted floors or large unprotected floor openings without approved stops shall be treated as one area with reference to pipe sizes, and the feed mains or risers shall be of the size required for the total number of sprinklers.

8-5.1.4 Stair Towers. Stairs, towers, or other construction with incomplete floors, if piped on independent risers, shall be treated as one area with reference to pipe sizes.

8-5.2 Schedule for Light Hazard Occupancies.

8-5.2.1 Branch lines shall not exceed eight sprinklers on either side of a cross main.

Exception: Where more than eight sprinklers on a branch line are necessary, lines shall be permitted to be increased to nine sprinklers by making the two end lengths 1 in. (25.4 mm) and $1^1/_4$ in. (33 mm), respectively, and the sizes thereafter standard. Ten sprinklers shall be permitted to be placed on a branch line, making the two end lengths 1 in. (25.4 mm) and $1^1/_4$ in. (33 mm), respectively, and feeding the tenth sprinkler by a $2^1/_2$-in. (64-mm) pipe.

8-5.2.2 Pipe sizes shall be in accordance with Table 8-5.2.2.

Exception: Each area requiring more sprinklers than the number specified for 3 1/2-in. (89-mm) pipe in Table 8-5.2.2 and without subdividing partitions (not necessarily fire walls) shall be supplied by mains or risers sized for ordinary hazard occupancies.

Table 8-5.2.2 Light Hazard Pipe Schedules

Steel		Copper	
1 in.	2 sprinklers	1 in.	2 sprinklers
1 1/4 in.	3 sprinklers	1 1/4 in.	3 sprinklers
1 1/2 in.	5 sprinklers	1 1/2 in.	5 sprinklers
2 in.	10 sprinklers	2 in.	12 sprinklers
2 1/2 in.	30 sprinklers	2 1/2 in.	40 sprinklers
3 in.	60 sprinklers	3 in.	65 sprinklers
3 1/2 in.	100 sprinklers	3 1/2 in.	115 sprinklers
4 in.	See Section 5-2	4 in.	See Section 5-2

For SI units, 1 in. = 25.4 mm.

8-5.2.3 Where sprinklers are installed above and below ceilings *[see Figures 8-5.2.3(a), (b), and (c)]* and such sprinklers are supplied from a common set of branch lines or separate branch lines from a common cross main, such branch lines shall not exceed eight sprinklers above and eight sprinklers below any ceiling on either side of the cross main. Pipe sizing up to and including 2 1/2 in. (64 mm) shall be as shown in Table 8-5.2.3 utilizing the greatest number of sprinklers to be found on any two adjacent levels.

Exception: Branch lines and cross mains supplying sprinklers installed entirely above or entirely below ceilings shall be sized in accordance with Table 8-5.2.2.

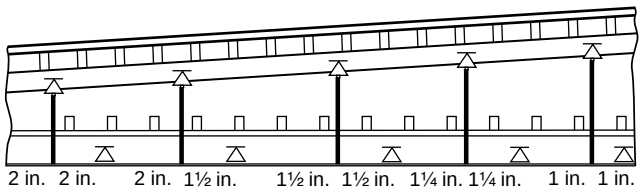
Table 8-5.2.3 Number of Sprinklers above and below a Ceiling

Steel		Copper	
1 in.	2 sprinklers	1 in.	2 sprinklers
1 1/4 in.	4 sprinklers	1 1/4 in.	4 sprinklers
1 1/2 in.	7 sprinklers	1 1/2 in.	7 sprinklers
2 in.	15 sprinklers	2 in.	18 sprinklers
2 1/2 in.	50 sprinklers	2 1/2 in.	65 sprinklers

For SI units, 1 in. = 25.4 mm.

8-5.2.3.1* Where the total number of sprinklers above and below a ceiling exceeds the number specified in Table 8-5.2.3 for 2 1/2-in. (64-mm) pipe, the pipe supplying such sprinklers shall be increased to 3 in. (76 mm) and sized thereafter according to the schedule shown in Table 8-5.2.2 for the number of sprinklers above or below a ceiling, whichever is larger.

Figure 8-5.2.3(a) Arrangement of branch lines supplying sprinklers above and below a ceiling.



For SI units, 1 in. = 25.4 mm.

Figure 8-5.2.3(b) Sprinkler on riser nipple from branch line in lower fire area.

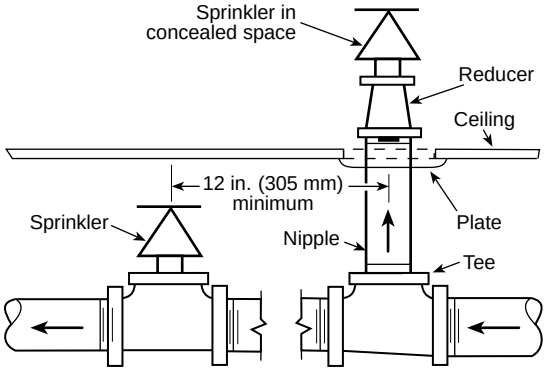
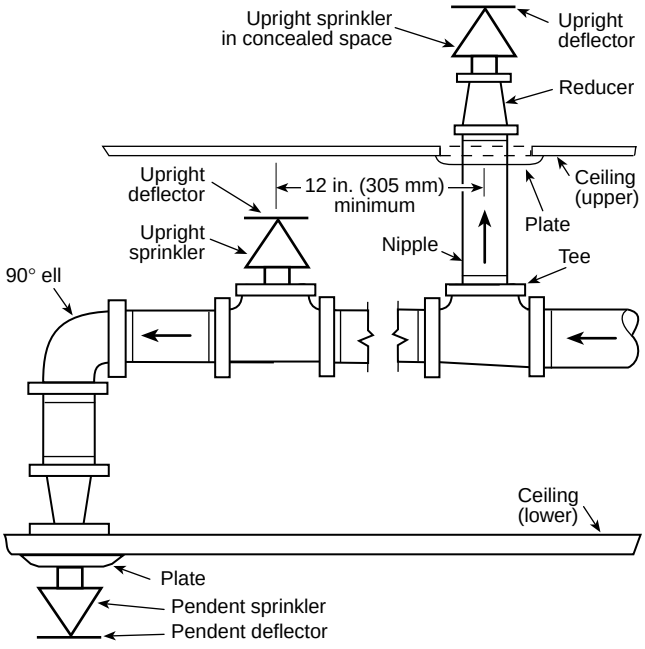


Figure 8-5.2.3(c) Arrangement of branch lines supplying sprinklers above, in between, and below ceilings.



8-5.3 Schedule for Ordinary Hazard Occupancies.

8-5.3.1 Branch lines shall not exceed eight sprinklers on either side of a cross main.

Exception: Where more than eight sprinklers on a branch line are necessary, lines shall be permitted to be increased to nine sprinklers by making the two end lengths 1 in. (25.4 mm) and 1 1/4 in. (33 mm), respectively, and the sizes thereafter standard. Ten sprinklers shall be permitted to be placed on a branch line, making the two end lengths 1 in. (25.4 mm) and 1 1/4 in. (33 mm), respectively, and feeding the tenth sprinkler by a 2 1/2-in. (64-mm) pipe.

8-5.3.2 Pipe sizes shall be in accordance with Table 8-5.3.2(a).

Exception: Where the distance between sprinklers on the branch line exceeds 12 ft (3.7 m) or the distance between the branch lines exceeds 12 ft (3.7 m), the number of sprinklers for a given pipe size shall be in accordance with Table 8-5.3.2(b).

Table 8-5.3.2(a) Ordinary Hazard Pipe Schedule

Steel		Copper	
1 in.	2 sprinklers	1 in.	2 sprinklers
1 1/4 in.	3 sprinklers	1 1/4 in.	3 sprinklers
1 1/2 in.	5 sprinklers	1 1/2 in.	5 sprinklers
2 in.	10 sprinklers	2 in.	12 sprinklers
2 1/2 in.	20 sprinklers	2 1/2 in.	25 sprinklers
3 in.	40 sprinklers	3 in.	45 sprinklers
3 1/2 in.	65 sprinklers	3 1/2 in.	75 sprinklers
4 in.	100 sprinklers	4 in.	115 sprinklers
5 in.	160 sprinklers	5 in.	180 sprinklers
6 in.	275 sprinklers	6 in.	300 sprinklers
8 in.	See Section 5-2	8 in.	See Section 5-2

For SI units, 1 in. = 25.4 mm.

Table 8-5.3.2(b) Number of Sprinklers — Greater than 12-ft (3.7-m) Separations

Steel		Copper	
2 1/2 in.	15 sprinklers	2 1/2 in.	20 sprinklers
3 in.	30 sprinklers	3 in.	35 sprinklers
3 1/2 in.	60 sprinklers	3 1/2 in.	65 sprinklers

For SI units, 1 in. = 25.4 mm.
Note: For other pipe and tube sizes, see Table 8-5.3.2(a).

8-5.3.3 Where sprinklers are installed above and below ceilings and such sprinklers are supplied from a common set of branch lines or separate branch lines supplied by a common cross main, such branch lines shall not exceed eight sprinklers above and eight sprinklers below any ceiling on either side of the cross main. Pipe sizing up to and including 3 in. (76 mm) shall be as shown in Table 8-5.3.3 *[see Figures 8-5.2.3(a), (b), and (c)]* utilizing the greatest number of sprinklers to be found on any two adjacent levels.

Exception: Branch lines and cross mains supplying sprinklers installed entirely above or entirely below ceilings shall be sized in accordance with Tables 8-5.3.2(a) or (b).

Table 8-5.3.3 Number of Sprinklers above and below a Ceiling

Steel		Copper	
1 in.	2 sprinklers	1 in.	2 sprinklers
1 1/4 in.	4 sprinklers	1 1/4 in.	4 sprinklers
1 1/2 in.	7 sprinklers	1 1/2 in.	7 sprinklers
2 in.	15 sprinklers	2 in.	18 sprinklers
2 1/2 in.	30 sprinklers	2 1/2 in.	40 sprinklers
3 in.	60 sprinklers	3 in.	65 sprinklers

For SI units, 1 in. = 25.4 mm.

8-5.3.3.1* Where the total number of sprinklers above and below a ceiling exceeds the number specified in Table 8-5.3.3 for 3-in. (76-mm) pipe, the pipe supplying such sprinklers shall be increased to 3 1/2 in. (89 mm) and sized thereafter according to the schedule shown in Table 8-5.2.2 or Table 8-5.3.2(a) for the number of sprinklers above or below a ceiling, whichever is larger.

Exception: Where the distance between the sprinklers protecting the occupied area exceeds 12 ft (3.7 m) or the distance between the branch lines exceeds 12 ft (3.7 m), the branch lines shall be sized in accordance with either Table 8-5.3.2(b), taking into consideration the sprinklers protecting the occupied area only, or 8-5.3.3, whichever requires the greater size of pipe.

8-5.4* Extra hazard occupancies shall be hydraulically calculated.

Exception: For existing systems, see A-8-5.4.

8-6 Deluge Systems. Open sprinkler and deluge systems shall be hydraulically calculated according to applicable standards.

8-7* Exposure Systems. Exposure sprinklers shall be hydraulically calculated using Table 8-7 and a relative classification of exposures guide number.

8-8 In-Rack Sprinklers.

8-8.1 Pipes to in-rack sprinklers shall be sized by hydraulic calculations.

8-8.2 Water demand of sprinklers installed in racks shall be added to ceiling sprinkler water demand over the same protected area at the point of connection. The demand shall be balanced to the higher pressure.

Table 8-7 Exposure Protection

Section A — Window Sprinklers

Guide Number	Level of Window Sprinkler	Window Sprinkler Orifice Size	Discharge Coefficient (K-factor)	Flow Rate (Q) (gpm)	Application Rate Over 25 ft of Window Area (gpm/ft^2)
1.50 or less	Top 2 levels	$^3/_8$ in. (9.5 mm)	2.8	7.4	0.30
	Next lower 2 levels	$^5/_{16}$ in. (7.9 mm)	1.9	5.0	0.20
	Next lower 2 levels	$^1/_4$ in. (6.4 mm)	1.4	3.7	0.15
1.51–2.20	Top 2 levels	$^1/_2$ in. (12.7 mm)	5.6	14.8	0.59
	Next lower 2 levels	$^7/_{16}$ in. (11.1 mm)	4.2	11.1	0.44
	Next lower 2 levels	$^3/_8$ in. (9.5 mm)	2.8	7.4	0.30
2.21–13.15	Top 2 levels	$^5/_8$ in. (15.9 mm)	11.2	29.6	1.18
	Next lower 2 levels	$^{17}/_{32}$ in. (13.5 mm)	8.0	21.2	0.85
	Next lower 2 levels	$^1/_2$ in. (12.7 mm)	5.6	14.8	0.59

Section B — Cornice Sprinklers

Guide Number	Cornice Sprinkler Orifice Size	Application Rate per Lineal Foot (gpm)
1.50 or less	$^3/_8$ in. (9.5 mm)	0.75
1.51–2.20	$^1/_2$ in. (12.7 mm)	1.50
2.21–13.15	$^5/_8$ in. (15.9 mm)	3.00

For SI units, 1 in. = 25.4 mm; 1 gpm = 3.785 L/min; 1 gpm/ft^2 = 40.76 mm/min.

Chapter 9 Water Supplies

9-1 General.

9-1.1 Number of Supplies. Every automatic sprinkler system shall have at least one automatic water supply.

9-1.2 Capacity. Water supplies shall be capable of providing the required flow and pressure for the required duration as specified in Chapter 7.

9-1.3 Size of Fire Mains. No pipe smaller than 6 in. (152.4 mm) in diameter shall be installed as a private service main.

Exception: For mains that do not supply hydrants, sizes smaller than 6 in. (152.4 mm) shall be permitted to be used subject to the following restrictions:

(a) The main supplies only automatic sprinkler systems, open sprinkler systems, water spray fixed systems, foam systems, or Class II standpipe systems.

(b) Hydraulic calculations show that the main will supply the total demand at the appropriate pressure. Systems that are not hydraulically calculated shall have a main at least as large as the riser.

9-1.4 Underground Supply Pipe. For pipe schedule systems, the underground supply pipe shall be at least as large as the system riser.

9-1.5 Water Supply Treatment. In areas with water supplies known to have contributed to microbiologically influenced corrosion (MIC) of sprinkler system piping, water supplies shall be tested and appropriately treated prior to filling or testing of metallic piping systems.

9-1.6 Arrangement.

9-1.6.1 Connection Between Underground and Aboveground Piping. The connection between the system piping and underground piping shall be made with a suitable transition piece and shall be properly strapped or fastened by approved devices. The transition piece shall be protected against possible damage from corrosive agents, solvent attack, or mechanical damage.

9-1.6.2* Connection Passing Through or Under Foundation Walls. When system piping pierces a foundation wall below grade or is located under the foundation wall, clearance shall be provided to prevent breakage of the piping due to building settlement.

9-1.7* Meters. Where meters are required by other authorities, they shall be listed.

9-1.8* Connection from Waterworks System. Where connections are made from public waterworks systems, it might be

necessary to guard against possible contamination of the public supply. The requirements of the public health authority having jurisdiction shall be determined and followed. Where equipment is installed to guard against possible contamination of the public water system, such equipment and devices shall be listed for fire protection service.

9-2 Types.

9-2.1* Connections to Water Works Systems. A connection to a reliable water works system shall be an acceptable water supply source. The volume and pressure of a public water supply shall be determined from waterflow test data. An adjustment to the waterflow test data to account for daily and seasonal fluctuations, possible interruption by flood or ice conditions, large simultaneous industrial use, future demand on the water supply system, or any other condition that could affect the water supply shall be made as appropriate.

9-2.2* Pumps. A single automatically controlled fire pump installed in accordance with NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, shall be an acceptable water supply source.

9-2.3 Pressure Tanks.

9-2.3.1 Acceptability.

9-2.3.1.1 A pressure tank installed in accordance with NFPA 22, *Standard for Water Tanks for Private Fire Protection*, shall be an acceptable water supply source.

9-2.3.1.2 Pressure tanks shall be provided with an approved means for automatically maintaining the required air pressure. Where a pressure tank is the sole water supply, there shall also be provided an approved trouble alarm to indicate low air pressure and low water level with the alarm supplied from an electrical branch circuit independent of the air compressor.

9-2.3.1.3 Pressure tanks shall not be used to supply other than sprinklers and hand hose attached to sprinkler piping.

9-2.3.2 Capacity. In addition to the requirements of 9-1.2, the water capacity of a pressure tank shall include the extra capacity needed to fill dry pipe or preaction systems where installed. The total volume shall be based on the water capacity plus the air capacity required by 9-2.3.3.

9-2.3.3* Water Level and Air Pressure. Pressure tanks shall be kept with a sufficient supply of water to meet the demand of the fire protection system as calculated in Chapter 8 for the duration required by Chapter 7. The pressure shall be sufficient to push all of the water out of the tank while maintaining the necessary residual pressure (required by Chapter 8) at the top of the system.

9-2.4 Gravity Tanks. An elevated tank installed in accordance with NFPA 22, *Standard for Water Tanks for Private Fire Protection*, shall be an acceptable water supply source.

9-2.5 Penstocks or Flumes, Rivers, or Lakes. Water supply connections from penstocks, flumes, rivers, lakes, or reservoirs shall be arranged to avoid mud and sediment and shall be provided with approved double removable screens or approved strainers installed in an approved manner.

Chapter 10 Systems Acceptance

10-1 Approval of Sprinkler Systems and Private Fire Service Mains. The installing contractor shall do the following:

(1) Notify the authority having jurisdiction and owner's representative of the time and date testing will be performed
(2) Perform all required acceptance tests *(see Section 10-2)*
(3) Complete and sign the appropriate contractor's material and test certificate(s) *[see Figures 10-1(a) and 10-1(b)]*

Figure 10-1(a) Contractor's material and test certificate for aboveground piping.

Contractor's Material and Test Certificate for Aboveground Piping

PROCEDURE

Upon completion of work, inspection and tests shall be made by the contractor's representative and witnessed by an owner's representative. All defects shall be corrected and system left in service before contractor's personnel finally leave the job.

A certificate shall be filled out and signed by both representatives. Copies shall be prepared for approving authorities, owners, and contractor. It is understood the owner's representative's signature in no way prejudices any claim against contractor for faulty material, poor workmanship, or failure to comply with approving authority's requirements or local ordinances.

Property name	Date
Property address	

Plans

Accepted by approving authorities (names)

Address

Installation conforms to accepted plans ☐ Yes ☐ No

Equipment used is approved ☐ Yes ☐ No
If no, explain deviations

Instructions

Has person in charge of fire equipment been instructed as to location of control valves and care and maintenance of this new equipment? ☐ Yes ☐ No
If no, explain?

Have copies of the following been left on the premises? ☐ Yes ☐ No

1. System components instructions ☐ Yes ☐ No
2. Care and maintenance instructions ☐ Yes ☐ No
3. NFPA 25 ☐ Yes ☐ No

Location of system

Supplies buildings

Sprinklers

Make	Model	Year of manufacture	Orifice size	Quantity	Temperature rating

Pipe and fittings

Type of pipe _____

Type of fittings _____

Alarm valve or flow indicator

Alarm device			Maximum time to operate through test connection	
Type	Make	Model	Minutes	Seconds

Dry pipe operating test

Dry valve			Q. O. D.		
Make	Model	Serial no.	Make	Model	Serial no.

	Time to trip through test connection[1]		Water pressure	Air pressure	Trip point air pressure	Time water reached test outlet[1]		Alarm operated properly	
	Minutes	Seconds	psi	psi	psi	Minutes	Seconds	Yes	No
Without Q.O.D.									
With Q.O.D.									

If no, explain

[1] Measured from time inspector's test connection is opened

Figure 10-1(a) ***(Continued)***

Deluge and preaction valves

Operation ☐ Pneumatic ☐ Electric ☐ Hydraulics

Piping supervised ☐ Yes ☐ No | Detecting media supervised ☐ Yes ☐ No

Does valve operate from the manual trip, remote, or both control stations? ☐ Yes ☐ No

Is there an accessible facility in each circuit for testing? ☐ Yes ☐ No | If no, explain

Make	Model	Does each circuit operate supervision loss alarm?		Does each circuit operate valve release?		Maximum time to operate release	
		Yes	No	Yes	No	Minutes	Seconds

Pressure reducing valve test

Location and floor	Make and model	Setting	Static pressure		Residual pressure (flowing)		Flow rate
			Inlet (psi)	Outlet (psi)	Inlet (psi)	Outlet (psi)	Flow (gpm)

Test description

Hydrostatic: Hydrostatic tests shall be made at not less than 200 psi (13.6 bar) for 2 hours or 50 psi (3.4 bar) above static pressure in excess of 150 psi (10.2 bar) for 2 hours. Differential dry-pipe valve clappers shall be left open during the test to prevent damage. All aboveground piping leakage shall be stopped.

Pneumatic: Establish 40 psi (2.7 bar) air pressure and measure drop, which shall not exceed 1½ psi (0.1 bar) in 24 hours. Test pressure tanks at normal water level and air pressure and measure air pressure drop, which shall not exceed 1½ psi (0.1 bar) in 24 hours.

Tests

All piping hydrostatically tested at _____ psi (___ bar) for ____ hours ☐ Yes ☐ No | If no, state reason

Dry piping pneumatically tested ☐ Yes ☐ No

Equipment operates properly ☐ Yes ☐ No

Do you certify as the sprinkler contractor that additives and corrosive chemicals, sodium silicate or derivatives of sodium silicate, brine, or other corrosive chemicals were not used for testing systems or stopping leaks? ☐ Yes ☐ No

Drain test | Reading of gauge located near water supply test connection: _____ psi (____ bar) | Residual pressure with valve in test connection open wide: _____ psi (____ bar)

Underground mains and lead in connections to system risers flushed before connection made to sprinkler piping

Verified by copy of the U Form No. 85B ☐ Yes ☐ No | Other Explain

flushed by installer of underground sprinkler piping ☐ Yes ☐ No

If powder-driven fasteners are used in concrete, has representative sample testing be satisfactorily completed? ☐ Yes ☐ No | If no, explain

Blank testing gaskets

Number used	Locations	Number removed

Welding

Welding piping ☐ Yes ☐ No

If yes. . .

Do you certify as the sprinkler contractor that welding procedures comply with the requirements of at least AWS B2.1? ☐ Yes ☐ No

Do you certify that the welding was performed by welders qualified in compliance with the requirements of at least AWS B2.1? ☐ Yes ☐ No

Do you certify that the welding was carried out in compliance with a documented quality control procedure to ensure that all discs are retrieved, that openings in piping are smooth, that slag and other welding residue are removed, and that the internal diameters of piping are not penetrated? ☐ Yes ☐ No

Cutouts (discs)

Do you certify that you have a control feature to ensure that all cutouts (discs) are retrieved? ☐ Yes ☐ No

Figure 10-1(a) ***(Continued)***

Hydraulic data nameplate	Nameplate provided ☐ Yes ☐ No	If no, explain	
Remarks	Date left in service with all control valves open		
Signatures	Name of sprinkler contractor		
	Tests witnessed by		
	For property owner (signed)	Title	Date
	For sprinkler contractor (signed)	Title	Date
Additional explanations and notes			

Figure 10-1(b) Contractor's material and test certificate for underground piping.

Contractor's Material and Test Certificate for Underground Piping

PROCEDURE

Upon completion of work, inspection and tests shall be made by the contractor's representative and witnessed by an owner's representative. All defects shall be corrected and system left in service before contractor's personnel finally leave the job.

A certificate shall be filled out and signed by both representatives. Copies shall be prepared for approving authorities, owners, and contractor. It is understood the owner's representative's signature in no way prejudices any claim against contractor for faulty material, poor workmanship, or failure to comply with approving authority's requirements or local ordinances.

Property name		Date
Property address		
Plans	Accepted by approving authorities (names)	
	Address	
	Installation conforms to accepted plans	☐ Yes ☐ No
	Equipment used is approved If no, state deviations	☐ Yes ☐ No
Instructions	Has person in charge of fire equipment been instructed as to location of control valves and care and maintenance of this new equipment? If no, explain	☐ Yes ☐ No
	Have copies of appropriate instructions and care and maintenance charts been left on premises? If no, explain	☐ Yes ☐ No
Location	Supplies buildings	
Underground pipes and joints	Pipe types and class	Type joint
	Pipe conforms to _____ standard Fittings conforms to _____ standard If no, explain	☐ Yes ☐ No ☐ Yes ☐ No
	Joints needed anchorage clamped, strapped, or blocked in accordance with _____ standard If no, explain	☐ Yes ☐ No
Test description	Flushing: Flow the required rate until water is clear as indicated by no collection of foreign material in burlap bags at outlets such as hydrants and blow-offs. Flush at flows not less than 390 gpm (1476 L/min) for 4-in. pipe, 880 gpm (3331 L/min) for 6-in. pipe, 1560 gpm (5905 L/min) for 8-in. pipe, 2440 gpm (9235 L/min) for 10-in. pipe, and 3520 gpm (13,323 L/min) for 12-in. pipe. When supply cannot produce stipulated flow rates, obtain maximum available. Hydrostatic: Hydrostatic tests shall be made at not less than 200 psi (13.8 bar) for 2 hours or 50 psi (3.4 bar) above static pressure in excess of 150 psi (10.3 bar) for 2 hours. Leakage: New pipe laid with rubber gasketed joints shall, if the workmanship is satisfactory, have little or no leakage at the joints. The amount of leakage at the joints shall not exceed 2 quarts per hour (1.89 L/hr) per 100 joints irrespective of pipe diameter. The leakage shall be distributed over all joints. If such leakage occurs at a few joints, the installation shall be considered unsatisfactory and necessary repairs made. The amount of allowable leakage specified above can be increased by 1 fluid ounce per inch valve diameter per hr. (30 mL/25 mm/hr) for each metal seated valve isolating the test section. If dry barrel hydrants are tested with the main valve open so the hydrants are under pressure, an additional 5 ounces per minute (150 mL/min) leakage is permitted for each hydrant.	
Flushing tests	New underground piping flushed according to _____ standard by (company) If no, explain	☐ Yes ☐ No
	How flushing flow was obtained ☐ Public water ☐ Tank or reservoir ☐ Fire pump	Through what type opening ☐ Hydrant butt ☐ Open pipe
	Lead-ins flushed according to _____ standard by (company) If no, explain	☐ Yes ☐ No
	How flushing flow was obtained ☐ Public water ☐ Tank or reservoir ☐ Fire pump	Through what type opening ☐ Y connection to flange and spigot ☐ Open pipe

Figure 10-1(b) ***(Continued)***

Hydrostatic test	All new underground piping hydrostatically tested at _____ psi for _____ hours		Joints covered ☐ Yes ☐ No
Leakage test	Total amount of leakage measured _____ gallons _____ hours		
	Allowable leakage _____ gallons _____ hours		
Hydrants	Number installed	Type and make	All operate satisfactorily ☐ Yes ☐ No
Control valves	Water control valves left wide open If no, state reason		☐ Yes ☐ No
	Hose threads of fire department connections and hydrants interchangeable with those of fire department answering alarm		☐ Yes ☐ No
Remarks	Date left in service		
Signatures	Name of installing contractor		
	Tests witnessed by		
	For property owner (signed)	Title	Date
	For installing contractor (signed)	Title	Date
Additional explanation and notes			

10-2 Acceptance Requirements.

10-2.1* Flushing of Piping. Fire service mains (from the water supply to the system riser) and lead-in connections to system risers shall be completely flushed before connection is made to sprinkler piping. The flushing operation shall be continued for a sufficient time to ensure thorough cleaning. The minimum rate of flow shall be not less than one of the following:

(1) The hydraulically calculated water demand rate of the system including any hose requirements
(2) That flow necessary to provide a velocity of 10 ft/sec (3.1 m/sec) *[see Table 10-2.1(2)]*
(3) The maximum flow rate available to the system under fire conditions

10-2.2 Hydrostatic Tests.

10-2.2.1* All piping and attached appurtenances subjected to system working pressure shall be hydrostatically tested at 200 psi (13.8 bar) and shall maintain that pressure without loss for 2 hours. Loss shall be determined by a drop in gauge pressure or visual leakage. The test pressure shall be read from a gauge located at the low elevation point of the system or portion being tested.

Exception No. 1: Portions of systems normally subjected to system working pressures in excess of 150 psi (10.4 bar) shall be tested as described in 10-2.2.1 at a pressure of 50 psi (3.5 bar) in excess of system working pressure.

Exception No. 2: Where cold weather will not permit testing with water, an interim air test shall be permitted to be conducted as described in 10-2.3.

Exception No. 3: Modifications affecting 20 or fewer sprinklers shall not require testing in excess of system working pressure.

Exception No. 4: Where addition or modification is made to an existing system affecting more than 20 sprinklers, the new portion shall be isolated and tested at not less than 200 psi (13.8 bar) for 2 hours.

Exception No. 5: Modifications that cannot be isolated, such as relocated drops, shall not require testing in excess of system working pressure.

Exception No. 6: In buried pipe, leakage shall be permitted as follows:

(a) The amount of leakage at the joints shall not exceed 2 qt/hr (1.89 L/hr) per 100 gaskets or joints, irrespective of pipe diameter.*

(b) The amount of allowable leakage specified in item (a) of this exception shall be permitted to be increased by 1 fluid ounce (30 ml) per inch valve diameter per hour for each metal seated valve isolating the test section.*

(c) If dry barrel hydrants are tested with the main valve open so the hydrants are under pressure, an additional 5 oz/min (150 ml/min) of leakage shall be permitted for each hydrant.

(d) The amount of leakage in buried piping shall be measured at the specified test pressure by pumping from a calibrated container.

Table 10-2.1(2) Flow Required to Produce a Velocity of 10 ft/sec (3 m/sec) in Pipes

Pipe Size		Flow Rate	
in.	mm	gpm	L/min
4	102	390	1476
6	152	880	3331
8	203	1560	5905
10	254	2440	9235
12	305	3520	13323

10-2.2.2 Additives, corrosive chemicals such as sodium silicate or derivatives of sodium silicate, brine, or other chemicals shall not be used while hydrostatically testing systems or for stopping leaks.

10-2.2.3 Piping between the exterior fire department connection and the check valve in the fire department inlet pipe shall be hydrostatically tested in the same manner as the balance of the system.

10-2.2.4 When deluge systems are being hydrostatically tested, plugs shall be installed in fittings and replaced with open sprinklers after the test is completed, or the operating elements of automatic sprinklers shall be removed after the test is completed.

10-2.2.5* The trench shall be backfilled between joints before testing to prevent movement of pipe.

Exception: Where required for safety measures presented by the hazards of open trenches, the pipe and joints shall be permitted to be backfilled provided the installing contractor takes the responsibility for locating and correcting leakage in excess of that permitted in 10-2.2.1, Exception No. 6.

10-2.2.6 Provision shall be made for the proper disposal of water used for flushing or testing.

10-2.2.7* Test blanks shall have painted lugs protruding in such a way as to clearly indicate their presence. The test blanks shall be numbered, and the installing contractor shall have a recordkeeping method ensuring their removal after work is completed.

10-2.2.8 When subject to hydrostatic test pressures, the clapper of a differential-type valve shall be held off its seat to prevent damaging the valve.

10-2.3 Dry Pipe and Double Interlock System(s) Air Test. In addition to the standard hydrostatic test, an air pressure leakage test at 40 psi (2.8 bar) shall be conducted for 24 hours. Any leakage that results in a loss of pressure in excess of $1^1/_2$ psi (0.1 bar) for the 24 hours shall be corrected.

10-2.3.1 Where systems are installed in spaces that are capable of being operated at temperatures below 32°F (0°C), air pressure leakage tests required in 10-2.3 shall be conducted at the lowest nominal temperature of the space.

10-2.4 System Operational Tests.

10-2.4.1 Waterflow detecting devices including the associated alarm circuits shall be flow tested through the inspector's test connection and shall result in an audible alarm on the premises within 5 minutes after such flow begins and until such flow stops.

10-2.4.2 A working test of the dry pipe valve alone and with a quick-opening device, if installed, shall be made by opening the inspector's test connection. The test shall measure the time to trip the valve and the time for water to be discharged from the inspector's test connection. All times shall be measured from the time the inspector's test connection is completely opened. The results shall be recorded using the contractor's material and test certificate for aboveground piping.

10-2.4.3 The automatic operation of a deluge or preaction valve shall be tested in accordance with the manufacturer's instructions. The manual and remote control operation, where present, shall also be tested.

10-2.4.4 The main drain valve shall be opened and remain open until the system pressure stabilizes. The static and residual pressures shall be recorded on the contractor's test certificate.

10-2.4.5 Operating Test.

10-2.4.5.1 Each hydrant shall be fully opened and closed under system water pressure, and dry barrel hydrants shall be checked for proper drainage. Where fire pumps are available, this check shall be done with the pumps running.

10-2.4.5.2 All control valves shall be fully closed and opened under system water pressure to ensure proper operation.

10-2.5 Each pressure-reducing valve shall be tested upon completion of installation to ensure proper operation under flow and no-flow conditions. Testing shall verify that the device properly regulates outlet pressure at both maximum and normal inlet pressure conditions. The results of the flow test of each pressure-reducing valve shall be recorded on the contractor's test certificate. The results shall include the static and residual inlet pressures, static and residual outlet pressures, and the flow rate.

10-2.6 The backflow prevention assembly shall be forward flow tested to ensure proper operation. The minimum flow rate shall be the system demand, including hose stream demand where applicable.

10-2.7 Operating tests shall be made of exposure protection systems upon completion of the installation, where such tests do not risk water damage to the building on which they are installed or to adjacent buildings.

10-3 Circulating Closed Loop Systems. For sprinkler systems with non-fire protection connections, additional information shall be appended to the Contractor's Material and Test Certificate for Aboveground Piping shown in Figure 10-1(a) as follows:

(1) Certification that all auxiliary devices, such as heat pumps, circulating pumps, heat exchangers, radiators, and luminaries, if a part of the system, have a pressure rating of at least 175 psi or 300 psi (12.1 bar or 20.7 bar) if exposed to pressures greater than 175 psi (12.1 bar).
(2) All components of sprinkler system and auxiliary system have been pressure tested as a composite system in accordance with 10-2.2.
(3) Waterflow tests have been conducted and waterflow alarms have operated while auxiliary equipment is in each of the possible modes of operation.

(4) With auxiliary equipment tested in each possible mode of operation and with no flow from sprinklers or test connection, waterflow alarm signals did not operate.
(5) Excess temperature controls for shutting down the auxiliary system have been properly field tested.

Discharge tests of sprinkler systems with non-fire protection connections shall be conducted using system test connections described in 3-8.2. Pressure gauges shall be installed at critical points and readings shall be taken under various modes of auxiliary equipment operation. Waterflow alarm signals shall be responsive to discharge of water through system test pipes while auxiliary equipment is in each of the possible modes of operation.

10-4 Instructions. The installing contractor shall provide the owner with the following:

(1) All literature and instructions provided by the manufacturer describing proper operation and maintenance of any equipment and devices installed
(2) NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*

10-5* Hydraulic Design Information Sign. The installing contractor shall identify a hydraulically designed sprinkler system with a permanently marked weatherproof metal or rigid plastic sign secured with corrosion-resistant wire, chain, or other approved means. Such signs shall be placed at the alarm valve, dry pipe valve, preaction valve, or deluge valve supplying the corresponding hydraulically designed area. The sign shall include the following information:

(1) Location of the design area or areas
(2) Discharge densities over the design area or areas
(3) Required flow and residual pressure demand at the base of the riser
(4) Occupancy classification or commodity classification and maximum permitted storage height and configuration
(5) Hose stream demand included in addition to the sprinkler demand

Chapter 11 Marine Systems

11-1 General. This chapter outlines the deletions, modifications, and additions that shall be required for marine application. All other requirements of this standard shall apply to merchant vessel systems except as modified by this chapter.

11-1.1 The following definitions shall be applicable to this chapter.

A-Class Boundary. A boundary designed to resist the passage of smoke and flame for 1 hour when tested in accordance with ASTM E 119, *Standard Test Methods for Fire Tests of Building Construction and Materials.*

B-Class Boundary. A boundary designed to resist the passage of flame for $^1/_2$ hour when tested in accordance with ASTM E 119, *Standard Test Methods for Fire Tests of Building Construction and Materials.*

Central Safety Station. A continuously manned control station from which all of the fire control equipment is monitored. If this station is not the bridge, direct communication with the bridge shall be provided by means other than the ship's service telephone.

Heat-Sensitive Material.* A material whose melting point is below 1700°F (926.7°C).

Heel. The inclination of a ship to one side.

Heel Angle. The angle defined by the intersection of a vertical line through the center of a vessel and a line perpendicular to the surface of the water.

International Shore Connection.* A universal connection complying with ASTM F 1121, *Standard Specification for International Shore Connections for Marine Fire Applications,* to which shoreside fire-fighting hose are to be connected.

Marine System.* A sprinkler system installed on a ship, boat, or other floating structure that takes its supply from the water on which the vessel floats.

Marine Thermal Barrier.* An assembly that is constructed of noncombustible materials and made intact with the main structure of the vessel, such as shell, structural bulkheads, and decks. A marine thermal barrier shall meet the requirements of a B-Class boundary. In addition, a marine thermal barrier shall be insulated such that, if tested in accordance with ASTM E 119, *Standard Test Methods for Fire Tests of Building Construction and Materials,* for 15 minutes, the average temperature of the unexposed side does not rise more than 250°F (193°C) above the original temperature, nor does the temperature at any one point, including any joint, rise more than 405°F (225°C) above the original temperature.

Supervision. A visual and audible alarm signal given at the central safety station to indicate when the system is in operation or when a condition that would impair the satisfactory operation of the system exists. Supervisory alarms shall give a distinct indication for each individual system component that is monitored.

Survival Angle. The maximum angle to which a vessel is permitted to heel after the assumed damage required by stability regulations is imposed.

Type 1 Stair. A fully enclosed stair that serves all levels of a vessel in which persons can be employed.

Water Supply. The supply portion of the sprinkler system from the water pressure tank or the sea suction of the designated sprinkler system pump up to and including the valve that isolates the sprinkler system from these two water sources.

11-1.2* Occupancy Classifications. Marine environment classifications shall be in accordance with Section 2-1.

11-1.3* Partial installation of automatic sprinklers shall not be permitted.

Exception No. 1: Spaces shall be permitted to be protected with an alternative, approved fire suppression system where such areas are separated from the sprinklered areas with a 1-hour-rated assembly.

Exception No. 2: Where specific sections of this standard permit the omission of sprinklers.

11-2 System Components, Hardware, and Use.

11-2.1* Sprinklers shall have a nominal discharge coefficient greater than 1.9.

11-2.2* Sprinkler piping penetrations shall be designed to preserve the fire integrity of the ceiling or bulkhead penetrated.

11-2.3 Spare Sprinklers.

11-2.3.1 The required stock of spare sprinklers shall be carried for each type of sprinkler installed onboard the vessel. Where fewer than six sprinklers of a particular type are installed, 100 percent spares shall be kept in stock. Where

applicable, at least one elastometric gasket shall be kept in the cabinet for each fire department connection that is installed onboard the vessel.

11-2.3.2 The cabinet containing spare sprinklers, special wrenches, and elastometric gaskets shall be located in the same central safety station that contains the alarm annunciator panel(s) and supervisory indicators.

11-2.4 System Pipe and Fittings.

11-2.4.1* When ferrous materials are used for piping between the sea chest and zone control valves, these materials shall be protected against corrosion by hot dip galvanizing or by the use of Schedule 80 piping.

11-2.4.2 Maximum design pressure for copper and brass pipe shall not exceed 250 psi (17.2 bar).

11-2.5 Pipe Support.

11-2.5.1* Pipe supports shall comply with the following:

(a) Pipe supports shall be designed to provide adequate lateral, longitudinal, and vertical sway bracing. The design shall account for the degree of bracing, which varies with the route and operation of the vessel. Bracing shall be designed to ensure the following:

(1) Slamming, heaving, and rolling will not shift sprinkler piping, potentially moving sprinklers above ceilings, bulkheads, or other obstructions.

(2) Piping and sprinklers will remain in place at a steady heel angle at least equal to the maximum required damaged survival angle.

(b) Pipe supports shall be welded to the structure. Hangers that can loosen during ship motion or vibration, such as screw-down-type hangers, shall not be permitted.

Exception: Hangers that are listed for seismic use shall be permitted to be used in accordance with their listing.

11-2.5.2 Sprinkler piping shall be supported by the primary structural members of the vessel such as beams, girders, and stiffeners.

11-2.5.3* The components of hanger assemblies that are welded directly to the ship structure shall not be required to be listed.

11-2.5.4* U-hook sizes shall be no less than that specified in Table 6-1.4.1.

11-2.6 Valves.

11-2.6.1* All indicating, supply, and zone control valves shall be supervised open from a central safety station.

11-2.6.2 Drain and test valves shall meet the applicable requirements of 46 *CFR* 56.20 and 56.60.

11-2.6.3 Valve markings shall include the information required by 46 *CFR* 56.20-5(a).

11-2.7 Fire Department Connections and International Shore Connections.

11-2.7.1* A fire department connection and an International Shore Connection shall be installed.

Exception: Fire department connections shall not be required on vessels that operate primarily on international voyages.

11-2.7.2 Connections shall be located near the gangway or other shore access point so that they are readily accessible to the land-based fire department. Fire department and International Shore Connections shall be colored and marked so that the connections are easily located from the shore access point (i.e., gangway location) and will not be confused with a fire-main connection. An 18 in. × 18 in. (0.46 m × 0.46 m) sign displaying standard symbol 4-2.1 of NFPA 170, *Standard for Fire Safety Symbols*, shall be placed at the connection so that it is in plain sight from the shore access point. Connections on both sides of the vessel shall be provided where shore access arrangements make it necessary.

11-2.7.3* Fire department connection thread type shall be compatible with fire department equipment.

11-3 System Requirements.

11-3.1* Relief Valves. Relief valves shall be provided on all wet pipe systems.

11-3.2 Spare Detection Devices. The number of spare detection devices or fusible elements used for protection systems that shall be carried per temperature rating is as follows:

(1) Vessels shall have two spare detection devices or fusible elements when operating voyages are normally less than 24 hours.
(2) Vessels shall have four spare detection devices or fusible elements when operating voyages are normally more than 24 hours.

11-3.3 System Piping Supervision. All preaction sprinkler systems shall be supervised regardless of the number of sprinklers supplied.

11-3.4 Circulating Closed Loop Systems. Circulating closed loop systems shall not be permitted.

11-4 Installation Requirements.

11-4.1 Temperature Zones. Intermediate temperature–rated sprinklers shall be installed under a noninsulated steel deck that is exposed to sunlight.

11-4.2* Residential Sprinklers. Residential sprinklers shall be permitted for use only in sleeping accommodation areas.

11-4.3 Window Protection. Where required, windows shall be protected by sprinklers installed at a distance not exceeding 1 ft (0.3 m) from the glazing at a spacing not exceeding 6 ft (1.8 m) such that the entire glazing surface is wetted at a linear density not less than 6 gpm/ft (75 mm/min).

Exception: Window sprinkler protection systems installed in accordance with their installation and testing criteria.

11-4.4* Concealed Spaces. Concealed spaces that are constructed of combustible materials, or materials with combustible finishes or that contain combustible materials, shall be sprinklered.

Exception: Spaces that contain only nonmetallic piping that is continuously filled with water are not required to be sprinklered.

11-4.5 Vertical Shafts.

11-4.5.1 Sprinklers are not required in vertical shafts used as duct, electrical, or pipe shafts that are nonaccessible, noncombustible, and enclosed in an A-Class-rated assembly.

11-4.5.2 Stairway enclosures shall be fully sprinklered.

11-4.6 Bath Modules. Sprinklers shall be installed in bath modules (full room modules) constructed with combustible materials, regardless of room fire load.

11-4.7 Ceiling Types. Drop-out ceilings shall not be used in conjunction with sprinklers.

11-4.8 Return Bends. To prevent sediment buildup, return bends shall be installed in all shipboard sprinkler systems where pendent-type or dry pendent–type sprinklers are used in wet systems *(see Figure 5-13.19)*. Consideration shall be given concerning the intrusion of saltwater into the system. Specifically, sprinklers shall not be rendered ineffective by corrosion related to saltwater entrapment within the return bend.

11-4.9 Hose Connections. Sprinkler system piping shall not be used to supply hose connections or hose connections for fire department use.

11-4.10 Heat-Sensitive Piping Materials.

11-4.10.1 Portions of the piping system constructed with a heat-sensitive material shall be subject to the following restrictions:

(1) Piping shall be of non-heat-sensitive type from the sea suction up through the penetration of the last A-Class barrier enclosing the space(s) in which the heat-sensitive piping is installed.
(2) B-Class draft stops shall be fitted not more than 45 ft (13.7 m) apart between the marine thermal barrier *(see definitions in 11-1.1)* and the deck or shell.
(3) Portions of a system that are constructed from heat-sensitive materials shall be installed behind a marine thermal barrier.

*Exception: *Piping materials with brazed joints shall not be required to be installed behind a marine thermal barrier, provided the following conditions are met:*

(a) The system is of the wet pipe type.

(b) The piping is not located in spaces containing boilers, internal combustion engines, or piping containing flammable or combustible liquids or gases under pressure, cargo holds, or vehicle decks.

(c) A relief valve in compliance with 4-1.2 is installed in each section of piping that is capable of being isolated by a valve(s).

(d) A valve(s) isolating the section of piping from the remainder of the system is installed in accordance with 11-4.10.2.

11-4.10.2 Each zone in which heat-sensitive piping is installed shall be fitted with a valve capable of segregating that zone from the remainder of the system. The valve shall be supervised and located outside of the zone controlled and within a readily accessible compartment having A-Class boundaries or within a Type 1 stair.

11-4.11 Discharge of Drain Lines.

11-4.11.1 Drain lines shall not be connected to housekeeping, sewage, or deck drains. Drains shall be permitted to be discharged to bilges. Overboard discharges shall meet the requirements of 46 *CFR* 56.50-95 and shall be corrosion resistant in accordance with 46 *CFR* 56.60. Systems that contain water additives that are not permitted to be discharged into the environment shall be specially designed to prevent such discharge.

11-4.11.2 Discharges shall be provided with a down-turned elbow.

11-4.12 Alarm Signals and Devices.

11-4.12.1* A visual and audible alarm signal shall be given at the central safety station to indicate when the system is in operation or when a condition that would impair the satisfactory operation of the system exists. Alarm signals shall be provided for, but not limited to, each of the following: monitoring position of control valves, fire pump power supplies and operating condition, water tank levels and temperatures, zone waterflow alarms, pressure of tanks, and air pressure on dry pipe valves. Alarms shall give a distinct indication for each individual system component that is monitored. An audible alarm shall be given at the central safety station within 30 seconds of waterflow.

11-4.12.2 Waterflow alarms shall be installed for every zone of the sprinkler system. Sprinkler zones shall not encompass more than two adjacent decks or encompass more than one main vertical zone.

11-4.12.3 Electrically operated alarm attachments shall comply with, meet, and be installed in accordance with the requirements of 46 *CFR*, Subchapter J, "Electrical Engineering." All wiring shall be chosen and installed in accordance with IEEE 45, *Marine Supplement*.

11-4.13 Test Connections. Where test connections are below the bulkhead deck, they shall comply with the overboard discharge arrangements of 46 *CFR* 56.50-95.

11-4.14 Copper tubing materials shall be protected against physical damage in areas where vehicles and stores handling equipment operate.

11-5 Design Approaches.

11-5.1 Design Options. Marine sprinkler systems shall be designed using the hydraulic calculation procedure of Chapter 7. The pipe schedule method shall not be used to determine the water demand requirements.

11-5.2* Window Protection. Minimum water demand requirements shall include sprinklers that are installed for the protection of windows as described in 11-4.3.

11-5.3* Hose Stream Allowance. No allowance for hose stream use shall be required.

11-6 Plans and Calculations.

11-6.1 Additional Information. The pressure tank size, high pressure relief setting, high and low water alarm settings, low pressure alarm setting, and pump start pressure shall be provided.

11-6.2 Sprinklers specifically installed for the protection of windows under 11-4.3 are permitted to be of a different size from those protecting the remainder of the occupancy classification. All of the window sprinklers, however, shall be of the same size.

11-6.3* Marine sprinkler systems shall be designed and installed to be fully operational without a reduction in system performance when the vessel is upright and inclined at the angles of inclination specified in 46 *CFR* 58.01-40.

11-7 Water Supplies.

11-7.1 General. The water supply requirements for marine applications shall be in accordance with Section 11-7.

11-7.2 Pressure Tank.

11-7.2.1 A pressure tank shall be provided. The pressure tank shall be sized and constructed so that the following occurs:

(1) The tank shall contain a standing charge of fresh water equal to that specified by Table 11-7.2.1.
(2) The pressure tank shall be sized in accordance with 9-2.3.2.
(3) A glass gauge shall be provided to indicate the correct level of water within the pressure tank.
(4) Arrangements shall be provided for maintaining an air pressure in the tank such that, while the standing charge of water is being expended, the pressure will not be less than that necessary to provide the design pressure and flow of the hydraulically most remote design area.
(5) Suitable means of replenishing the air under pressure and the fresh water standing charge in the tank shall be provided.
(6) Tank construction shall be in accordance with the applicable requirements of 46 *CFR*, Subchapter F, "Marine Engineering."

Exception: In lieu of a pressure tank, a dedicated pump connected to a fresh water tank shall be permitted to be used, provided the following conditions are met:

(a) The pump is listed for marine use and is sized to meet the required system demand.

(b) The suction for the fire pump is located below the suction for the fresh water system so that there shall be a minimum water supply of at least 1 minute for the required system demand.

(c) Pressure switches are provided in the system and the controller for the pump that automatically start the pump within 10 seconds after detection of a pressure drop of more than 5 percent.

(d) There shall be a reduced pressure zone backflow preventer to prevent contamination of the potable water system by salt water.

(e) There are at least two sources of power for this pump. Where the sources of power are electrical, these shall be a main generator and an emergency source of power. One supply shall be taken from the main switchboard, by separate feeder reserved solely for that purpose. This feeder shall be run to an automatic change-over switch situated near the sprinkler unit and the switch shall normally be kept closed to the feeder from the emergency switchboard. The changeover switch shall be clearly labeled and no other switch shall be permitted in these feeders.

Table 11-7.2.1 Required Water Supply

System Type	Additional Water Volume
Wet pipe system	Flow requirement of the hydraulically most remote system demand for 1 minute
Dry pipe system Preaction system Deluge system	Flow requirement of the hydraulically most remote system demand for 1 minute of system demand plus the volume needed to fill all dry piping

11-7.2.2 Relief valves shall be installed on the tank to avoid overpressurization and false actuation of any dry pipe valve. Relief valves shall comply with 46 *CFR* 54.15-10.

11-7.2.3 There shall be not less than two sources of power for the compressors that supply air to the pressure tank. Where the sources of power are electrical, these shall be a main generator and an emergency source of power. One supply shall be taken from the main switchboard, by separate feeders reserved solely for that purpose. Such feeders shall be run to a changeover switch situated near the air compressor, and the switch normally shall be kept closed to the feeder from the emergency switchboard. The changeover switch shall be clearly labeled, and no other switch shall be permitted in these feeders.

11-7.2.4 More than one pressure tank can be installed provided that each is treated as a single water source when determining valve arrangements. Check valves shall be installed to prohibit flow from tank to tank or from pump to tank.

Exception: Arrangements where a tank is designed to hold only pressurized air.

11-7.2.5 In systems subject to use with saltwater, valves shall be so arranged as to prohibit contamination of the pressure tank with saltwater.

11-7.2.6* Where applicable, a means shall be provided to restrict the amount of air that can enter the pressure tank from the air supply system. A means shall also be provided to prevent water from backflowing into the air supply system.

11-7.3 Fire Pump.

11-7.3.1 A dedicated, automatically controlled pump that is listed for marine service, which takes suction from the sea, shall be provided to supply the sprinkler system. Where two pumps are required to ensure the reliability of the water supply, the pump that supplies the fire main shall be allowed to serve as the second fire pump.

11-7.3.2* The pump shall be sized to meet the water demand of the hydraulically most demanding area. Pumps shall be designed to not exceed 120 percent of the rated capacity of the pump.

11-7.3.3 The system shall be designed so that, before the supply falls below the design criteria, the fire pump shall be automatically started and shall supply water to the system until manually shut off.

Exception: Where pump and fresh water tank arrangement is used in lieu of the pressure tank, there must be a pressure switch that senses a system pressure drop of 25 percent, and the controller must automatically start the fire pump(s) if pressure is not restored within 20 seconds.

11-7.3.4 There shall be not less than two sources of power supply for the fire pumps. Where the sources of power are electrical, these shall be a main generator and an emergency source of power. One supply shall be taken from the main switchboard by separate feeders reserved solely for that purpose. Such feeders shall be run to a changeover switch situated near to the sprinkler unit, and the switch normally shall be kept closed to the feeder from the emergency switchboard. The changeover switch shall be clearly labeled and no other switch shall be permitted in these feeders.

11-7.3.5 A test valve(s) shall be installed on the discharge side of the pump with a short open-ended discharge pipe. The area of the pipe shall be adequate to permit the release of the required water output to supply the demand of the hydraulically most remote area.

11-7.3.6 Where two fire pumps are required to ensure the reliability of the water supply, each fire pump shall meet the requirements of 11-7.3.1 through 11-7.3.4. In addition, a system that is required to have more than one pump shall be designed to accommodate the following features:

(a) *Pump controls and system sensors shall be arranged such that the secondary pump will automatically operate if the primary pump fails to operate or deliver the required water pressure and flow. *[Figure A-11-7.3.6(a) is an example of an acceptable dual pump arrangement.]*

(b) Both pumps shall be served from normal and emergency power sources. However, where approved by the authority having jurisdiction, the secondary pump shall be permitted to be nonelectrically driven.

(c) Pump failure or operation shall be indicated at the central safety station.

11-7.3.7* If not specifically prohibited, the fire pump that supplies the fire main is permitted to be used as the second pump, provided the following conditions are met:

(1) The pump is adequately sized to meet the required fire hose and sprinkler system pressure and flow demands simultaneously.
(2) The fire main system is segregated from the sprinkler system by a normally closed valve that is designed to automatically open upon failure of the designated fire pump.
(3) The fire pump that supplies the fire main is automatically started in the event of dedicated fire pump failure or loss of pressure in the sprinkler main. *(See Figure A-11-7.3.7.)*

11-7.4 Water Supply Configurations.

11-7.4.1 The pressure tank and fire pump shall be located in a position reasonably remote from any machinery space of Category A.

11-7.4.2 All valves within the water supply piping system shall be supervised.

11-7.4.3 Only fresh water shall be used as the initial charge within the piping network.

11-7.4.4 The sprinkler system shall be cross-connected with the ship's fire main system and fitted with a lockable screw-down nonreturn valve such that backflow from the sprinkler system to the fire main is prevented.

11-7.4.5 The piping, tanks, and pumps that make up the water supply shall be installed in accordance with the applicable requirements of 46 *CFR*, Subchapter F, "Marine Engineering."

11-7.4.6* When a shore water supply is to be used during extended dockside periods, the water supply shall be qualified in the manner described in 9-2.1. Tests shall be conducted in accordance with the requirements of the local shore-based authority having jurisdiction. The water supply information listed in Section 8-3 shall then be provided to the authority having jurisdiction.

11-8 System Acceptance.

11-8.1 Hydrostatic Tests. In addition to the interior piping, the test required by 10-2.2.3 shall also be conducted on all external water supply connections including international shore and fireboat connections.

11-8.2 Alarm Test. A waterflow test shall result in an alarm at the central safety station within 30 seconds after flow through the test connection begins.

11-8.3 Operational Tests. Pressure tank and pump operation, valve actuation, and waterflow shall also be tested. Pump operation and performance shall be tested in accordance with Chapter 11 of NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*.

11-9 System Instructions and Maintenance. Instructions for operation, inspection, maintenance, and testing shall be kept on the vessel. Records of inspections, tests, and maintenance required by NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, shall also be kept on the vessel.

Chapter 12 System Inspection, Testing, and Maintenance

12-1* General. A sprinkler system installed in accordance with this standard shall be properly inspected, tested, and maintained in accordance with NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, to provide at least the same level of performance and protection as designed.

Chapter 13 Referenced Publications

13-1 The following documents or portions thereof are referenced within this standard as mandatory requirements and shall be considered part of the requirements of this standard. The edition indicated for each referenced mandatory document is the current edition as of the date of the NFPA issuance of this standard. Some of these mandatory documents might also be referenced in this standard for specific informational purposes and, therefore, are also listed in Appendix E.

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*, 1999 edition.

NFPA 13D, *Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes*, 1999 edition.

NFPA 13R, *Standard for the Installation of Sprinkler Systems in Residential Occupancies up to and Including Four Stories in Height*, 1999 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 20, *Standard for the Installation of Centrifugal Fire Pumps*, 1999 edition.

NFPA 22, *Standard for Water Tanks for Private Fire Protection*, 1998 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, 1998 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 1996 edition.

NFPA 30B, *Code for the Manufacture and Storage of Aerosol Products*, 1998 edition.

NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials*, 1995 edition.

NFPA 36, *Standard for Solvent Extraction Plants*, 1997 edition.

NFPA 40, *Standard for the Storage and Handling of Cellulose Nitrate Motion Picture Film*, 1997 edition.

NFPA 42, *Code for the Storage of Pyroxylin Plastic*, 1997 edition.

NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*, 1996 edition.

NFPA 51, *Standard for the Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes*, 1997 edition.

NFPA 51A, *Standard for Acetylene Cylinder Charging Plants*, 1996 edition.

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*, 1999 edition.

NFPA 55, *Standard for the Storage, Use, and Handling of Compressed and Liquefied Gases in Portable Cylinders*, 1998 edition.

NFPA 59, *Standard for the Storage and Handling of Liquefied Petroleum Gases at Utility Gas Plants*, 1998 edition.

NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*, 1996 edition.

NFPA 70, *National Electrical Code®*, 1999 edition.

NFPA 72, *National Fire Alarm Code®*, 1999 edition.

NFPA 75, *Standard for the Protection of Electronic Computer/Data Processing Equipment*, 1999 edition.

NFPA 82, *Standard on Incinerators and Waste and Linen Handling Systems and Equipment*, 1999 edition.

NFPA 86C, *Standard for Industrial Furnaces Using a Special Processing Atmosphere*, 1999 edition.

NFPA 96, *Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations*, 1998 edition.

NFPA 99, *Standard for Health Care Facilities*, 1999 edition.

NFPA *101®*, *Life Safety Code®*, 1997 edition.

NFPA 130, *Standard for Fixed Guideway Transit Systems*, 1997 edition.

NFPA 150, *Standard on Fire Safety in Racetrack Stables*, 1995 edition.

NFPA 170, *Standard for Fire Safety Symbols*, 1999 edition.

NFPA 214, *Standard on Water-Cooling Towers*, 1996 edition.

NFPA 220, *Standard on Types of Building Construction*, 1999 edition.

NFPA 231D, *Standard for Storage of Rubber Tires*, 1998 edition.

NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*, 1999 edition.

NFPA 307, *Standard for the Construction and Fire Protection of Marine Terminals, Piers, and Wharves*, 1995 edition.

NFPA 318, *Standard for the Protection of Cleanrooms*, 1998 edition.

NFPA 409, *Standard on Aircraft Hangars*, 1995 edition.

NFPA 415, *Standard on Airport Terminal Buildings, Fueling Ramp Drainage, and Loading Walkways*, 1997 edition.

NFPA 423, *Standard for Construction and Protection of Aircraft Engine Test Facilities*, 1999 edition.

NFPA 430, *Code for the Storage of Liquid and Solid Oxidizers*, 1995 edition.

NFPA 432, *Code for the Storage of Organic Peroxide Formulations*, 1997 edition.

NFPA 703, *Standard for Fire Retardant Impregnated Wood and Fire Retardant Coatings for Building Materials*, 1995 edition.

NFPA 803, *Standard for Fire Protection for Light Water Nuclear Power Plants*, 1998 edition.

NFPA 804, *Standard for Fire Protection for Advanced Light Water Reactor Electric Generating Plants*, 1995 edition.

NFPA 850, *Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations*, 1996 edition.

NFPA 851, *Recommended Practice for Fire Protection for Hydroelectric Generating Plants*, 1996 edition.

NFPA 1963, *Standard for Fire Hose Connections*, 1998 edition.

13-1.2 Other Publications.

13-1.2.1 ANSI Publications. American National Standards Institute, Inc., 11 West 42nd Street, 13th floor, New York, NY 10036.

ANSI B31.1, *Code for Power Piping*.

ANSI B36.10M, *Welded and Seamless Wrought Steel Pipe*, 1995.

13-1.2.2 ASME Publications. American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

ASME A17.1, *Safety Code for Elevators and Escalators*, 1993.

ASME B1.20.1, *Pipe Threads, General Purpose (Inch)*, 1983.

ASME B16.1, *Cast Iron Pipe Flanges and Flanged Fittings*, 1989.

ASME B16.3, *Malleable Iron Threaded Fittings*, 1992.

ASME B16.4, *Cast Iron Threaded Fittings*, 1992.

ASME B16.5, *Pipe Flanges and Flanged Fittings*, 1996.

ASME B16.9, *Factory-Made Wrought Steel Buttwelding Fittings*, 1993.

ASME B16.11, *Forged Steel Fittings, Socket-Welding and Threaded*, 1996.

ASME B16.18, *Cast Copper Alloy Solder Joint Pressure Fittings*, 1984.

ASME B16.22, *Wrought Copper and Copper Alloy Solder Joint Pressure Fittings*, 1995.

ASME B16.25, *Buttwelding Ends*, 1997.

13-1.2.3 ASTM Publications. American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM A 53, *Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless*, 1995.

ASTM A 135, *Standard Specification for Electric-Resistance-Welded Steel Pipe*, 1993.

ASTM A 153, *Standard Specification for Zinc Coating (Hot Dip) on Iron and Steel Hardware*, 1998.

ASTM A 234/A 234M, *Standard Specification for Piping Fittings of Wrought-Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures*, 1995.

ASTM A 795, *Standard Specification for Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Fire Protection Use*, 1995.

ASTM B 32, *Standard Specification for Solder Metal*, 1995.

ASTM B 75, *Standard Specification for Seamless Copper Tube*, 1995.

ASTM B 88, *Standard Specification for Seamless Copper Water Tube*, 1995.

ASTM B 251, *Standard Specification for General Requirements for Wrought Seamless Copper and Copper-Alloy Tube*, 1993.

ASTM B 446, *Standard Specification for Nickel-Chromium-Molybdenum-Columbium Alloy Rod and Bar*, 1993.

ASTM B 813, *Standard Specification for Liquid and Paste Fluxes for Soldering Applications of Copper and Copper-Alloy Tube*, 1993.

ASTM D 3309, *Standard Specification for Polybutylene (PB) Plastic Hot- and Cold-Water Distribution Systems*, 1995.

ASTM E 119, *Standard Test Methods for Fire Tests of Building Construction and Materials*, 1995.

ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, 1995.

ASTM F 437, *Standard Specification for Threaded Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80*, 1995.

ASTM F 438, *Standard Specification for Socket-Type Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 40*, 1993.

ASTM F 439, *Standard Specification for Socket-Type Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80*, 1993.

ASTM F 442, *Standard Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe (SDR-PR)*, 1994.

ASTM F 1121, *Standard Specification for International Shore Connections for Marine Fire Applications*, 1987.

ASTM SI 10, *Standard for Use of the International System of Units (SI): the Modern Metric System*, 1997.

13-1.2.4 AWS Publications. American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

AWS A5.8, *Specification for Filler Metals for Brazing and Braze Welding*, 1992.

AWS B2.1, *Specification for Qualification of Welding Procedures and Welders for Piping and Tubing*, 1998.

AWS D10.9, *Specification for Qualification of Welding Procedures and Welders for Piping and Tubing*, 1980.

13-1.2.5 AWWA Publications. American Water Works Association, 6666 West Quincy Avenue, Denver, CO 80235.

AWWA C104, *Cement Mortar Lining for Ductile Iron Pipe and Fittings for Water*, 1995.

AWWA C105, *Polyethylene Encasement for Ductile Iron Pipe Systems*, 1993.

AWWA C110, *Ductile Iron and Gray Iron Fittings, 3-in. Through 48-in., for Water and Other Liquids, 1993.*

AWWA C111, *Rubber Gasket Joints for Ductile Iron Pressure Pipe and Fittings*, 1990.

AWWA C115, *Flanged Ductile Iron Pipe with Ductile Iron or Gray Iron Threaded Flanges*, 1994.

AWWA C150, *Thickness Design of Ductile Iron Pipe*, 1996.

AWWA C151, *Ductile Iron Pipe, Centrifugally Cast for Water*, 1996.

AWWA C200, *Steel Water Pipe 6 in. and Larger*, 1986.

AWWA C203, *Coal-Tar Protective Coatings and Linings for Steel Water Pipelines Enamel and Tape — Hot Applied*, 1997.

AWWA C205, *Cement-Mortar Protective Lining and Coating for Steel Water Pipe 4 in. and Larger — Shop Applied*, 1995.

AWWA C206, *Field Welding of Steel Water Pipe*, 1997.

AWWA C207, *Steel Pipe Flanges for Waterworks Service — Sizes 4 in. Through 144 in.*, 1978.

AWWA C208, *Dimensions for Fabricated Steel Water Pipe Fittings*, 1996.

AWWA C300, *Reinforced Concrete Pressure Pipe, Steel-Cylinder Type for Water and Other Liquids*, 1997.

AWWA C301, *Prestressed Concrete Pressure Pipe, Steel-Cylinder Type, for Water and Other Liquids*, 1992.

AWWA C302, *Reinforced Concrete Pressure Pipe, Non-Cylinder Type, for Water and Other Liquids*, 1995.

AWWA C303, *Reinforced Concrete Pressure Pipe, Steel-Cylinder Type, Pretensioned, for Water and Other Liquids*, 1995.

AWWA C400, *Standard for Asbestos-Cement Distribution Pipe, 4 in. Through 16 in., for Water and Other Liquids*, 1993.

AWWA C401, *Standard Practice for the Selection of Asbestos-Cement Water Pipe*, 1993.

AWWA C600, *Standard for the Installation of Ductile-Iron Water Mains and Their Appurtenances*, 1982.

AWWA C602, *Cement-Mortar Lining of Water Pipe Lines 4 in. and Larger — in Place*, 1995.

AWWA C603, *Standard for the Installation of Asbestos-Cement Water Pipe*, 1978.

AWWA C900, *Polyvinyl Chloride (PVC) Pressure Pipe, 4 in. Through 12 in., for Water and Other Liquids*, 1989.

AWWA M11, *A Guide for Steel Pipe-Design and Installation*, 3rd edition, 1989.

13-1.2.6 IEEE Publication. Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.

IEEE 45, *Marine Supplement.*

13-1.2.7 UL Publication. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 300, *Standard for Safety Fire Testing of Fire Extinguishing Systems for Protection of Restaurant Cooking Areas*, 1996.

13-1.2.8 U.S. Government Publications. U.S. Government Printing Office, Washington, DC 20402.

Title 46, *Code of Federal Regulations*, Parts 54.15-10, 56.20, 56.20-5(a), 56.50-95, 56.60, and 58.01-40.

Title 46, *Code of Federal Regulations*, Subchapter F, "Marine Engineering."

Title 46, *Code of Federal Regulations*, Subchapter J, "Electrical Engineering."

Appendix A Explanatory Material

Appendix A is not a part of the requirements of this NFPA document but is included for informational purposes only. This appendix contains explanatory material, numbered to correspond with the applicable text paragraphs.

A-1-2 Since its inception, this document has been developed on the basis of standardized materials, devices, and design practices. However, Section 1-2 and other subsections such as 3-3.5 and 5-4.9 allow the use of materials and devices not specifically designated by this standard, provided such use is within parameters established by a listing organization. In using such materials or devices, it is important that all conditions, requirements, and limitations of the listing be fully understood and accepted and that the installation be in complete accord with such listing requirements.

A-1-4.1 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-4.1 Authority Having Jurisdiction. The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

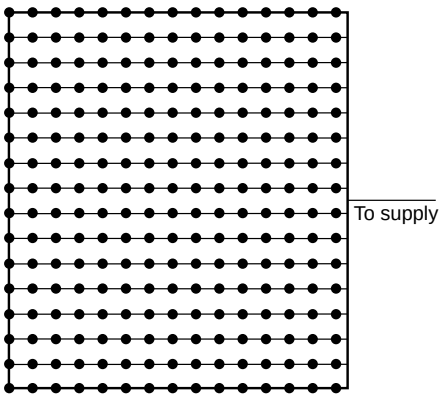
A-1-4.1 Listed. Evaluation of the product or service should address reliable operation and performance for the intended function. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product or device.

A-1-4.2 Miscellaneous Storage. The sprinkler system design criteria for miscellaneous storage at heights below 12 ft (3.7 m) is covered by this standard in Chapters 5 and 7. Paragraph 7-2.3.2.2 describes design criteria and Section 5-2 describes installation requirements (area limits). These requirements apply to all storage of 12 ft (3.7 m) or less in height.

A-1-4.2 Sprinkler System. A sprinkler system is considered to have a single system riser control valve. The design and installation of water supply facilities such as gravity tanks, fire pumps, reservoirs, or pressure tanks are covered by NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, and NFPA 22, *Standard for Water Tanks for Private Fire Protection*.

A-1-4.3 Gridded Sprinkler System. See Figure A-1-4.3(a).

Figure A-1-4.3(a) Gridded system.



A-1-4.3 Looped Sprinkler System. See Figure A-1-4.3(b).

A-1-4.3 Preaction Sprinkler System The actuating means of the valve are described in 4-3.2.1. Actuation of the detection system and sprinklers in the case of double-interlocked systems opens a valve that permits water to flow into the sprinkler piping system and to be discharged from any sprinklers that are open.

A-1-4.4 See Figure A-1-4.4.

Figure A-1-4.3(b) Looped system.

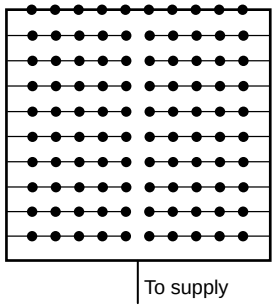
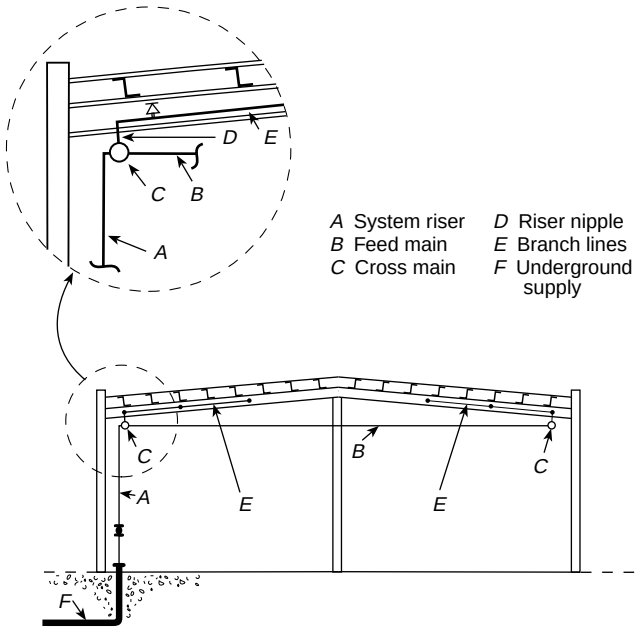


Figure A-1-4.4 Building elevation showing parts of sprinkler piping system.



A-1-4.5.1 The response time index (RTI) is a measure of the sensitivity of the sprinkler's thermal element as installed in a specific sprinkler. It is usually determined by plunging a sprinkler into a heated laminar airflow within a test oven. The plunge test is not currently applicable to certain sprinklers.

The RTI is calculated using the following:

(1) The operating time of the sprinkler
(2) The operating temperature of the sprinkler's heat-responsive element (as determined in a bath test)
(3) The air temperature of the test oven
(4) The air velocity of the test oven
(5) The sprinkler's conductivity *(c)* factor, which is the measure of conductance between the sprinkler's heat-responsive element and the sprinkler oven mount

Other factors affecting response include the temperature rating, sprinkler position, fire exposure, and radiation.

ISO standard 6182-1 currently recognizes the RTI range of greater than 50 (meters-seconds)$^{1/2}$ and less than 80 (meters-seconds)$^{1/2}$ as special response. Such sprinklers can be recognized as special sprinklers under 5-4.9.1.

It should be recognized that the term *fast response* (like the term *quick response* used to define a particular type of sprinkler) refers to the thermal sensitivity within the operating element of a sprinkler, not the time of operation in a particular installation. There are many other factors, such as ceiling height, spacing, ambient room temperature, and distance below ceiling, that affect the time of response of sprinklers. In most fire scenarios, sprinkler activation times will be shortest where the thermal elements are located 1 in. (25.4 mm) to 3 in. (76.2 mm) below the ceiling. A fast response sprinkler is expected to operate quicker than a standard response sprinkler in the same installation orientation. For modeling purposes, concealed sprinklers can be considered equivalent to pendent sprinklers having a similar thermal response sensitivity installed 12 in. (305 mm) below smooth unobstructed ceilings, and recessed sprinklers can be considered equivalent to pendent sprinklers having a similar thermal response sensitivity installed 8 in. (203 mm) below smooth unobstructed ceilings.

A-1-4.5.2 ESFR Sprinkler. It is important to realize that the effectiveness of these highly tested and engineered sprinklers depends on the combination of fast response and the quality and uniformity of the sprinkler discharge. It should also be realized that ESFR sprinklers cannot be relied upon to provide fire control, let alone suppression, if they are used outside the guidelines specified in 7-9.5.

A-1-4.5.2 QRES Sprinkler. Research into the development of QRES sprinklers is continuing under the auspices of the National Fire Protection Research Foundation. It is expected that the proposed design criteria will be added to the standard when a thorough analysis of the test data is completed.

A-1-4.5.4 Dry Sprinkler. Under certain ambient conditions, wet pipe systems having dry-pendent (or upright) sprinklers can freeze due to heat loss by conduction. Therefore, due consideration should be given to the amount of heat maintained in the heated space, the length of the nipple in the heated space, and other relevant factors.

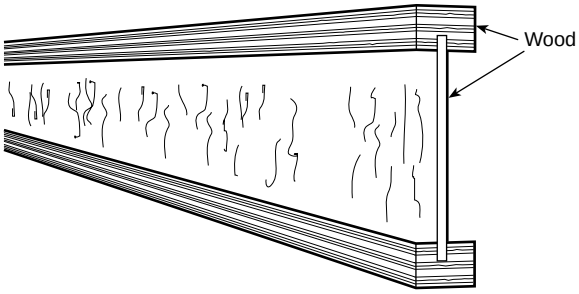
Dry sprinklers are intended to extend into an unheated area from a wet pipe system or to be used on a dry pipe system.

A-1-4.6 Obstructed Construction. The following are examples of obstructed construction. The definitions are provided to assist the user in determining the type of construction feature.

(a) *Beam and Girder Construction.* The term *beam and girder construction* as used in this standard includes noncombustible and combustible roof or floor decks supported by wood beams of 4 in. (102 mm) or greater nominal thickness or concrete or steel beams spaced 3 ft to $7^1/_2$ ft (0.9 m to 2.3 m) on center and either supported on or framed into girders. [Where supporting a wood plank deck, this includes semi-mill and panel construction, and where supporting (with steel framing) gypsum plank, steel deck, concrete, tile, or similar material, this includes much of the so-called noncombustible construction.]

(b) *Composite Wood Joist Construction.* The term *composite wood joist construction* refers to wood beams of "I" cross section constructed of wood flanges and solid wood web, supporting a floor or roof deck. Composite wood joists can vary in depth up to 48 in. (1.2 m), can be spaced up to 48 in. (1.2 m) on centers, and can span up to 60 ft (18 m) between supports. Joist channels should be firestopped to the full depth of the joists with material equivalent to the web construction so that individual channel areas do not exceed 300 ft^2 (27.9 m^2). *[See Figure A-1-4.6(a) for an example of composite wood joist construction.]*

Figure A-1-4.6(a) Typical composite wood joist construction.



(c) *Panel Construction.* The term *panel construction* as used in this standard includes ceiling panels formed by members capable of trapping heat to aid the operation of sprinklers and limited to a maximum of 300 ft^2 (27.9 m^2) in area. Beams spaced more than $7^1/_2$ ft (2.3 m) apart and framed into girders qualify as panel construction, provided the 300-ft^2 (27.9-m^2) area limitation is met.

(d) *Semi-Mill Construction.* The term *semi-mill construction* as used in this standard refers to a modified standard mill construction, where greater column spacing is used and beams rest on girders.

(e) *Wood Joist Construction.* The term *wood joist construction* refers to solid wood members of rectangular cross section, which can vary from 2 in. to 4 in. (51 mm to 102 mm) nominal width and can be up to 14 in. (356 mm) nominal depth, spaced up to 3 ft (0.9 m) on centers, and can span up to 40 ft (12 m) between supports, supporting a floor or roof deck. Solid wood members less than 4 in. (102 mm) nominal width and up to 14 in. (356 mm) nominal depth, spaced more than 3 ft (0.9 m) on centers, are also considered as wood joist construction.

A-1-4.6 Unobstructed Construction. The following are examples of unobstructed construction. The definitions are provided to assist the user in determining the type of construction feature.

(a) *Bar Joist Construction.* The term *bar joist construction* refers to construction employing joists consisting of steel truss-shaped members. Wood truss-shaped members, which consist of wood top and bottom chord members not exceeding 4 in. (102 mm) in depth with steel tube or bar webs, are also defined as bar joists. Bar joists include noncombustible or combustible roof or floor decks on bar joist construction. *[See Figures A-1-4.6(b) and A-1-4.6(c) for examples of bar joist construction.]*

Figure A-1-4.6(b) Wood bar joist construction.

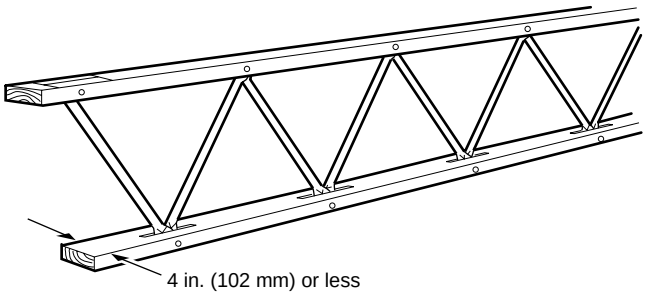
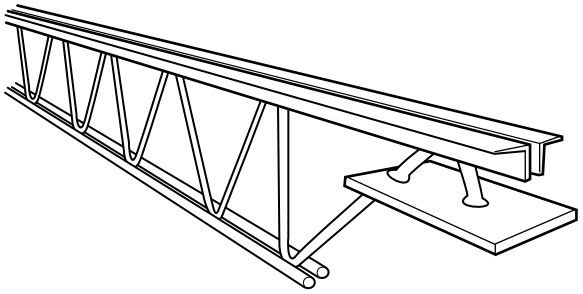


Figure A-1-4.6(c) Open-web bar joist construction.



(b) *Open-Grid Ceilings.* The term *open-grid ceilings* as used in this standard are ceilings in which the openings are $^1/_4$ in. (6.4 mm) or larger in the least dimension, the thickness of the ceiling material does not exceed the least dimension of the openings, and the openings constitute at least 70 percent of the ceiling area.

(c) *Smooth Ceiling Construction.* The term *smooth ceiling construction* as used in this standard includes the following:

(1) Flat slab, pan-type reinforced concrete

(2) Continuous smooth bays formed by wood, concrete, or steel beams spaced more than $7^1/_2$ ft (2.3 m) on centers — beams supported by columns, girders, or trusses

(3) Smooth roof or floor decks supported directly on girders or trusses spaced more than $7^1/_2$ ft (2.3 m) on center

(4) Smooth monolithic ceilings of at least $^3/_4$ in. (19 mm) of plaster on metal lath or a combination of materials of equivalent fire-resistive rating attached to the underside of wood joists, wood trusses, and bar joists

(5) Open-web-type steel beams, regardless of spacing

(6) Smooth shell-type roofs, such as folded plates, hyperbolic paraboloids, saddles, domes, and long barrel shells

(7) Suspended ceilings of combustible or noncombustible construction

(8) Smooth monolithic ceilings with fire resistance less than that specified under item (4) attached to the underside of wood joists, wood trusses, and bar joists

Combustible or noncombustible floor decks are permitted in the construction specified in A-1-4.6(c)(2) through (6). Item (2) would include standard mill construction.

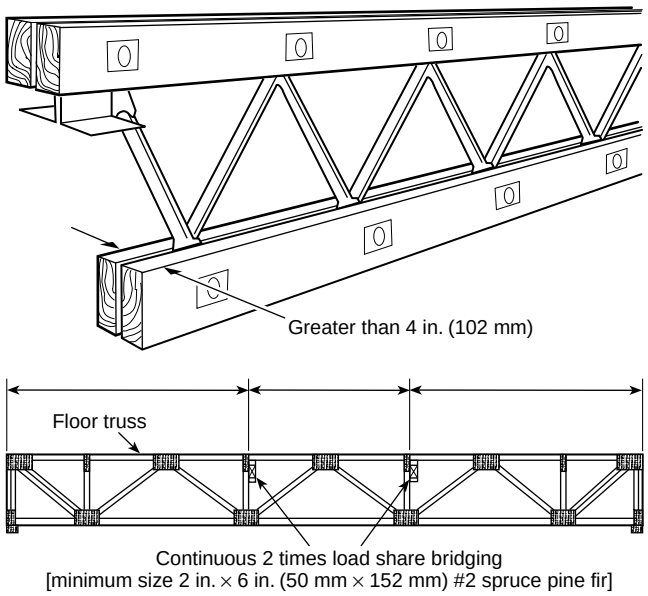
(d) *Standard Mill Construction.* The term *standard mill construction* as used in this standard refers to heavy timber construction as defined in NFPA 220, *Standard on Types of Building Construction.*

(e) *Wood Truss Construction.* The term *wood truss construction* refers to parallel or pitched wood chord members connected by open wood members (webbing) supporting a roof or floor deck. Trusses with steel webbing, similar to bar joist construction, having top and bottom wood chords exceeding 4 in. (102 mm) in depth, should also be considered wood truss construction. *[See Figure A-1-4.6(d).]*

A-1-4.7 Private Fire Service Main. See Figure A-1-4.7.

A-1-4.8 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.

Figure A-1-4.6(d) Examples of wood truss construction.



A-1-4.8 Available Height for Storage. For new sprinkler installations, the 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, the maximum height of storage is the maximum existing height, if space between the sprinklers and storage is equal to or greater than required.

A-1-4.8 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.

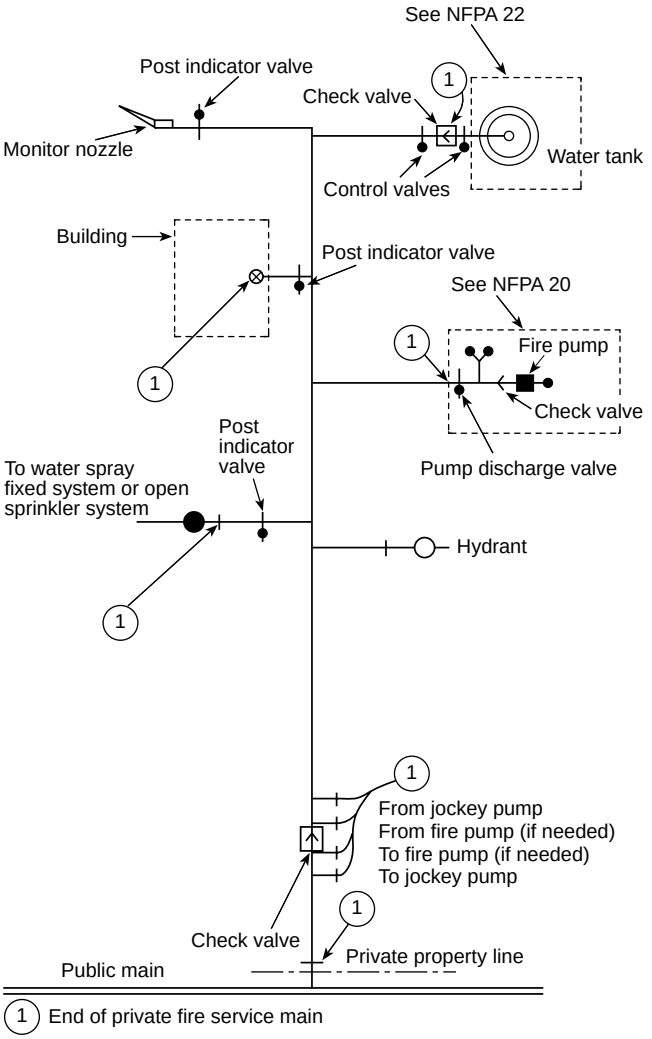
Other tests sponsored by the Society of Plastics Industry, Industrial Risk Insurers, Factory Mutual, and Kemper used two vertical pieces of carton (not corrugated) to form an "X" in the carton for separation of product. This arrangement was not considered compartmented, as the pieces of carton used for separations were flexible (not rigid), and only two pieces were used in each carton.

A-1-4.8 Container. The term container includes items such as cartons and wrappings. Fire-retardant containers or tote boxes do not by 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-1-4.8 Pile Stability, Stable Piles. Pile stability performance has been shown to be a difficult factor to judge prior to a pile being subjected to an actual fire. In the test work completed, compartmented cartons *(see A-1-4.8, Compartmented)* have been shown to be stable under fire conditions. Tests also indicated cartons that were not compartmented tended to be unstable under fire conditions.

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.

Figure A-1-4.7 Typical private fire service main.

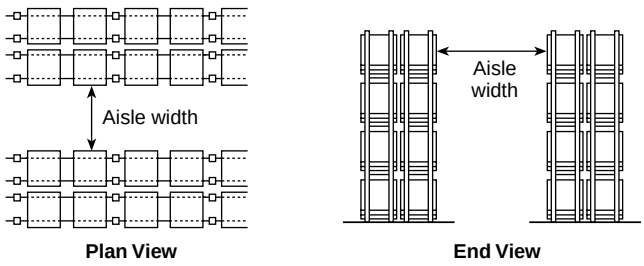


Note: The piping (aboveground or buried) shown is specific as to the end of the private fire service main and schematic only for illustrative purposes beyond. Details of valves and their location requirements are covered in the specific standard involved.

A-1-4.8 Pile Stability, Unstable Piles. 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.

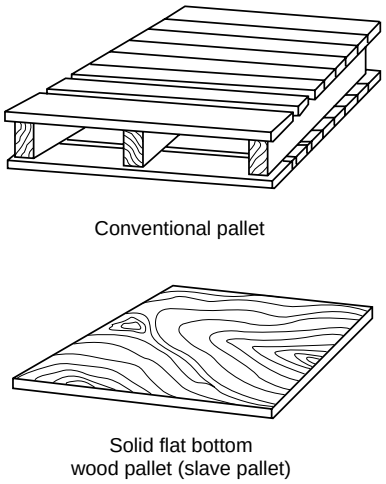
A-1-4.9 Aisle Width. See Figure A-1-4.9(a).

Figure A-1-4.9(a) Illustration of aisle width.



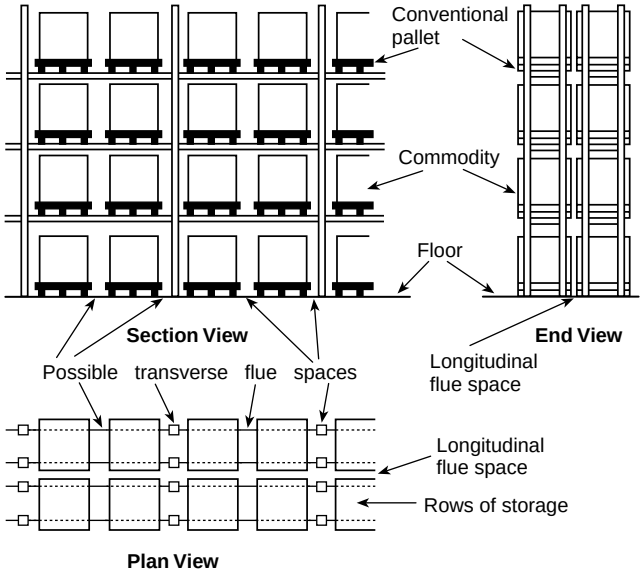
A-1-4.9 Conventional Pallets. See Figure A-1-4.9(b).

Figure A-1-4.9(b) Typical pallets.



A-1-4.9 Longitudinal Flue Space. See Figure A-1-4.9(c).

Figure A-1-4.9(c) Typical double-row (back-to-back) rack arrangement.



A-1-4.9 Rack. 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.

(a) *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-1-4.9(d) through (g).]*

(b) *Automatic Storage-Type Rack.* The pallet is supported by two rails running perpendicular to the aisle. *[See Figure A-1-4.9(h).]*

(c) *Multiple-Row Racks More than Two Pallets Deep, Measured Aisle to Aisle.* These racks 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-1-4.9(i) through (n).]*

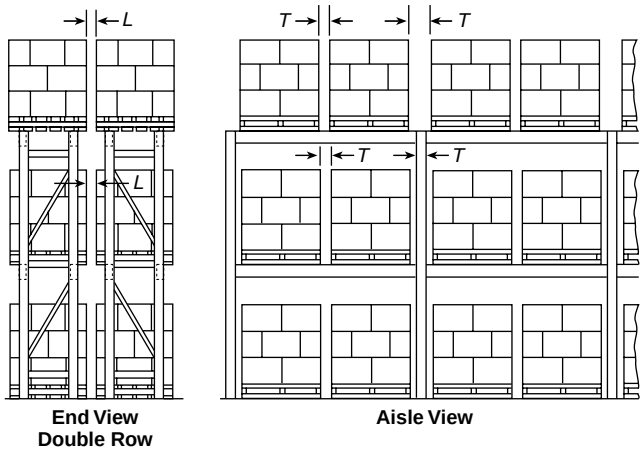
(d) *Movable Racks.* Movable racks are racks on fixed rails or guides. They can be moved back and forth only in a horizontal, two-dimensional plane. A moving aisle is created as abutting racks are either loaded or unloaded, then moved across the aisle to abut other racks. *[See Figure A-1-4.9(n).]*

(e) *Solid Shelving.* Conventional pallet racks with plywood shelves on the shelf beams *[see Figures A-1-4.9(f) and (g)]*. These racks are used in special cases. *(See Chapter 5.)*

(f) *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-1-4.9(m).]*

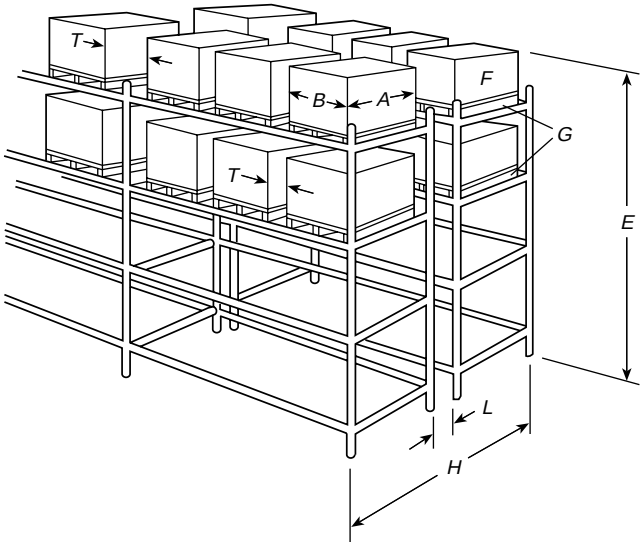
Load depth in conventional or automatic racks should be considered a nominal 4 ft (1.22 m). *[See Figure A-1-4.9(e).]*

Figure A-1-4.9(d) Conventional pallet rack.



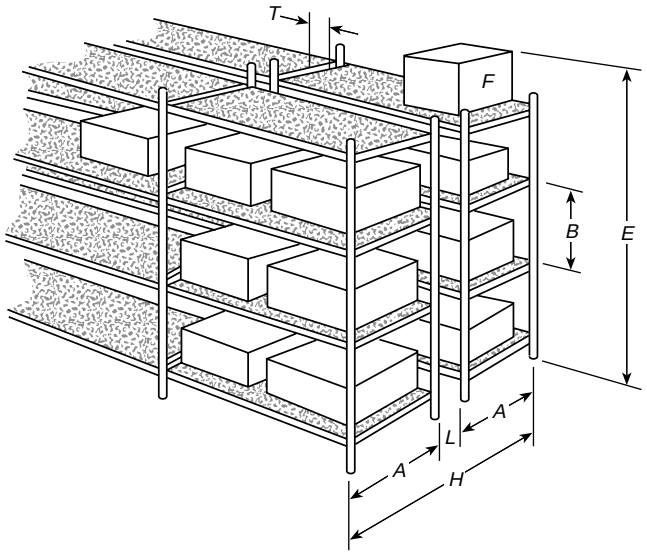
L Longitudinal flue space
T Transverse flue space

Figure A-1-4.9(e) Double-row racks without solid or slatted shelves.



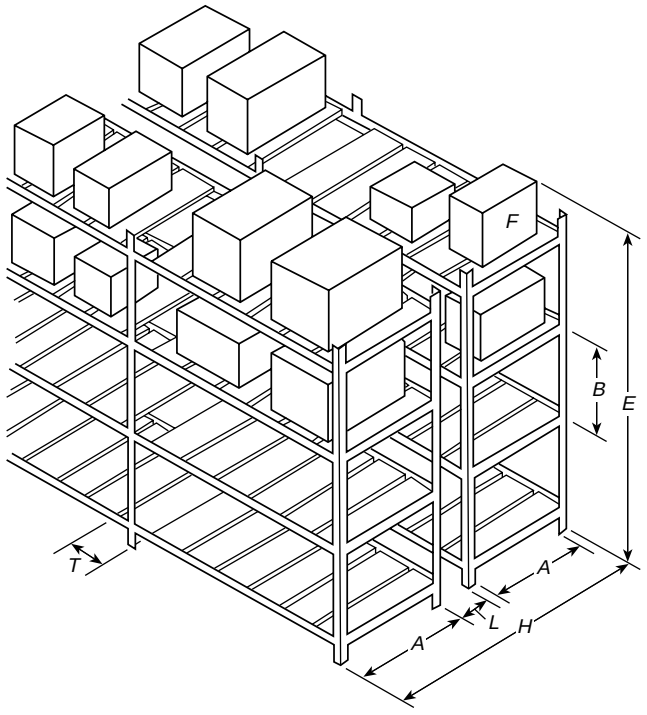
A Load depth
B Load width
E Storage height
F Commodity
G Pallet
H Rack depth
L Longitudinal flue space
T Transverse flue space

Figure A-1-4.9(f) Double-row racks with solid shelves.



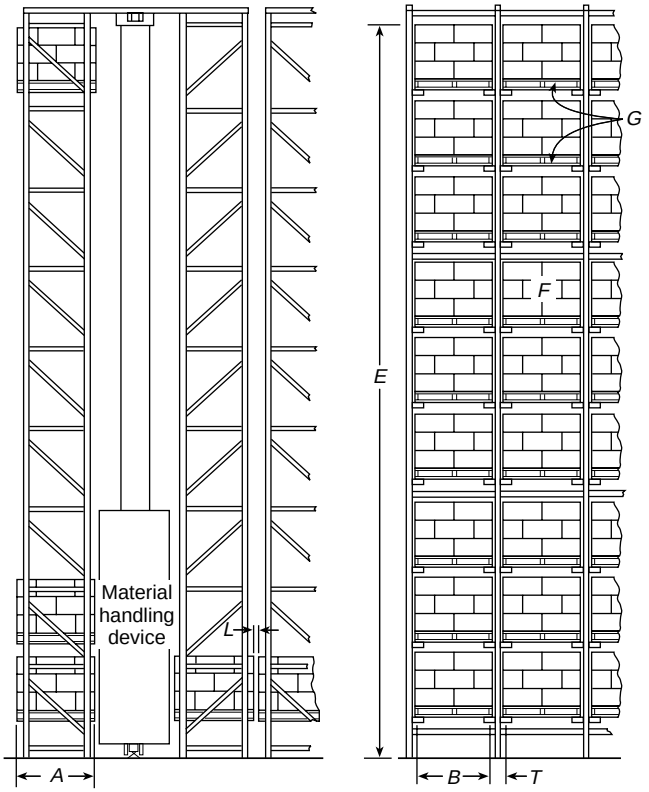
A Shelf depth
B Shelf height
E Storage height
F Commodity
H Rack depth
L Longitudinal flue space
T Transverse flue space

Figure A-1-4.9(g) Double-row racks with slatted shelves.



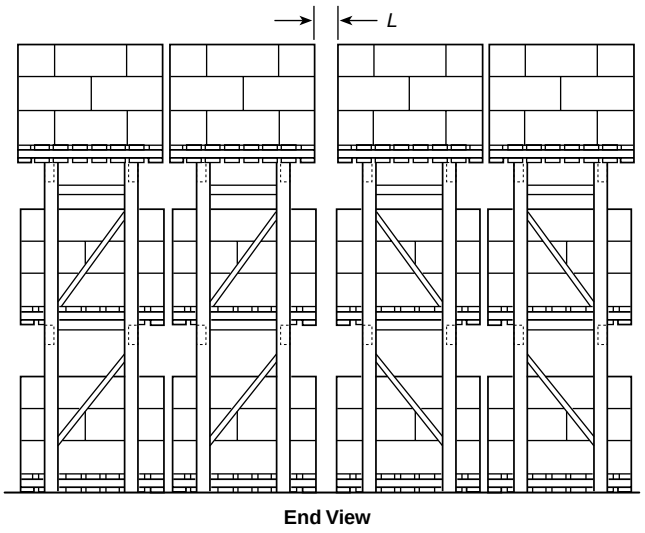
A Shelf depth
B Shelf height
E Storage height
F Commodity
H Rack depth
L Longitudinal flue space
T Transverse flue space

Figure A-1-4.9(h) Automatic storage-type rack.



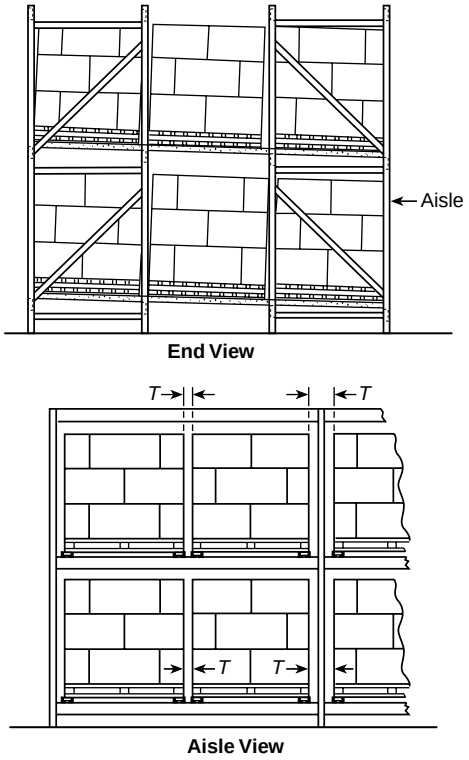
A Load depth
B Load width
E Storage height
F Commodity
G Pallet
L Longitudinal flue space
T Transverse flue space

Figure A-1-4.9(i) Multiple-row rack to be served by a reach truck.



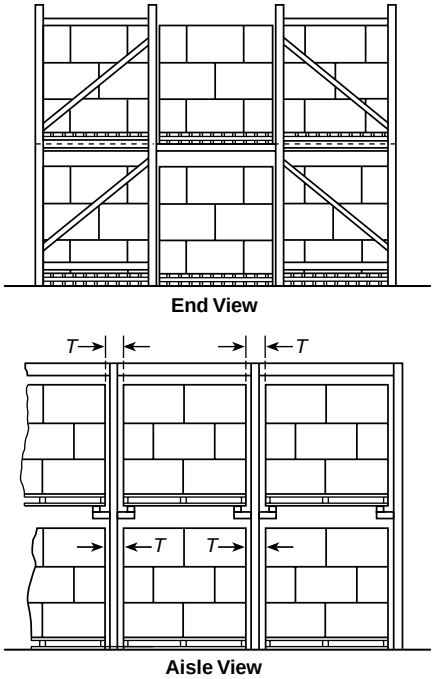
L Longitudinal flue space

Figure A-1-4.9(j) Flow-through pallet rack.



T Transverse flue space

Figure A-1-4.9(k) 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).



T Transverse flue space

Figure A-1-4.9(l) Flow-through racks (top) and portable racks (bottom).

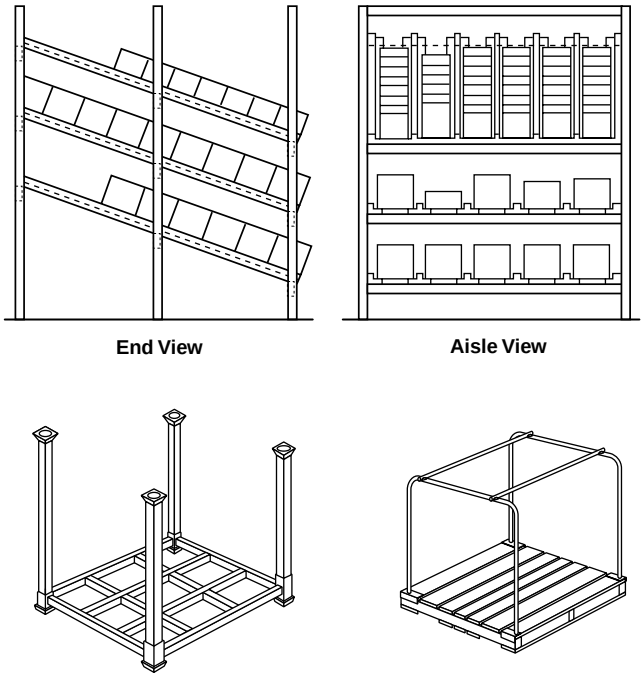


Figure A-1-4.9(m) Cantilever rack.

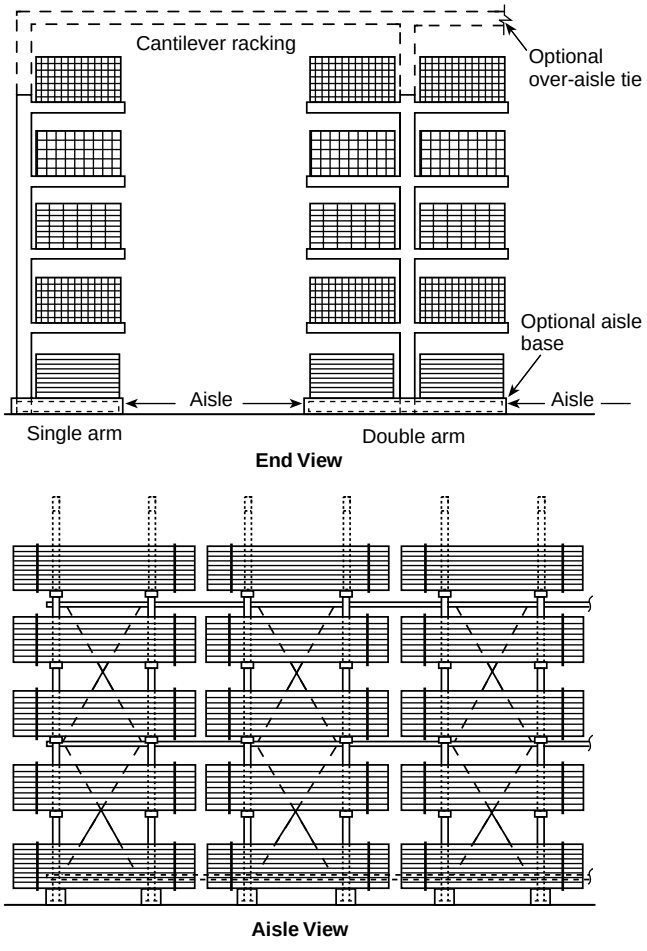
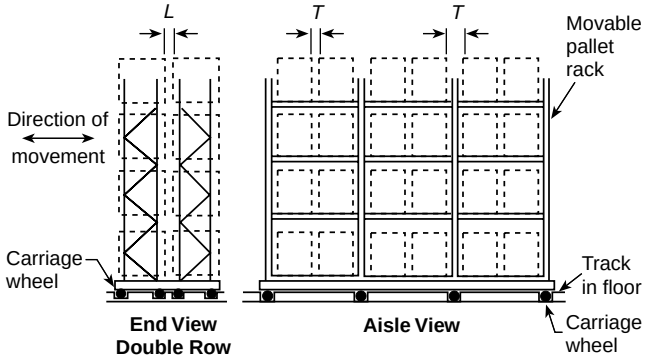


Figure A-1-4.9(n) Movable rack.



T Transverse flue space
L Longitudinal flue space

A-1-4.10 Miscellaneous Tire 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.

A-1-4.10.1 Figures A-1-4.10.1(a) through (g) do not necessarily cover all possible rubber tire storage configurations.

Figure A-1-4.10.1(a) Typical open portable tire rack unit.

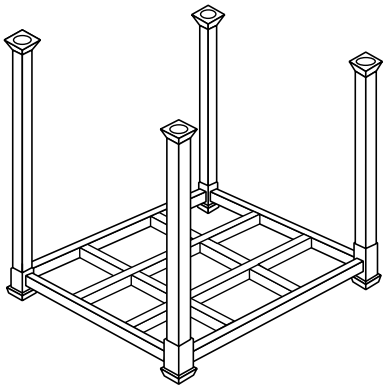


Figure A-1-4.10.1(b) Typical palletized portable tire rack units.

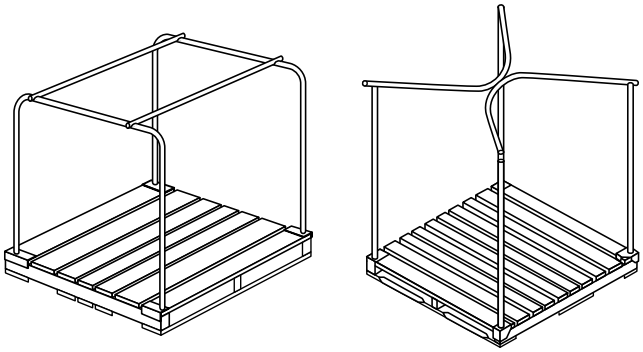


Figure A-1-4.10.1(c) Open portable tire rack.

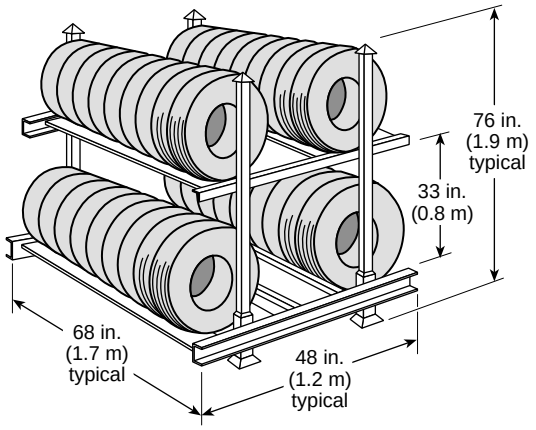
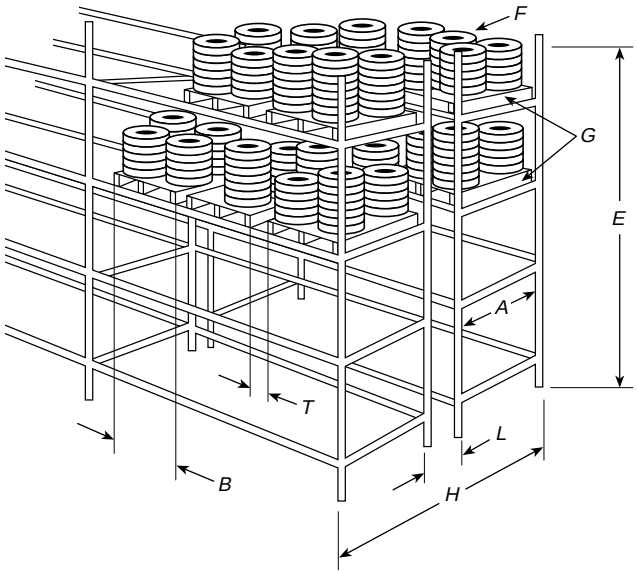


Figure A-1-4.10.1(d) Double-row fixed tire rack storage.



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 A-1-4.10.1(e) Palletized portable tire rack, on-side storage arrangement (banded or unbanded).

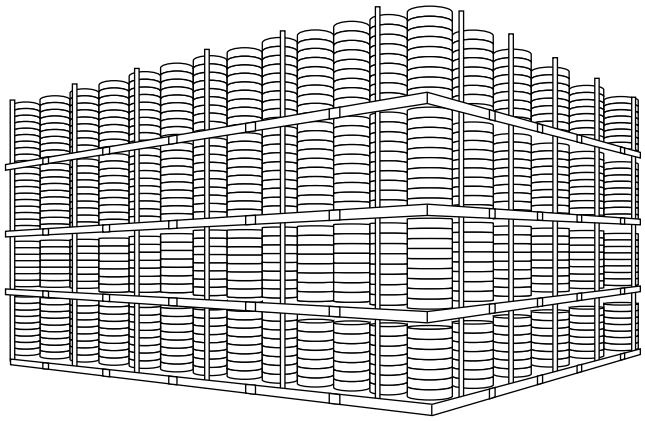


Figure A-1-4.10.1(f) On-floor storage; on-tread, normally banded.

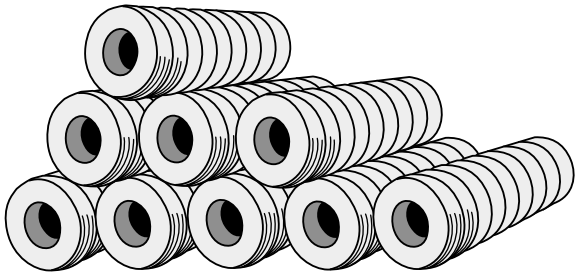


Figure A-1-4.10.1(g) Typical laced tire storage.

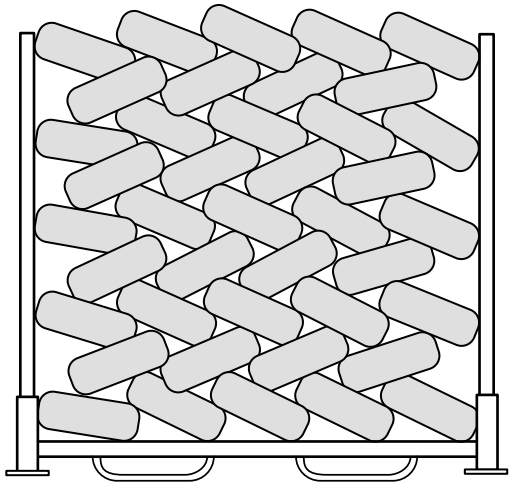


Table A-1-4.11 Typical Cotton Bale Types and Approximate Sizes

Bale Type	Dimensions		Average Weight		Volume		Density	
	in.	mm	lb	kg	ft^3	m^3	lb/ft^3	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-1-4.11 Baled Cotton. See Table A-1-4.11.

A-1-4.12 Array, Standard (Paper). The occasional presence of partially used rolls on top of columns of otherwise uniform diameter rolls does not appreciably affect the burning characteristics.

A-1-4.12 Roll Paper Storage, Wrapped. 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-1-4.12.

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.

A-1-4.12 Roll Paper Storage Height. The size of rolls and limitations of mechanical handling equipment should be considered in determining maximum storage height.

A-2-1 Occupancy examples in the listings as shown in the various hazard classifications are intended to represent the norm for those occupancy types. Unusual or abnormal fuel loadings or combustible characteristics and susceptibility for changes in these characteristics, for a particular occupancy, are considerations that should be weighed in the selection and classification.

The light hazard classification is intended to encompass residential occupancies; however, this is not intended to preclude the use of listed residential sprinklers in residential occupancies or residential portions of other occupancies.

A-2-1.1 Light hazard occupancies include occupancies having uses and conditions similar to the following:

Churches

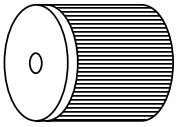
Clubs

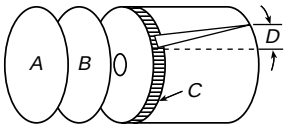
Eaves and overhangs, if of combustible construction with no combustibles beneath

Figure A-1-4.12 Wrapping and capping terms and methods.

Wrapper
Exterior wrapper
Body wrapper — General term for protective wrapping of sides and ends on roll.

Body wrap
Sleeve wrap
Wrap — do not cap — Wrapper placed around circumference of roll. No heads or caps needed.





Heads
Headers — Protection applied to the ends of the rolls (*A* and *B*). Heads do not lap over the end of the roll.

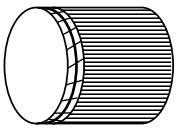
Inside heads — Protection applied to the ends of the rolls next to the roll itself (*B*). The wrapper of the rolls is crimped down over these heads.

Outside heads — Protection applied to the ends of the rolls on the outside (*A*). This head is applied after the wrapper is crimped.

Edge protectors
Edge bands — Refers to extra padding to prevent damage to roll edges (*C*).

Overwrap — The distance the body wrap or wrapper overlaps itself (*D*).

Roll cap — A protective cover placed over the end of a roll. Edges of cap lap over the end of the roll and are secured to the sides of the roll.



Educational
Hospitals
Institutional
Libraries, except large stack rooms
Museums
Nursing or convalescent homes
Offices, including data processing
Residential
Restaurant seating areas
Theaters and auditoriums, excluding stages and prosceniums
Unused attics

A-2-1.2.1 Ordinary hazard occupancies (Group 1) include occupancies having uses and conditions similar to the following:

Automobile parking and showrooms
Bakeries
Beverage manufacturing
Canneries
Dairy products manufacturing and processing
Electronic plants
Glass and glass products manufacturing
Laundries
Restaurant service areas

A-2-1.2.2 Ordinary hazard occupancies (Group 2) include occupancies having uses and conditions similar to the following:

Cereal mills
Chemical plants — ordinary
Confectionery products
Distilleries
Dry cleaners
Feed mills
Horse stables
Leather goods manufacturing
Libraries — large stack room areas
Machine shops
Metal working
Mercantile
Paper and pulp mills
Paper process plants
Piers and wharves
Post offices
Printing and publishing
Repair garages
Resin application area
Stages
Textile manufacturing
Tire manufacturing
Tobacco products manufacturing
Wood machining
Wood product assembly

A-2-1.3.1 Extra hazard occupancies (Group 1) include occupancies having uses and conditions similar to the following:

Aircraft hangars (except as governed by NFPA 409, *Standard on Aircraft Hangars*)
Combustible hydraulic fluid use areas
Die casting
Metal extruding
Plywood and particle board manufacturing
Printing [using inks having flash points below 100°F (38°C)]
Rubber reclaiming, compounding, drying, milling, vulcanizing
Saw mills
Textile picking, opening, blending, garnetting, or carding, combining of cotton, synthetics, wool shoddy, or burlap
Upholstering with plastic foams

A-2-1.3.2 Extra hazard occupancies (Group 2) include occupancies having uses and conditions similar to the following:

Asphalt saturating
Flammable liquids spraying
Flow coating
Manufactured home or modular building assemblies (where finished enclosure is present and has combustible interiors)
Open oil quenching
Plastics processing
Solvent cleaning
Varnish and paint dipping

A-2-1.4 Other NFPA standards contain design criteria for fire control or fire suppression *(see 2-1.4 and Chapter 13)*. While these can form the basis of design criteria, this standard describes the methods of design, installation, fabrication, calculation, and evaluation of water supplies that should be used for the specific design of the system.

Other NFPA standards contain sprinkler system design criteria for fire control or suppression of specific hazards. This information has been either referenced or copied into Chapters 5 and 7 using NFPA's extract policy.

A-2-2 Specification of the type, amount, and arrangement of combustibles for any commodity classification is essentially an attempt to define the potential fire severity, based on its burning characteristics, so the fire can be successfully controlled by the prescribed sprinkler protection for the commodity class. In actual storage situations, however, many storage arrays do not fit precisely into one of the fundamental classifications; therefore, the user needs to make judgments after comparing each classification to the existing storage conditions. Storage arrays consist of thousands of products, which make it impossible to specify all the acceptable variations for any class. As an alternative, a variety of common products are classified in this appendix based on judgment, loss experience, and fire test results.

Table A-2-2 provides examples of commodities not addressed by the classifications in Section 2-2.

Table A-2-2.3 is an alphabetized list of commodities with corresponding classifications.

Tables A-2-2.3.1 through A-2-2.3.4 and A-2-2.4.1 provide examples of commodities within a specific class.

Table A-2-2 Examples of Commodities Not Addressed by the Classifications in Section 2-2

Boxes, Crates
- Empty, wood slatted
Lighters (butane)
- Loose in large containers (Level 3 aerosol)

*Should be treated as idle pallets.

A-2-2.1.1 Commodity classification is governed by the types and amounts of materials (e.g., metal, paper, wood, plastics) that are a part of a product and its primary packaging. However, in a storage or warehousing situation, classification is also affected by such factors as the primary storage or shipping container material, the amount of air space, and the location of the more hazardous materials within the container. For example, a Group A plastic product enclosed in a five- or six-sided metal container can be considered Class II, while a ceramic product heavily wrapped in tissue paper and placed in a corrugated carton could be Class III.

A-2-2.3 See Table A-2-2.3.

Table A-2-2.3 Alphabetized Listing of Commodity Classes

Commodity	Commodity Class
Aerosols	
Cartoned or uncartoned	
- Level 1	Class III
Alcoholic Beverages	
Cartoned or uncartoned	
- Up to 20 percent alcohol in metal, glass, or ceramic containers	Class I
- Up to 20 percent alcohol in wood containers	Class II
Ammunition	
Small arms, shotgun	
- Packaged, cartoned	Class IV
Appliances, Major (i.e., stoves, refrigerators)	
- Not packaged, no appreciable plastic exterior trim	Class I
- Corrugated, cartoned, (no appreciable plastic trim)	Class II
Baked Goods	
Cookies, cakes, pies	
- Frozen, packaged in cartons[1]	Class II
- Packaged, in cartons	Class III
Batteries	
Dry cells (nonlithium or similar exotic metals)	
- Packaged in cartons	Class I
- Blister-packed in cartons	Class II
Automobile	
-Filled[2]	Class I
Truck or larger	
- Empty or filled[2]	Group A plastics
Beans	
Dried	
- Packaged, cartoned	Class III
Bottles, Jars	
Empty, cartoned	
- Glass	Class I
- Plastic PET (polyethylene terephthalate)	Class IV
Filled noncombustible powders	
- Plastic PET	Class II
- Glass, cartoned	Class I
- Plastic, cartoned [less than 1 gal (3.8 L)]	Class IV
- Plastic, uncartoned (other than PET), any size	Group A plastics
- Plastic, cartoned or exposed [greater than 1 gal (3.8 L)]	Group A plastics
- Plastic, solid plastic crates	Group A plastics
- Plastic, open plastic crates	Group A plastics
Filled noncombustible liquids	
- Glass, cartoned	Class I
- Plastic, cartoned [less than 5 gal (18.9 L)]	Class I
- Plastic, open or solid plastic crates[3]	Group A plastics
-Plastic, PET	Class I
Boxes, Crates	
- Empty, wood, solid walls	Class II
- Empty, wood, slatted[4]	Outside of scope
Bread	
Wrapped cartoned	Class III
Butter	
Whipped spread	Class III
Candles	
Packaged, cartoned	
- Treat as expanded plastic	Group A plastics
Candy	
Packaged, cartoned	Class III
Canned Foods	
In ordinary cartons	Class I
Cans	
Metal	
- Empty	Class I
Carpet Tiles	
Cartoned	Group A plastics
Cartons	
Corrugated	
- Unassembled (neat piles)	Class III
- Partially assembled	Class IV
Wax coated, single walled	Group A plastics
Cement	
Bagged	Class I
Cereals	
Packaged, cartoned	Class III
Charcoal	
Bagged	
- Standard	Class III
Cheese	
- Packaged, cartoned	Class III
- Wheels, cartoned	Class III

(continues)

Table A-2-2.3 Alphabetized Listing of Commodity Classes *(Continued)*

Commodity	Commodity Class
Chewing Gum	
Packaged, cartoned	Class III
Chocolate	
Packaged, cartoned	Class III
Cloth	
Cartoned and not cartoned	
- Natural fiber, viscose	Class III
- Synthetic[5]	Class IV
Cocoa Products	
Packaged, cartoned	Class III
Coffee	
- Canned, cartoned	Class I
- Packaged, cartoned	Class III
Coffee Beans	
Bagged	Class III
Cotton	
Packaged, cartoned	Class III
Diapers	
- Cotton, linen	Class III
- Disposable with plastics and nonwoven fabric (in cartons)	Class IV
- Disposable with plastics and nonwoven fabric (uncartoned), plastic wrapped	Group A plastics
Dried Foods	
Packaged, cartoned	Class III
Fertilizers	
Bagged	
- Phosphates	Class I
- Nitrates	Class II
Fiberglass Insulation	
- Paper-backed rolls, bagged or unbagged	Class IV
File Cabinets	
Metal	
- Cardboard box or shroud	Class I
Fish or Fish Products	
Frozen	
- Nonwaxed, nonplastic packaging	Class I
- Waxed-paper containers, cartoned	Class II
- Boxed or barreled	Class II
- Plastic trays, cartoned	Class III
Canned	
- Cartoned	Class I
Frozen Foods	
Nonwaxed, nonplastic packaging	Class I
- Waxed-paper containers, cartoned	Class II
- Plastic trays	Class III

Table A-2-2.3 Alphabetized Listing of Commodity Classes *(Continued)*

Commodity	Commodity Class
Fruit	
Fresh	
- Nonplastic trays or containers	Class I
- With wood spacers	Class I
Furniture	
Wood	
- No plastic coverings or foam plastic cushioning	Class III
- With plastic coverings	Class IV
- With foam plastic cushioning	Group A plastics
Grains — Packaged in Cartons	
- Barley	Class III
- Rice	Class III
- Oats	Class III
Ice Cream	Class I
Leather Goods	Class III
Leather Hides	
Baled	Class II
Light Fixtures	
Nonplastic	
- Cartoned	Class II
Lighters	
Butane	
- Blister-packed, cartoned	Group A plastics
- Loose in large containers (Level 3 aerosol)	Outside of scope
Liquor	
100 proof or less, 1 gal (3.8 L) or less, cartoned	
- Glass (palletized)[6]	Class IV
- Plastic bottles	Class IV
Marble	
Artificial sinks, countertops	
- Cartoned, crated	Class II
Margarine	
- Up to 50 percent oil (in paper or plastic containers)	Class III
- Between 50 percent and 80 percent oil (in any packaging)	Group A plastics
Matches	
Packaged, cartoned	
- Paper	Class IV
- Wood	Group A plastics
Mattresses	
- Standard (box spring)	Class III
- Foam (in finished form)	Group A plastics
Meat, Meat Products	
- Bulk	Class I
- Canned, cartoned	Class I

Table A-2-2.3 Alphabetized Listing of Commodity Classes *(Continued)*

Commodity	Commodity Class
- Frozen, nonwaxed, nonplastic containers	Class I
- Frozen, waxed-paper containers	Class II
- Frozen, expanded plastic trays	Class II
Metal Desks	
- With plastic tops and trim	Class I
Milk	
- Nonwaxed-paper containers	Class I
- Waxed-paper containers	Class I
- Plastic containers	Class I
- Containers in plastic crates	Group A plastics
Motors	
- Electric	Class I
Nail Polish	
- 1-oz to 2-oz (29.6-ml to 59.1-ml) glass, cartoned	Class IV
- 1-oz to 2-oz (29.6-ml to 59.1-ml) plastic bottles, cartoned	Group A plastics
Nuts	
- Canned, cartoned	Class I
- Packaged, cartoned	Class III
- Bagged	Class III
Paints	
Friction-top cans, cartoned	
- Water-based (latex)	Class I
- Oil-based	Class IV
Paper Products	
- Books, magazines, stationery, plastic-coated paper food containers, newspapers, cardboard games, or cartoned tissue products	Class III
- Tissue products, uncartoned and plastic wrapped	Group A plastics
Paper, Rolled	
In racks or on side - Medium- or heavyweight	Class III
In racks - Lightweight	Class IV
Paper, Waxed	
Packaged in cartons	Class IV
Pharmaceuticals	
Pills, powders	
- Glass bottles, cartoned	Class II
- Plastic bottles, cartoned	Class IV
Nonflammable liquids	
- Glass bottles, cartoned	Class II
Photographic Film	
- Motion picture or bulk rolls of film in polycarbonate, polyethylene, or metal cans; polyethylene bagged in cardboard boxes	Class II
- 35-mm in metal film cartridges in polyethylene cans in cardboard boxes	Class III
- Paper, in sheets, bagged in polyethylene, in cardboard boxes	Class III
- Rolls in polycarbonate plastic cassettes, bulk wrapped in cardboard boxes	Class IV
Plastic Containers (except PET)	
- Noncombustible liquids or semiliquids in plastic containers less than 5 gal (18.9 L) capacity	Class I
- Noncombustible liquids or semiliquids (such as ketchup) in plastic containers with nominal wall thickness of $^1/_4$ in. (6.4 mm) or less and larger than 5 gal (18.9) capacity	Class II
- Noncombustible liquids or semiliquids (such as ketchup) in plastic containers with nominal wall thickness greater than $^1/_4$ in. (6.4 mm) and larger than 5 gal (18.9 L) capacity	Group A plastics
Polyurethane	
- Cartoned or uncartoned expanded	Group A plastics
Poultry Products	
- Canned, cartoned	Class I
- Frozen, nonwaxed, nonplastic containers	Class I
- Frozen (on paper or expanded plastic trays)	Class II
Powders	
Ordinary combustibles — free flowing	
- In paper bags (i.e., flour, sugar)	Class II
PVA (polyvinyl alcohol) Resins	
PVC (polyvinyl chloride)	
- Flexible (e.g., cable jackets, plasticized sheets)	Class III
- Rigid (e.g., pipe, pipe fittings)	Class III
- Bagged resins	Class III
Rags	
Baled	
- Natural fibers	Class III
- Synthetic fibers	Class IV
Rubber	
- Natural, blocks in cartons	Class IV
- Synthetic	Group A plastics
Salt	
- Bagged	Class I
- Packaged, cartoned	Class II

(continues)

Table A-2-2.3 Alphabetized Listing of Commodity Classes *(Continued)*

Commodity	Commodity Class
Shingles	
- Asphalt-coated fiberglass	Class III
- Asphalt-impregnated felt	Class IV
Shock Absorbers	
- Metal dust cover	Class II
- Plastic dust cover	Class III
Signatures	
Books, magazines	
- Solid array on pallet	Class II
Skis	
- Wood	Class III
- Foam core	Class IV
Stuffed Toys	
Foam or synthetic	Group A plastics
Syrup	
- Drummed (metal containers)	Class I
- Barreled, wood	Class II
Textiles	
Natural fiber clothing or textile products	Class III
Synthetics (except rayon and nylon) —50/50 blend or less	
- Thread, yarn on wood or paper spools	Class III
- Fabrics	Class III
- Thread, yarn on plastic spools	Class IV
- Baled fiber	Group A plastics
Synthetics (except rayon and nylon) —greater than 50/50 blend	
- Thread, yarn on wood or paper spools	Class IV
- Fabrics	Class IV
- Baled fiber	Group A plastics
- Thread, yarn on plastic spools	Group A plastics
Rayon and nylon	
- Baled fiber	Class IV
- Thread, yarn on wood or paper spools	Class IV
- Fabrics	Class IV
- Thread, yarn on plastic spools	Group A plastics
Tobacco Products	
In paperboard cartons	Class III
Transformers	
Dry and oil filled	Class I
Vinyl-Coated Fabric	
Cartoned	Group A plastics
Vinyl Floor Coverings	
- Tiles in cartons	Class IV
- Rolled	Group A plastics

Table A-2-2.3 Alphabetized Listing of Commodity Classes *(Continued)*

Commodity	Commodity Class
Wax-Coated Paper	
Cups, plates	
- Boxed or packaged inside cartons (emphasis on packaging)	Class IV
- Loose inside large cartons	Group A plastics
Wax	
Paraffin, blocks, cartoned	Group A plastics
Wire	
- Bare wire on metal spools on wood skids	Class I
- Bare wire on wood or cardboard spools on wood skids	Class II
- Bare wire on metal, wood, or cardboard spools in cardboard boxes on wood skids	Class II
- Single- or multiple-layer PVC-covered wire on metal spools on wood skids	Class II
- Insulated (PVC) cable on large wood or metal spools on wood skids	Class II
- Bare wire on plastic spools in cardboard boxes on wood skids	Class IV
- Single- or multiple-layer PVC-covered wire on plastic spools in cardboard boxes on wood skids	Class IV
- Single, multiple, or power cables (PVC) on large plastic spools	Class IV
- Bulk storage of empty plastic spools	Group A plastics
Wood Products	
- Solid piles — lumber, plywood, particleboard, pressboard (smooth ends and edges)	Class II
- Spools (empty)	Class III
- Toothpicks, clothespins, hangers in cartons	Class III
- Doors, windows, wood cabinets, and furniture	Class III
- Patterns	Class IV

[1]The product is presumed to be in a plastic-coated package in a corrugated carton. If packaged in a metal foil, it can be considered Class I.
[2]Most batteries have a polypropylene case and, if stored empty, should be treated as a Group A plastic. Truck batteries, even where filled, should be considered a Group A plastic because of their thicker walls.
[3]As the openings in plastic crates become larger, the product behaves more like a Class III commodity. Conversely, as the openings become smaller, the product behaves more like a plastic.
[4]These items should be treated as idle pallets.
[5]Tests clearly indicate that a synthetic or synthetic blend is considered greater than Class III.
[6]When liquor is stored in glass containers in racks, it should be considered a Class III commodity; where it is palletized, it should be considered a Class IV commodity.

A-2-2.3.1 See Table A-2-2.3.1.

Table A-2-2.3.1 Examples of Class I Commodities

Alcoholic Beverages
Cartoned or uncartoned
- Up to 20 percent alcohol in metal, glass, or ceramic containers
Appliances, Major (i.e., stoves, refrigerators)
- Not packaged, no appreciable plastic exterior trim
Batteries
Dry cells (nonlithium or similar exotic metals)
- Packaged in cartons
Automobile
- Filled*
Bottles, Jars
Empty, cartoned
- Glass
Filled noncombustible liquids
- Glass, cartoned
- Plastic, cartoned [less than 5 gal (18.9 L)]
- Plastic, PET
Filled noncombustible powders
- Glass, cartoned
Canned Foods
In ordinary cartons
Cans
Metal
- Empty
Cement
Bagged
Coffee
Canned, cartoned
Fertilizers
Bagged
- Phosphates
File Cabinets
Metal
- Cardboard box or shroud
Fish or Fish Products
Frozen
- Nonwaxed, nonplastic packaging
Canned
- Cartoned
Frozen Foods
Nonwaxed, nonplastic packaging
Fruit
Fresh
- Nonplastic trays or containers
- With wood spacers
Ice Cream
Meat, Meat Products
- Bulk
- Canned, cartoned
- Frozen, nonwaxed, nonplastic containers
Metal Desks
- With plastic tops and trim
Milk
- Nonwaxed-paper containers
- Waxed-paper containers
- Plastic containers
Motors
- Electric
Nuts
- Canned, cartoned
Paints
Friction-top cans, cartoned
- Water-based (latex)
Plastic Containers
- Noncombustible liquids or semiliquids in plastic containers less than 5 gal (18.9 L) capacity
Poultry Products
- Canned, cartoned
- Frozen, nonwaxed, nonplastic containers
Salt
Bagged
Syrup
Drummed (metal containers)
Transformers
Dry and oil filled
Wire
Bare wire on metal spools on wood skids

*Most batteries have a polypropylene case and, if stored empty, should be treated as a Group A plastic. Truck batteries, even where filled, should be considered a Group A plastic because of their thicker walls.

A-2-2.3.2 See Table A-2-2.3.2.

Table A-2-2.3.2 Examples of Class II Commodities

Alcoholic Beverages
Up to 20 percent alcohol in wood containers
Appliances, major (e.g., stoves)
Corrugated, cartoned (no appreciable plastic trim)
Baked Goods
Cookies, cakes, pies
- Frozen, packaged in cartons*
Batteries
Dry cells (nonlithium or similar exotic metals) in blister pack in cartons
Bottles, Jars
Filled noncombustible powders
- Plastic PET
Boxes, Crates
Empty, wood, solid walls
Fertilizers
Bagged
- Nitrates
Fish or Fish Products
Frozen
- Waxed-paper containers, cartoned
- Boxed or barreled
Frozen Foods
Waxed-paper containers, cartoned
Leather Hides
Baled
Light Fixtures
Nonplastic
- Cartoned
Marble
Artificial sinks, countertops
- Cartoned, crated
Meat, Meat Products
- Frozen, waxed-paper containers
- Frozen, expanded plastic trays
Pharmaceuticals
Pills, powders
- Glass bottles, cartoned
Nonflammable liquids
- Glass bottles, cartoned
Photographic Film
- Motion picture or bulk rolls of film in polycarbonate, polyethylene, or metal cans; polyethylene bagged in cardboard boxes
Plastic Containers
Noncombustible liquids or semiliquids (such as ketchup) in plastic containers with nominal wall thickness of $^1/_4$ in. (6.4 mm) or less and larger than 5 gal (18.9 L) capacity
Poultry Products
Frozen (on paper or expanded plastic trays)
Powders (ordinary combustibles — free flowing)
In paper bags (i.e., flour, sugar)
Salt
Packaged, cartoned
Shock Absorbers
Metal dust cover
Signatures
Book, magazines
- Solid array on pallet
Syrup
Barreled, wood
Wire
- Bare wire on wood or cardboard spools on wood skids
- Bare wire on metal, wood, or cardboard spools in cardboard boxes on wood skids
- Single- or multiple-layer PVC-covered wire on metal spools on wood skids
- Insulated (PVC) cable on large wood or metal spools on wood skids
Wood Products
Solid piles
- Lumber, plywood, particle board, pressboard (smooth ends and edges)

*The product is in a plastic-coated package in a corrugated carton. If packaged in a metal foil, it can be considered Class I.

A-2-2.3.3 See Table A-2-2.3.3.

Table A-2-2.3.3 Examples of Class III Commodities

Aerosols
Cartoned or uncartoned
- Level 1
Baked Goods
Cookies, cakes, pies
- Packaged, in cartons
Beans
Dried
- Packaged, cartoned
Bread
Wrapped, cartoned
Butter
Whipped spread
Candy
Packaged, cartoned
Cartons
Corrugated
- Unassembled (neat piles)
Cereals
Packaged, cartoned
Charcoal
Bagged
- Standard
Cheese
- Packaged, cartoned
- Wheels, cartoned
Chewing Gum
Packaged, cartoned
Chocolate
Packaged, cartoned
Cloth
Cartoned and not cartoned
- Natural fiber, viscose
Cocoa Products
Packaged, cartoned
Coffee
Packaged, cartoned
Coffee Beans
Bagged
Cotton
Packaged, cartoned
Diapers
Cotton, linen
Dried Foods
Packaged, cartoned
Fish or Fish Products
Frozen
- Plastic trays, cartoned
Frozen Foods
Plastic trays

Table A-2-2.3.3 Examples of Class III Commodities

Furniture
Wood
- No plastic coverings or foam plastic cushioning
Grains — Packaged in cartons
- Barley
- Rice
- Oats
Margarine
Up to 50 percent oil (in paper or plastic containers)
Mattresses
Standard (box spring)
Nuts
- Packaged, cartoned
- Bagged
Paper Products
Books, magazines, stationery, plastic-coated paper food containers, newspapers, cardboard games, cartoned tissue products
Paper, Rolled
In racks or on side
- Medium or heavyweight
Photographic Film
- 35-mm in metal film cartridges in polyethylene cans in cardboard boxes
- Paper, in sheets, bagged in polyethylene, in cardboard boxes
PVC (polyvinyl chloride)
- Flexible (e.g., cable jackets, plasticized sheets)
- Rigid (e.g., pipe, pipe fittings)
- Bagged resins
Rags
Baled
- Natural fibers
Shingles
Asphalt-coated fiberglass
Shock Absorbers
Plastic dust cover
Skis
Wood
Textiles
Natural fiber clothing or textile products
Synthetics (except rayon and nylon) — 50/50 blend or less
- Thread, yarn on wood or paper spools
- Fabrics
Tobacco Products
In paperboard cartons
Wood Products
- Spools (empty)
- Toothpicks, clothespins, hangers in cartons
- Doors, windows, wood cabinets, and furniture

A-2-2.3.4 See Table A-2-2.3.4.

Table A-2-2.3.4 Examples of Class IV Commodities

Ammunition
Small arms, shotgun
- Packaged, cartoned
Bottles, Jars
Empty, cartoned
- Plastic PET (polyethylene terephthalate)
Filled noncombustible powders
- Plastic, cartoned [less than 1 gal (3.8 L)]
Cartons
Corrugated
- Partially assembled
Cloth
Cartoned and not cartoned
- Synthetic[1]
Diapers
- Disposable with plastics and nonwoven fabric (in cartons)
Fiberglass Insulation
- Paper-backed rolls, bagged or unbagged
Furniture
Wood
- With plastic coverings
Liquor
100 proof or less, 1 gal (3.8 L) or less, cartoned
- Glass (palletized)[2]
- Plastic bottles
Matches
Packaged, cartoned
- Paper
Nail Polish
1-oz to 2-oz (29.6-ml to 59.1-ml) glass, cartoned
Paints
Friction-top cans, cartoned
- Oil based
Paper, Rolled
In racks
- Lightweight
Paper, Waxed
Packaged in cartons
Pharmaceuticals
Pills, powders
- Plastic bottles, cartoned
Photographic Film
- Rolls in polycarbonate plastic cassettes, bulk wrapped in cardboard boxes
PVA (polyvinyl alcohol) Resins
Bagged
Rags
Baled
- Synthetic fibers
Rubber
Natural, blocks in cartons
Shingles
Asphalt-impregnated felt
Skis
Foam core
Textiles
Synthetics (except rayon and nylon) —
50/50 blend or less
- Thread, yarn on plastic spools
Synthetics (except rayon and nylon) — greater than 50/50 blend
- Thread, yarn on wood or paper spools
- Fabrics
Rayon and nylon
- Baled fiber
- Thread, yarn on wood or paper spools
- Fabrics
Vinyl Floor Coverings
Tiles in cartons
Wax-Coated Paper
Cups, plates
- Boxed or packaged inside cartons (emphasis is on packaging)
Wire
- Bare wire on plastic spools in cardboard boxes on wood skids
- Single- or multiple-layer PVC-covered wire on plastic spools in cardboard boxes on wood skids
- Single, multiple, or power cables (PVC) on large plastic spools
Wood Products
Patterns

[1]Tests clearly indicate that a synthetic or synthetic blend is considered greater than Class III.
[2]Where liquor is stored in glass containers in racks, it should be considered a Class III commodity; where it is palletized, it should be considered a Class IV commodity.

A-2-2.4 The categories listed in 2-2.4.1, 2-2.4.2, and 2-2.4.3 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.

A-2-2.4.1 See Table A-2-2.4.1.

Table A-2-2.4.1 Examples of Group A Plastic Commodities

Batteries
Truck or larger
- Empty or filled[1]
Bottles, Jars
Empty, cartoned
- Plastic (other than PET), any size
Filled noncombustible liquids
- Plastic, open or solid plastic crates[2]
Filled noncombustible powders
- Plastic, cartoned or uncartoned [greater than 1 gal (3.8 L)]
- Plastic, solid plastic crates
- Plastic, open plastic crates
Candles
Packaged, cartoned
- Treat as expanded plastic
Carpet Tiles
Cartoned
Cartons
Wax coated, single walled
Diapers
Disposable with plastics and nonwoven fabric (uncartoned), plastic wrapped
Furniture
Wood
- With foam plastic cushioning
Lighters
Butane
- Blister-packed, cartoned
Margarine
Between 50 percent and 80 percent oil (in any packaging)
Matches
Packaged, cartoned
- Wood
Mattresses
Foam (in finished form)
Milk
Containers in plastic crates
Nail Polish
1-oz to 2-oz (29.6-ml to 59.1-ml) plastic bottles, cartoned
Paper Products
Tissue products, uncartoned and plastic wrapped
Plastic Containers
- Combustible or noncombustible solids in plastic containers and empty plastic containers
- Noncombustible liquids or semiliquids (such as ketchup) in plastic containers with nominal wall thickness greater than $^1/_4$ in. (6.4 mm) and larger than 5 gal (18.9 L) capacity
Polyurethane
Cartoned or uncartoned expanded
Rubber
Synthetic
Stuffed Toys
Foam or synthetic
Textiles
Synthetics (except rayon and nylon) —
50/50 blend or less
- Baled fiber
Synthetics (except rayon and nylon)— greater than 50/50 blend
- Baled fiber
- Thread, yarn on plastic spools
Rayon and nylon
- Thread, yarn on plastic spools
Vinyl-Coated Fabric
Cartoned
Vinyl Floor Coverings
Rolled
Wax-Coated Paper
Cups, plates
- Loose inside large cartons
Wax
Paraffin, blocks, cartoned
Wire
Bulk storage of empty plastic spools

[1] Most batteries have a polypropylene case and, if stored empty, should be treated as a Group A plastic. Truck batteries, even where filled, should be considered a Group A plastic because of their thicker walls.

[2] As the openings in plastic crates become larger, the product behaves more like Class III. Conversely, as the openings become smaller, the product makeup behaves more like a plastic.

A-2-2.5 *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 1000-ft^2 (92.9-m^2) sheet. 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 3000-ft^2 (278.7-m^2) sheet. 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:

(1) *Bond paper* — 500 sheets, 17 in. × 22 in. (432 mm × 559 mm) = 1300 ft^2 (120.8 m^2) per ream
(2) *Book paper* — 500 sheets, 25 in. × 38 in. (635 mm × 965 mm) = 3300 ft^2 (306.6 m^2) per ream
(3) *Index paper* — 500 sheets, $25^1/_2$ in. × $30^1/_2$ in. (648 mm × 775 mm) = 2700 ft^2 (250.8 m^2) per ream
(4) *Bristol paper* — 500 sheets, $22^1/_2$ in. × 35 in. (572 mm × 889 mm) = 2734 ft^2 (254 m^2) per ream
(5) *Tag paper* — 500 sheets, 24 in. × 36 in. (610 mm × 914 mm) = 3000 ft^2 (278.7 m^2) per 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:

$$\frac{\text{Basis weight}}{1000\ \text{ft}^2} = \text{basis weight} \times \frac{1000}{\text{measured area}}$$

Example: To determine the basis weight per 1000 ft^2 (92.9 m^2) of 16-lb (7.3-kg) bond paper:

$$\left(\frac{16\ \text{lb}}{1300\ \text{ft}^2}\right)1000 = \frac{12.3\ \text{lb}}{1000\ \text{ft}^2}$$

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:

(1) *Linerboard* — 42 lb/1000 ft^2 (19.1 kg/92.9 m^2) nominal basis weight
(2) *Newsprint* — 10 lb/1000 ft^2 (4.5 kg/92.9 m^2) nominal basis weight
(3) *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:

(1) Heavyweight — Basis weight of 20 lb/1000 ft^2 (9.1 kg/92.9 m^2) or greater
(2) Mediumweight — Basis weight of 10 lb to 20 lb/1000 ft^2 (4.5 kg to 9.1 kg/92.9 m^2)
(3) 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 four major categories are provided in Table A-2.2.5.

Table A-2.2.5 Paper Classification

Heavyweight	Mediumweight	Lightweight	Tissue
Linerboards	Bond and 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 Included among items requiring listing are sprinklers, some pipe and some fittings, hangers, alarm devices, valves controlling flow of water to sprinklers, valve tamper switches, and gauges.

A-3-2.2 The four- to six-character identification number, with no intervening spaces, is intended to identify the sprinkler operating characteristics. The number, marked on the deflector of most sprinklers and elsewhere on decorative ceiling sprinklers, consists of one or two characters identifying the manufacturer, followed by three or four digits identifying the model.

Sprinkler manufacturers have identified their manufacturer designations for the listing organizations. Each change in orifice size, response characteristics, or deflector (distribution) characteristics results in a new model number. The model numbers do not identify specific characteristics of sprinklers but can be referenced in the database information

compiled by the listing organizations. At the plan review stage, the model number should be checked against such a database or the manufacturer's literature to ensure that sprinklers are being used properly and within the limitations of their listings. Field inspections can include spot checks to ensure that the model numbers on the plans are those actually installed.

A-3-2.3.1 See Table A-3-2.3.1.

Table A-3-2.3.1 Nominal Sprinkler Orifice Sizes

Nominal K-factor	Nominal Orifice Size	
	in.	mm
1.4	1/4	6.4
1.9	5/16	8.0
2.8	3/8	9.5
4.2	7/16	11.0
5.6	1/2	12.7
8.0	17/32	13.5
11.2	5/8	15.9
14.0	3/4	19.0
16.8	—	—
19.6	—	—
22.4	—	—
25.2	—	—
28.0	—	—

A-3-2.5 Information regarding the highest temperature that can be encountered in any location in a particular installation can be obtained by use of a thermometer that will register the highest temperature encountered; it should be hung for several days in the location in question, with the plant in operation.

A-3-2.6.1 Examples of such locations include the following:

(1) Paper mills
(2) Packing houses
(3) Tanneries
(4) Alkali plants
(5) Organic fertilizer plants
(6) Foundries
(7) Forge shops
(8) Fumigation, pickle, and vinegar works
(9) Stables
(10) Storage battery rooms
(11) Electroplating rooms
(12) Galvanizing rooms
(13) Steam rooms of all descriptions, including moist vapor dry kilns
(14) Salt storage rooms
(15) Locomotive sheds or houses
(16) Driveways
(17) Areas exposed to outside weather, such as piers and wharves exposed to salt air
(18) Areas under sidewalks
(19) Areas around bleaching equipment in flour mills
(20) All portions of cold storage buildings where a direct ammonia expansion system is used
(21) Portions of any plant where corrosive vapors prevail

A-3-2.6.2 Care should be taken in the handling and installation of wax-coated or similar sprinklers to avoid damaging the coating.

A-3-2.6.3 Painting of sprinklers can retard the thermal response of the heat-responsive element, can interfere with the free movement of parts, and can render the sprinkler inoperative. Moreover, painting can invite the application of subsequent coatings, thus increasing the possibility of a malfunction of the sprinkler.

A-3-2.7.2 The use of the wrong type of escutcheon with recessed or flush-type sprinklers can result in severe disruption of the spray pattern, which can destroy the effectiveness of the sprinkler.

A-3-2.8 Sprinklers under open gratings should be provided with shields. Shields over automatic sprinklers should not be less, in least dimension, than four times the distance between the shield and fusible element, except special sprinklers incorporating a built-in shield need not comply with this recommendation if listed for the particular application.

A-3-3.2 See Table A-3-3.2.

A-3-3.4 See Table A-3-3.4.

A-3-3.5 Other types of pipe and tube that have been investigated and listed for sprinkler applications include lightweight steel pipe and thermoplastic pipe and fittings. While these products can offer advantages, such as ease of handling and installation, cost-effectiveness, reduction of friction losses, and improved corrosion resistance, it is important to recognize that they also have limitations that are to be considered by those contemplating their use or acceptance.

Corrosion studies have shown that, in comparison to Schedule 40 pipe, the effective life of lightweight steel pipe can be reduced, the level of reduction being related to its wall thickness. Further information with respect to corrosion resistance is contained in the individual listings for such pipe.

With respect to thermoplastic pipe and fittings, exposure of such piping to elevated temperatures in excess of that for which it has been listed can result in distortion or failure. Accordingly, care must be exercised when locating such systems to ensure that the ambient temperature, including seasonal variations, does not exceed the rated value.

The upper service temperature limit of currently listed CPVC sprinkler pipe is 150°F (65.5°C) at 175 psi (12.1 bar). The upper service temperature limit of currently listed polybutylene sprinkler pipe is 120°F (49°C) at 175 psi (12.1 bar).

Not all pipe or tube made to ASTM F 442, *Standard Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe (SDR-PR),* and ASTM D 3309, *Standard Specification for Polybutylene (PB) Plastic Hot- and Cold-Water Distribution Systems,* as described in 3-3.5, is listed for fire sprinkler service. Listed pipe is identified by the logo of the listing agency.

Not all fittings made to ASTM F 437, *Standard Specification for Threaded Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80;* ASTM F 438, *Standard Specification for Socket-Type Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 40;* and ASTM F 439, *Standard Specification for Socket-Type Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80,* as described in 3-5.2, are listed for fire sprinkler service. Listed fittings are identified by the logo of the listing agency.

Table A-3-3.2 Steel Pipe Dimensions

Nominal Pipe Size	Outside Diameter		Schedule 10[a]				Schedule 30				Schedule 40			
			Inside Diameter		Wall Thickness		Inside Diameter		Wall Thickness		Inside Diameter		Wall Thickness	
(in.)	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
1/2[b]	0.840	21.3	0.674	17.0	0.083	2.1	—	—	—	—	0.622	15.8	0.109	2.8
3/4[b]	1.050	26.7	0.884	22.4	0.083	2.1	—	—	—	—	0.824	21.0	0.113	2.9
1	1.315	33.4	1.097	27.9	0.109	2.8	—	—	—	—	1.049	26.6	0.133	3.4
1 1/4	1.660	42.2	1.442	36.6	0.109	2.8	—	—	—	—	1.380	35.1	0.140	3.6
1 1/2	1.900	48.3	1.682	42.7	0.109	2.8	—	—	—	—	1.610	40.9	0.145	3.7
2	2.375	60.3	2.157	54.8	0.109	2.8	—	—	—	—	2.067	52.5	0.154	3.9
2 1/2	2.875	73.0	2.635	66.9	0.120	3.0	—	—	—	—	2.469	62.7	0.203	5.2
3	3.500	88.9	3.260	82.8	0.120	3.0	—	—	—	—	3.068	77.9	0.216	5.5
3 1/2	4.000	101.6	3.760	95.5	0.120	3.0	—	—	—	—	3.548	90.1	0.226	5.7
4	4.500	114.3	4.260	108.2	0.120	3.0	—	—	—	—	4.026	102.3	0.237	6.0
5	5.563	141.3	5.295	134.5	0.134	3.4	—	—	—	—	5.047	128.2	0.258	6.6
6	6.625	168.3	6.357	161.5	0.134[c]	3.4	—	—	—	—	6.065	154.1	0.280	7.1
8	8.625	219.1	8.249	209.5	0.188[c]	4.8	8.071	205.0	0.277	7.0	7.981	—	0.322	—
10	10.750	273.1	10.370	263.4	0.188[c]	4.8	10.140	257.6	0.307	7.8	10.020	—	0.365	—
12	12.750	—	12.090	—	0.330	—	—	—	—	—	11.938	—	0.406	—

[a]Schedule 10 defined to 5-in. (127-mm) nominal pipe size by ASTM A 135, *Standard Specification for Electric-Resistance-Welded Steel Pipe.*
[b]These values applicable when used in conjunction with 5-13.20.2 and 5-13.20.3.
[c]Wall thickness specified in 3-3.2 and 3-3.3.

Table A-3-3.4 Copper Tube Dimensions

Nominal Tube Size	Outside Diameter		Type K				Type L				Type M			
			Inside Diameter		Wall Thickness		Inside Diameter		Wall Thickness		Inside Diameter		Wall Thickness	
(in.)	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
3/4	0.875	22.2	0.745	18.9	0.065	1.7	0.785	19.9	0.045	1.1	0.811	20.6	0.032	0.8
1	1.125	28.6	0.995	25.3	0.065	1.7	1.025	26.0	0.050	1.3	1.055	26.8	0.035	0.9
1 1/4	1.375	34.9	1.245	31.6	0.065	1.7	1.265	32.1	0.055	1.4	1.291	32.8	0.042	1.1
1 1/2	1.625	41.3	1.481	37.6	0.072	1.8	1.505	38.2	0.060	1.5	1.527	38.8	0.049	1.2
2	2.125	54.0	1.959	49.8	0.083	2.1	1.985	50.4	0.070	1.8	2.009	51.0	0.058	1.5
2 1/2	2.625	66.7	2.435	61.8	0.095	2.4	2.465	62.6	0.080	2.0	2.495	63.4	0.065	1.7
3	3.125	79.4	2.907	73.8	0.109	2.8	2.945	74.8	0.090	2.3	2.981	75.7	0.072	1.8
3 1/2	3.625	92.1	3.385	86.0	0.120	3.0	3.425	87.0	0.100	2.5	3.459	87.9	0.083	2.1
4	4.125	104.8	3.857	98.0	0.134	3.4	3.905	99.2	0.110	2.8	3.935	99.9	0.095	2.4
5	5.125	130.2	4.805	122.0	0.160	4.1	4.875	123.8	0.125	3.2	4.907	124.6	0.109	2.8
6	6.125	155.6	5.741	145.8	0.192	4.9	5.845	148.5	0.140	3.6	5.881	149.4	0.122	3.1
8	8.125	206.4	7.583	192.6	0.271	6.9	7.725	196.2	0.200	5.1	7.785	197.7	0.170	4.3
10	10.130	257.3	9.449	240.0	0.338	8.6	9.625	244.5	0.250	6.4	9.701	246.4	0.212	5.4

Consideration must also be given to the possibility of exposure of the piping to elevated temperatures during a fire. The survival of thermoplastic piping under fire conditions is primarily due to the cooling effect of the discharge from the sprinklers it serves. As this discharge might not occur simultaneously with the rise in ambient temperature and, under some circumstances, can be delayed for periods beyond the tolerance of the piping, protection in the form of a fire-resistant membrane is generally required. (Some listings do provide for the use of exposed piping in conjunction with residential or quick-response sprinklers, but only under specific, limited installation criteria.)

Where protection is required, it is described in the listing information for each individual product, and the requirements given must be followed. It is equally important that such protection must be maintained. Removal of, for example, one or more panels in a lay-in ceiling can expose piping in the concealed space to the possibility of failure in the event of a fire. Similarly, the relocation of openings through protective ceilings that expose the pipe to heat, inconsistent with the listing, would place the system in jeopardy. The potential for loss of the protective membrane under earthquake conditions should also be considered.

While the listings of thermoplastic piping do not prohibit its installation in combustible concealed spaces where the provision of sprinkler protection is not required, and while the statistical record of fire originating in such spaces is low, it should be recognized that the occurrence of a fire in such a space could result in failure of the piping system.

The investigation of pipe and tube other than described in Table 3-3.1 should involve consideration of many factors, including the following:

(1) Pressure rating
(2) Beam strength (hangers)
(3) Unsupported vertical stability
(4) Movement during sprinkler operation (affecting water distribution)
(5) Corrosion (internal and external), chemical and electrolytic
(6) Resistance to failure when exposed to elevated temperatures
(7) Methods of joining (strength, permanence, fire hazard)
(8) Physical characteristics related to integrity during earthquakes

A-3-4 Loop systems for yard piping are recommended for increased reliability and improved hydraulics. Loop systems should be sectionalized by placing valves at branches and at strategic locations to minimize the extent of impairments.

A-3-4.1 Copper tubing (Type K) with brazed joints conforming to Table 3-3.1 and 3-6.4 is acceptable for underground service. Listing and labeling information, along with applicable publications for reference, follows.

(a) *Listing and Labeling.* Testing laboratories list or label cast-iron and ductile iron pipe (cement-lined and unlined, coated and uncoated), asbestos-cement pipe and couplings, steel pipe, copper pipe, fiberglass filament–wound epoxy pipe and couplings, polyethylene pipe, and polyvinyl chloride (PVC) pipe and couplings. Underwriters Laboratories Inc. lists, under re-examination service, reinforced concrete pipe (cylinder pipe, nonprestressed and prestressed).

(b) *Pipe Standards.* The various types of pipe are usually manufactured to one of the following standards:

ASTM C296, *Standard Specification for Asbestos-Cement Pressure Pipe*

AWWA C151, *Ductile Iron Pipe, Centrifugally Cast for Water*

AWWA C300, *Reinforced Concrete Pressure Pipe, Steel-Cylinder Type, for Water and Other Liquids*

AWWA C301, *Prestressed Concrete Pressure Pipe, Steel-Cylinder Type, for Water and Other Liquids*

AWWA C302, *Reinforced Concrete Pressure Pipe, Non-Cylinder Type, for Water and Other Liquids*

AWWA C303, *Reinforced Concrete Pressure Pipe, Steel-Cylinder Type, Pretensioned, for Water and Other Liquids*

AWWA C400, *Standard for Asbestos-Cement Distribution Pipe, 4 in. Through 16 in., for Water and Other Liquids*

AWWA C900, *Polyvinyl Chloride (PVC) Pressure Pipe, 4 in. Through 12 in., for Water and Other Liquids*

A-3-4.2 The following pipe design manuals can be used as guides:

AWWA C150, *Thickness Design of Ductile Iron Pipe*

AWWA C401, *Standard Practice for the Selection of Asbestos-Cement Water Pipe*

AWWA M14, *Ductile Iron Pipe and Fittings*

Concrete Pipe Handbook, American Concrete Pipe Association

A-3-4.4 The following standards apply to the application of coating and linings:

AWWA C104, *Cement Mortar Lining For Ductile Iron Pipe and Fittings for Water*

AWWA C105, *Polyethylene Encasement for Ductile Iron Pipe Systems*

AWWA C203, *Coal-Tar Protective Coatings and Linings for Steel Water Pipelines Enamel and Tape — Hot Applied*

AWWA C205, *Cement-Mortar Protective Lining and Coating for Steel Water Pipe 4 in. and Larger — Shop Applied*

AWWA C602, *Cement-Mortar Lining of Water Pipe Lines 4 in. and Larger — in Place*

A-3-5.2 Rubber-gasketed pipe fittings and couplings should not be installed where ambient temperatures can be expected to exceed 150°F (66°C) unless listed for this service. If the manufacturer further limits a given gasket compound, those recommendations should be followed.

A-3-5.3 The rupture strength of cast-iron fittings 2 in. (50.8 mm) in size and smaller and malleable iron fittings 6 in. (152.4 mm) in size and smaller is sufficient to provide an adequate factor of safety.

A-3-5.4 Listed flexible connections are permissible and encouraged for sprinkler installations in racks to reduce the possibility of physical damage. Where flexible tubing is used, it should be located so that it will be protected against mechanical injury.

A-3-5.6 Fittings generally used are cast iron with joints made to the specifications of the manufacturer of the particular type of pipe *(see the standards listed in A-3-4.1.)* Steel fittings also have some applications. The following standards apply to fittings:

ASME B16.1, *Cast-Iron Pipe Flanges and Flanged Fittings for 25, 125, 250 and 800 lb*

AWWA C110, *Ductile Iron and Gray Iron Fittings, 3-in. Through 48-in., for Water and Other Liquids*

AWWA C153, *Ductile Iron Compact Fittings, 3 in. through 24 in. and 54 in. through 64 in. for Water Service*

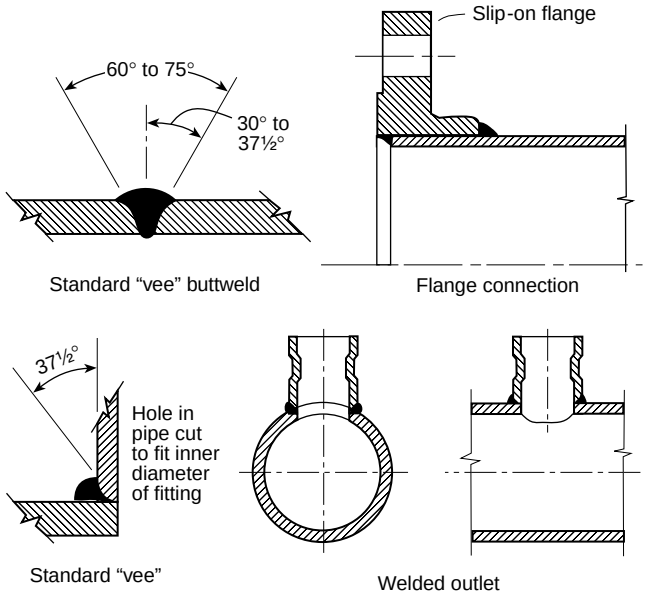
AWWA C208, *Dimensions for Fabricated Steel Water Pipe Fittings*

A-3-6.1.2 Some steel piping material having lesser wall thickness than specified in 3-6.1.2 has been listed for use in sprinkler systems where joined with threaded connections. The service life of such products can be significantly less than that of Schedule 40 steel pipe, and it should be determined if this service life will be sufficient for the application intended.

All such threads should be checked by the installer using working ring gauges conforming to the "Basic Dimensions of Ring Gauges for USA (American) Standard Taper Pipe Threads, NPT," as per Table 8 of ASME B1.20.1, *Pipe Threads, General Purpose, (Inch).*

A-3-6.2 See Figures A-3-6.2(a) and A-3-6.2(b).

Figure A-3-6.2(a) Acceptable weld joints.



A-3-6.2.2 Cutting and welding operations account for 4 percent of fires each year in nonresidential properties and 8 percent in industrial and manufacturing properties. In-place welding of sprinkler piping introduces a significant hazard that can normally be avoided by shop-welding the piping and installing the welded sections with mechanical fittings. As a result, the standard requires that all piping be shop-welded. When such situations cannot be avoided, the exceptions outline procedures and practices that minimize the increase in hazard.

A-3-6.2.5(1) Listed, shaped, contoured nipples meet the definition of fabricated fittings.

A-3-6.4 The fire hazard of the brazing and soldering processes should be suitably safeguarded.

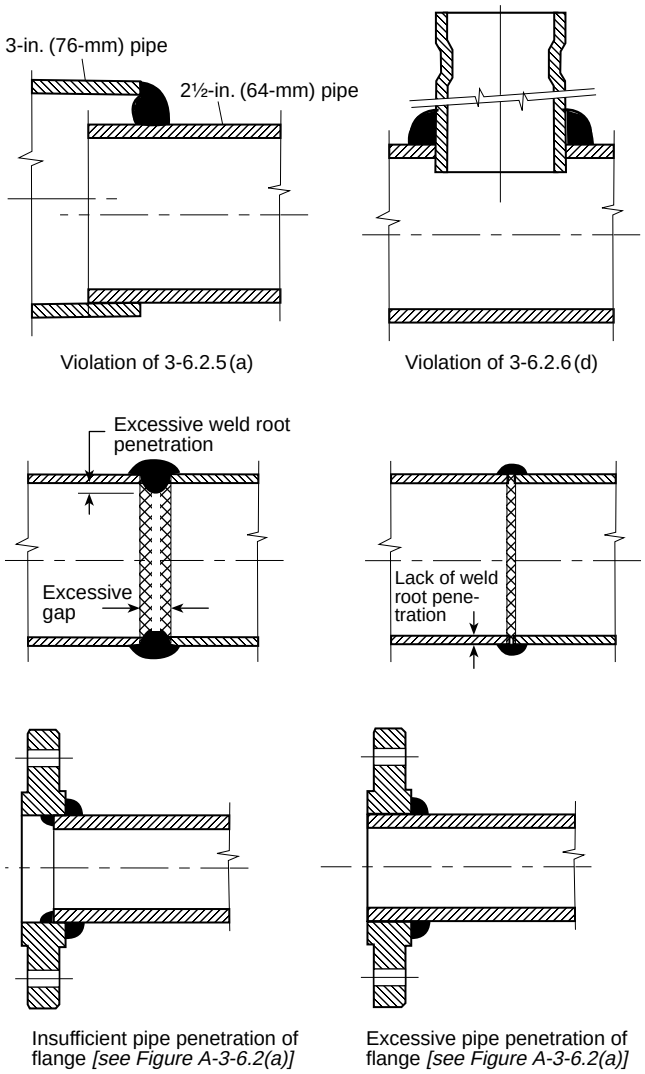
A-3-6.4.1 Soldering fluxes manufactured to the specifications required by Table 3-3.1 are unlikely to cause damage to the seats of sprinklers. When brazing flux is used, it must be of a type not likely to damage the seats of sprinklers.

A-3-6.7 The following standards apply to joints used with the various types of pipe:

ASME B16.1, *Cast-Iron Pipe Flanges and Flanged Fittings for 25, 125, 250 and 800 lb*

AWWA C111, *Rubber Gasket Joints for Ductile Iron Pressure Pipe and Fittings*

Figure A-3-6.2(b) Unacceptable weld joints.



AWWA C115, *Flanged Ductile Iron Pipe with Ductile Iron or Gray Iron Threaded Flanges*

AWWA C206, *Field Welding of Steel Water Pipe*

AWWA C606, *Grooved and Shouldered Joints*

A-3-7 See Section 6-1 for information pertaining to the type of hangers and hanger components acceptable for use on a sprinkler system.

A-3-8.3 The intent of 3-8.3 is to provide assistance in determining the area of a building served by a particular control valve.

A-3-10.2.4 The surge of water that occurs when the valve trips can seriously damage the device.

A-3-10.3.1 Audible alarms are normally located on the outside of the building. Listed electric gongs, bells, horns, or sirens inside the building, or a combination of such used inside and outside, are sometimes advisable.

Outside alarms can be omitted where the sprinkler system is used as part of a central station, auxiliary, remote station, or proprietary signaling fire alarm system utilizing listed audible inside alarm devices.

A-3-10.3.2 All alarm apparatus should be so located and installed that all parts are accessible for inspection, removal, and repair, and such apparatus should be substantially supported.

The water motor gong bell mechanism should be protected from weather-related elements such as rain, snow, or ice. To the extent practicable, it should also be protected from other influencing factors such as birds or other small animals that might attempt to nest in such a device.

A-3-10.5 Switches that will silence electric alarm-sounding devices by interruption of electric current are not desirable; however, if such means are provided, then the electric alarm-sounding device circuit should be arranged so that, when the sounding device is electrically silenced, that fact should be indicated by means of a conspicuous light located in the vicinity of the riser or alarm control panel. This light should remain in operation during the entire period of the electric circuit interruption.

A-4-2 A dry pipe system should be installed only where heat is not adequate to prevent freezing of water in all parts of, or in sections of, the system. Dry pipe systems should be converted to wet pipe systems when they become unnecessary because adequate heat is provided. Sprinklers should not be shut off in cold weather.

Where two or more dry pipe valves are used, systems preferably should be divided horizontally to prevent simultaneous operation of more than one system and the resultant increased time delay in filling systems and discharging water and to prevent receipt of more than one waterflow alarm signal.

Where adequate heat is present in sections of the dry pipe system, consideration should be given to dividing the system into a separate wet pipe system and dry pipe system. Minimized use of dry pipe systems is desirable where speed of operation is of particular concern.

A-4-2.2 Exception No. 1. Installation limitations of listed dry pendent sprinklers can vary with different products. Limitations should be included in product installation instructions to warn the user of the potential accumulation of water, scale, and sediment from collecting at the sprinkler.

A-4-2.3 The capacities of the various sizes of pipe given in Table A-4-2.3 are for convenience in calculating the capacity of a system.

A-4-2.3.1 The 60-second limit does not apply to dry systems with capacities of 500 gal (1893 L) or less, nor to dry systems with capacities of 750 gal (2839 L) or less if equipped with a quick-opening device.

A-4-2.5 The dry pipe valve should be located in an accessible place near the sprinkler system it controls. Where exposed to cold, the dry pipe valve should be located in a valve room or enclosure of adequate size to properly service equipment.

A-4-2.6.2 The compressor should draw its air supply from a place where the air is dry and not too warm. Moisture from condensation can cause trouble in the system.

Table A-4-2.3 Capacity of One Foot of Pipe (Based on Actual Internal Pipe Diameter)

Nominal Pipe Diameter (in.)	Pipe Schedule 40 (gal)	Pipe Schedule 10 (gal)	Nominal Pipe Diameter (in.)	Pipe Schedule 40 (gal)	Pipe Schedule 10 (gal)
$^3/_4$	0.028		3	0.383	0.433
1	0.045	0.049	$3^1/_2$	0.513	0.576
$1^1/_4$	0.078	0.085	4	0.660	0.740
$1^1/_2$	0.106	0.115	5	1.040	1.144
2	0.174	0.190	6	1.501	1.649[b]
$2^1/_2$	0.248	0.283	8	2.66[a]	2.776[c]

For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m; 1 gal = 3.785 L.
[a]Schedule 30.
[b]0.134 wall pipe.
[c]0.188 wall pipe.

A-4-3.1 Conditions of occupancy or special hazards might require quick application of large quantities of water, and, in such cases, deluge systems might be needed.

Fire detection devices should be selected to assure operation yet guard against premature operation of sprinklers based on normal room temperatures and draft conditions.

In locations where ambient temperature at the ceiling is high from heat sources other than fire conditions, heat-responsive devices that operate at higher than ordinary temperature and that are capable of withstanding the normal high temperature for long periods of time should be selected.

Where corrosive conditions exist, materials or protective coatings that resist corrosion should be used.

To help avoid ice formation in piping due to accidental tripping of dry pipe valves in cold storage rooms, a deluge automatic water control valve can be used on the supply side of the dry pipe valve. Where this method is employed, the following also apply:

(1) Dry systems can be manifolded to a deluge valve, with the protected area not exceeding 40,000 ft^2 (3716 m^2).
(2) Where a dry system is manifolded to a deluge valve, the distance between valves should be as short as possible to minimize water hammer.
(3) The dry pipe valves should be pressurized to 50 psi (3.4 bar) to reduce the possibility of dry pipe valve operation from water hammer.

A-4-3.2.3 Supervision, either electrical or mechanical, as used in 4-3.2.3 refers to constant monitoring of piping and detection equipment to ensure the integrity of the system.

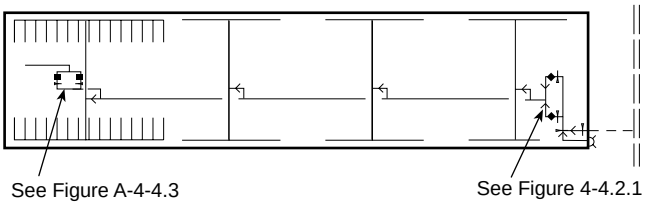
A-4-3.2.4 Exception No. 1. See A-4-2.2 Exception No. 1.

A-4-3.3 Where 8-in. (203-mm) piping is employed to reduce friction losses in a system operated by fire detection devices, a 6-in. (152-mm) preaction or deluge valve and a 6-in. (152-mm) gate valve between tapered reducers should be permitted.

A-4-4.1 Systems described by Section 4-4 are special types of non-interlocking preaction systems intended for use in, but not limited to, structures where a number of dry pipe valves would be required if a dry pipe system were installed. These systems are primarily used in piers and wharves.

A-4-4.1.1 See Figure A-4-4.1.1.

Figure A-4-4.1.1 Typical piping layout for combined dry pipe and preaction sprinkler system.



A-4-4.1.4 Exception No. 1. See A-4-2.2 Exception No. 1.

A-4-4.3 See Figure A-4-4.3.

A-4-5.1 Antifreeze solutions can be used for maintaining automatic sprinkler protection in small, unheated areas. Antifreeze solutions are recommended only for systems not exceeding 40 gal (151 L).

Because of the cost of refilling the system or replenishing to compensate for small leaks, it is advisable to use small dry valves where more than 40 gal (151 L) are to be supplied.

A-4-5.2 Listed CPVC sprinkler pipe and fittings should be protected from freezing with glycerine only. The use of diethylene, ethylene, or propylene glycols are specifically prohibited. Laboratory testing shows that glycol-based antifreeze solutions present a chemical environment detrimental to CPVC.

A-4-5.2.3 Beyond certain limits, an increased proportion of antifreeze does not lower the freezing point of solution *(see Figure A-4-5.2.3)*.

Glycerine, diethylene glycol, ethylene glycol, and propylene glycol should never be used without mixing with water in proper proportions, because these materials tend to thicken near 32°F (0°C).

Figure A-4-4.3 Arrangement of air exhaust valves for combined dry pipe and preaction sprinkler system.

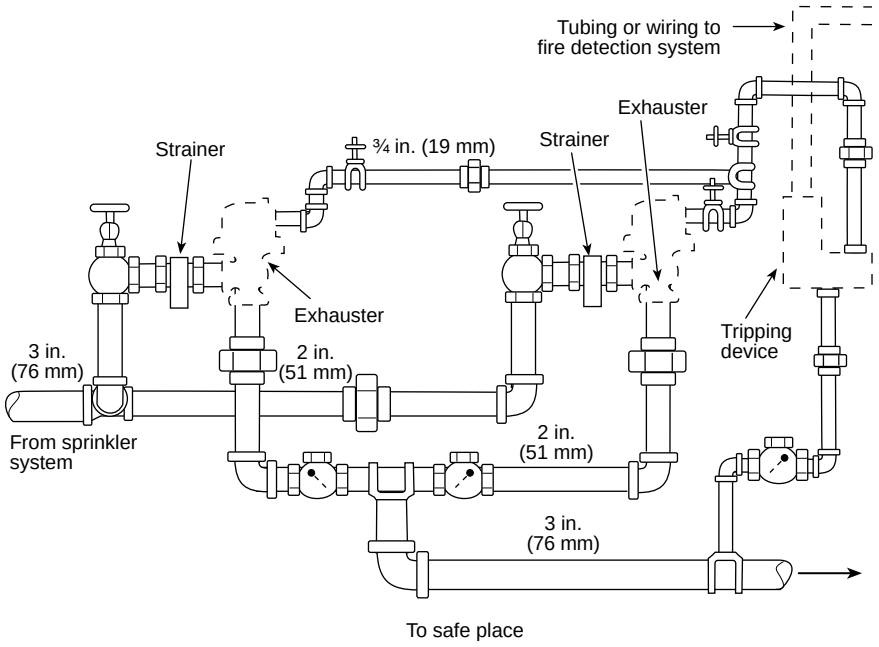
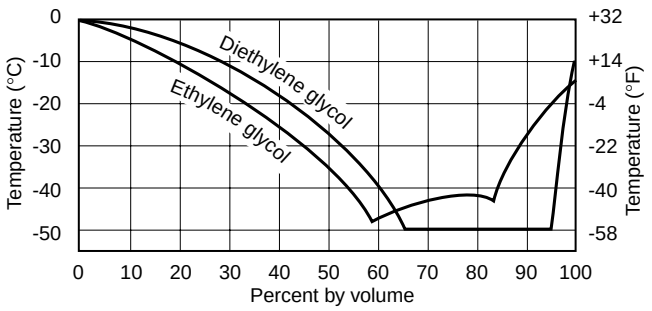


Figure A-4-5.2.3 Freezing points of water solutions of ethylene glycol and diethylene glycol.



A-4-5.3.1 All permitted antifreeze solutions are heavier than water. At the point of contact (interface), the heavier liquid will be below the lighter liquid, preventing diffusion of water into the unheated areas.

A-4-5.3.2 One formula for sizing the chamber is as follows. Other methods also exist.

$$\Delta L = S_V\left(\frac{D_L}{D_H} - 1\right)$$

where:

ΔL = change in antifreeze solution volume (gal) due to thermal expansion

S_V = volume (gal) of antifreeze system, not including the expansion chamber

D_L = density (gm/ml) of antifreeze solution at lowest expected temperature

D_H = density (gm/ml) of antifreeze solution at highest expected temperature

This method is based on the following information:

$$\frac{P_0 \cdot V_0}{T_0} = \frac{P_1 \cdot V_1}{T_1} = \frac{P_2 \cdot V_2}{T_2}$$

where:

V_{EC} = minimum required volume (gal) of expansion chamber

V_0 = air volume (gal) in expansion chamber at pre-charge (before installation)

V_1 = air volume (gal) in expansion chamber at normal static pressure

V_2 = air volume (gal) in expansion chamber at post-expansion pressure (antifreeze at high temperature)

P_0 = absolute pre-charge pressure (psia) on expansion chamber before installation

P_1 = absolute static pressure (psi) on water (supply) side of backflow preventer

P_2 = absolute maximum allowable working pressure (psi) for antifreeze system

T_0 = temperature (°R) of air in expansion chamber at pre-charge

T_1 = temperature (°R) of air in expansion chamber when antifreeze system piping is at lowest expected temperature

T_2 = temperature (°R) of air in expansion chamber when antifreeze system piping is at highest expected temperature

This equation is one formulation of the ideal gas law from basic chemistry. The amount of air in the expansion chamber will not change over time. The pressure, temperature, and volume of the air at different times will be related in accordance with this formula.

$$V_2 = V_1 - \Delta L$$

The antifreeze in the system is essentially incompressible, so the air volume in the expansion chamber will decrease by an amount equal to the expansion of the antifreeze.

It is assumed that there is no trapped air in the system piping, so the only air in the system is in the expansion chamber. This is a conservative assumption, since more air is better. In reality, there will be at least some trapped air. However, only the air in the expansion chamber can be relied upon to be available when needed.

$$V_{EC} = V_0$$

At pre-charge, the chamber will be completely full of air.

$$V_{EC} = \frac{P_1 \cdot T_0 \cdot P_2 \cdot \Delta L \cdot T_1}{P_0 \cdot T_1 (P_2 \cdot T_1 - P_1 \cdot T_2)}$$

A-4-6.1.2 Outlets should be provided at critical points on sprinkler system piping to accommodate attachment of pressure gauges for test purposes.

A-4-7.2.1 The water supply should be capable of furnishing the total demand for all exposure sprinklers operating simultaneously for protection against the exposure fire under consideration for a duration of not less than 60 minutes.

A-4-8 Careful installation and maintenance, and some special arrangements of piping and devices as outlined in this section, are needed to avoid the formation of ice and frost inside piping in cold storage rooms that will be maintained at or below 32°F (0°C). Conditions are particularly favorable to condensation where pipes enter cold rooms from rooms having temperatures above freezing.

Whenever the opportunity offers, fittings such as those specified in 4-8.1, as well as flushing connections, should be provided in existing systems.

Where possible, risers should be located in stair towers or other locations outside of refrigerated areas, which would reduce the probabilities of ice or frost formation within the riser (supply) pipe.

Cross mains should be connected to risers or feed mains with flanges. In general, flanged fittings should be installed at points that would allow easy dismantling of the system. Split ring or other easily removable types of hangers will facilitate the dismantling.

Because it is not practical to allow water to flow into sprinkler piping in spaces that might be constantly subject to freezing, or where temperatures must be maintained at or below 40°F (4.4°C), it is important that means be provided at the time of system installation to conduct trip tests on dry pipe valves that service such systems. NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems,* contains requirements in this matter.

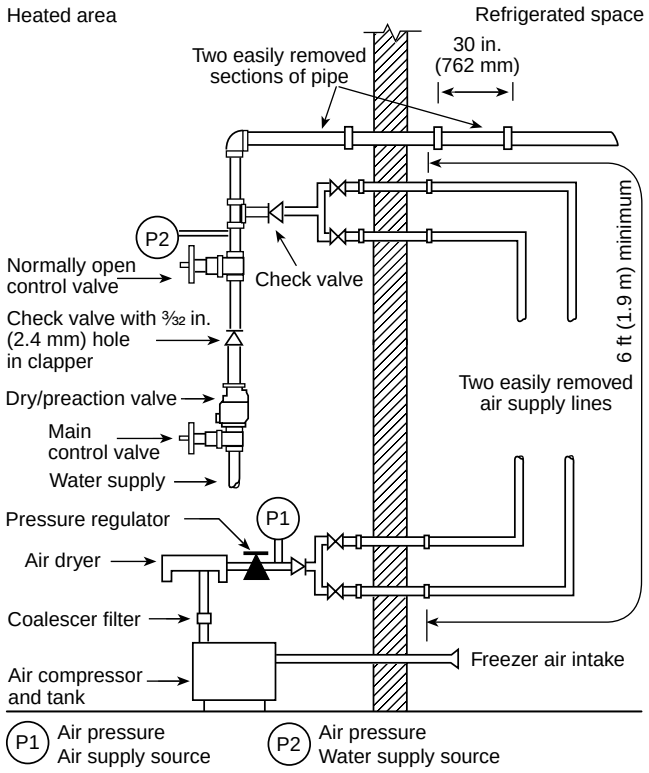
A-4-8.2 The requirements in 4-8.2 are intended to minimize the chances of ice plug formation inside sprinkler system piping protecting freezers.

A-4-8.2.4 A higher degree of preventing the formation of ice blocks can be achieved by lowering the moisture of the air supply entering the refrigerated space to a pressure dew point no greater than 20°F (–6.6°C) below the lowest nominal temperature of the refrigerated space. The pressure dew point of the air supply can cause moisture to condense and freeze in sprinkler pipe even when the air supply is from the freezer. One method of reducing the moisture content of the air by use of air drying systems is illustrated in Figure A-4-8.2.4.

When compressors and dryers are used for an air supply, consideration should be given to pressure requirements of the regenerative dryers, compressor size, air pressure regulator capacity, and air fill rate. Application of these factors could necessitate the use of increased air pressures and a larger air compressor.

The compressed air supply should be properly prepared prior to entering a regenerative-type air dryer, such as minimum air pressure, maximum inlet air temperature, and proper filtration of compressed air.

Figure A-4-8.2.4 Refrigerator area sprinkler systems used to minimize the chances of developing ice plugs.



Notes:
1. If pressure gauge P1 and P2 do not indicate equal pressures, it could mean the air line is blocked or the air supply is malfunctioning.
2. Air dryer and coalescer filter not required when system piping capacity is less than 250 gal (946 L).

A-4-8.2.5 A major factor contributing to the introduction of moisture into the system piping is excessive air compressor operation caused by system leakage. Where excessive compressor operation is noted or ice accumulates in the air supply piping, the system should be checked for leakage and appropriate corrective action should be taken.

A-4-8.2.6 The purpose of the check valve is to prevent evaporation of prime water into the system piping.

A-4-8.2.7 The dual lines feeding the system air entering the cold area are intended to facilitate continued service of the system when one line is removed for inspection. It should be noted that, when using a system as described in Figure A-4-8.2.4, differences in the pressures at gauge P1 and gauge P2 indicate blockage in the air supply line or other malfunctions.

A-4-9.2 See Figure A-4-9.2.

A-5-1 The installation requirements are specific for the normal arrangement of structural members. There will be arrangements of structural members not specifically detailed by the requirements. By applying the basic principles, layouts for such construction can vary from specific illustrations, provided the maximum specified for the spacing and location of sprinklers (Section 5-4) are not exceeded.

Where buildings or portions of buildings are of combustible construction or contain combustible material, standard fire barriers should be provided to separate the areas that are sprinkler protected from adjoining unsprinklered areas. All openings should be protected in accordance with applicable standards, and no sprinkler piping should be placed in an unsprinklered area unless the area is permitted to be unsprinklered by this standard.

Water supplies for partial systems should be designed with consideration to the fact that in a partial system more sprinklers might be opened in a fire that originates in an unprotected area and spreads to the sprinklered area than would be the case in a completely protected building. Fire originating in a nonsprinklered area might overpower the partial sprinkler system.

Where sprinklers are installed in corridors only, sprinklers should be spaced up to the maximum of 15 ft (4.5 m) along the corridor, with one sprinkler opposite the center of any door or pair of adjacent doors opening onto the corridor, and with an additional sprinkler installed inside each adjacent room above the door opening. Where the sprinkler in the adjacent room provides full protection for that space, an additional sprinkler is not required in the corridor adjacent to the door.

A-5-1.1 This standard contemplates full sprinkler protection for all areas. Other NFPA standards that mandate sprinkler installation might not require sprinklers in certain areas. The requirements of this standard should be used insofar as they are applicable. The authority having jurisdiction should be consulted in each case.

A-5-1.2 The components need not be open or exposed. Doors, removable panels, or valve pits can satisfy this need. Such equipment should not be obstructed by such permanent features as walls, ducts, columns, or direct burial.

A-5-3.1.1 The evaluation for usage should be based upon a review of available technical data.

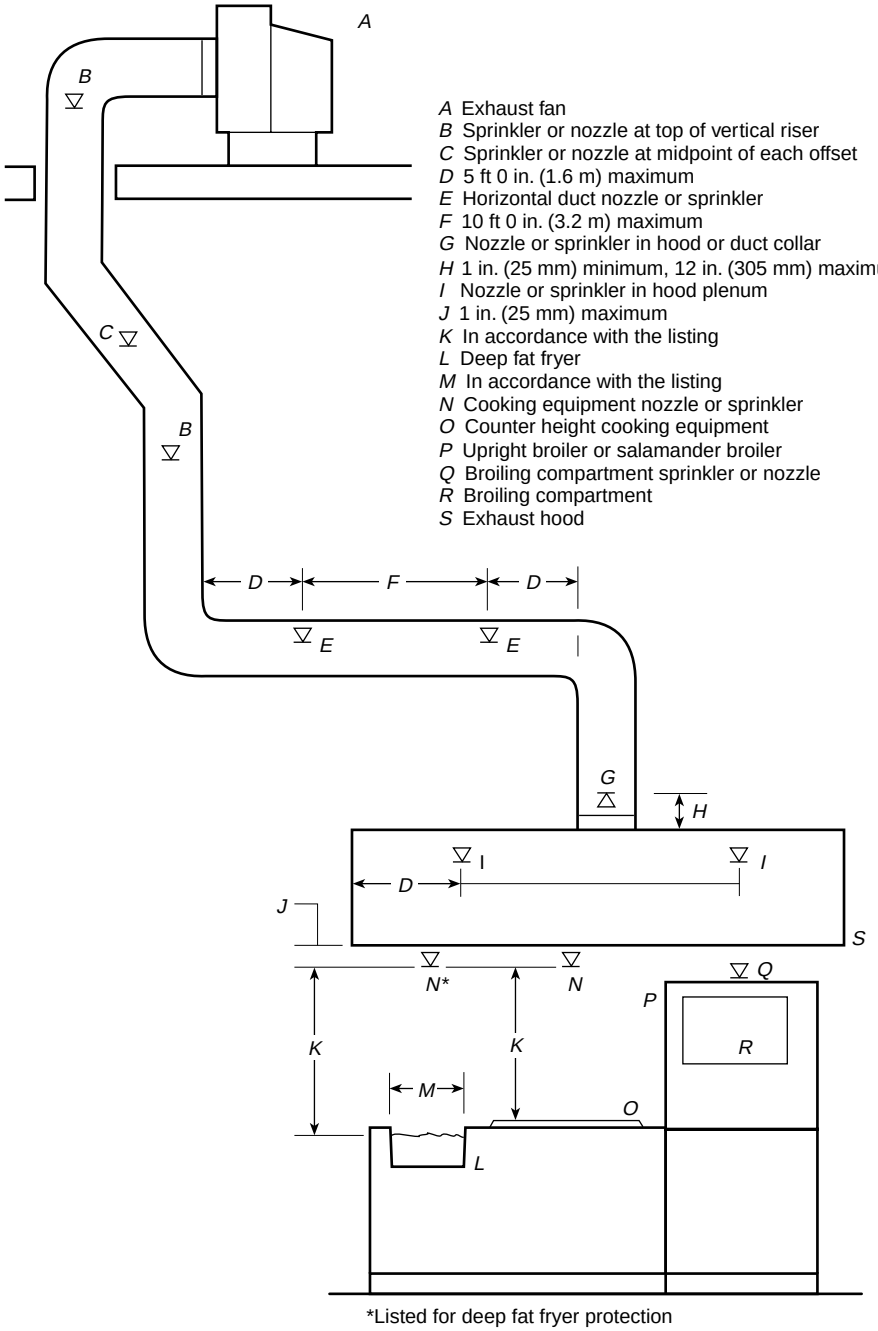
A-5-3.1.2 The purpose of this requirement is to minimize the obstruction of the discharge pattern.

A-5-3.1.4.1 For protection of baled cotton, 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-5-3.1.4.4 Where high temperature–rated sprinklers are installed at the ceiling, high temperature–rated sprinklers also should extend beyond storage in accordance with Table A-5-3.1.4.4.

A-5-3.1.5.1 When renovations occur in an existing building and no changes are made in the existing sprinkler system, this section is not intended to require the replacement of existing standard sprinklers with quick-response sprinklers.

Figure A-4-9.2 Typical installation showing automatic sprinklers or automatic nozzles being used for the protection of commercial cooking equipment and ventilation systems.



A-5-4 The selection of a sprinkler type will vary by occupancy. Where more than one type of sprinkler is used within a compartment, sprinklers with similar response characteristics should be used (i.e., standard or quick response). However, some hazards might benefit from designs that include the use of both standard and quick-response sprinklers. Examples include rack storage protected by standard-response ceiling sprinklers and quick-response in-rack sprinklers. Another case might include opening protection using closely spaced quick-response sprinklers with standard-response sprinklers in the adjoining areas. Other designs can be compromised when sprinklers of differing sensitivity are mixed. An example is a system utilizing ESFR sprinklers adjacent to a system using high-temperature standard-response sprinklers as might be found in a warehouse. In this case, a fire occurring near the boundary might open ESFR sprinklers, which would not be contemplated in the standard-response system design.

Table A-5-3.1.4.4 Distance Beyond Perimeter of Storage for High-Hazard Occupancies Protected with High Temperature–Rated Sprinklers

Design Area		Distance	
ft^2	m^2	ft	m
2000	186.0	30	9.1
3000	278.7	40	12.0
4000	371.6	45	13.7
5000	464.5	50	15.2
6000	557.4	55	16.7

A-5-4.5.1 The response and water distribution pattern of listed residential sprinklers have been shown by extensive fire testing to provide better control than spray sprinklers in residential occupancies. These sprinklers are intended to prevent flashover in the room of fire origin, thus improving the chance for occupants to escape or be evacuated.

The protection area for residential sprinklers is defined in the listing of the sprinkler as a maximum square or rectangular area. Listing information is presented in even 2-ft (0.65-m) increments from 12 ft to 20 ft (3.9 m to 6.5 m). When a sprinkler is selected for an application, its area of coverage must be equal to or greater than both the length and width of the hazard area. For example, if the hazard to be protected is a room 13 ft 6 in. (4.4 m) wide and 17 ft 6 in. (5.6 m) long, a sprinkler that is listed to protect a rectangular area of 14 ft × 18 ft (4.5 m × 5.8 m) or a square area of 18 ft × 18 ft (5.8 m × 5.8 m) must be selected. The flow used in the calculations is then selected as the flow required by the listing for the selected coverage.

A-5-4.6.3 Storage in single-story or multistory buildings can be permitted, provided the maximum ceiling/roof height as specified in Table 5-11.2.2 is satisfied for each storage area.

A-5-4.7.2 The purpose of this requirement is to avoid scale accumulation.

A-5-4.9.1 Tests of standard sprinklers by approved laboratories have traditionally encompassed a fire test using a 350-lb (160-kg) wood crib and water distribution tests in which water is collected in pans from several arrangements of sprinklers to evaluate distribution under non-fire conditions.

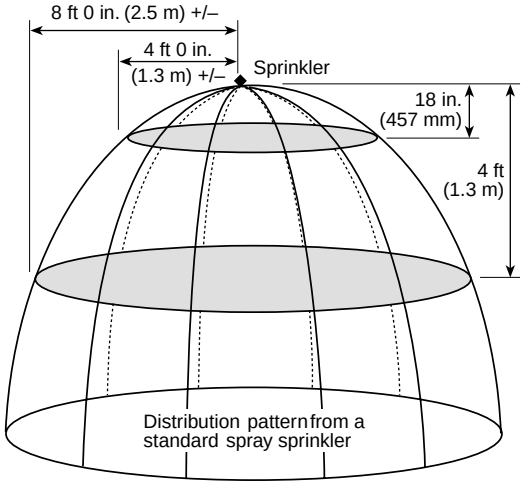
Tests of special sprinklers are customized to evaluate responsiveness, distribution, and other unique characteristics of the sprinkler to control or extinguish. These tests include variables such as the following:

(1) The location of the fire relative to the sprinklers (i.e., below one sprinkler or between two, four, or six sprinklers)
(2) Fire conditions that encompass a variety of fire growth rates representative of anticipated conditions of use
(3) Tests of room areas where sprinklers are expected to function in multiple arrays
(4) Adverse conditions of use (i.e., pipe shadows or other obstructions to discharge)
(5) Effect of a fire plume on water distribution and discharge under a variety of heat release rates

A-5-5.4.1 Batt insulation creates an effective thermal barrier and can be considered the ceiling/roof deck when determining distances between deflector and ceiling. The insulation needs to be installed in each pocket (not just above the sprinkler) and attached to the ceiling/roof in such a manner that it will not fall out during a fire prior to sprinkler activation.

A-5-5.5.1 See Figure A-5-5.5.1.

Figure A-5-5.5.1 Obstructions to sprinkler discharge pattern development for standard upright or pendent spray sprinklers.



A-5-5.5.2 Where of a depth that will obstruct the spray discharge pattern, girders, beams, or trusses forming narrow pockets of combustible construction along walls can require additional sprinklers.

A-5-5.5.3 Frequently, additional sprinkler equipment can be avoided by reducing the width of decks or galleries and providing proper clearances. Slatting of decks or walkways or the use of open grating as a substitute for automatic sprinklers thereunder is not acceptable. The use of cloth or paper dust tops for rooms forms obstruction to water distribution. If dust tops are used, the area below should be sprinklered.

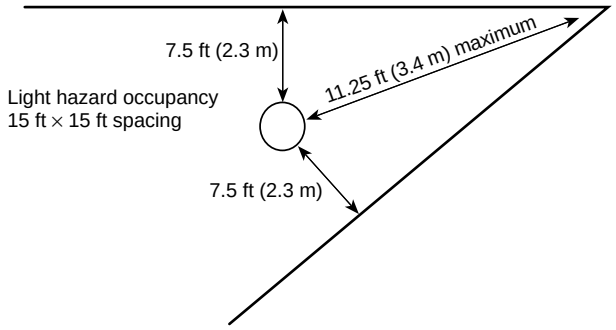
A-5-5.6 The fire protection system design should consider the maximum storage height. For new sprinkler installations, maximum storage height is the usable height at which commodities can be stored above the floor while the minimum required unobstructed space below sprinklers is maintained. Where evaluating existing situations, maximum storage

height is the maximum existing storage height if space between the sprinklers and storage is equal to or greater than that required.

Building heights where baled cotton is stored 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.

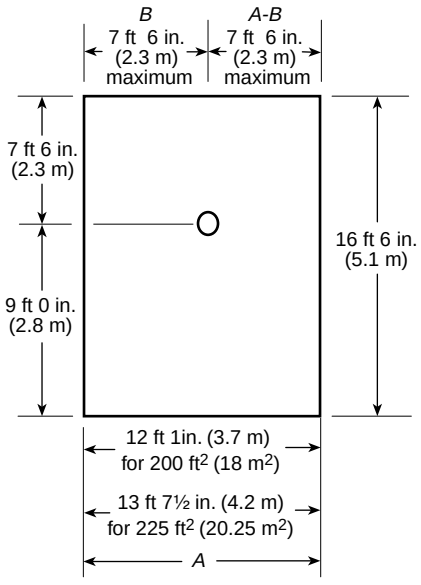
A-5-6.3.2.1 See Figure A-5-6.3.2.1(a).

Figure A-5-6.3.2.1(a) Maximum distance from walls.



A-5-6.3.2.1 Exception. An example of sprinklers in small rooms for hydraulically designed and pipe schedule systems is shown in Figure A-5-6.3.2.1(b), and examples for hydraulically designed systems only are shown in Figures A-5-6.3.2.1(c), (d), and (e).

Figure A-5-6.3.2.1(b) Small room provision — one sprinkler.



A-5-6.4.1.2 Exception No. 4. For concrete joists spaced less than 3 ft (0.91 m) on center, the rules for obstructed construction shown in 5-6.4.1.2 apply. *(See Figure A-5-6.4.1.2.)*

A-5-6.4.1.3 Saw-toothed roofs have regularly spaced monitors of saw tooth shape, with the nearly vertical side glazed and usually arranged for venting. Sprinkler placement is limited to a maximum of 3 ft (0.91 m) down the slope from the peak because of the effect of venting on sprinkler sensitivity.

Figure A-5-6.3.2.1(c) Small room provision — two sprinklers centered between sidewalls.

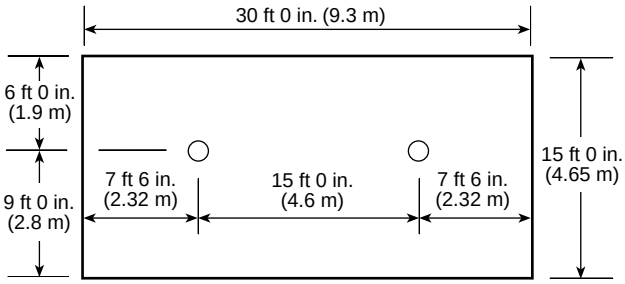


Figure A-5-6.3.2.1(d) Small room provision — two sprinklers centered between top and bottom walls.

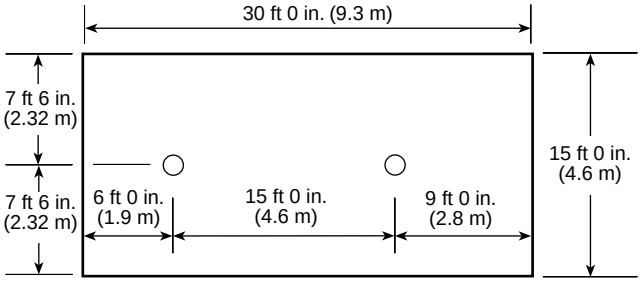


Figure A-5-6.3.2.1(e) Small room provision — four sprinklers.

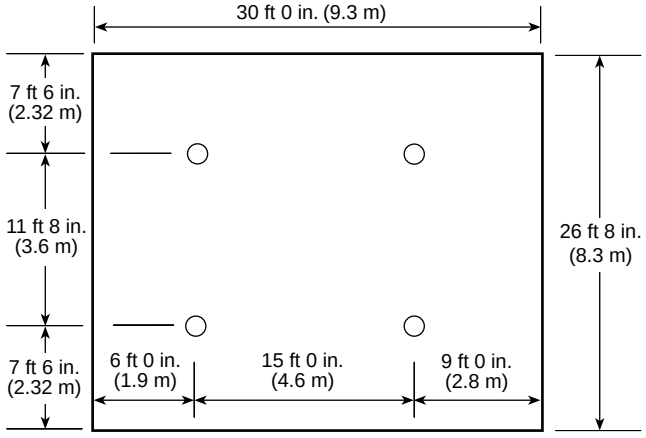


Figure A-5-6.4.1.2 Typical concrete joist construction.

A-5-6.4.2 On sprinkler lines larger than 2 in. (51 mm), consideration should be given to the distribution interference caused by the pipe, which can be minimized by installing sprinklers on riser nipples or installing sprinklers in the pendent position.

A-5-6.5.2.1 The rules of 5-6.5.2.2 (known as the "Three Times Rule") have been written to apply to obstructions where the sprinkler can be expected to get water to both sides of the obstruction without allowing a significant dry shadow on the other side of the obstruction. This works for small noncontin-

uous obstructions and for continuous obstructions where the sprinkler can throw water over and under the obstruction, such as the bottom chord of an open truss or joist. For solid continuous obstructions, such as a beam, the Three Times Rule is ineffective since the sprinkler cannot throw water over and under the obstruction. Sufficient water must be thrown under the obstruction to adequately cover the floor area on the other side of the obstruction. To ensure this, compliance with the rules of 5-6.5.1.2 is necessary.

A-5-6.5.2.3 The distances given in Table 5-6.5.2.3 were determined through tests in which privacy curtains with either a solid fabric or close mesh [$^1/_4$ in. (6.4 mm)] top panel were installed. For broader-mesh top panels — for example, $^1/_2$ in. (13 mm) or greater measured on the diagonal — the obstruction of the sprinkler spray is not likely to be severe and the authority having jurisdiction might not need to apply the requirements in 5-6.5.2.3.

A-5-6.5.3 See A-5-5.5.3.

A-5-6.6 The 18-in. (457-mm) dimension is not intended to limit the height of shelving on a wall or shelving against a wall in accordance with 5-6.6. Where shelving is installed on a wall and is not directly below sprinklers, the shelves, including storage thereon, can extend above the level of a plane located 18 in. (457 mm) below ceiling sprinkler deflectors. Shelving, and any storage thereon, directly below the sprinklers cannot extend above a plane located 18 in. (457 mm) below the ceiling sprinkler deflectors.

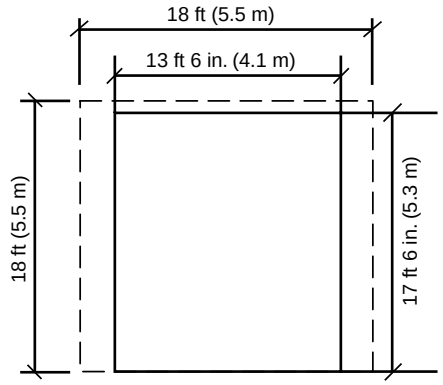
A-5-7.5.2.1 The rules of 5-7.5.2.2 (known as the "Three Times Rule") have been written to apply to obstructions where the sprinkler can be expected to get water to both sides of the obstruction without allowing a significant dry shadow on the other side of the obstruction. This works for small noncontinuous obstructions and for continuous obstructions where the sprinkler can throw water over and under the obstruction, such as the bottom chord of an open truss or joist. For solid continuous obstructions, such as a beam, the Three Times Rule is ineffective since the sprinkler cannot throw water over and under the obstruction. Sufficient water must be thrown under the obstruction to adequately cover the floor area on the other side of the obstruction. To ensure this, compliance with the rules of 5-7.5.1.2 is necessary.

A-5-7.5.3 See A-5-5.5.3.

A-5-8.2.1 The protection area for extended coverage upright and pendent sprinklers is defined in the listing of the sprinkler as a maximum square area. Listing information is presented in even 2-ft (0.6-m) increments up to 20 ft (6.1 m). When a sprinkler is selected for an application, its area of coverage must be equal to or greater than both the length and width of the hazard area. For example, if the hazard to be protected is a room $13^1/_2$ ft (4.1 m) wide and $17^1/_2$ ft (5.3 m) long as indicated in Figure A-5-8.2.1, a sprinkler that is listed to protect an area of 18 ft × 18 ft (5.5 m × 5.5 m) must be selected. The flow used in the calculations is then selected as the flow required by the listing for the selected coverage.

A-5-8.4.1.3 Saw-toothed roofs have regularly spaced monitors of saw tooth shape, with the nearly vertical side glazed and usually arranged for venting. Sprinkler placement is limited to a maximum of 3 ft (0.91 m) down the slope from the peak because of the effect of venting on sprinkler sensitivity.

Figure A-5-8.2.1 Determination of protection area of coverage for extended coverage upright and pendent sprinklers.



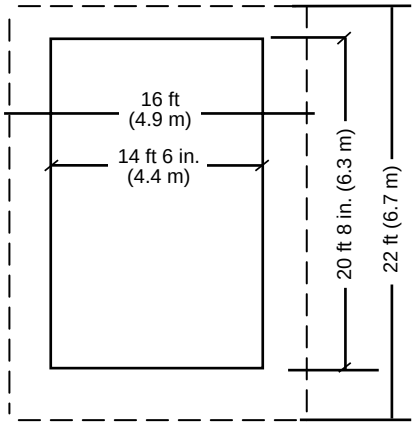
A-5-8.5.2.1 The rules of 5-8.5.2.2 (known as the "Four Times Rule") have been written to apply to obstructions where the sprinkler can be expected to get water to both sides of the obstruction without allowing a significant dry shadow on the other side of the obstruction. This works for small noncontinuous obstructions and for continuous obstructions where the sprinkler can throw water over and under the obstruction, such as the bottom chord of an open truss or joist. For solid continuous obstructions, such as a beam, the Four Times Rule is ineffective since the sprinkler cannot throw water over and under the obstruction. Sufficient water must be thrown under the obstruction to adequately cover the floor area on the other side of the obstruction. To ensure this, compliance with the rules of 5-8.5.1.2 is necessary.

A-5-8.5.3 See A-5-5.5.3.

A-5-9.2.1 The protection area for extended coverage sidewall spray sprinklers is defined in the listing of the sprinkler as a maximum square or rectangular area. Listing information is presented in even 2-ft (0.65-m) increments up to 28 ft (9 m) for extended coverage sidewall spray sprinklers. When a sprinkler is selected for an application, its area of coverage must be equal to or greater than both the length and width of the hazard area. For example, if the hazard to be protected is a room $14^1/_2$ ft (4.4 m) wide and $20^2/_3$ ft (6.3 m) long as indicated in Figure A-5-9.2.1, a sprinkler that is listed to protect an area of 16 ft × 22 ft (4.9 m × 6.7 m) must be selected. The flow used in the calculations is then selected as the flow required by the listing for the selected coverage.

A-5-9.5.2.1 The rules of 5-9.5.2.2 (known as the "Four Times Rule") have been written to apply to obstructions where the sprinkler can be expected to get water to both sides of the obstruction without allowing a significant dry shadow on the other side of the obstruction. This works for small noncontinuous obstructions and for continuous obstructions where the sprinkler can throw water over and under the obstruction, such as the bottom chord of an open truss or joist. For solid continuous obstructions, such as a beam, the Four Times Rule is ineffective since the sprinkler cannot throw water over and under the obstruction. Sufficient water must be thrown under the obstruction to adequately cover the floor area on the other side of the obstruction. To ensure this, compliance with the rules of 5-9.5.1.2 is necessary.

Figure A-5-9.2.1 Determination of protection area of coverage for extended coverage sidewall sprinklers.



A-5-9.5.3 See A-5-5.5.3.

A-5-10.2 Tests involving areas of coverage over 100 ft^2 (9.3 m^2) for large drop sprinklers are limited in number, and use of areas of coverage over 100 ft^2 (9.3 m^2) should be carefully considered.

A-5-10.3.1 It is important that sprinklers in the immediate vicinity of the fire center not skip, and this requirement imposes certain restrictions on the spacing.

A-5-10.4.1 If all other factors are held constant, the operating time of the first sprinkler will vary exponentially with the distance between the ceiling and deflector. At distances greater than 7 in. (178 mm), for other than open wood joist construction, the delayed operating time will permit the fire to gain headway, with the result that substantially more sprinklers operate. At distances less than 7 in. (178 mm), other effects occur. Changes in distribution, penetration, and cooling nullify the advantage gained by faster operation. The net result again is increased fire damage accompanied by an increase in the number of sprinklers operated. The optimum clearance between deflectors and ceiling is, therefore, 7 in. (178 mm). For open wood joist construction, the optimum clearance between deflectors and the bottom of joists is $3^1/_2$ in. (89 mm).

A-5-10.5 To a great extent, large drop sprinklers rely on direct attack to gain rapid control of both the burning fuel and ceiling temperatures. Therefore, interference with the discharge pattern and obstructions to the distribution should be avoided.

A-5-10.5.2.1 The rules of 5-10.5.2.2 (known as the "Three Times Rule") have been written to apply to obstructions where the sprinkler can be expected to get water to both sides of the obstruction without allowing a significant dry shadow on the other side of the obstruction. This works for small noncontinuous obstructions and for continuous obstructions where the sprinkler can throw water over and under the obstruction, such as the bottom chord of an open truss or joist. For solid continuous obstructions, such as a beam, the Three Times Rule is ineffective since the sprinkler cannot throw water over and under the obstruction. Sufficient water must be thrown under the obstruction to adequately cover the floor area on the other side of the obstruction. To ensure this, compliance with the rules of 5-10.5.1.2 is necessary.

A-5-10.5.3 See A-5-5.5.3.

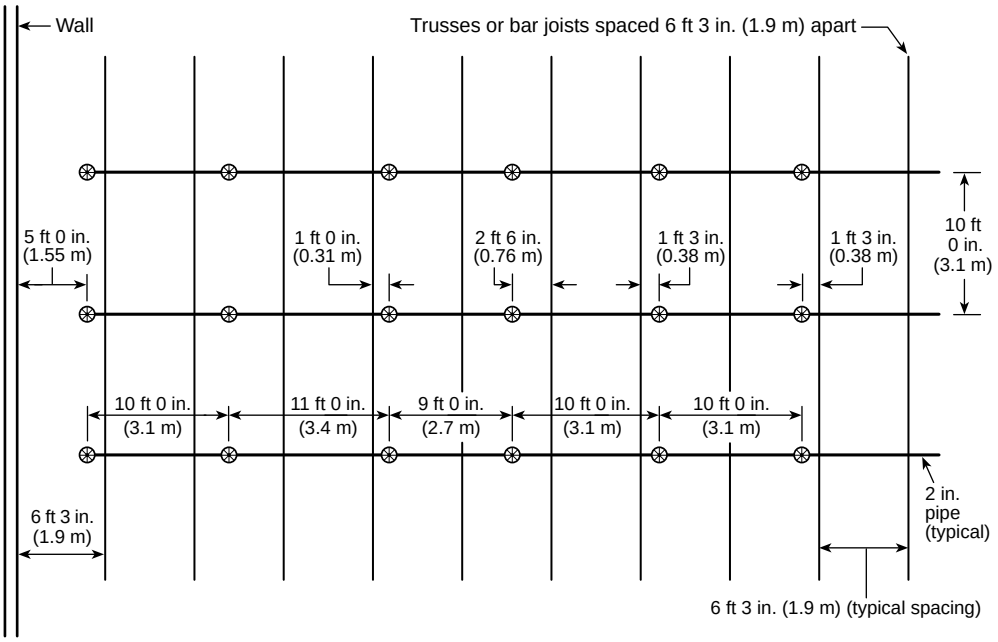
A-5-11.2.2 Exception. See Figure A-5-11.2.2.

A-5-11.3.1 Exception No. 2. See Figure A-5-11.2.2.

A-5-11.5.2 Isolated obstructions that block adjacent sprinklers in a similar manner should be treated as a continuous obstruction.

A-5-13.1.1 Exception Nos. 1, 2, and 3 do not require sprinkler protection because it is not physically practical to install sprinklers in the types of concealed spaces discussed in these three exceptions. To reduce the possibility of uncontrolled fire spread, consideration should be given in these unsprinklered concealed space situations to using Exception Nos. 5, 8, and 10.

Figure A-5-11.2.2 ESFR sprinkler spacing within trusses and bar joists.



A-5-13.2.2 Where practicable, sprinklers should be staggered at the alternate floor levels, particularly where only one sprinkler is installed at each floor level.

A-5-13.3.3 See Figures A-5-13.3.3(a) and (b). Sprinklers would be required in the case shown in Figure A-5-13.3.3(a) but not in the case shown in Figure A-5-13.3.3(b).

Figure A-5-13.3.3(a) Noncombustible stair shaft serving two fire sections.

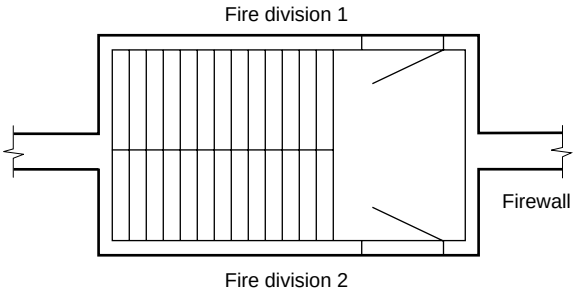
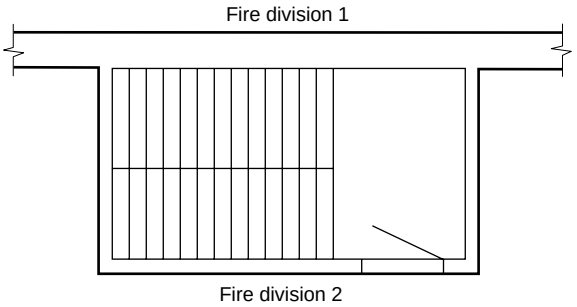
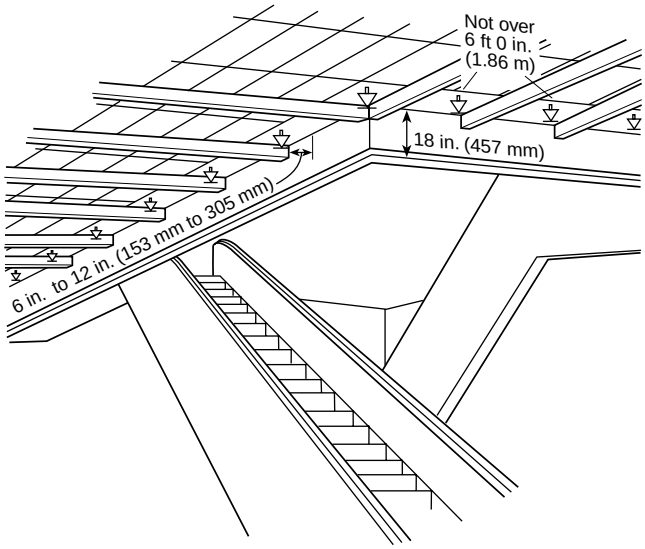


Figure A-5-13.3.3(b) Noncombustible stair shaft serving one fire section.



A-5-13.4 Where sprinklers in the normal ceiling pattern are closer than 6 ft (1.8 m) from the water curtain, it might be preferable to locate the water curtain sprinklers in recessed baffle pockets. *(See Figure A-5-13.4.)*

Figure A-5-13.4 Sprinklers around escalators.

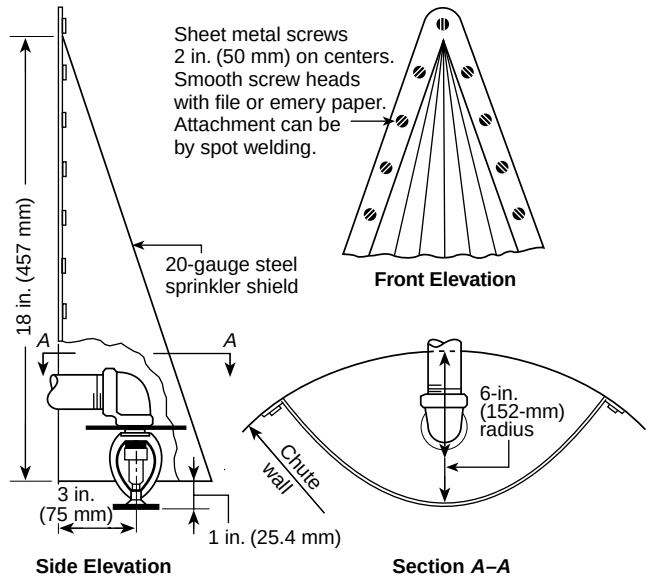


A-5-13.4 Exception No. 2(b). Subsection 6-2.4.4 of the 1997 edition of NFPA *101*,® *Life Safety Code*® requires a 2-hour separation for enclosures connecting four stories or more in new construction, a 1-hour separation for other enclosures in new construction, and a 30-minute separation for existing buildings. Special rules for residential construction exist in Chapters 16–20 of NFPA *101*.

A-5-13.5 The installation of sprinklers at floor levels should be arranged so as to protect the sprinklers from mechanical injury and falling materials and not cause obstruction within the chute. This installation usually can be accomplished by

recessing the sprinkler in the wall of the chute or by providing a protective deflector canopy over the sprinkler. Sprinklers should be placed so that there will be minimum interference of the discharge from the sprinklers. Sprinklers with special directional discharge characteristics might be advantageous. *(See Figure A-5-13.5.)*

Figure A-5-13.5 Canopy for protecting sprinklers in building service chutes.



A-5-13.6.1 The sprinklers in the pit are intended to protect against fires cause by debris, which can accumulate over time. Ideally, the sprinklers should be located near the side of the pit below the elevator doors, where most debris accumulates. However, care should be taken that the sprinkler location does not interfere with the elevator toe guard, which extends below the face of the door opening.

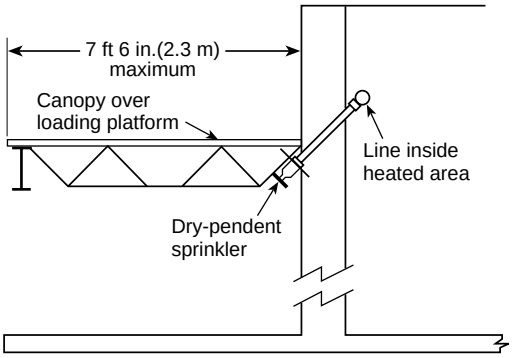
ASME A17.1, *Safety Code for Elevators and Escalators*, allows the sprinklers within 2 ft (0.65 m) of the bottom of the pit to be exempted from the special arrangements of inhibiting waterflow until elevator recall has occurred.

A-5-13.6.2 ASME A17.1, *Safety Code for Elevators and Escalators*, requires the shutdown of power to the elevator upon or prior to the application of water in elevator machine rooms or hoistways. This shutdown can be accomplished by a detection system with sufficient sensitivity that operates prior to the activation of the sprinklers *(see also NFPA 72, National Fire Alarm Code®)*. As an alternative, the system can be arranged using devices or sprinklers capable of effecting power shutdown immediately upon sprinkler activation, such as a waterflow switch without a time delay. This alternative arrangement is intended to interrupt power before significant sprinkler discharge.

A-5-13.6.3 Passenger elevator cars that have been constructed in accordance with ASME A17.1, *Safety Code for Elevators and Escalators*, Rule 204.2a (under A17.1a-1985 and later editions of the code) have limited combustibility. Materials exposed to the interior of the car and the hoistway, in their end-use composition, are limited to a flame spread rating of 0 to 75 and a smoke development rating of 0 to 450.

A-5-13.8 Small loading docks, covered platforms, ducts, or similar small unheated areas can be protected by dry-pendent sprinklers extending through the wall from wet sprinkler piping in an adjacent heated area. Where protecting covered platforms, loading docks, and similar areas, a dry-pendent sprinkler should extend down at a 45-degree angle. The width of the area to be protected should not exceed $7^1/_2$ ft (2.3 m). Sprinklers should be spaced not over 12 ft (3.7 m) apart. *(See Figure A-5-13.8.)*

Figure A-5-13.8 Dry-pendent sprinklers for protection of covered platforms, loading docks, and similar areas.



A-5-13.8.2 Short-term transient storage, such as that for delivered packages, and the presence of planters, newspaper machines, and so forth, should not be considered storage or handling of combustibles.

A-5-13.9.1 Fiberglass units are only considered noncombustible where indicated as such by testing.

A-5-13.9.2 Portable wardrobe units, such as those typically used in nursing homes and mounted to the wall, do not require sprinklers to be installed in them. Although the units are attached to the finished structure, this standard views those units as pieces of furniture rather than as a part of the structure; thus, sprinklers are not required.

A-5-13.12 The combustible materials present inside industrial ovens and furnaces can be protected by automatic sprinklers. Wet sprinkler systems are preferred. However, water-filled piping exposed to heat within an oven or furnace can incur deposition and buildup of minerals within the pipe. If the oven or furnace could be exposed to freezing temperatures, dry-pendent sprinklers are an alternative to wet pipe systems. Another option is to use a dry pipe system.

The preferred arrangement for piping is outside of the oven; the sprinkler should be installed in the pendent position. The sprinkler temperature rating should be at least 50°F (28°C) greater than the high-temperature limit setting of the oven or applicable zone. As a minimum, the sprinkler system inside the oven or furnace should be designed to provide 15 psi (1 bar) with all sprinklers operating inside the oven/furnace. Sprinkler spacing on each branch line should not exceed 12 ft (3.7 m).

A-5-13.13 The installation of open-grid egg crate, louver, or honeycomb ceilings beneath sprinklers restricts the sideways travel of the sprinkler discharge and can change the character of discharge.

A-5-13.14.3 Drop-out ceilings do not provide the required protection for soft-soldered copper joints or other piping that requires protection.

A-5-13.14.4 The ceiling tiles might drop before sprinkler operation. Delayed operation might occur because heat must then bank down from the deck above before sprinklers will operate.

A-5-13.15 Exception No. 1. For tests of sprinkler performance in fur vaults see "Fact Finding Report on Automatic Sprinkler Protection for Fur Storage Vaults" of Underwriters Laboratories Inc., dated November 25, 1947.

Sprinklers should be listed old-style with orifice sizes selected to provide a flow rate as close as possible to, but not less than, 20 gpm (76 L/min) per sprinkler, for four sprinklers, based on the water pressure available.

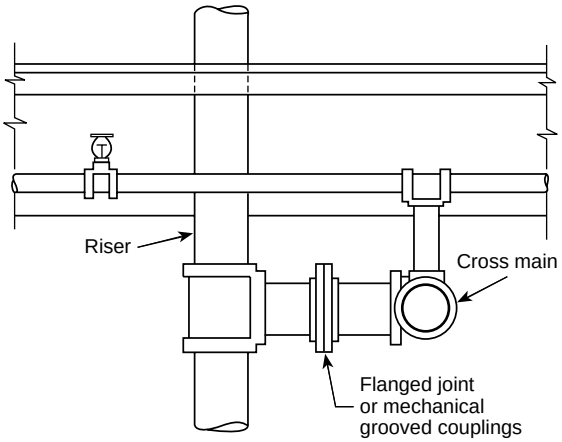
Sprinklers in fur storage vaults should be located centrally over the aisles between racks and should be spaced not over 5 ft (1.5 m) apart along the aisles.

Where sprinklers are spaced 5 ft (1.5 m) apart along the sprinkler branch lines, pipe sizes should be in accordance with the following schedule:

1 in. (25.4 mm) — 4 sprinklers
$1^1/_4$ in. (31.8 mm) — 6 sprinklers
$1^1/_2$ in. (38.1 mm) — 10 sprinklers
2 in. (51 mm) — 20 sprinklers
$2^1/_2$ in. (63.5 mm) — 40 sprinklers
3 in. (76.2 mm) — 80 sprinklers

A-5-13.22 See Figure A-5-13.22.

Figure A-5-13.22 One arrangement of flanged joint at sprinkler riser.



A-5-14.1.1 See Figure A-5-14.1.1.

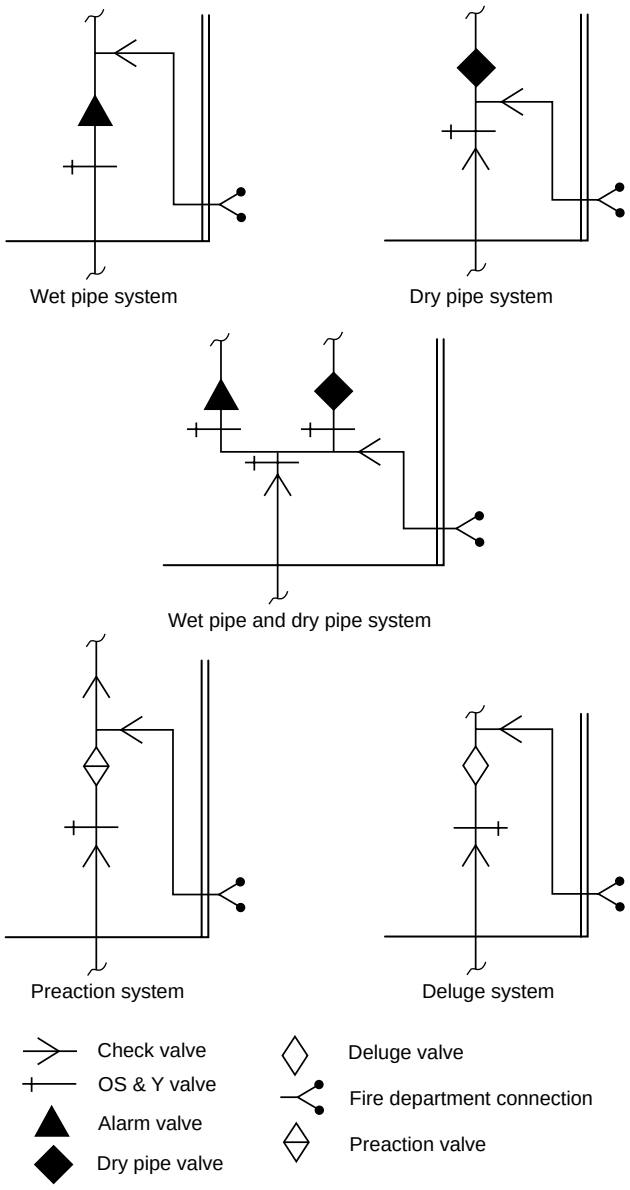
A-5-14.1.1.1 A water supply connection should not extend into a building or through a building wall unless such connection is under the control of an outside listed indicating valve or an inside listed indicating valve located near the outside wall of the building.

All valves controlling water supplies for sprinkler systems or portions thereof, including floor control valves, should be accessible to authorized persons during emergencies. Permanent ladders, clamped treads on risers, chain-operated hand wheels, or other accepted means should be provided where necessary.

Outside control valves are suggested in the following order of preference:

(1) Listed indicating valves at each connection into the building at least 40 ft (12.2 m) from buildings if space permits
(2) Control valves installed in a cutoff stair tower or valve room accessible from outside
(3) Valves located in risers with indicating posts arranged for outside operation.
(4) Key-operated valves in each connection into the building

Figure A-5-14.1.1 Examples of acceptable valve arrangements.



A-5-14.1.1.3 The management is responsible for the supervision of valves controlling water supply for fire protection and should exert every effort to see that the valves are maintained in the normally open position. This effort includes special precautions to ensure that protection is promptly restored by completely opening valves that are necessarily closed during repairs or alternations. The precautions apply equally to valves controlling sprinklers and other fixed water-based fire suppression systems, hydrants, tanks, standpipes, pumps, street connections, and sectional valves.

Either one or a combination of the methods of valve supervision described in the following list is considered essential to ensure that the valves controlling fire protection systems are in the normally open position. The methods described are

intended as an aid to the person responsible for developing a systematic method of determining that the valves controlling sprinkler systems and other fire protection devices are open.

Continual vigilance is necessary if valves are to be kept in the open position. Responsible day and night employees should be familiar with the location of all valves and their proper use.

The authority having jurisdiction should be consulted as to the type of valve supervision required. Contracts for equipment should specify that all details are to be subject to the approval of the authority having jurisdiction.

(a) *Central Station Supervisory Service.* Central station supervisory service systems involve complete, constant, and automatic supervision of valves by electrically operated devices and circuits continually under test and operating through an approved outside central station, in compliance with NFPA 72, *National Fire Alarm Code.* It is understood that only such portions of NFPA 72 that relate to valve supervision should apply.

(b) *Proprietary Supervisory Service Systems.* Proprietary supervisory service systems include systems where the operation of a valve produces some form of signal and record at a common point by electrically operated devices and circuits continually under test and operating through a central supervising station at the property protected, all in compliance with the standards for the installation, maintenance, and use of local protective, auxiliary protective, remote station protective, and proprietary signaling systems. It is understood that only portions of the standards that relate to valve supervision should apply.

The standard method of locking, sealing, and tagging valves to prevent, so far as possible, their unnecessary closing, to obtain notification of such closing, and to aid in restoring the valve to normal condition is a satisfactory alternate to valve supervision. The authority having jurisdiction should be consulted as to details for specific cases.

Where electrical supervision is not provided, locks or seals should be provided on all valves and should be of a type acceptable to the authority having jurisdiction.

Seals can be marked to indicate the organization under whose jurisdiction the sealing is conducted. All seals should be attached to the valve in such a manner that the valves cannot be operated without breaking the seals. Seals should be of a character to prevent injury in handling and to prevent reassembly when broken. When seals are used, valves should be inspected weekly. The authority having jurisdiction can require a valve tag to be used in conjunction with the sealing.

A padlock, with a chain where necessary, is especially desirable to prevent unauthorized closing of valves in areas where valves are subject to tampering. When such locks are employed, valves should be inspected monthly.

If valves are locked, any distribution of keys should be restricted to only those directly responsible for the fire protection system. Multiple valves should not be locked together; they should be individually locked.

The individual performing the inspections should determine that each valve is in the normal position, properly locked or sealed, and so note on an appropriate record form while still at the valve. The authority having jurisdiction should be consulted for assistance in preparing a suitable report form for this activity.

Identification signs should be provided at each valve to indicate its function and what it controls.

The position of the spindle of OS&Y valves or the target on the indicator valves cannot be accepted as conclusive proof that the valve is fully open. The opening of the valve should be followed by a test to determine that the operating parts have functioned properly.

The test consists of opening the main drain valve and permitting free flow of water until the gauge reading becomes stationary. If the pressure drop is excessive for the water supply involved, the cause should be determined immediately and the proper remedies taken. When sectional valves or other special conditions are encountered, other methods of testing should be used.

If it becomes necessary to break a seal for emergency reasons, the valve, following the emergency, should be opened by the person responsible for the fire protection of the plant, or his or her designated representative, and this person should apply a seal at the time of the valve opening. This seal should be maintained in place until such time as the authority having jurisdiction can replace it with one of its own.

Seals or locks should not be applied to valves reopened after closure until such time as the inspection procedure is carried out.

Where water is shut off to the sprinkler or other fixed water-based fire suppression systems, a guard or other qualified person should be placed on duty and required to continuously patrol the affected sections of the premises until such time as protection is restored.

During specific critical situations, a person should be stationed at the valve so that the valve can be reopened promptly if necessary. It is the intent of this section that the person remain within sight of the valve and have no other duties beyond this responsibility. This procedure is considered imperative when fire protection is shut off immediately following a fire.

An inspection of all other fire protection equipment should be made prior to shutting off water in order to make sure it is in operative condition.

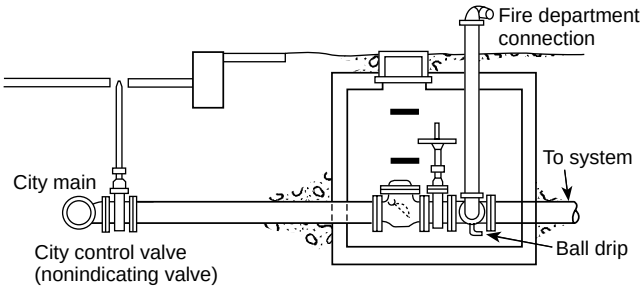
In case of changes to fire protection equipment, all possible work should be done in advance of shutting off the water so that final connections can be made quickly and protection restored promptly. Many times it will be found that by careful planning open outlets can be plugged and protection restored on a portion of the equipment while the alterations are being made.

Where changes are being made in underground piping, all possible piping should be laid before shutting off the water for final connections. Where possible, temporary feed lines, such as temporary piping for reconnection of risers by hose lines, and so forth, should be used to afford maximum protection. The plant, public fire department, and other authorities having jurisdiction should be notified of all impairments to fire protection equipment.

A-5-14.1.1.7 Where a system having only one dry pipe valve is supplied with city water and a fire department connection, it will be satisfactory to install the main check valve in the water supply connection immediately inside of the building. In instances where there is no outside control valve, the system indicating valve should be placed at the service flange, on the supply side of all fittings.

A-5-14.1.1.8 See Figure A-5-14.1.1.8. For additional information on controlling valves, see NFPA 22, *Standard for Water Tanks for Private Fire Protection.*

Figure A-5-14.1.1.8 Pit for gate valve, check valve, and fire department connection.



A-5-14.1.1.9 For additional information on controlling valves, see NFPA 22, *Standard for Water Tanks for Private Fire Protection.*

A-5-14.1.1.10 Check valves on tank or pump connections, when located underground, can be placed inside of buildings and at a safe distance from the tank riser or pump, except in cases where the building is entirely of one fire area, when it is ordinarily considered satisfactory to locate the check valve overhead in the lowest level.

A-5-14.1.1.11 It might be necessary to provide valves located in pits with an indicator post extending above grade or other means so that the valve can be operated without entering the pit.

A-5-14.1.2.3 Where the relief valve operation would result in water being discharged onto interior walking or working surfaces, consideration should be given to piping the discharge from the valve to a drain connection or other safe location.

A-5-14.1.3 Outside control valves are suggested in the following order of preference:

(1) Listed indicating valves at each connection into the building at least 40 ft (12.2 m) from buildings if space permits
(2) Control valves installed in a cutoff stair tower or valve room accessible from outside
(3) Valves located in risers with indicating posts arranged for outside operation
(4) Key-operated valves in each connection into the building

Post-indicator valves should be located not less than 40 ft (12.2 m) from buildings. When post-indicator valves cannot be placed at this distance, they are permitted to be located closer, or wall post-indicator valves can be used, provided they are set in locations by blank walls where the possibility of injury be falling walls is unlikely and from which people are not likely to be driven by smoke or heat. Usually, in crowded plant yards, they can be placed beside low buildings, near brick stair towers, or at angles formed by substantial brick walls that are not likely to fall.

A-5-14.1.4.2 A valve wrench with a long handle should be provided at a convenient location on the premises.

A-5-14.1.6 In-rack sprinklers and ceiling sprinklers selected for protection should be controlled by at least two separate indicating valves and drains. 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-5-14.2.1 All piping should be arranged where practicable to drain to the main drain valve.

A-5-14.2.5.2.3 An example of an accessible location would be a valve located approximately 7 ft (2 m) above the floor level to which a hose could be connected to discharge the water in an acceptable manner.

A-5-14.2.6.1 Where possible, the main sprinkler riser drain should discharge outside the building at a point free from the possibility of causing water damage. Where it is not possible to discharge outside the building wall, the drain should be piped to a sump, which in turn should discharge by gravity or be pumped to a waste water drain or sewer. The main sprinkler riser drain connection should be of a size sufficient to carry off water from the fully open drain valve while it is discharging under normal water system pressures. Where this is not possible, a supplementary drain of equal size should be provided for test purposes with free discharge, located at or above grade.

A-5-14.3.2.1 Types of locations where corrosive conditions can exist include bleacheries, dye houses, metal plating processes, animal pens, and certain chemical plants.

If corrosive conditions are not of great intensity and humidity is not abnormally high, good results can be obtained by a protective coating of red lead and varnish or by a good grade of commercial acid-resisting paint. The paint manufacturer's instructions should be followed in the preparation of the surface and in the method of application.

Where moisture conditions are severe but corrosive conditions are not of great intensity, copper tube or galvanized steel pipe, fittings, and hangers might be suitable. The exposed threads of steel pipe should be painted.

In instances where the piping is not readily accessible and where the exposure to corrosive fumes is severe, either a protective coating of high quality can be employed or some form of corrosion-resistant material used.

A-5-14.4 *Installation Standards.* The following documents apply to the installation of pipe and fittings:

AWWA C603, *Standard for the Installation of Asbestos-Cement Water Pipe*

AWWA C600, *Standard for the Installation of Ductile-Iron Water Mains and Their Appurtenances*

AWWA M11, *A Guide for Steel Pipe-Design and Installation*

AWWA M41, *Ductile Iron Pipe and Fittings.*

Concrete Pipe Handbook, American Concrete Pipe Association

Handbook of PVC Pipe, Uni-Bell Plastic Pipe Association

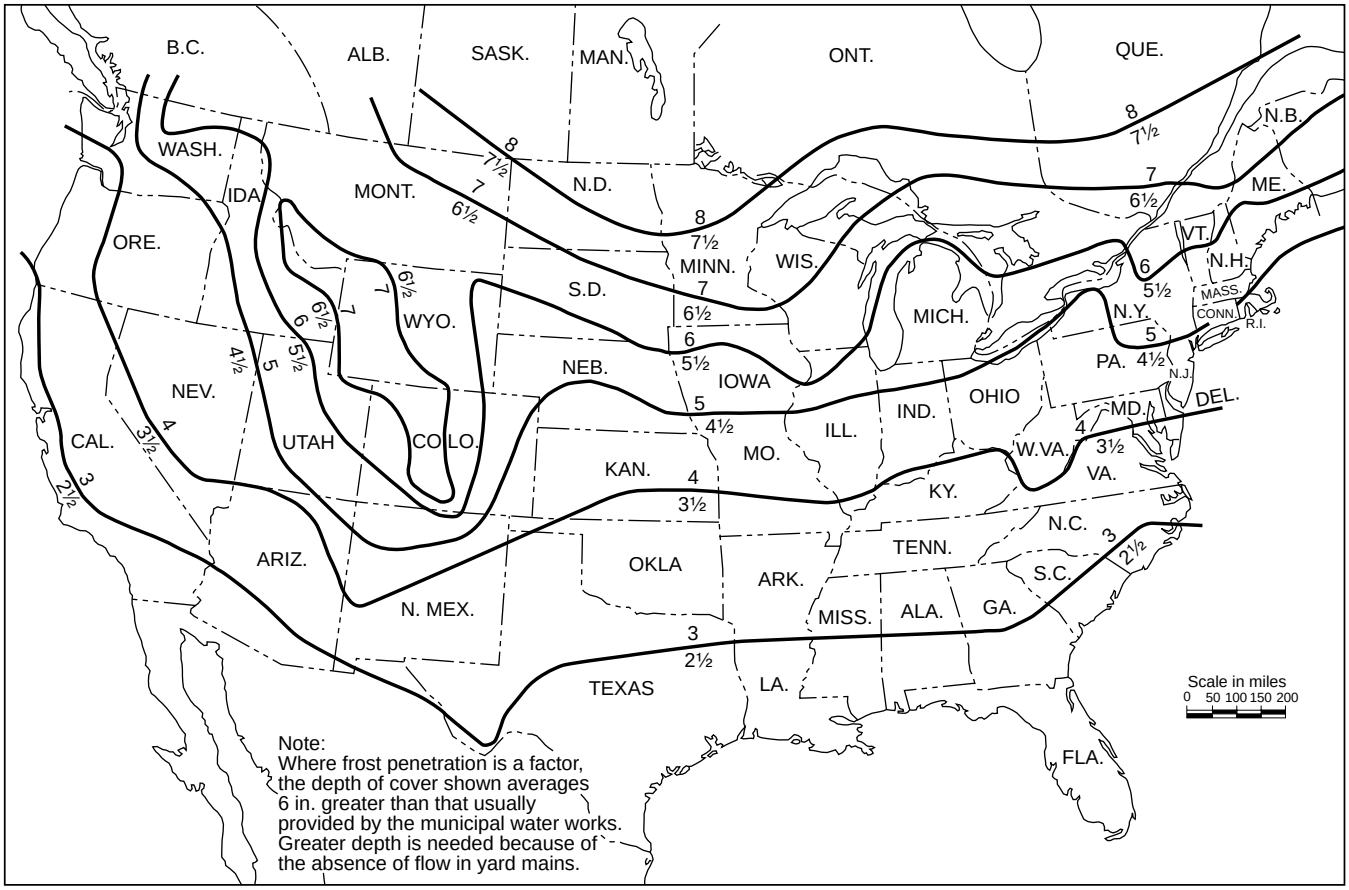
Installation Guide for Ductile Iron Pipe, Ductile Iron Pipe Research Association

Thrust Restraint Design for Ductile Iron Pipe, Ductile Iron Pipe Research Association

A-5-14.4.1.1 As there is normally no circulation of water in private fire mains, they require greater depth of covering than do public mains. Greater depth is required in a loose gravelly soil (or in rock) than in compact, clayey soil. Recommended depth of cover above the top of underground yard mains is shown in Figure A-5-14.4.1.1.

A-5-14.4.3.4 Gray cast iron is not considered galvanically dissimilar to ductile iron. Rubber gasket joints (unrestrained push-on or mechanical joints) are not considered connected electrically. Metal thickness should not be considered a protection against corrosive environments. In the case of cast-iron or ductile iron pipe for soil evaluation and external protection systems, see Appendix A of AWWA C105, *Polyethelene Encasement for Ductile Iron Pipe Systems.*

Figure A-5-14.4.1.1 Recommended depth of cover (in feet) above top of underground yard mains.



A-5-15.1 Central station, auxiliary, remote station, or proprietary protective signaling systems are a highly desirable supplement to local alarms, especially from a safety to life standpoint. *(See 5-15.1.6.)*

Approved identification signs, as shown in Figure A-5-15.1, should be provided for outside alarm devices. The sign should be located near the device in a conspicuous position and should be worded as follows:

Figure A-5-15.1 Identification sign.

SPRINKLER FIRE ALARM — WHEN BELL RINGS CALL FIRE DEPARTMENT OR POLICE.

A-5-15.1.5 Water motor–operated devices should be located as near as practicable to the alarm valve, dry pipe valve, or other waterflow detecting device. The total length of the pipe to these devices should not exceed 75 ft (22.9 m), nor should the water motor–operated device be located over 20 ft (6.1 m) above the alarm device or dry pipe valve.

A-5-15.1.6 Monitoring should include but not be limited to control valves, building temperatures, fire pump power supplies and running conditions, and water tank levels and temperatures. Pressure supervision should also be provided on pressure tanks.

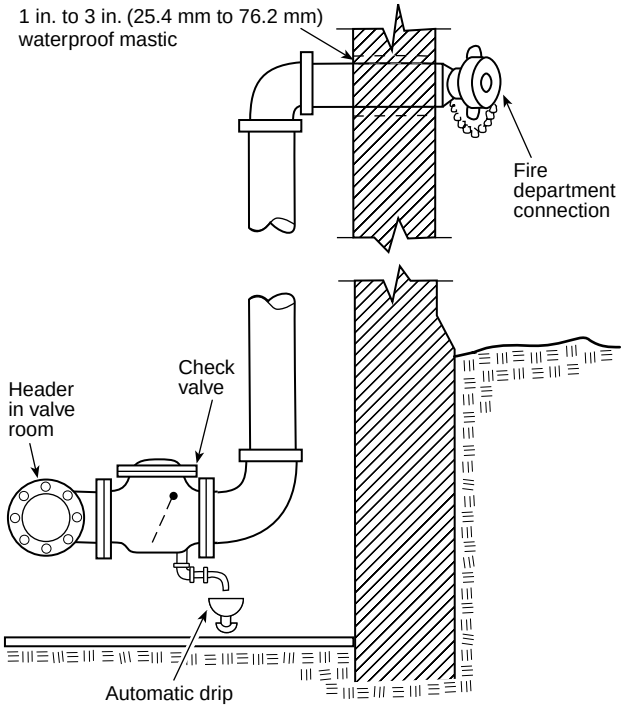
Check valves can be required to prevent false waterflow signals on floors where sprinklers have not activated — for example, floor systems interconnected to two supply risers.

A-5-15.1.7 For further information, see NFPA 72, *National Fire Alarm Code.*

A-5-15.2 The fire department connection should be located not less than 18 in. (457 mm) and not more than 4 ft (1.2 m) above the level of the adjacent grade or access level.

Typical fire department connections are shown in Figures A-5-15.2(a) and A-5-15.2(b). See NFPA 13E, *Guide for Fire Department Operations in Properties Protected by Sprinkler and Standpipe Systems.*

Figure A-5-15.2(a) Fire department connection.



A-5-15.2.1 Fire department connections should be located and arranged so that hose lines can be readily and conveniently attached without interference from nearby objects including buildings, fences, posts, or other fire department connections. Where a hydrant is not available, other water supply sources such as a natural body of water, a tank, or reservoir should be utilized. The water authority should be consulted when a nonpotable water supply is proposed as a suction source for the fire department.

A-5-15.2.3 The check valve should be located to maximize accessibility and minimize freezing potential.

A-5-15.4.1 See Figure A-5-15.4.1.

A-5-15.4.2 This test connection should be in the upper story, and the connection preferably should be piped from the end of the most remote branch line. The discharge should be at a point where it can be readily observed. In locations where it is not practical to terminate the test connection outside the building, the test connection is permitted to terminate into a drain capable of accepting full flow under system pressure. In this event, the test connection should be made using an approved sight test connection containing a smooth bore corrosion-resistant orifice giving a flow equivalent to one sprinkler simulating the least flow from an individual sprinkler in the system. *[See Figures A-5-15.4.2(a) and A-5-15.4.2(b).]* The test valve should be located at an accessible point and preferably not over 7 ft (2.1 m) above the floor. The control valve on the test connection should be located at a point not exposed to freezing.

A-5-15.4.3 See Figure A-5-15.4.3.

A-5-15.4.6.1 The full flow test of the backflow prevention valve can be performed with a test header or other connection downstream of the valve. A bypass around the check valve in the fire department connector line with a control valve in the normally closed position can be an acceptable arrangement. When flow to a visible drain cannot be accomplished, closed loop flow can be acceptable if a flow meter or site glass is incorporated into the system to ensure flow.

A-5-15.5.1.1 In areas used to store baled cotton, due consideration to access aisle configuration should be given with maximum hose lengths not exceeding 100 ft (30.1 m). Additionally, in these areas, where a separate piping system is used to supply hose lines it should be in accordance with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems.*

A-5-15.5.1.2 This standard covers $1^1/_2$-in. (38-mm) hose connections for use in storage occupancies and other locations where standpipe systems are not required. Where Class II standpipe systems are required, see the appropriate provisions of NFPA 14, *Standard for the Installation of Standpipe and Hose Systems,* with respect to hose stations and water supply for hose connections from sprinkler systems.

A-5-15.5.2 Combined automatic sprinkler and standpipe risers should not be interconnected by sprinkler system piping.

A-5-16.2 Automatic sprinklers in spray areas, including the interior of spray booths and exhaust ducts, should be wet pipe, preaction, or deluge system in order that water can be placed on the fire in the shortest possible time. Automatic sprinklers in spray booths and exhaust ducts should be of the lowest practical temperature rating. Sprinklers outside the temperature rating. Sprinklers outside the booth at ceiling level should be high temperature–rated [286°F (141°C)]. The delay in application of water with ordinary dry pipe sprinklers can permit a fire to spread so rapidly that final extinguishment is difficult without large resulting damage.

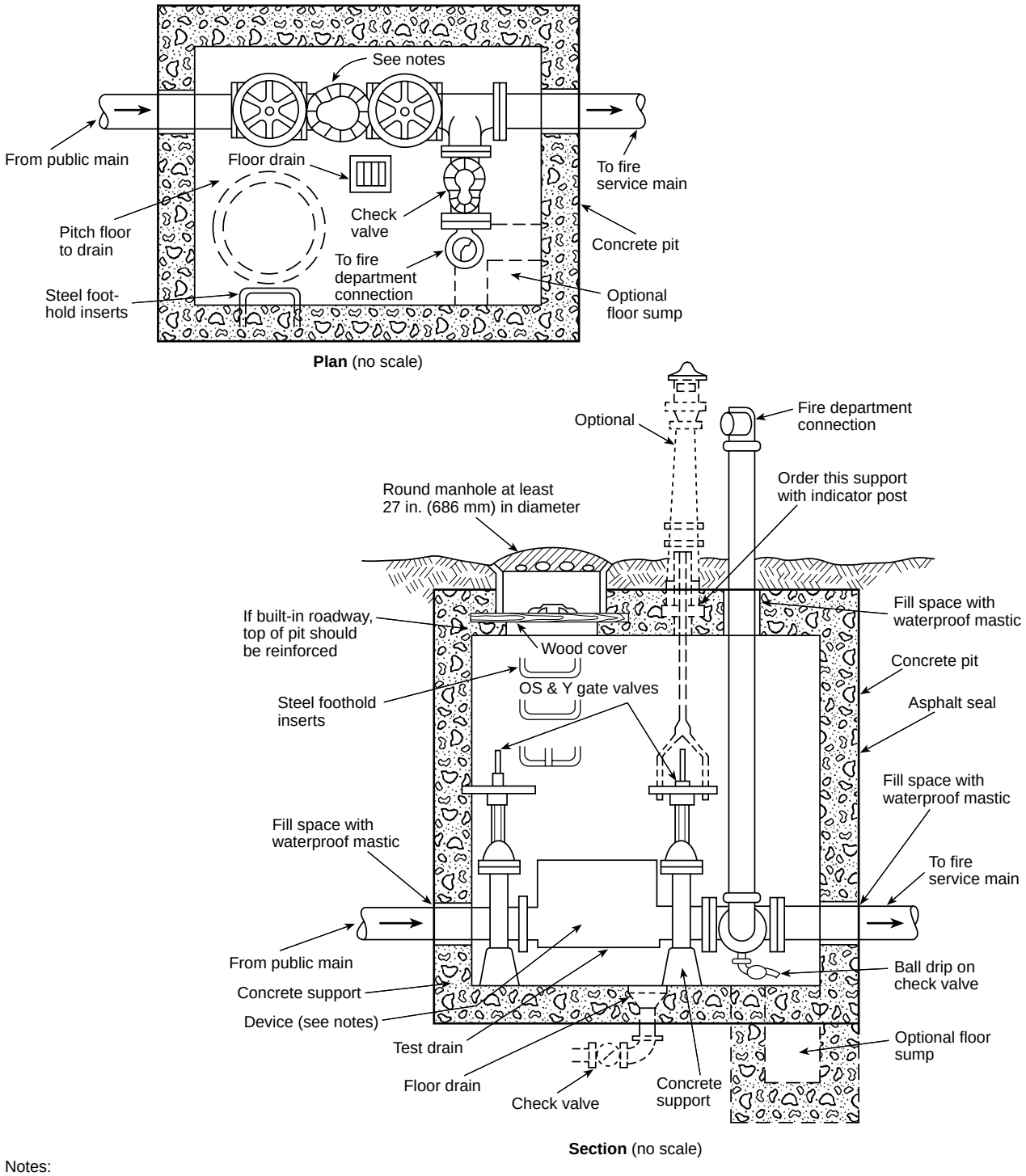
The location of the sprinklers inside spray booths should be selected with care in order to avoid sprinklers being placed in the direct path of spray and yet afford protection for the entire booth interior. When in the direct path of spray even one day's operation can result in deposits on the sprinkler head that insulate the fusible link or choke open head orifices to the extent that sprinklers cannot operate efficiently.

Automatic sprinklers should also be located so that areas subject to substantial accumulations of overspray residue are protected. Generally, sprinklers are located no more than 4 ft (1.2 m) from side walls of booths and rooms and from dry overspray collectors (where applicable). Sprinklers in booths or rooms should be on extra hazard occupancy spacing of 90 ft^2 (9.4 m^2).

Sprinklers or sprinkler systems protecting stacks or ducts should be automatic and of a type not subject to freezing. Dry pendent sprinklers are often used inside buildings near exhaust duct penetrations to the outside. Nonfreeze or dry type sprinkler systems are often used for ducts outside buildings. Sprinklers should be spaced no more than 12 ft (3.7 m) apart in the duct for adequate protection.

All sprinklers in spray areas should be controlled by an accessible control valve, preferably an OS&Y valve. (**33:** A-7-2.4)

Figure A-5-15.2(b) Typical city water pit—valve arrangement.



Notes:

1. Various backflow prevention regulations accept different devices at the connection between public water mains and private fire service mains.
2. The device shown in the pit could be any or a combination of the following:
   (a) Gravity check valve
   (b) Detector check valve
   (c) Double check valve assembly
   (d) Reduced pressure zone (RPZ) device
   (e) Vacuum breaker
3. Some backflow prevention regulations prohibit these devices from being installed in a pit.
4. In all cases, the device(s) in the pit should be approved or listed as necessary. The requirements of the local or municipal water department should be reviewed prior to design or installation of the connection.
5. Pressure drop should be considered prior to the installation of any backflow prevention devices.

Figure A-5-15.4.1 Water supply connection with test connection.

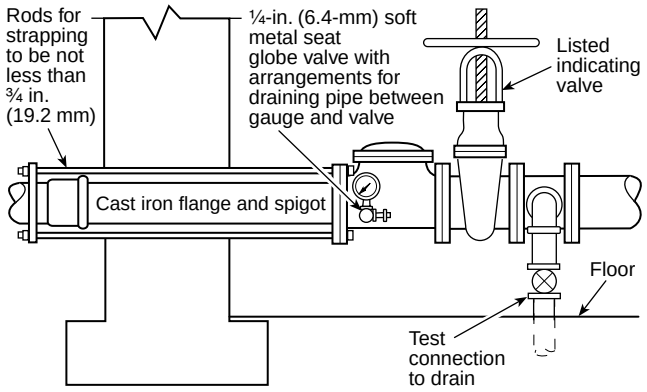


Figure A-5-15.4.2(b) Floor control valve.

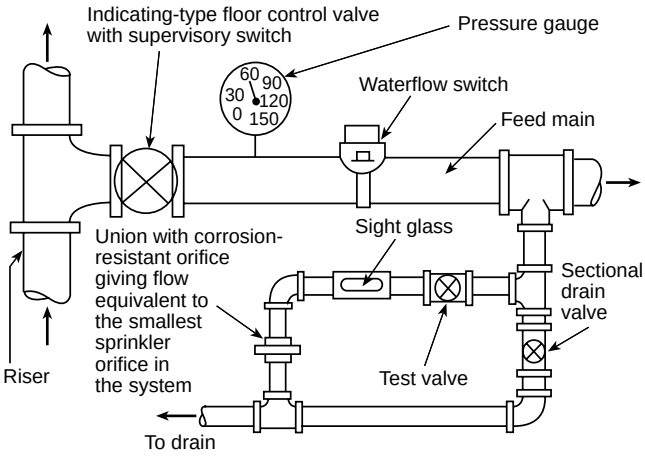
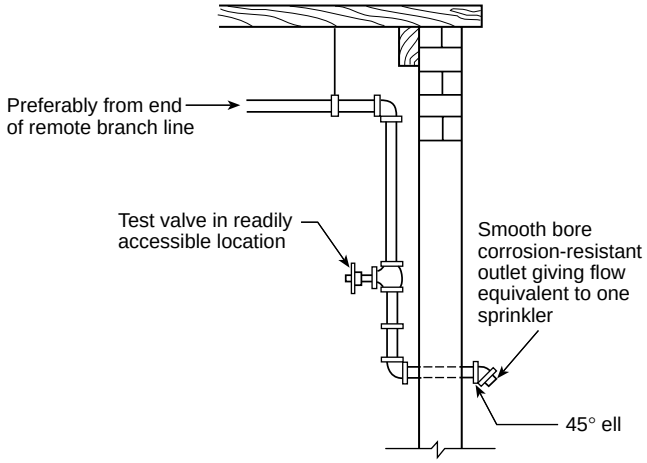


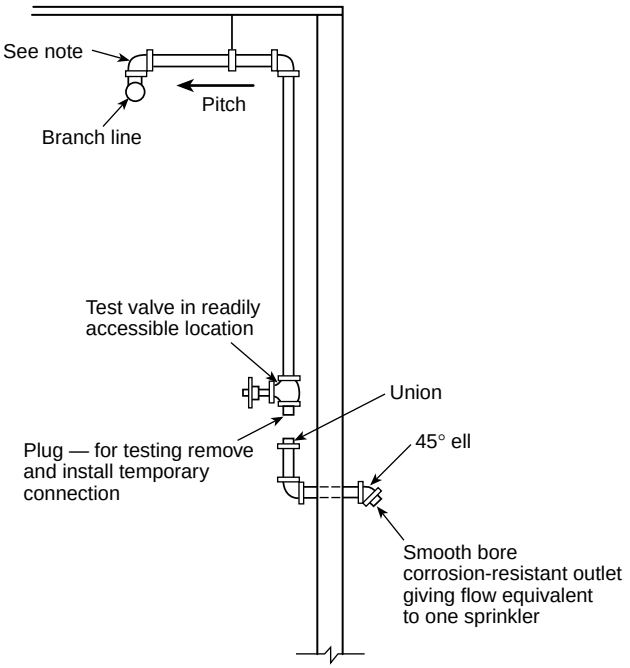
Figure A-5-15.4.2(a) System test connection on wet pipe system.



Elevation

Note: Not less than 4 ft (1.2 m) of exposed test pipe in warm room beyond valve where pipe extends through wall to outside.

Figure A-5-15.4.3 System test connection on dry pipe system.



Note: To minimize condensation of water in the drop to the test connection, provide a nipple-up off of the branch line.

A-5-18.5 See Figures A-5-18.5(a) and (b).

Figure A-5-18.5(a) Raw stock storage vault, showing general arrangement of sprinklers, racks, and baffles. [42: Figure 4-3.3.7(a)]

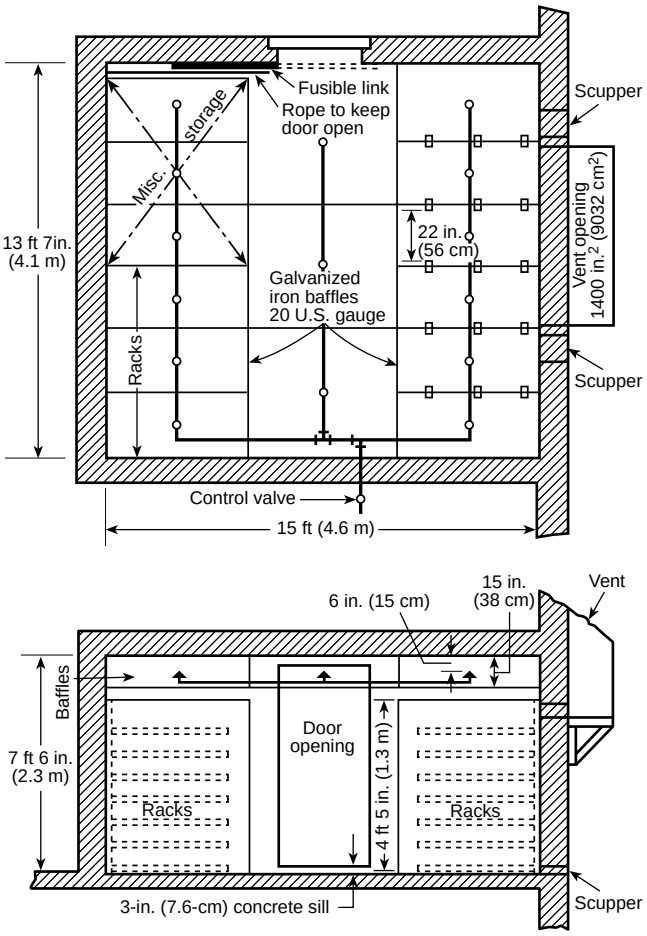
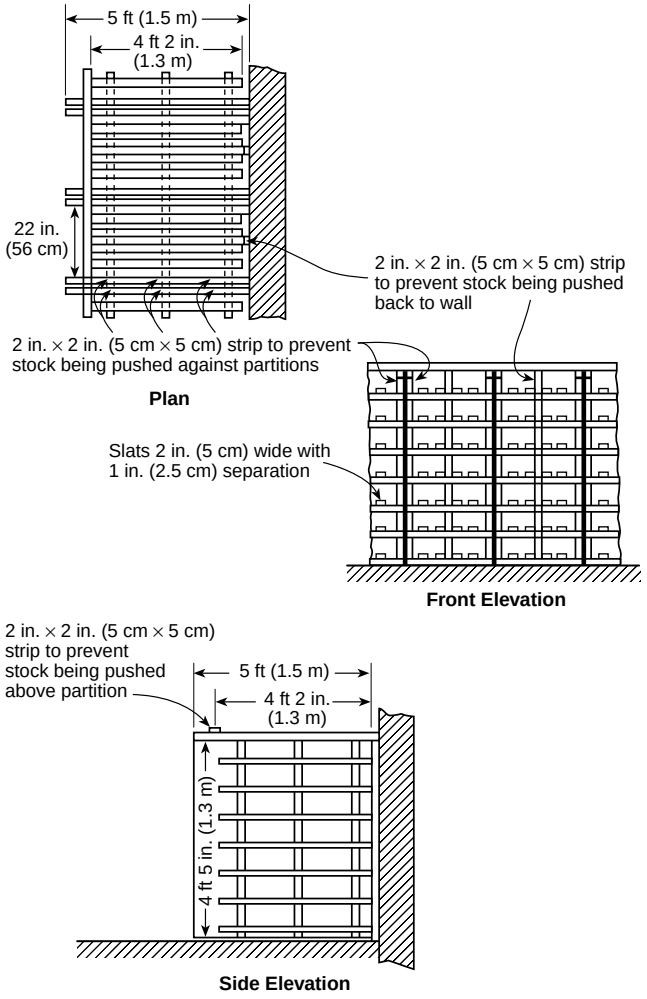


Figure A-5-18.5(b) Details of storage racks in raw stock storage vault. [42: Figure 4-3.3.7(b)]



A-5-18.6 See Figures A-5-18.6(a) and (b).

Figure A-5-18.6(a) Tote-box storeroom showing general arrangement of racks and sprinklers. [42: Figure 4-7]

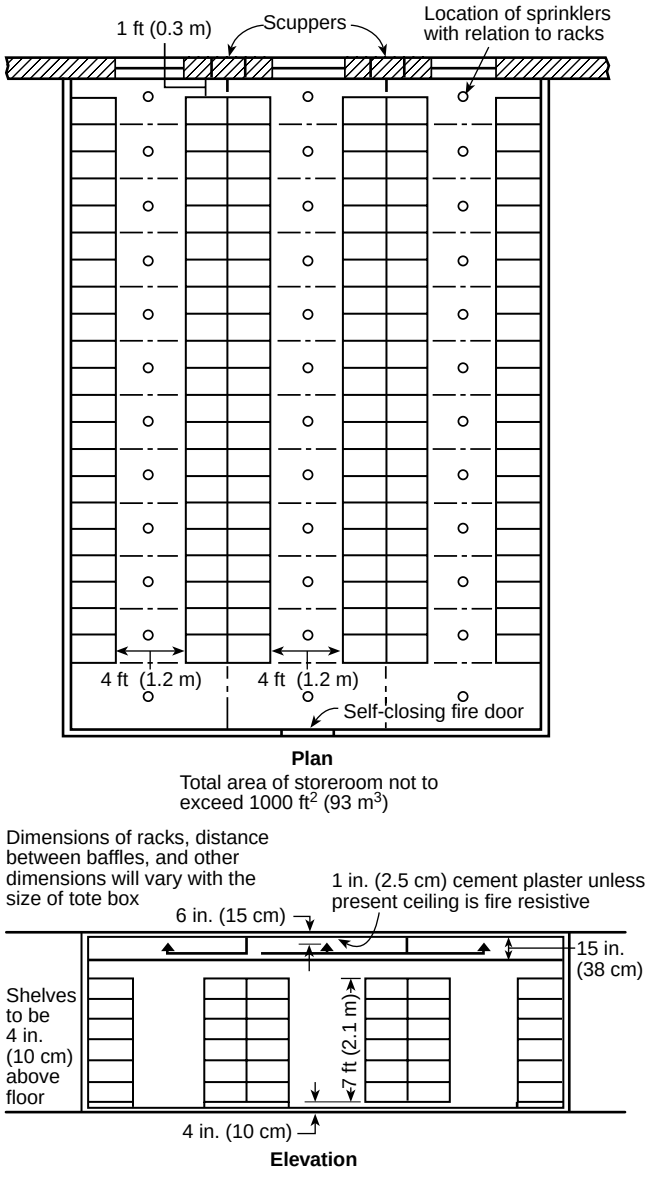
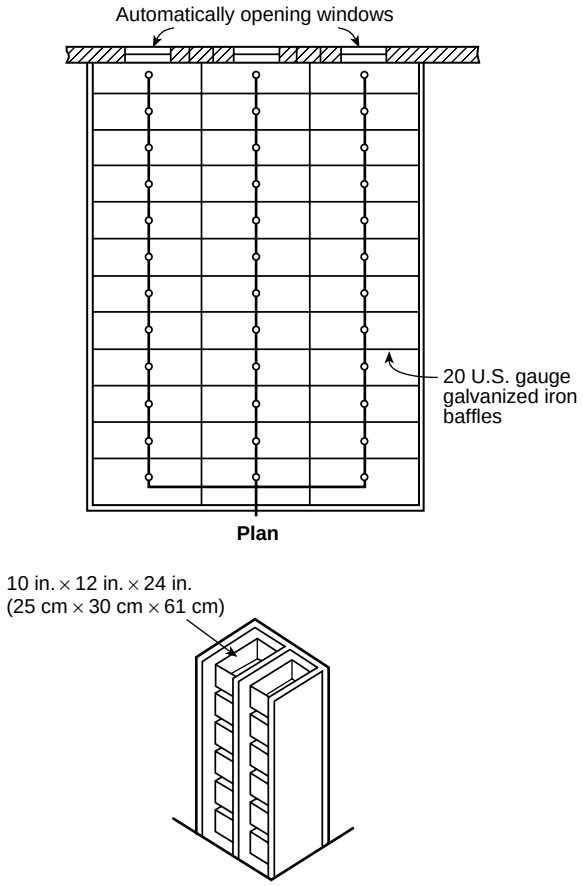


Figure A-5-18.6(b) Tote-box storeroom showing arrangement of sprinklers and baffles and section of tote-box storage rack. [42: Figure 4-7.7]



A-5-18.7 See Figures A-5-18.7(a) and (b).

Figure A-5-18.7(a) Finished-stock storeroom showing general arrangement of racks. [42: Figure 4-8 (top)]

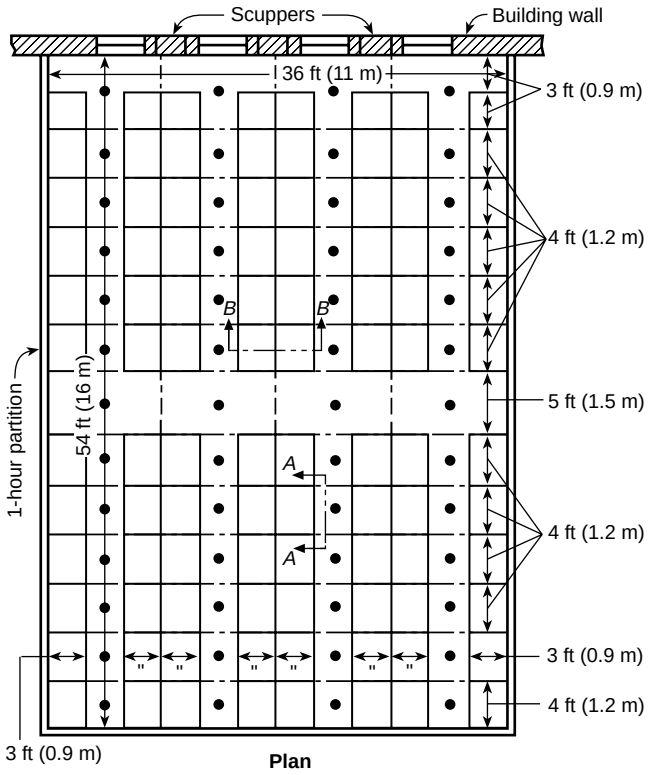
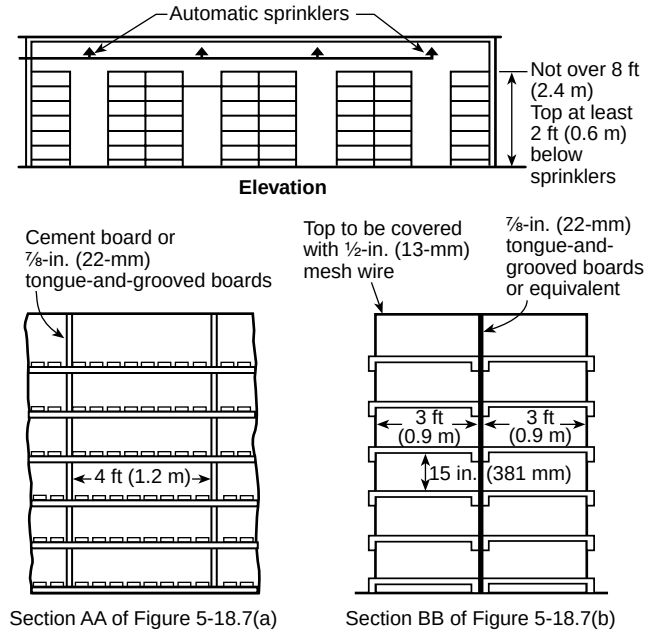
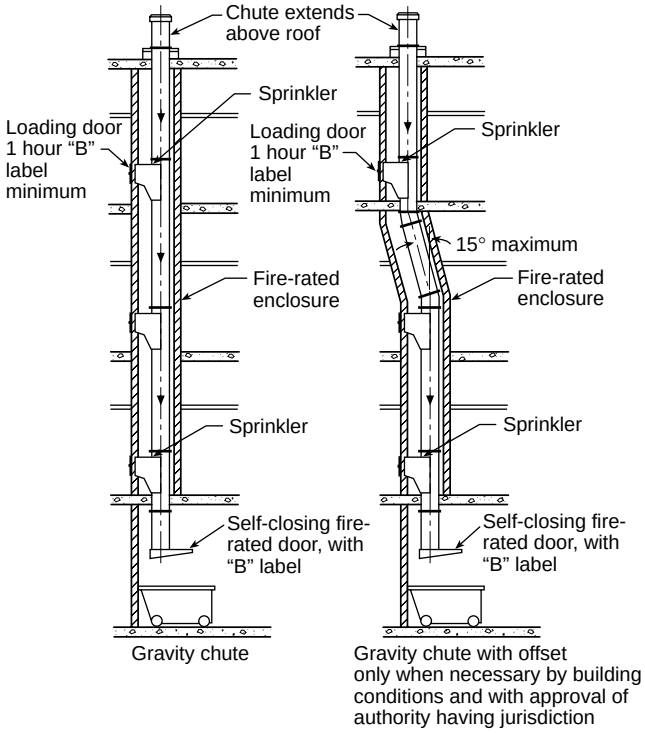


Figure A-5-18.7(b) Finished-stock storeroom showing arrangement of sprinklers, baffles, shelves, and rack partitions. [42: Figure 4-8 (bottom)]



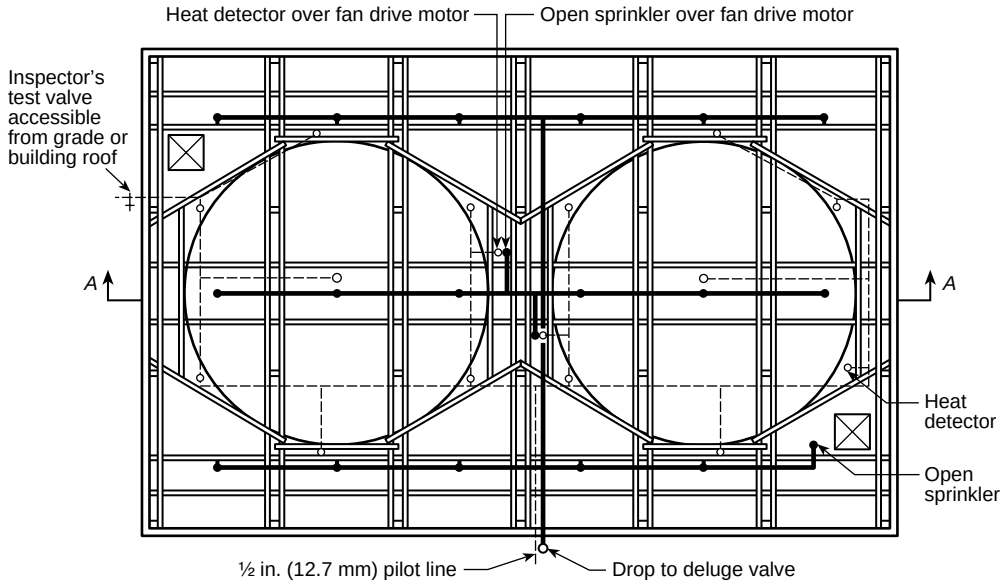
A-5-21.3.1 See Figure A-5-21.3.1.

Figure A-5-21.3.1 Gravity chute. [82: Figure 3-2.5.1]



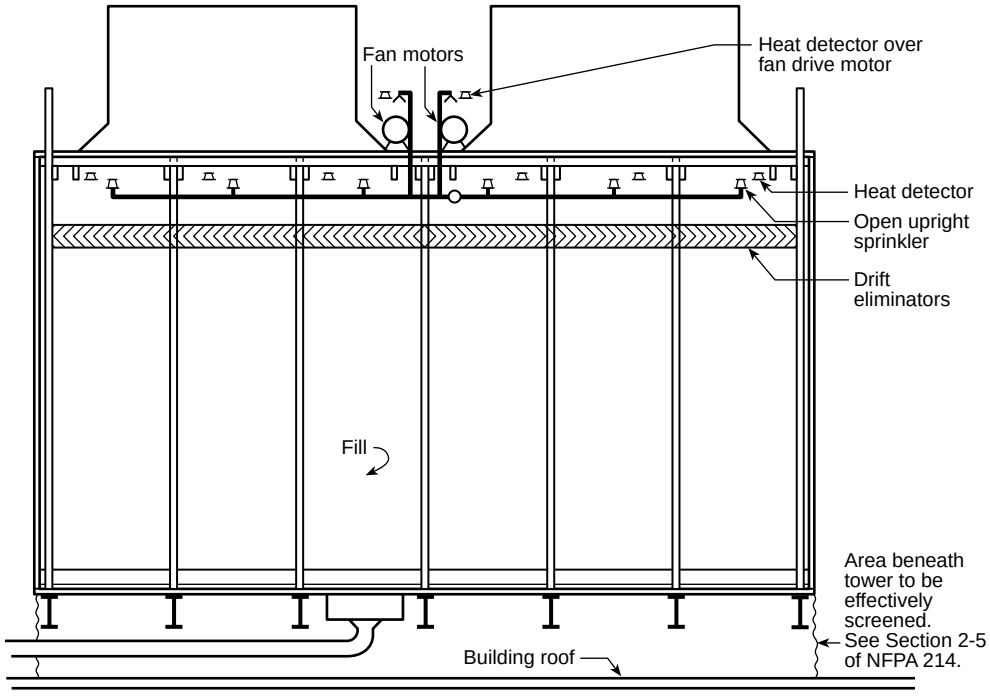
A-5-23.3 See Figures A-5-23.3(a) through (d).

Figure A-5-23.3(a) Typical deluge fire protection arrangement for counterflow towers, illustration 1. [214: Figure A-3-2.4.1(a)]



Plan

Figure A-5-23.3(b) Typical deluge fire protection arrangement for counterflow towers, illustration 2. [214: Figure A-3-2.4.1(b)]



Section A-A

Figure A-5-23.3(c) Typical deluge or dry pipe fire protection arrangement for counterflow towers, illustration 1. [214: Figure A-3-2.4.1(c)]

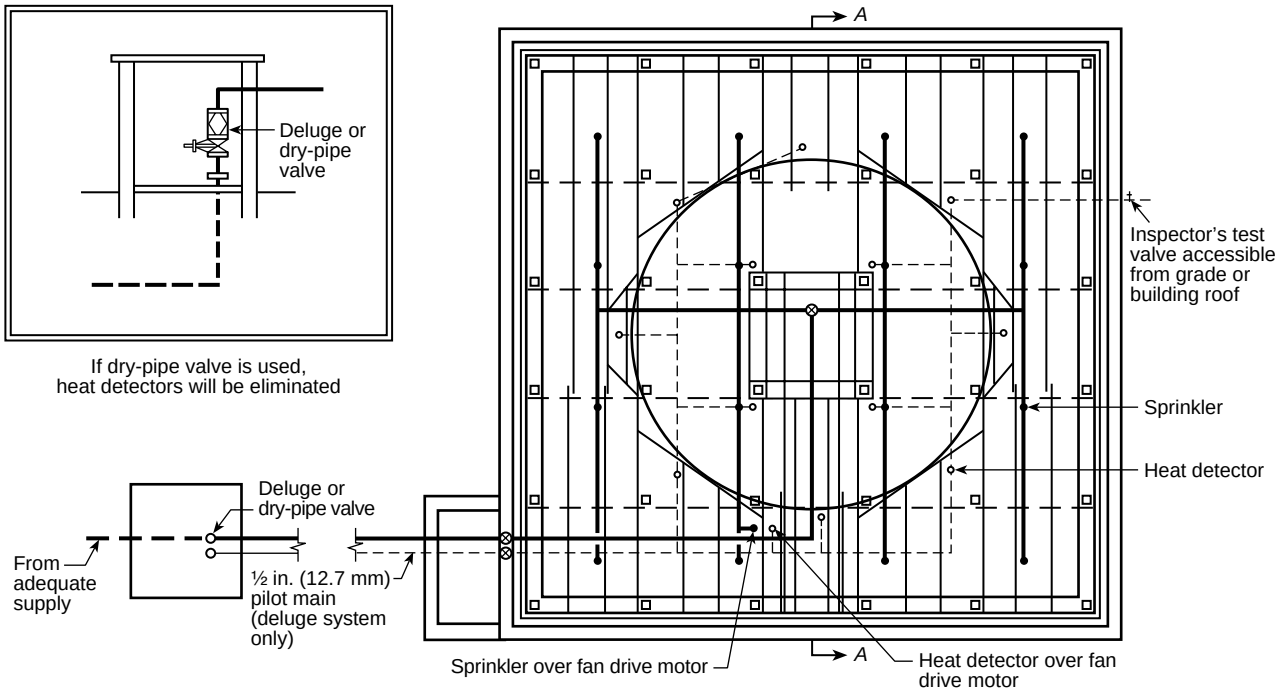
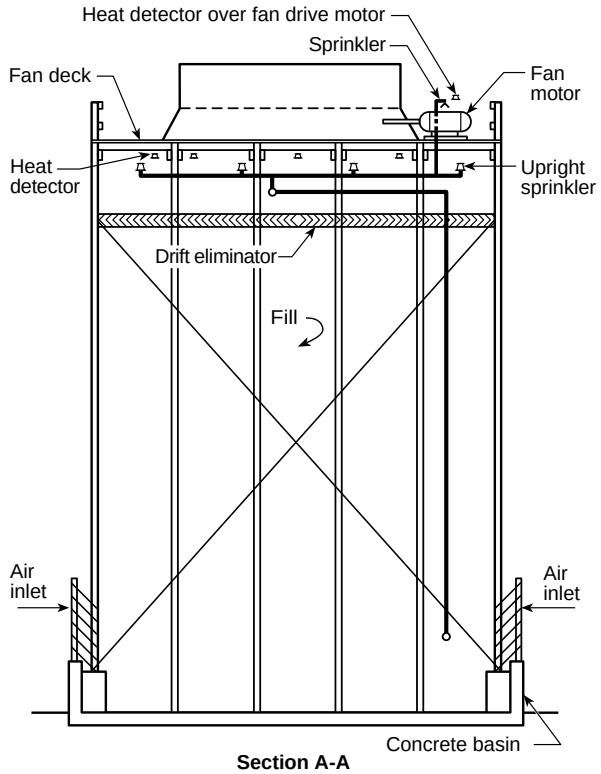


Figure A-5-23.3(d) Typical deluge or dry pipe fire protection arrangement for counterflow towers, illustration 2. [214: Figure A-3-2.4.1(d)]



A-5-23.4 See Figures A-5-23.4(a) through (d).

Figure A-5-23.4(a) Typical deluge fire protection arrangement for crossflow towers, illustration 1. [214: Figure A-3-2.4.2(a)]

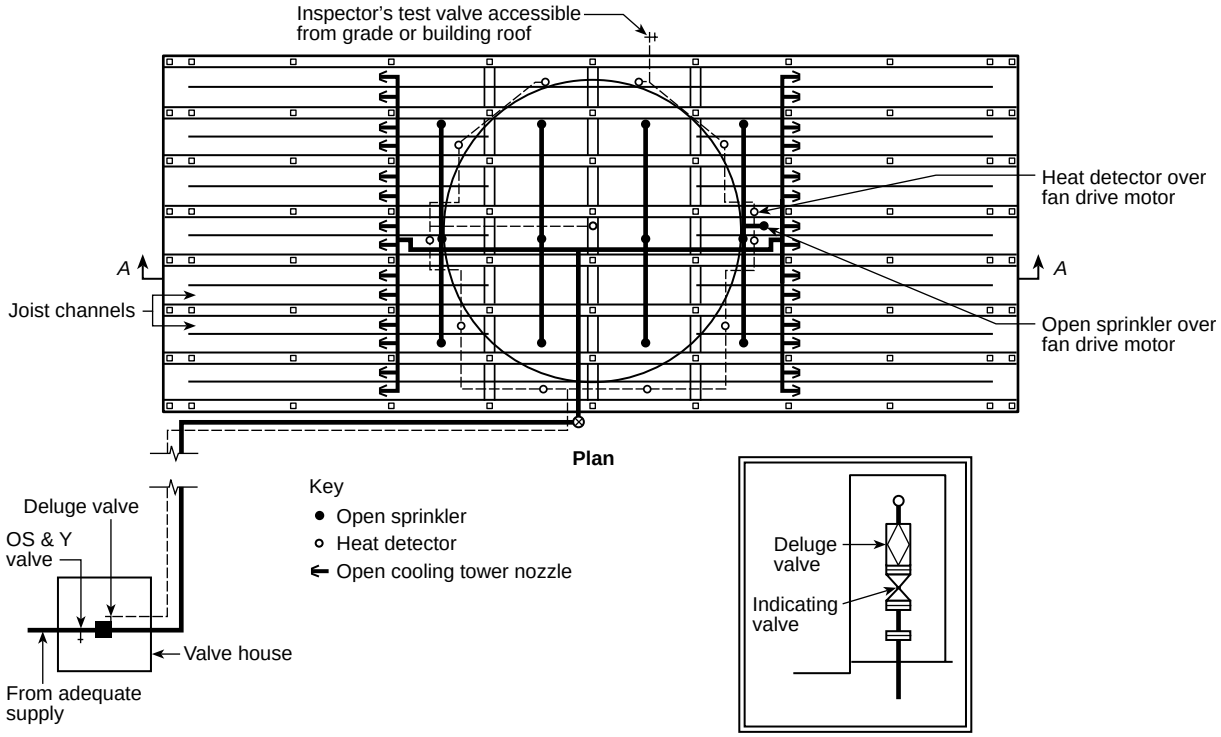


Figure A-5-23.4(b) Typical deluge fire protection arrangement for crossflow towers, illustration 2. [214: Figure A-3-2.4.2(b)]

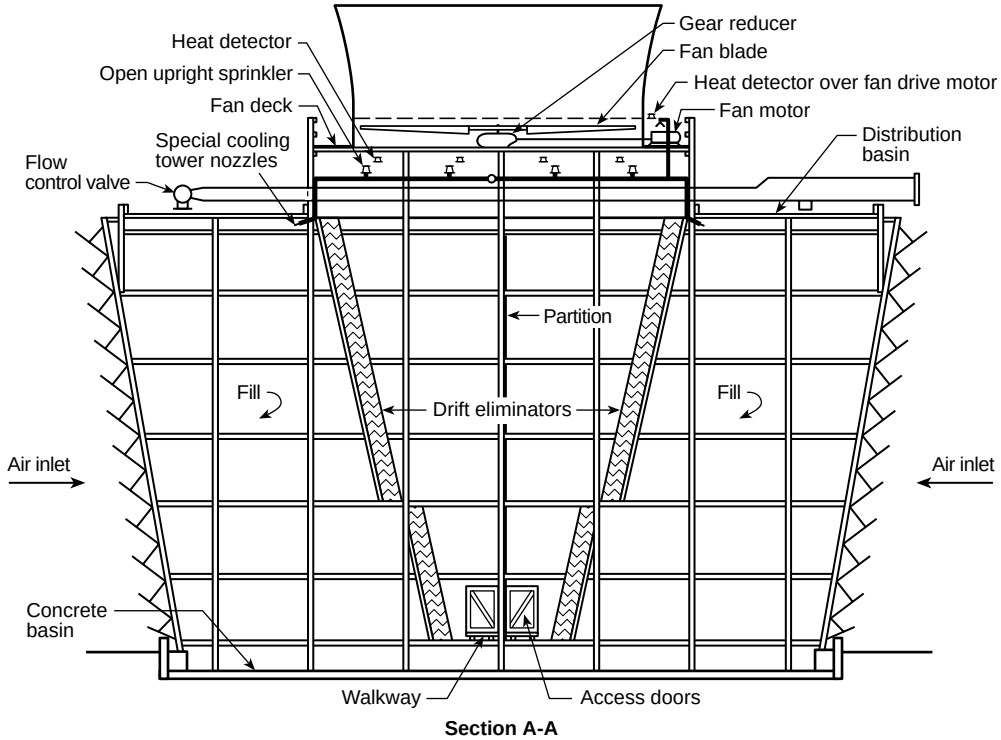
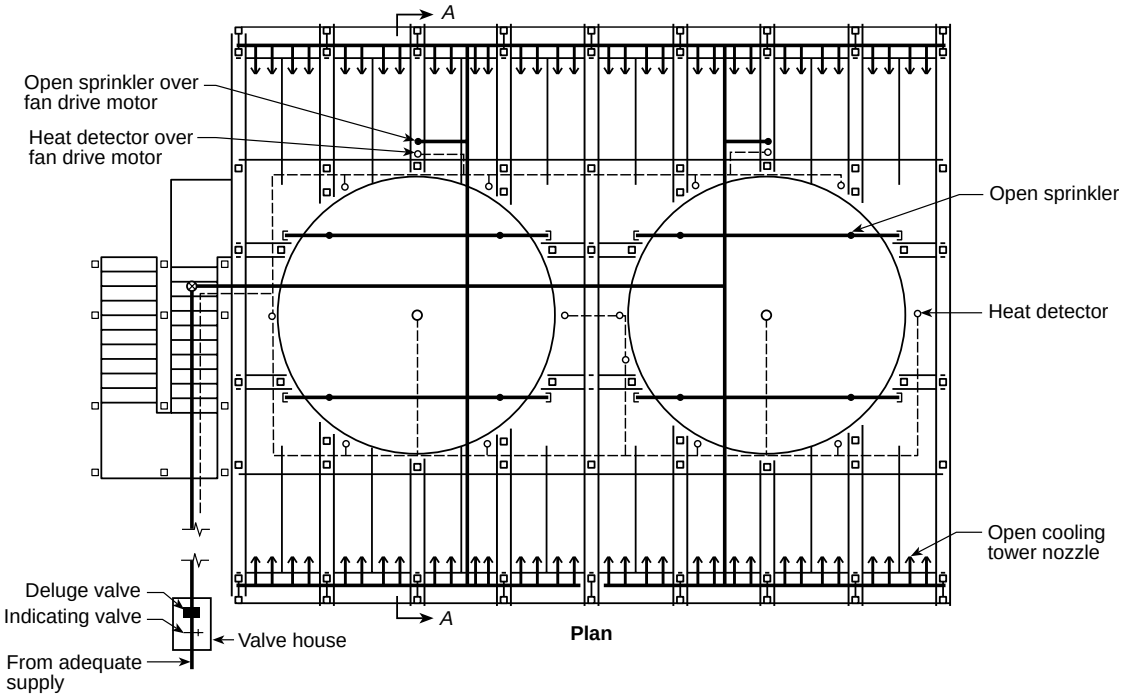
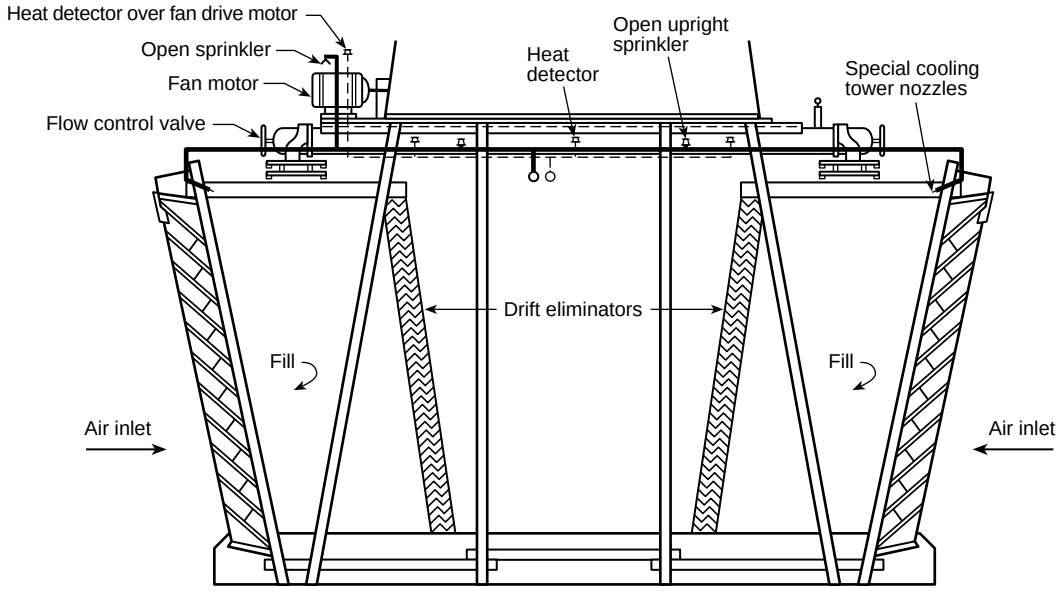


Figure A-5-23.4(c) Typical deluge fire protection arrangement for crossflow towers, illustration 3. [214: Figure A-3-2.4.2(c)]



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-5-23.4(d) Typical deluge fire protection arrangement for crossflow towers, illustration 4. [214: Figure A-3-2.3.2(d)]



Note: Where air seal boards prevent installation of cooling tower nozzles on drift eliminator side of fill, this nozzle location should be used.

A-5-23.5 Location of the nozzle relative to surfaces to be protected should 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, and so forth, in the water. *[See Figures A-5-23.5(a) and (b).]*

A-5-23.6.1 See Figure A-5-23.6.1.

A-5-25.4 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.) (**318:** A-2-1.2.2)

A-5-25.5 Small orifice sprinklers, $^{3}/_{8}$ in. (9.5 mm) or larger, can be used. (**318:** A-2-1.2.6.1)

A-5-27 At the time of the publication of this standard, the Technical Committee on Sprinkler System Installation Criteria is aware of ongoing research concerning the sprinkler protection of solid oxidizers. This research is being conducted by the National Fire Protection Research Foundation.

A-5-31 Where an adequate and reliable water supply, such as a lake, cooling pond, river, or municipal water system, is unavailable, at least two separate water supplies should be provided for fire protection purposes with each supply capable of meeting the fire waterflow requirements determined by 4-2.1 of NFPA 850. (**850:** 4-2.2)

Each water supply should be connected to the yard main by separate connections arranged and valve controlled to minimize the possibility of multiple supplies being impaired simultaneously. (**850:** 4-2.3)

Indicator control valves should be installed to provide adequate sectional control of the fire main loop to minimize plant protection impairments. (**850:** 4-4.1.4)

Each hydrant should be equipped with a separate shutoff valve located on the branch connection to the supply main. (**850:** 4-4.1.5)

Interior fire protection loops are considered an extension of the yard main and should be provided with at least two valved connections to the yard main with appropriate sectional control valves on the interior loop. (**850:** 4-4.1.6)

If a sprinkler system is used to protect the coal conveyor, particular care should be exercised in locating closed sprinkler so that they will be in the path of the heat produced by the fire and still be in a position to provide good coverage of all belt surfaces along the conveyor. (**850:** 5-4.6.2.1)

Protection inside dust collectors should include the clean air plenum and the bag section. If the hopper is shielded from water discharge, sprinklers also should be provided in the hopper section.

All areas beneath the turbine-generator operating floor that are subject to oil flow, oil spray, or oil accumulation should be protected by an automatic sprinkler or foam-water sprinkler system. This coverage normally includes all areas beneath the operating floor in the turbine building. (**850:** 5-7.4.1.1)

Lubricating oil lines above the turbine operating floor should be protected with an automatic sprinkler system covering those areas subject to oil accumulation including the area within the turbine lagging (skirt). (**850:** 5-7.4.1.2)

Turbine-generator bearings should be protected with a manually or automatically operated closed-head sprinkler system utilizing directional nozzles. (**850:** 5-7.4.2.1)

Due to the large quantity of platforms, equipment, and walkways, care should be taken to include coverage under all obstructions greater than 4 ft (1.2 m) wide. (**850:** 7-4.4.8)

Figure A-5-23.5(a) Typical deluge fire protection arrangement for crossflow towers with completely enclosed distribution basins, illustration 1. [214: Figure A-3-2.4.3(a)]

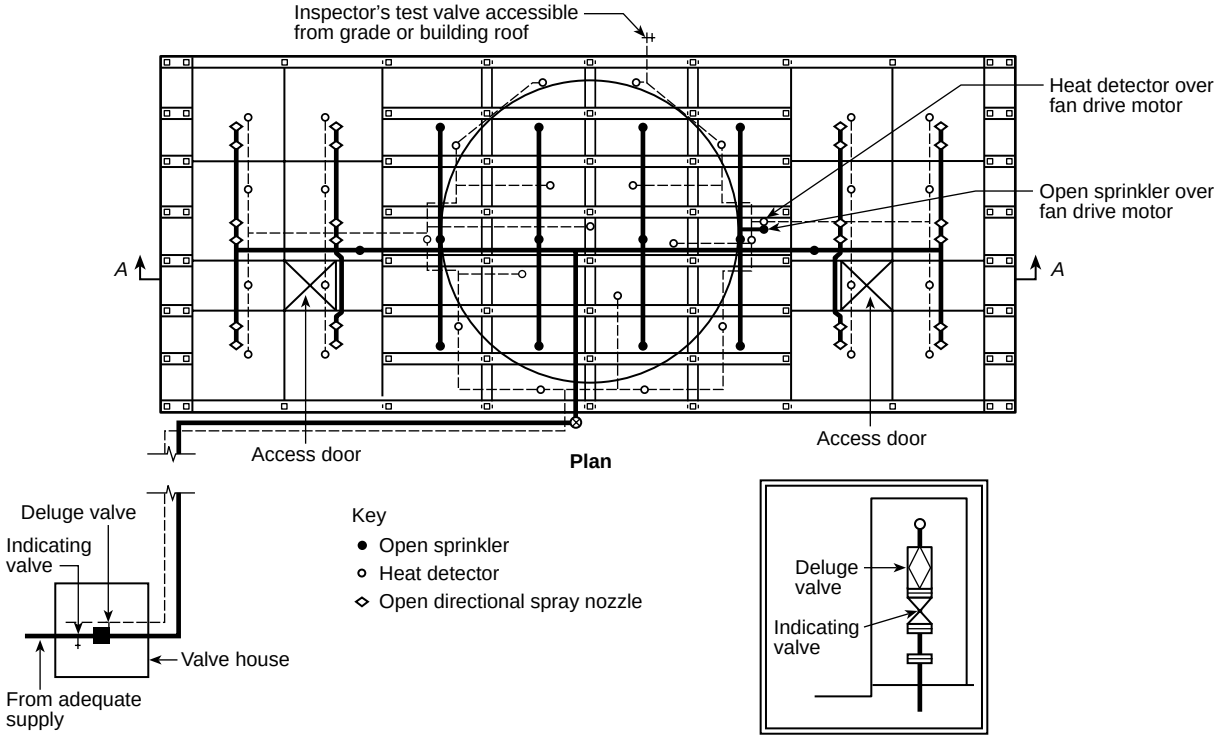


Figure A-5-23.5(b) Typical deluge fire protection arrangement for crossflow towers with completely enclosed distribution basins, illustration 2. [214: Figure A-3-2.4.3(b)]

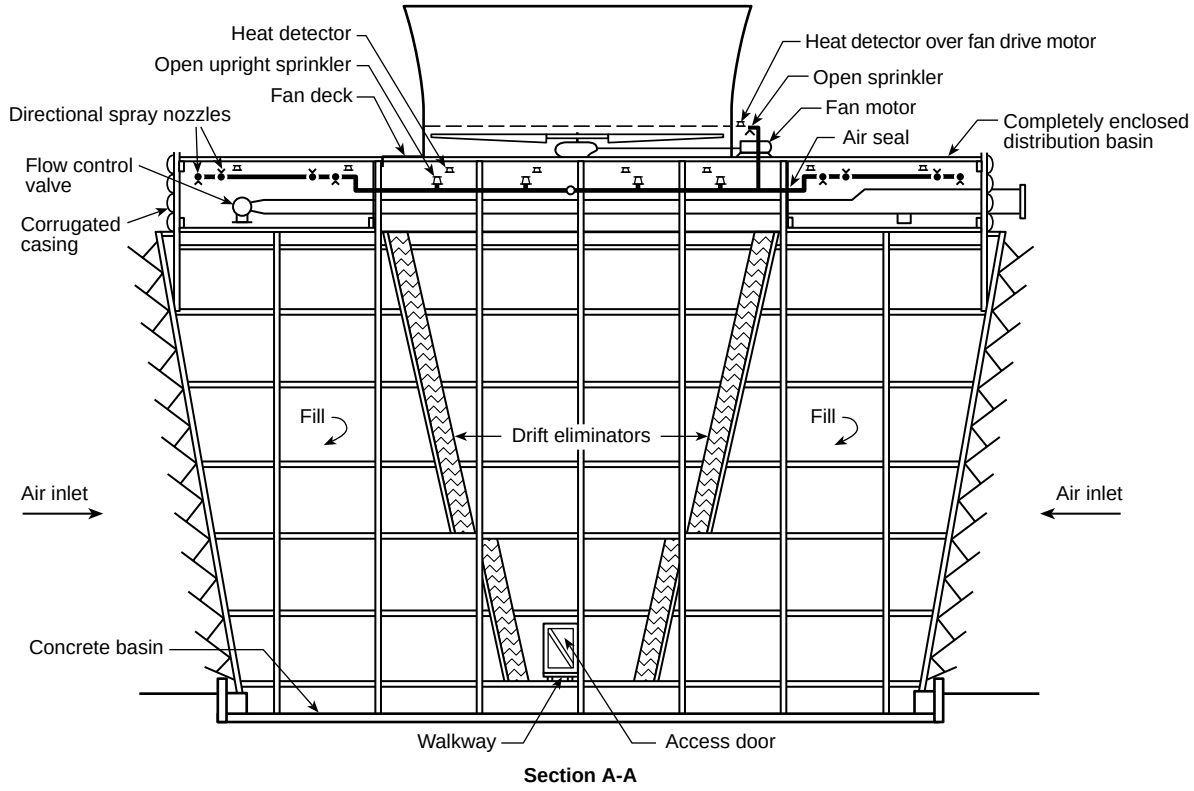


Figure A-5-23.6.1 Typical deluge fire protection arrangement for crossflow towers with covers completely enclosing distribution basins. [214: Figure A-3-2.4.5]

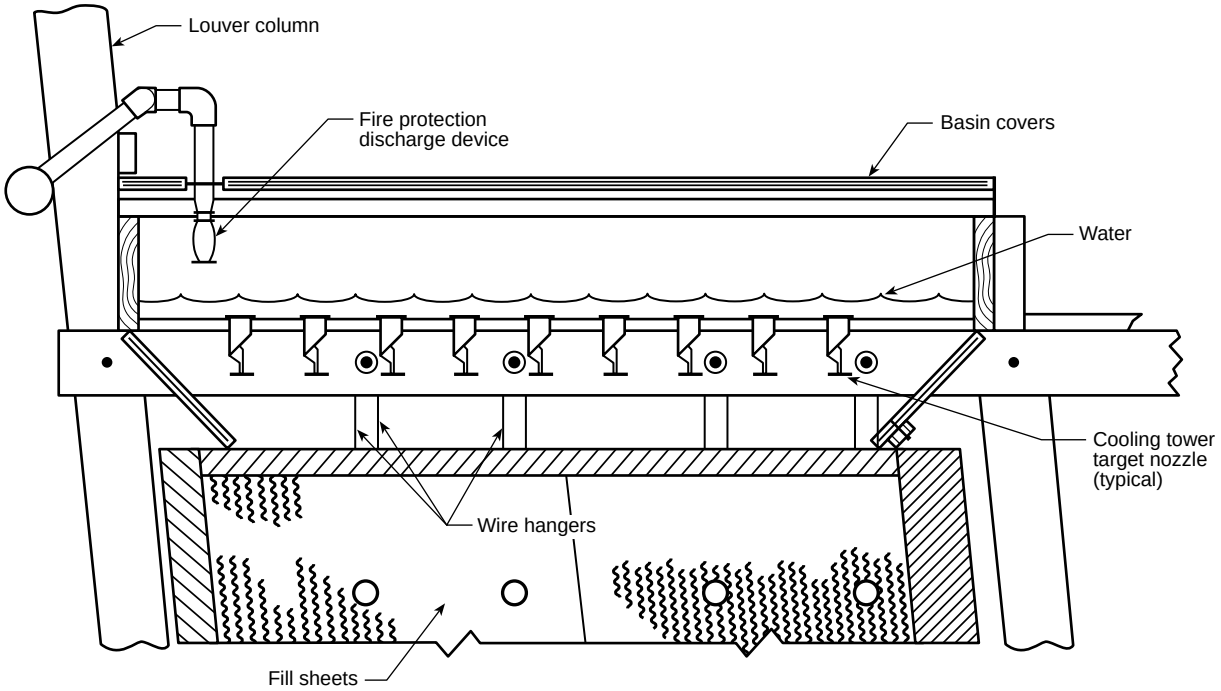
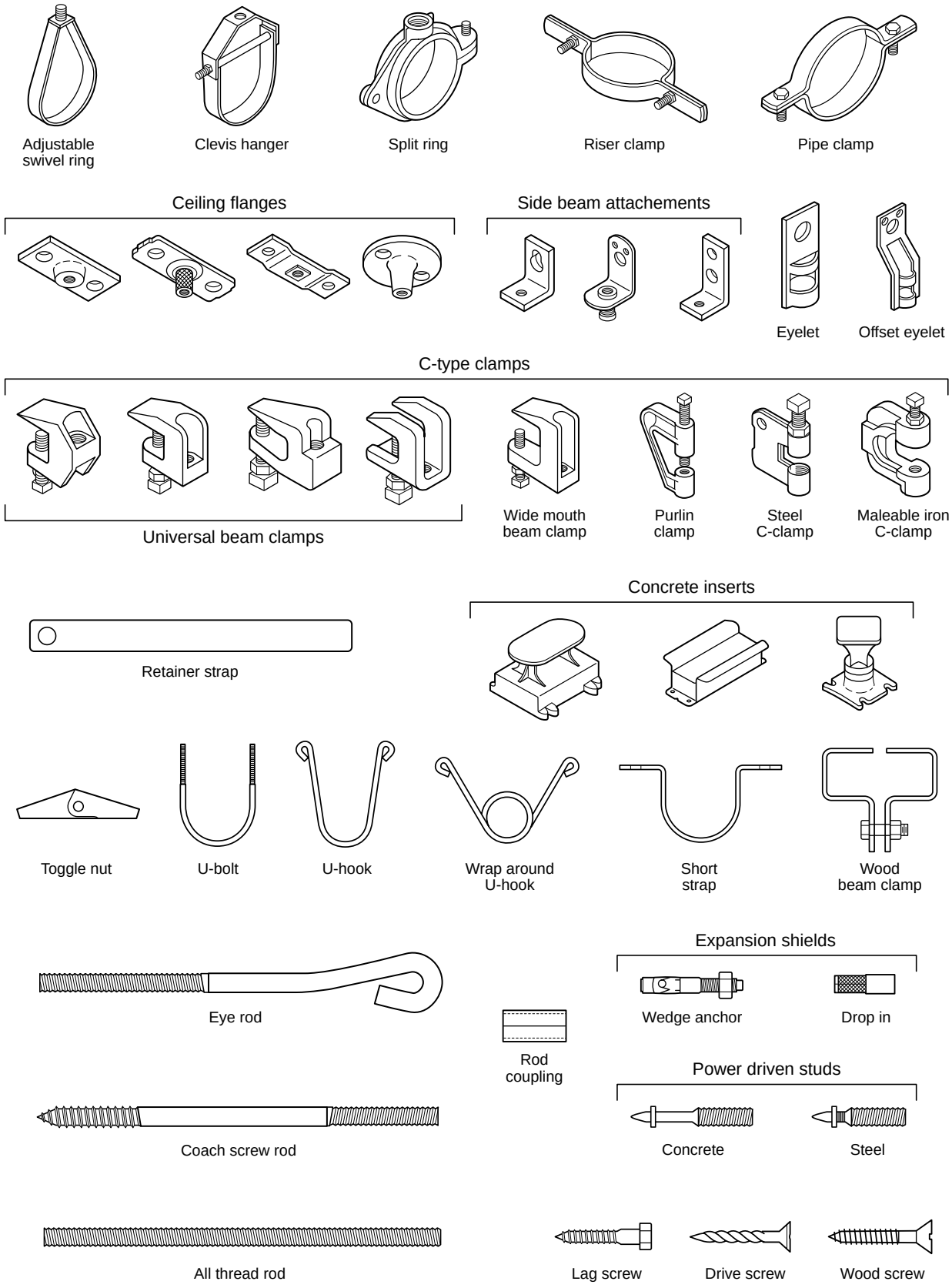


Figure A-6-1.1 Common types of acceptable hangers.



A-5-32 Upstream water is frequently the fire protection water supply. Water for fire suppression should not be taken downstream from any closure device in a penstock, flume, or forebay. (**851:** 4-2.6)

Fire extinguishing systems, where installed for lube oil systems employing combustible-type oil, should include protection for the reservoirs, pumps, and all oil lines, especially where unions exist on piping and beneath any shielded area where flowing oil can collect. Facilities not provided with curbs or drains should extend coverage for a distance of 20 ft (6.1 m) from the oil lines, when measured from the outermost oil line. (**851:** 5-2.7)

A-6-1.1 See Figure A-6-1.1.

A-6-1.1.3 Table 6-1.1.3(a) assumes that the load from 15 ft (5 m) of water-filled pipe, plus 250 lb (114 kg), is located at the midpoint of the span of the trapeze member, with a maximum allowable bending stress of 15 ksi (111 kg). If the load is applied at other than the midpoint, for the purpose of sizing the trapeze member, an equivalent length of trapeze can be used, derived from the following formula:

$$L = \frac{4ab}{a+b}$$

where:

L = equivalent length

a = distance from one support to the load

b = distance from the other support to the load

Where multiple mains are to be supported or multiple trapeze hangers are provided in parallel, the required or available section modulus can be added.

A-6-1.1.5 The rules covering the hanging of sprinkler piping take into consideration the weight of water-filled pipe plus a safety factor. No allowance has been made for the hanging of nonsystem components from sprinkler piping.

A-6-1.3.1 Powder-driven studs should not be used in steel of less than $^{3}/_{16}$ in. (4.8 mm) total thickness.

A-6-1.3.2 The ability of concrete to hold the studs varies widely according to type of aggregate, quality of concrete, and proper installation.

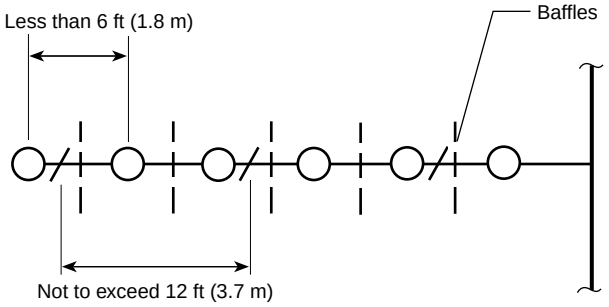
A-6-2.1.3 The method used to attach the hanger to the structure and the load placed on the hanger should take into account any limits imposed by the structure. Design manual information for pre-engineered structures or other specialty construction materials should be consulted, if appropriate.

System mains hung to a single beam, truss, or purlin can affect the structural integrity of the building by introducing excessive loads not anticipated in the building design. Also, special conditions such as collateral and concentrated load limits, type or method of attachment to the structural components, or location of attachment to the structural components might need to be observed when hanging system piping in pre-engineered metal buildings or buildings using other specialty structural components such as composite wood joists or combination wood and tubular metal joists.

A-6-2.2 Where copper tube is to be installed in moist areas or other environments conducive to galvanic corrosion, copper hangers or ferrous hangers with an insulating material should be used.

A-6-2.3.1 Exception No. 1. See Figure A-6-2.3.1.

Figure A-6-2.3.1 Distance between hangers.



A-6-2.3.3 Sprinkler piping should be adequately secured to restrict the movement of piping upon sprinkler operation. The reaction forces caused by the flow of water through the sprinkler could result in displacement of the sprinkler, thereby adversely affecting sprinkler discharge. Listed CPVC pipe and listed polybutylene pipe have specific requirements for piping support to include additional pipe bracing of sprinklers. See Figure A-6-2.3.3(a).

A-6-2.3.3 Exception. See Figures A-6-2.3.3(b) and A-6-2.3.3(c).

Figure A-6-2.3.3(a) Distance from sprinkler to hanger.

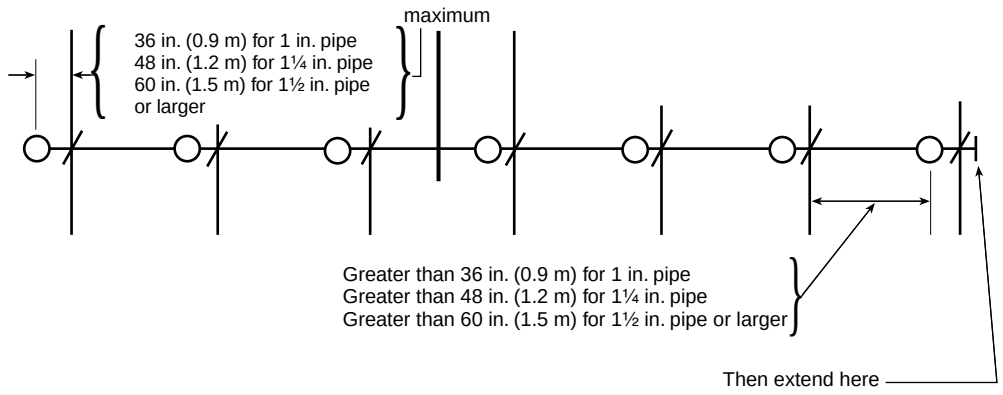


Figure A-6-2.3.3(b) Distance from sprinkler to hanger where maximum pressure exceeds 100 psi (6.9 bar) and a branch line above a ceiling supplies pendent sprinklers below the ceiling.

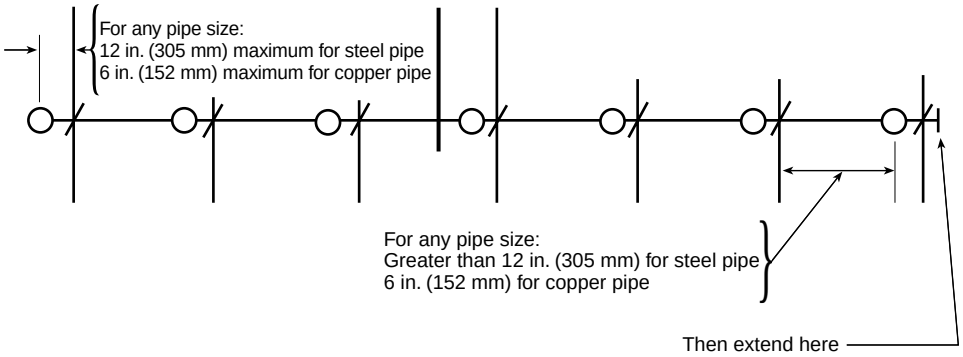
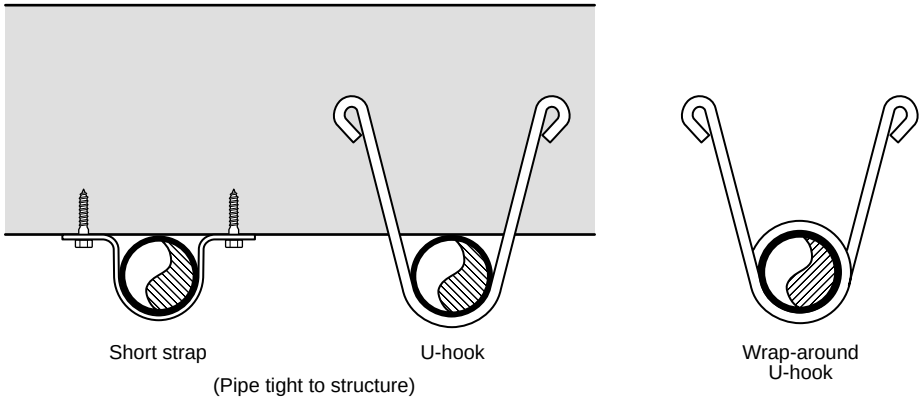
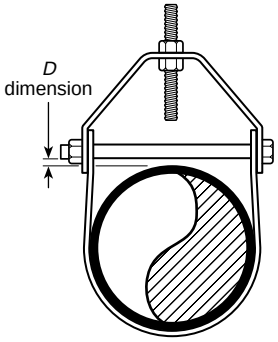
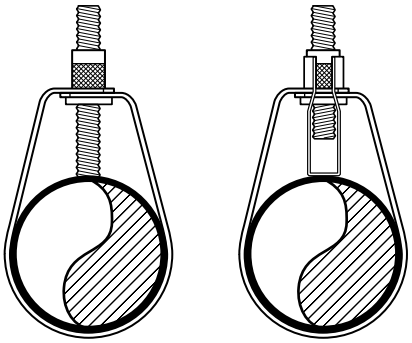


Figure A-6-2.3.3(c) Examples of acceptable hangers for end-of-line (or armover) pendent sprinklers.





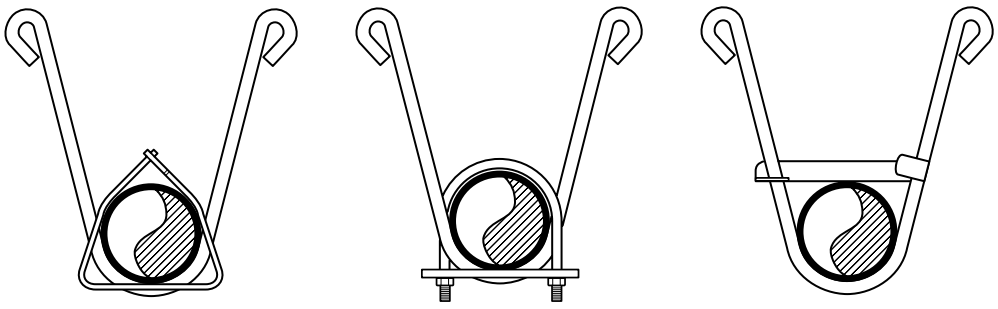
Pipe size	D dimension
1 in.	⅛ in.
1¼ in.	⅛ in.
1½ in.	⅛ in.
2 in.	¼ in.
2½ in.	¼ in.



Clevis hanger

Adjustable swivel ring — rod tight to pipe

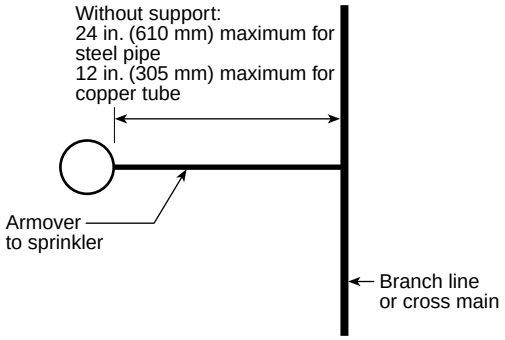
Adjustable swivel ring with surge suppressor



Clip-on wraparound U-hook devices

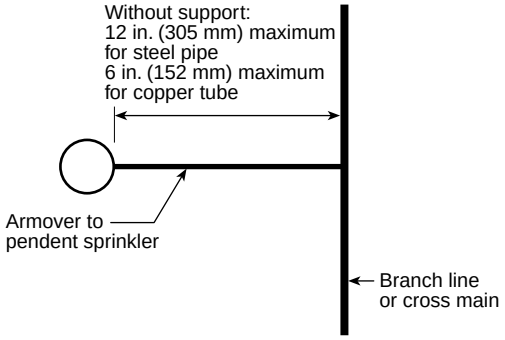
A-6-2.3.4 See Figure A-6-2.3.4(a).

Figure A-6-2.3.4(a) Maximum length for unsupported armover.



A-6-2.3.4 Exception. See Figure A-6-2.3.4(b).

Figure A-6-2.3.4(b) Maximum length of unsupported armover where the maximum pressure exceeds 100 psi (6.9 bar) and a branch line above a ceiling supplies pendent sprinklers below the ceiling.



Note: The pendent sprinkler can be installed either directly in the fitting at the end of the armover or in a fitting at the bottom of a drop nipple.

A-6-3.1.1 It is a fundamental design principle of fluid mechanics that dynamic and static pressures, acting at changes in size or direction of a pipe, produce unbalanced thrust forces at bends, tees, wyes, deadends, reducers offsets, and so forth. This procedure includes consideration of lateral soil pressure and pipe/soil friction, variables that can be reliably determined using present-day soils engineering knowledge. Refer to A-3-4.1 for a list of references for use in calculating and determining joint restraint systems.

Except for the case of welded joints and approved special restrained joints, such as provided by approved mechanical joint retainer glands or locked mechanical and push-on joints, the usual joints for underground pipe are expected to be held in place by the soil in which the pipe is buried. Gasketed push-on and mechanical joints without special locking devices have limited ability to resist separation due to movement of the pipe.

A-6-3.2 Concrete thrust blocks are one of the most common methods of restraint now in use, provided stable soil conditions prevail and space requirements permit placement. Successful blocking is dependent upon factors such as location, availability and placement of concrete, and possibility of disturbance by future excavations.

Resistance is provided by transferring the thrust force to the soil through the larger bearing area of the block such that the resultant pressure against the soil does not exceed the horizontal bearing strength of the soil. Design of thrust blocks consists of determining the appropriate bearing area of the block for a particular set of conditions. The parameters involved in the design include pipe size, design pressure, angle of the bend (or configuration of the fitting involved), and the horizontal bearing strength of the soil.

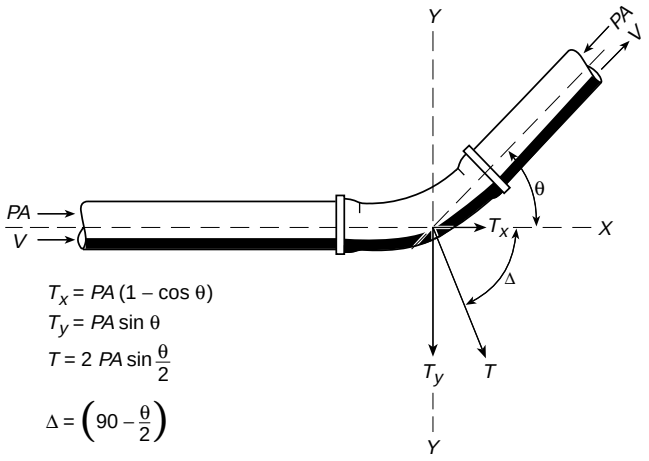
Table A-6-3.2(a) gives the nominal thrust at fittings for various sizes of ductile iron and PVC piping. Figure A-6-3.2(a) shows an example of how thrust forces act on a piping bend. Figure A-6-3.2(b) shows an example of a typical connection to a fire protection systems riser.

Table A-6-3.2(a) Thrust at Fittings at 100 psi (6.9 bar) Water Pressure for Ductile Iron and PVC Pipe

Nominal Pipe Diameter (in.)	Total Pounds					
	Dead End	90-Degree Bend	45-Degree Bend	$22^1/_2$-Degree Bend	$11^1/_4$-Degree Bend	$5^1/_8$-Degree Bend
4	1,810	2,559	1,385	706	355	162
6	3,739	5,288	2,862	1,459	733	334
8	6,433	9,097	4,923	2,510	1,261	575
10	9,677	13,685	7,406	3,776	1,897	865
12	13,685	19,353	10,474	5,340	2,683	1,224
14	18,385	26,001	14,072	7,174	3,604	1,644
16	23,779	33,628	18,199	9,278	4,661	2,126
18	29,865	42,235	22,858	11,653	5,855	2,670
20	36,644	51,822	28,046	14,298	7,183	3,277
24	52,279	73,934	40,013	20,398	10,249	4,675
30	80,425	113,738	61,554	31,380	15,766	7,191
36	115,209	162,931	88,177	44,952	22,585	10,302
42	155,528	219,950	119,036	60,684	30,489	13,907
48	202,683	286,637	155,127	79,083	39,733	18,124

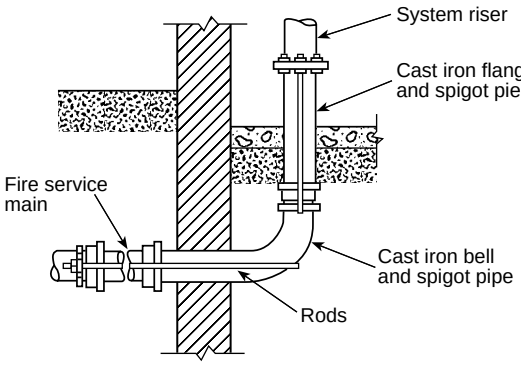
Note: To determine thrust at pressure other than 100 psi (6.9 bar), multiply the thrust obtained in the table by the ratio of the pressure to 100 psi (6.9 bar). For example, the thrust on a 12-in., 90-degree bend at 125 psi (8.6 bar) is 19,353 × 125/100 = 24,191 pounds.

Figure A-6-3.2(a) Thrust forces acting on a bend.



- T Thrust force resulting from change in direction of flow
- T_x Component of the thrust force acting parallel to the original direction of flow
- T_y Component of the thrust force acting perpendicular to the original direction of flow
- P Water pressure
- A Cross-sectional area of the pipe interior
- V Velocity in direction of flow

Figure A-6-3.2(b) Typical connection to a fire protection system riser.



Thrust blocks are generally categorized into two groups — bearing and gravity blocks. Figure A-6-3.2(c) depicts a typical bearing thrust block on a horizontal bend.

The following are general criteria for bearing block design.

(a) Bearing surface should, where possible, be placed against undisturbed soil. Where it is not possible, the fill between the bearing surface and undisturbed soil must be compacted to at least 90 percent Standard Proctor density.

(b) Block height *(h)* should be equal to or less than one-half the total depth to the bottom of the block *(H_t)* but not less than the pipe diameter *(D)*.

(c) Block height *(h)* should be chosen such that the calculated block width *(b)* varies between one and two times the height.

The required block area is as follows:

$$A_b = (h)(b) = \frac{T(S_f)}{S_b}$$

Then, for a horizontal bend, the following formula is used:

$$b = \frac{2(S_f)(P)(A_b)\ \sin(\Theta/2)}{(h)(S_b)}$$

where S_f is a safety factor (usually 1.5 thrust block design). A similar approach can be used to design bearing blocks to resist the thrust forces at tees, dead ends, and so forth. Typical values for conservative horizontal bearing strengths of various soil types are listed in Table A-6-3.2(b).

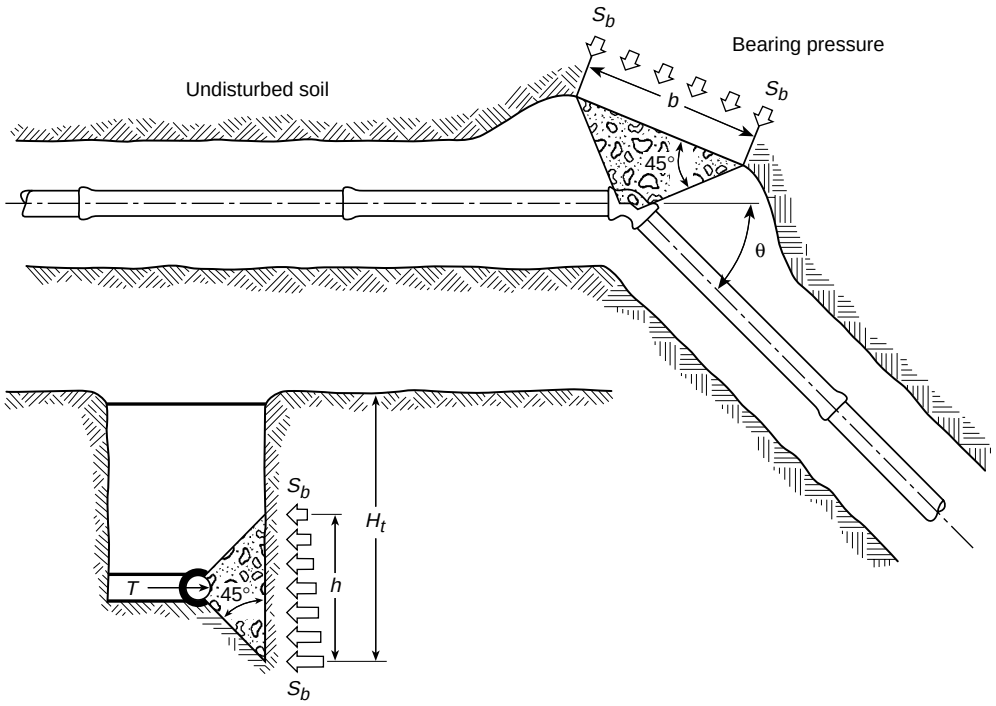
In lieu of the values for soil bearing strength shown in Table A-6-3.2(b), a designer might choose to use calculated Rankine passive pressure *(P_p)* or other determination of soil bearing strength based on actual soil properties.

Table A-6-3.2(b) Horizontal Bearing Strengths

	Bearing Strength, S_b	
Soil	**lb/ft²**	**KN/m²**
Muck	0	0
Soft clay	1000	47.9
Silt	1500	71.8
Sandy silt	3000	143.6
Sand	4000	191.5
Sandy clay	6000	287.3
Hard clay	9000	430.9

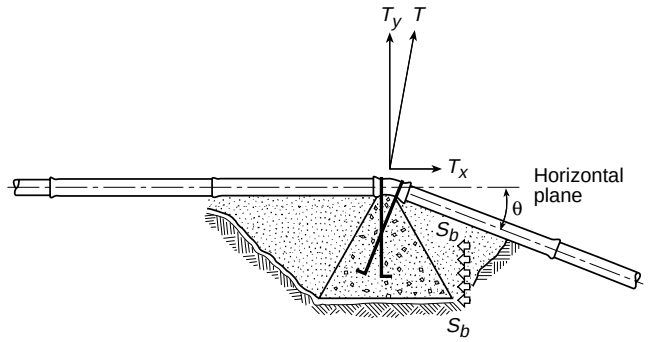
Notes:
1. Although the bearing strength values in this table have been used successfully in the design of thrust blocks and are considered to be conservative, their accuracy is totally dependent on accurate soil identification and evaluation. The ultimate responsibility for selecting the proper bearing strength of a particular soil type must rest with the design engineer.
2. Gravity thrust blocks can be used to resist thrust at vertical down bends. In a gravity thrust block, the weight of the block is the force providing equilibrium with the thrust force. The design problem is then to calculate the required volume of the thrust block of a known density. The vertical component of the thrust force in Figure A-6-3.2(d) is balanced by the weight of the block.

Figure A-6-3.2(c) Bearing thrust block.



T Thrust force resulting from the change in direction of flow
S_b Horizontal bearing strength of the soil

Figure A-6-3.2(d) Gravity thrust block.



T Thrust force resulting from the change of direction of flow
T_x Horizontal component of the thrust force
T_y Vertical component of the thrust force
S_b Horizontal bearing strength of the soil

It can be easily be shown that $T_y = PA \sin \theta$. The required volume of the block is as follows:

$$V_g = \frac{S_f PA \sin\Theta}{W_m}$$

where W_m is the density of the block material. In a case such as the one shown, the horizontal component of thrust force, which is calculated as follows,

$$T_x = PA(1 - \cos \theta)$$

must be resisted by the bearing of the right side of the block against the soil. Analysis of this aspect will follow the same principles as the previous section on bearing blocks.

A-6-3.3.5 Examples of materials and the standards covering these materials are as follows:

(1) Clamps, steel *(see Note)*
(2) Rods, steel *(see Note)*
(3) Bolts, steel (ASTM A 307, *Standard Specification for Carbon Steel Bolts and Studs*)
(4) Washers, steel *(see Note);* cast iron (Class A cast iron as defined by ASTM A 126, *Standard Specification for Gray Iron Casting for Valves, Flanges and Pipe Fittings*)
(5) Anchor straps and plug straps, steel *(see Note)*
(6) Rod couplings or turnbuckles, malleable iron (ASTM A 197, *Standard Specification for Cupola Malleable Iron*)

Steel of modified range merchant quality as defined in U.S. Federal Standard No. 66C, *Standard for Steel Chemical Composition and Harden Ability*, April 18, 1967, change notice No. 2, April 16, 1970, as promulgated by the U.S. Federal Government General Services Administration.

The materials specified in A-6-3.3.5(1) through (6) do not preclude the use of other materials that will also satisfy the requirements of this section.

A-6-4.1 Sprinkler systems are protected against earthquake damage by means of the following:

(1) Stresses that would develop in the piping due to differential building movement are minimized through the use of flexible joints or clearances.
(2) Bracing is used to keep the piping fairly rigid when supported from a building component expected to move as a unit, such as a ceiling.

Areas known to have a potential for earthquakes have been identified in building code and insurance maps. Examples of two such maps are shown in Figures A-6-4.1(a) and A-6-4.1(b).

Figure A-6-4.1(a) Seismic zone map of the United States.

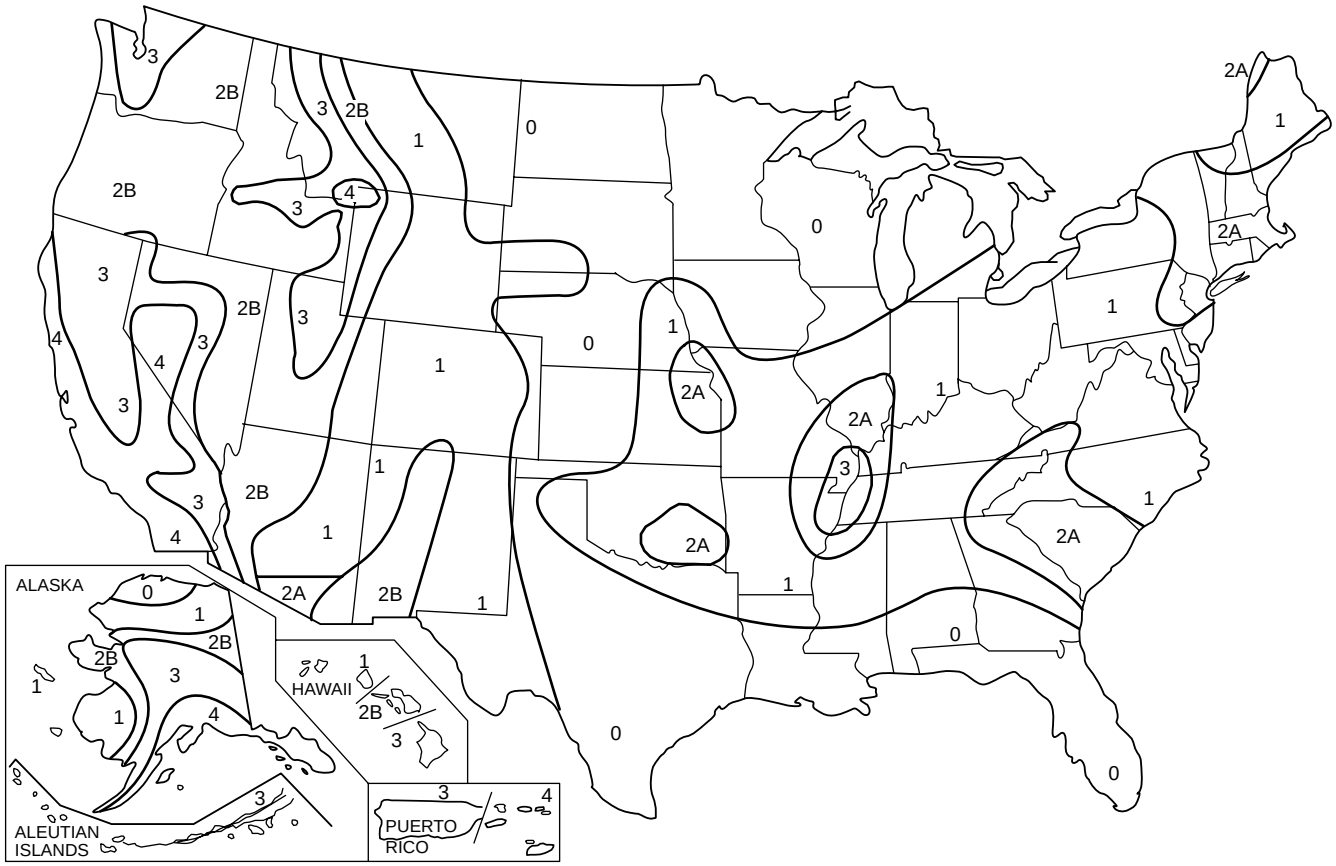
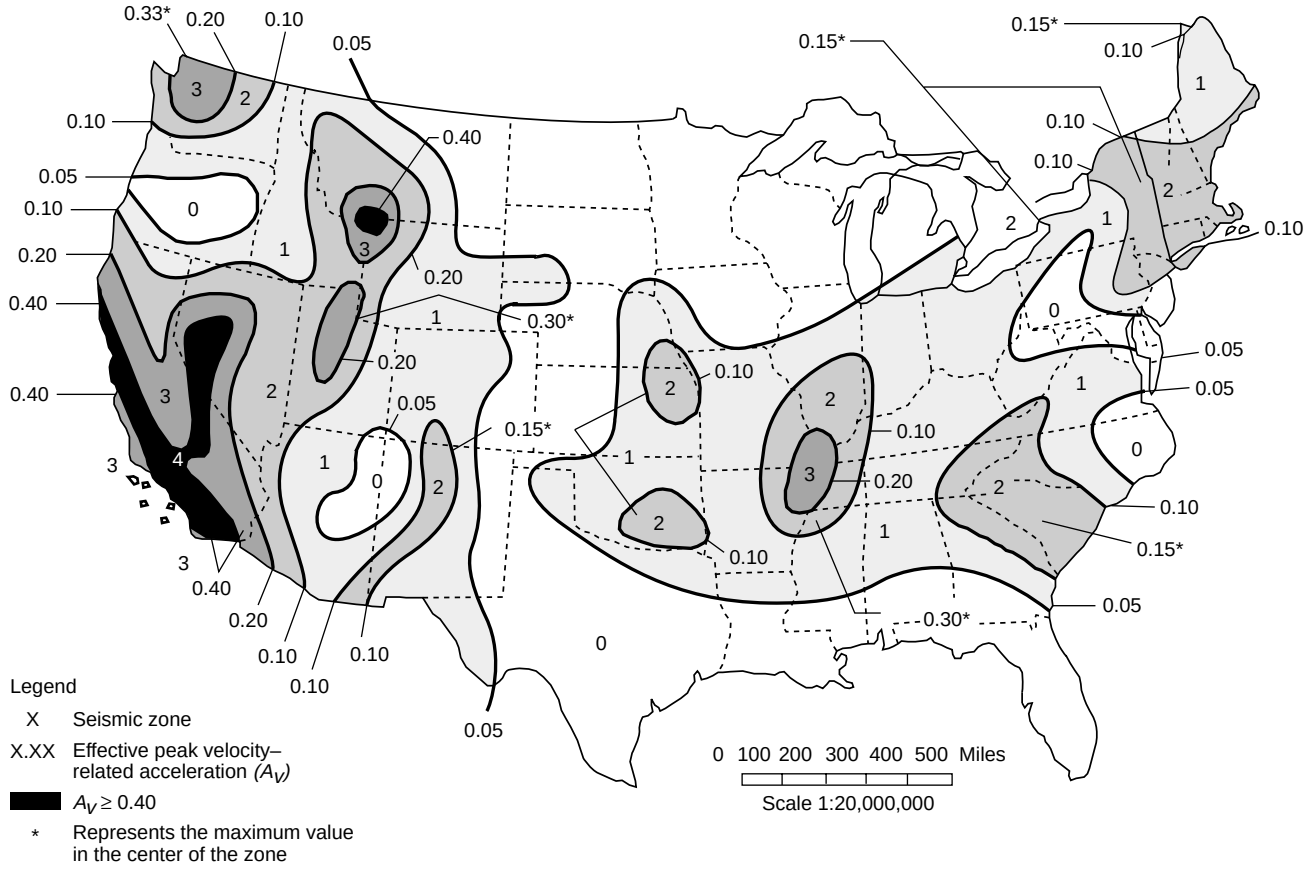


Figure A-6-4.1(b) Map of seismic zones and effective peak velocity–related acceleration (A_v) for the contiguous 48 states; linear interpolation between contours is acceptable.

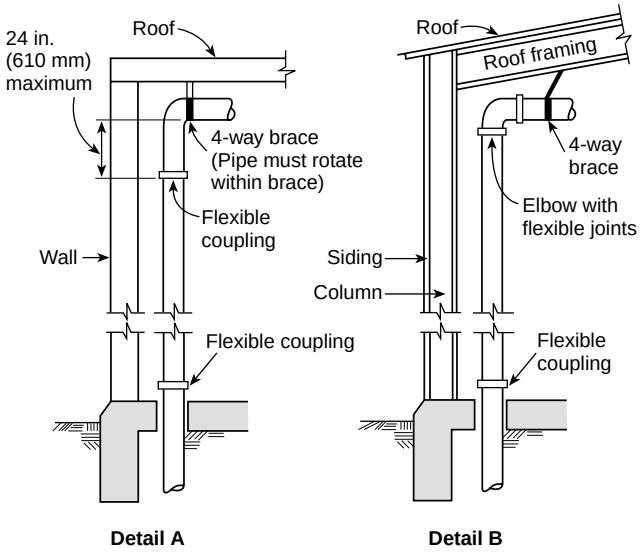


A-6-4.2 Strains on sprinkler piping can be greatly lessened and, in many cases, damage prevented by increasing the flexibility between major parts of the sprinkler system. One part of the piping should never be held rigidly and another part allowed to move freely without provision for relieving the strain. Flexibility can be provided by using listed flexible couplings, by joining grooved end pipe at critical points, and by allowing clearances at walls and floors.

Tank or pump risers should be treated the same as sprinkler risers for their portion within a building. The discharge pipe of tanks on buildings should have a control valve above the roof line so any pipe break within the building can be controlled.

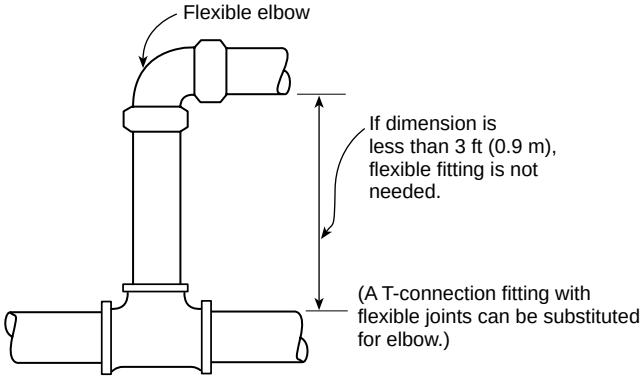
Piping 2 in. (51 mm) or smaller in size is pliable enough so that flexible couplings are not usually necessary. "Rigid-type" couplings that permit less than 1 degree of angular movement at the grooved connections are not considered to be flexible couplings. *[See Figures A-6-4.2(a) and (b).]*

Figure A-6-4.2(a) Riser details.



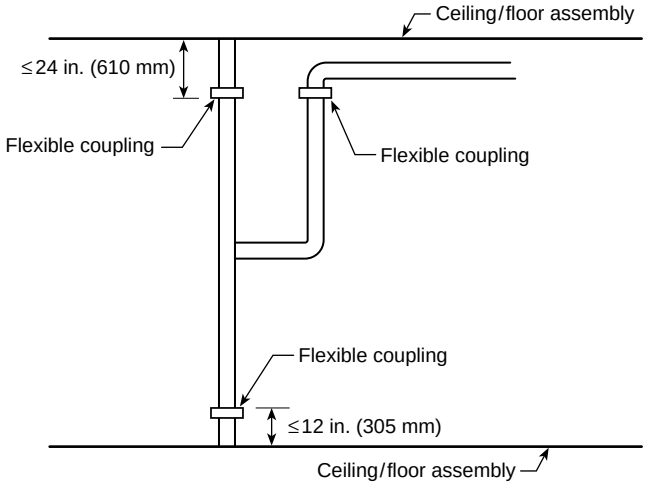
Note to Detail A: The four-way brace should be attached above the upper flexible coupling required for the riser and preferably to the roof structure if suitable. The brace should not be attached directly to a plywood or metal deck.

Figure A-6-4.2(b) Detail at short riser.



A-6-4.2(2) The flexible coupling should be at the same elevation as the flexible coupling on the main riser. See Figure A-6-4.2(2).

Figure A-6-4.2(2) Flexible coupling on main riser and branch line riser.



A-6-4.2(4) A building expansion joint is usually a bituminous fiber strip used to separate blocks or units of concrete to prevent cracking due to expansion as a result of temperature changes. Where building expansion joints are used, the flexible coupling is required on one side of the joint by 6-4.2(4).

For seismic separation joints, considerably more flexibility is needed, particularly for piping above the first floor. Figure A-6-4.3 shows a method of providing additional flexibility through the use of swing joints.

A-6-4.3 Plan and elevation views of a seismic separation assembly assembled with flexible elbows are shown in Figure A-6-4.3.

A seismic separation assembly is considered to be an assembly of fittings, pipe, and couplings or an assembly of pipe and couplings that permits movement in all directions. The extent of permitted movement should be sufficient to accommodate calculated differential motions during earthquakes. In lieu of calculations, permitted movement can be made at least twice the actual separations, at right angles to the separation as well as parallel to it.

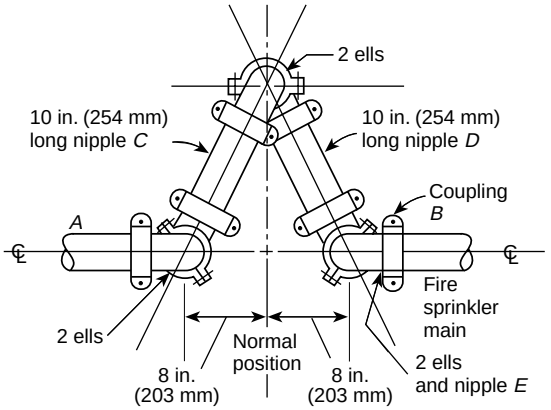
A-6-4.4 While clearances are necessary around the sprinkler piping to prevent breakage due to building movement, suitable provision should also be made to prevent passage of water, smoke, or fire.

Drains, fire department connections, and other auxiliary piping connected to risers should not be cemented into walls or floors; similarly, pipes that pass horizontally through walls or foundations should not be cemented solidly or strains will accumulate at such points.

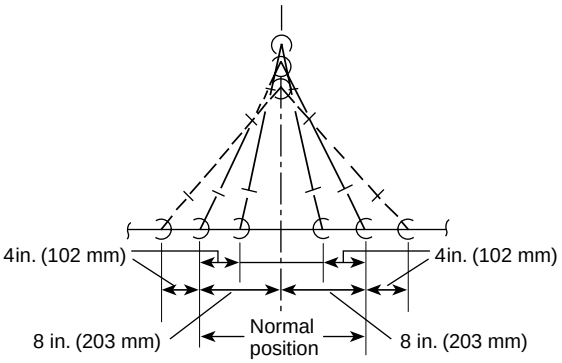
Where risers or lengths of pipe extend through suspended ceilings, they should not be fastened to the ceiling framing members.

A-6-4.5 Figures A-6-4.5(a) and A-6-4.5(b) are examples of forms used to aid in the preparation of bracing calculations.

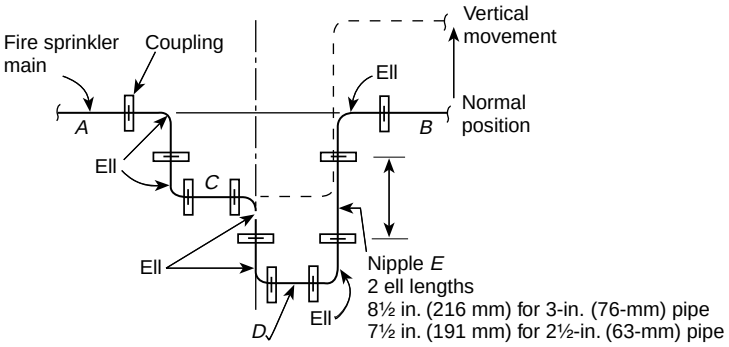
Figure A-6-4.3 Seismic separation assembly. Shown are an 8-in. (203-mm) separation crossed by pipes up to 4 in. (102 mm) in nominal diameter. For other separation distances and pipe sizes, lengths and distances should be modified proportionally.



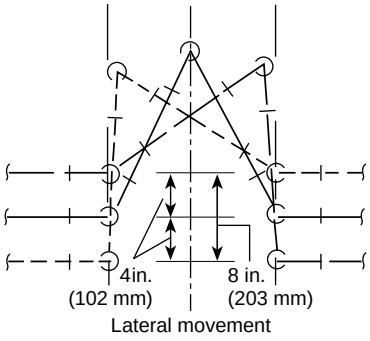
Plan



Longitudinal movement



Elevation



Lateral movement

Horizontal Views

Figure A-6-4.5(a) Seismic bracing calculation form.

Seismic Bracing Calculations

Sheet _____ of _____

Project: _____ Contractor: _____

Address: _____ Address: _____

_____ _____

Telephone: _____

Fax: _____

Brace Information

Length of brace: _____

Diameter of brace: _____

Type of brace: _____

Angle of brace: _____

Least radius of gyration:* _____

L/R value:* _____

Maximum horizontal load: _____

Fastener Information

Orientation of connecting surface: _____

Fastener:

Type: _____

Diameter: _____

Length (in wood): _____

Maximum load: _____

Seismic Brace Attachments

Structure attachment fitting or tension-only bracing system:

Make: _____ Model: _____

Listed load rating: _____ Adjusted load rating per 6-4.5.7: _____

Sway brace (pipe attachment) fitting:

Make: _____ Model: _____

Listed load rating: _____ Adjusted load rating per 6-4.5.7: _____

Seismic Brace Assembly Detail

(Provide detail on plans)

Brace identification no. (to be used on plans) _____

☐ Lateral brace ☐ Longitudinal brace

Sprinkler System Load Calculation

Diameter	Type	Length (ft)	Total (ft)	½ Weight per ft	½ Total Weight
				lb/ft	lb
				lb/ft	lb
				lb/ft	lb
				lb/ft	lb
				lb/ft	lb
				lb/ft	lb
				Total ½ weight of water-filled pipe	lb

* Excludes tension-only bracing systems

Figure A-6-4.5(b) Sample seismic bracing calculation.

Seismic Bracing Calculations

Sheet _____ of _____

Project: Acme Warehouse
Address: 321 First Street
Any City, Any State

Contractor: Smith Sprinkler Company
Address: 123 Main Street
Any City, Any State
Telephone: (555) 555-1234
Fax: (555) 555-4321

Brace Information

Length of brace: 8 ft 8 in.
Diameter of brace: 1 in.
Type of brace: Schedule 40
Angle of brace: 30° to 45°
Least radius of gyration:* 0.42
L/R value:* 200
Maximum horizontal load: 1767 lb

Fastener Information

Orientation of connecting surface: "D"

Fastener:
Type: Through bolt
Diameter: 5/8 in.
Length (in wood): 4 in.
Maximum load: 491 lb

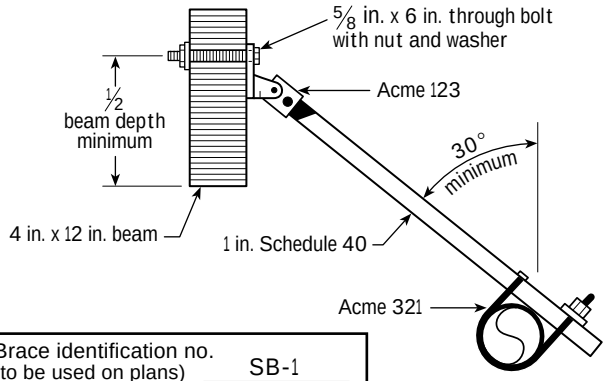
Seismic Brace Attachments

Structure attachment fitting or tension-only bracing system:
Make: Acme Model: 123
Listed load rating: _____ Adjusted load rating per 6-4.5.7: _____

Sway brace (pipe attachment) fitting:
Make: Acme Model: 321
Listed load rating: _____ Adjusted load rating per 6-4.5.7: _____

Seismic Brace Assembly Detail

(Provide detail on plans)



Brace identification no. (to be used on plans): SB-1

☒ Lateral brace ☐ Longitudinal brace

Sprinkler System Load Calculation

Diameter	Type	Length (ft)	Total (ft)	½ Weight per ft	½ Total Weight
1 in.	Sch 40	15 ft + 25 ft + 8 ft + 22 ft	70 ft	1.03 lb/ft	72.1 lb
1¼ in.	Sch 40	25 ft + 33 ft + 18 ft	76 ft	1.47 lb/ft	111.7 lb
1½ in.	Sch 40	8 ft + 8 ft + 10 ft + 10 ft	36 ft	1.81 lb/ft	65.2 lb
2 in.	Sch 40	20 ft	20 ft	2.57 lb/ft	51.4 lb
4 in.	Sch 10	20 ft	20 ft	5.89 lb/ft	117.8 lb
				lb/ft	lb
				Total ½ weight of water-filled pipe	418.2 lb

* Excludes tension-only bracing systems

A-6-4.5.2 Exception. The investigation of tension-only bracing using materials, connection methods, or both, other than those described in Table 6-4.5.8, should involve consideration of the following:

(a) Corrosion resistance.

(b) Prestretching to eliminate permanent construction stretch and to obtain a verifiable modulus of elasticity.

(c) Color coding or other verifiable marking of each different size cable for field verification.

(d) The capacity of all components of the brace assemblies, including the field connections, to maintain the manufacturer's minimum certified break strength.

(e) Manufacturer's published design data sheets/manual showing product design guidelines, including connection details, load calculation procedures for sizing of braces, and the maximum recommended horizontal load-carrying capacity of the brace assemblies including the associated fasteners as described in Table 6-4.5.9. The maximum allowable horizontal loads shall not exceed the manufacturer's minimum certified break strength of the brace assemblies, excluding fasteners, after taking a safety factor of 1.5 and then adjusting for the brace angle.

(f) Brace product shipments accompanied by the manufacturer's certification of the minimum break strength and prestretching and installation instructions.

(g) The manufacturer's literature, including any special tools or precautions required to ensure proper installation.

(h) A means to prevent vertical motion due to seismic forces when required.

Table A-6-4.5.2 identifies some specially listed tension-only bracing systems.

Table A-6-4.5.2 Specially Listed Tension-Only Seismic Bracing

Materials and Dimensions	Standard
Manual for Structural Application of Steel Cables	ASCE 19-96
Wire Rope Users Manual of the Wire Rope Technical Board	ASCE 19-96
Mechanical Strength Requirements	ASTM A 603
Breaking Strength Failure Testing	ASTM E 8

A-6-4.5.5 The four-way brace provided at the riser can also provide longitudinal and lateral bracing for adjacent mains.

A-6-4.5.6 *Location of Sway Bracing.* Two-way braces are either longitudinal or lateral depending on their orientation with the axis of the piping. *[See Figures A-6-4.5.6(a), (b), (c), and (d).]* The simplest form of two-way brace is a piece of steel pipe or angle. Because the brace must act in both compression and tension, it is necessary to size the brace to prevent buckling.

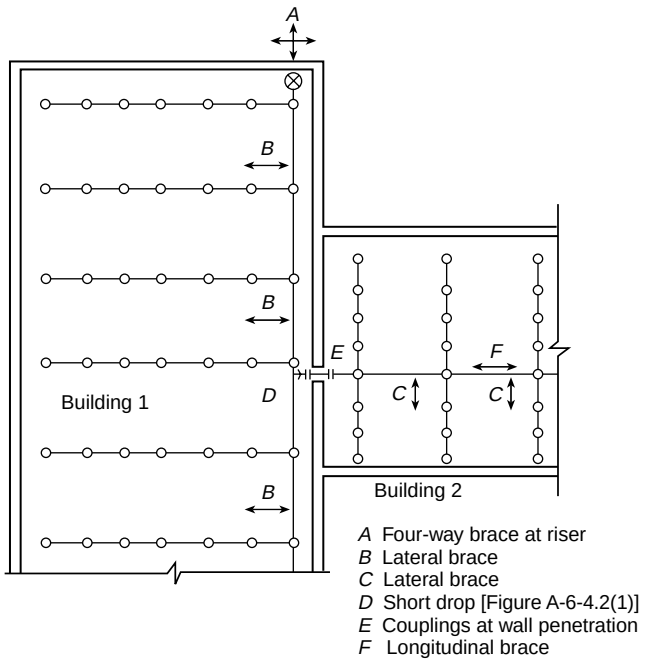
An important aspect of sway bracing is its location. In Building 1 of Figure A-6-4.5.6(a), the relatively heavy main will pull on the branch lines when shaking occurs. If the branch lines are held rigidly to the roof or floor above, the fittings can fracture due to the induced stresses.

Bracing should be on the main as indicated at Location B. With shaking in the direction of the arrows, the light branch lines will be held at the fittings. Where necessary, a lateral brace or other restraint should be installed to prevent a branch line from striking against building components or equipment.

A four-way brace is indicated at Location A. This keeps the riser and main lined up and also prevents the main from shifting.

In Building 1, the branch lines are flexible in a direction parallel to the main, regardless of building movement. The heavy main cannot shift under the roof or floor, and it also steadies the branch lines. While the main is braced, the flexible couplings on the riser allow the sprinkler system to move with the floor or roof above, relative to the floor below.

Figure A-6-4.5.6(a) Earthquake protection for sprinkler piping.



Figures A-6-4.5.6(b), (c), and (d) show typical locations of sway bracing.

Figure A-6-4.5.6(b) Typical location of bracing on a tree system.

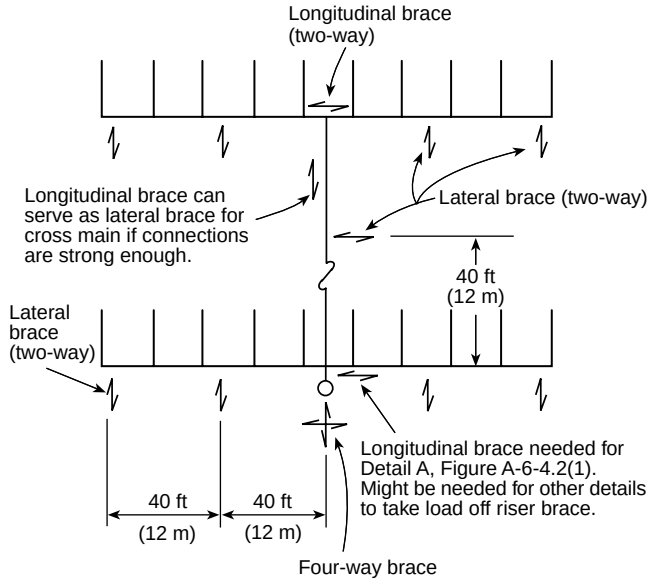


Figure A-6-4.5.6(c) Typical location of bracing on a gridded system.

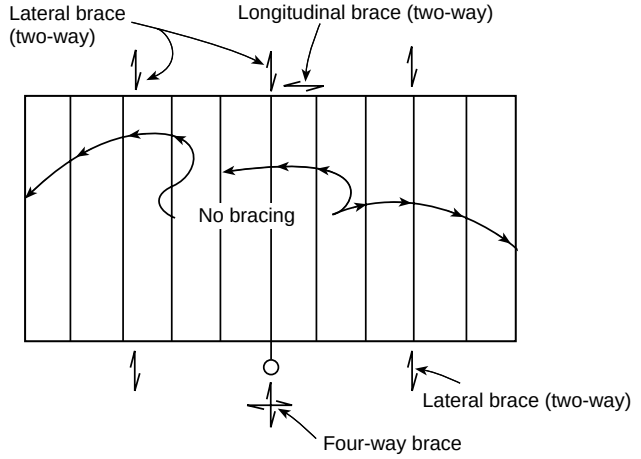
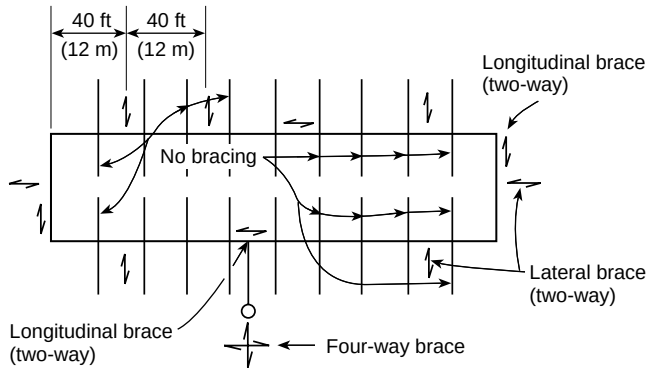


Figure A-6-4.5.6(d) Typical location of bracing on a looped system.



For all threaded connections, sight holes or other means should be provided to permit indication that sufficient thread is engaged.

To properly size and space braces, it is necessary to employ the following steps:

(a) Based on the distance of mains from the structural members that will support the braces, choose brace shapes and sizes from Table 6-4.5.8 such that the maximum slenderness ratios, l/r, do not exceed 300. The angle of the braces from the vertical should be at least 30 degrees and preferably 45 degrees or more.

(b) Tentatively space lateral braces at 40-ft (12-m) maximum distances along mains and tentatively space longitudinal braces at 80-ft (24-m) maximum distances along mains. Lateral braces should meet the piping at right angles, and longitudinal braces should be aligned with the piping.

(c) Determine the total load tentatively applied to each brace in accordance with the examples shown in Figure A-6-4.5.6(e) and the following:

(1) For the loads on lateral braces on cross mains, add one-half the weight of the branch to one-half the weight of the portion of the cross main within the zone of influence of the brace. *[See examples 1, 3, 6, and 7 in Figure A-6-4.5.6(e).]*

(2) For the loads on longitudinal braces on cross mains, consider only one-half the weight of the cross mains and feed mains within the zone of influence. Branch lines need not be included. *[See examples 2, 4, 5, 7, and 8 in Figure A-6-4.5.6(e).]* For the four-way bracing at the top of the riser, half the weight of the riser should be assigned to both of the lateral and longitudinal loads as they are separately considered.

(3) For the four-way brace at the riser, add the longitudinal and lateral loads within the zone of influence of the brace *[see examples 2, 3, and 5 in Figure A-6-4.5.6(e)]*. For the four-way bracing at the top of the riser, half the weight of the riser should be assigned to both the lateral and longitudinal loads as they are separately considered.

(d) If the total expected loads are less than the maximums permitted in Table 6-4.5.8 for the particular brace and orientation, go on to step (e). If not, add additional braces to reduce the zones of influence of overloaded braces.

(e) Check that fasteners connecting the braces to structural supporting members are adequate to support the expected loads on the braces in accordance with Table 6-4.5.8. If not, again add additional braces or additional means of support.

Use the information on weights of water-filled piping contained within Table A-6-4.5.6.

Figure A-6-4.5.6(e) Examples of load distribution to bracing.

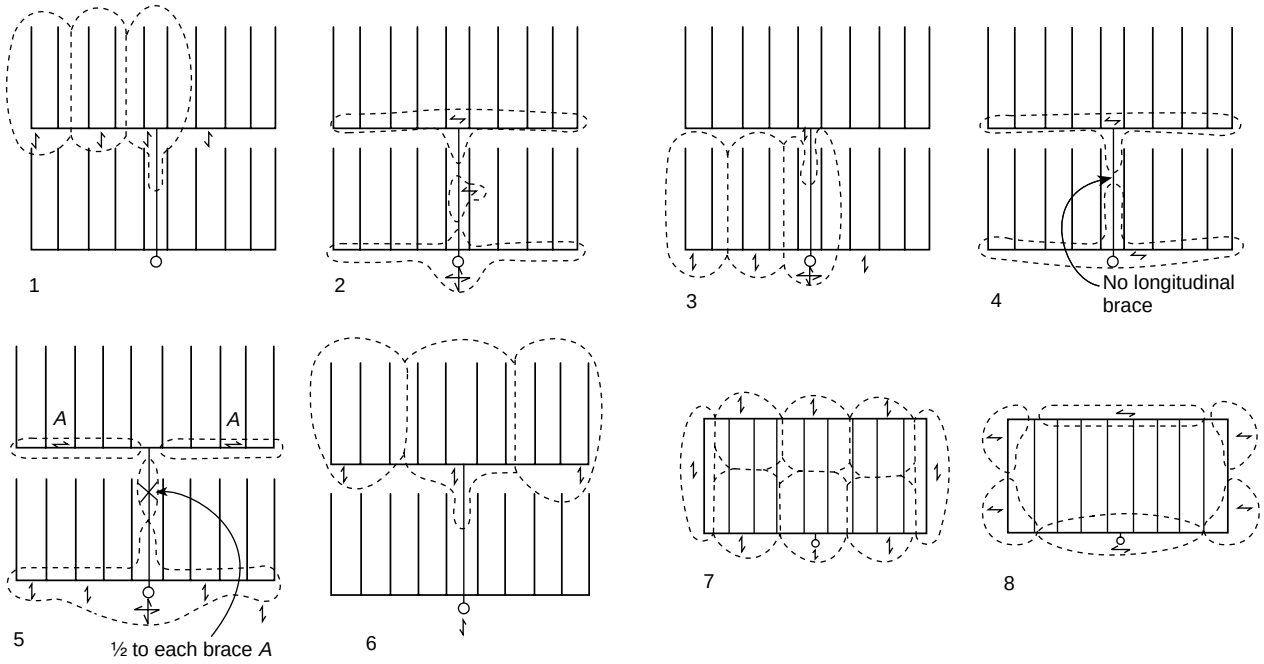


Table A-6-4.5.6 Piping Weights for Determining Horizontal Load

Nominal Dimensions	Weight of Water-Filled Pipe		One-Half Weight of Water-Filled Pipe	
	lb/ft	kg/m	lb/ft	kg/m
Schedule 40 Pipe (in.)				
1	2.05	3.05	1.03	1.5
$1^1/_4$	2.93	4.36	1.47	2.2
$1^1/_2$	3.61	5.37	1.81	2.7
2	5.13	7.63	2.57	3.8
$2^1/_2$	7.89	11.74	3.95	5.9
3	10.82	16.10	5.41	8.1
$3^1/_2$	13.48	20.06	6.74	10.0
4	16.40	24.41	8.20	12.2
5	23.47	34.93	11.74	17.5
6	31.69	47.16	15.85	23.6
8*	47.70	70.99	23.85	35.5

Table A-6-4.5.6 Piping Weights for Determining Horizontal Load *(Continued)*

Nominal Dimensions	Weight of Water-Filled Pipe		One-Half Weight of Water-Filled Pipe	
	lb/ft	kg/m	lb/ft	kg/m
Schedule 10 Pipe (in.)				
1	1.81	2.69	0.91	1.4
$1^1/_4$	2.52	3.75	1.26	1.9
$1^1/_2$	3.04	4.52	1.52	2.3
2	4.22	6.28	2.11	3.1
$2^1/_2$	5.89	8.77	2.95	4.4
3	7.94	11.82	3.97	5.9
$3^1/_2$	9.78	14.55	4.89	7.3
4	11.78	17.53	5.89	8.8
5	17.30	25.75	8.65	12.9
6	23.03	34.27	11.52	17.1
8	40.08	59.65	20.04	29.8

*Schedule 30.

A-6-4.5.8 Sway brace members should be continuous. Where necessary, splices in sway bracing members should be designed and constructed to insure that brace integrity is maintained.

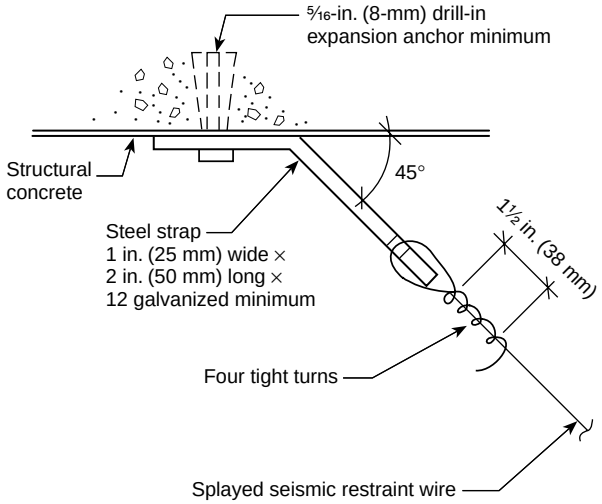
A-6-4.5.9 The criteria in Table 6-4.5.8 are based upon the use of a shield-type expansion anchor. Use of other anchors in concrete should be in accordance with the listing provisions of the anchor.

Current fasteners for anchoring to concrete are referred to as expansion anchors. Expansion anchors come in two types. Deformation-controlled anchors are set by driving a plug into the expansion port in the anchor or driving the anchor over a plug that expands the end of the anchor into the concrete. Torque-controlled expansion anchors are set by applying a torque to the anchor, usually to a nut, which causes the expansion sleeves to be pressed against the wall of the drilled hole.

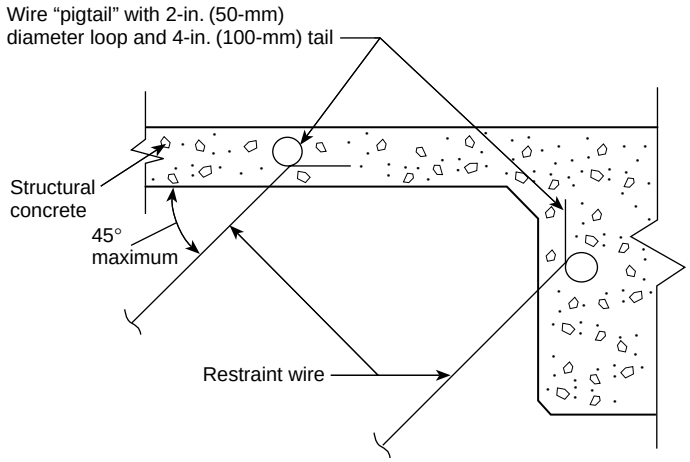
Consideration should be given with respect to the position near the edge of the concrete and to the type of bolts used in conjunction with the anchors.

A-6-4.6.1 Wires used for piping restraints should be attached to the branch line with two tight turns around the pipe and fastened with four tight turns within $1^1/_2$ in. (38 mm), and should be attached to the structure in accordance with the details shown in Figures A-6-4.6.1(a) through (d) or other approved method.

Figure A-6-4.6.1(a) Wire attachment to cast-in-place concrete.

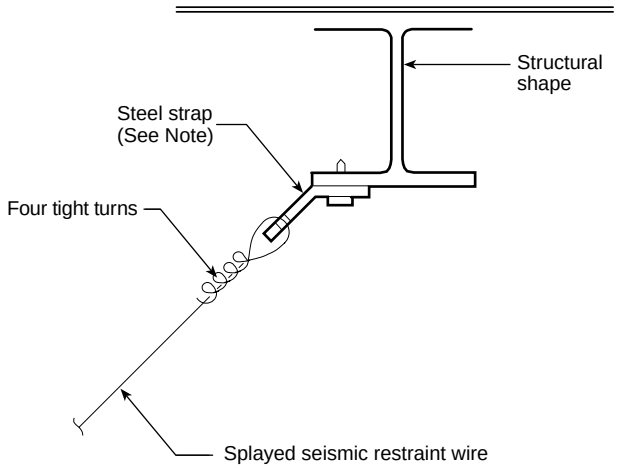


Detail A — Splayed seismic restraint wire attachment



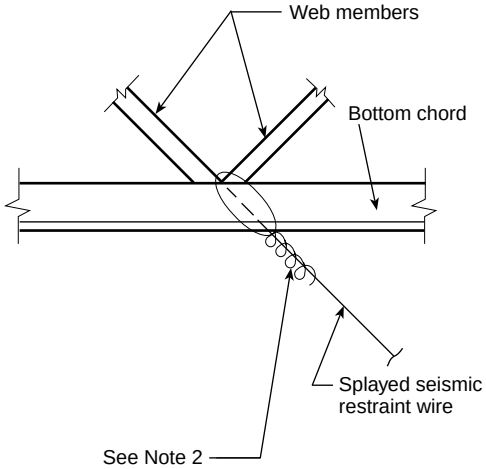
Detail B

Figure A-6-4.6.1(b) Acceptable details — wire connections to steel framing.



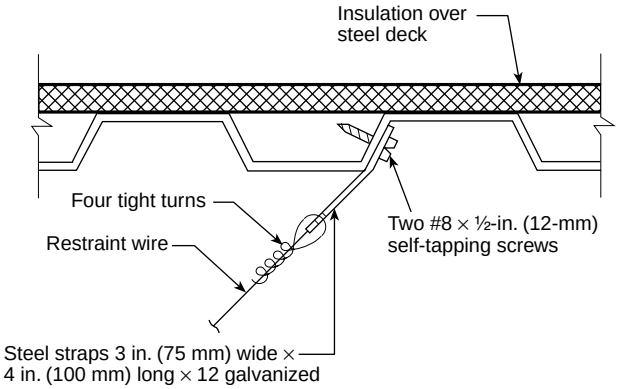
Note: See Figure A-6-4.6.1(a), Detail B.

Detail A — At steel beams



Notes:
1. Splay wires parallel to joist. Splay wires cannot be perpendicular to joist.
2. See Figure A-6-4.6.1(a), Detail A.

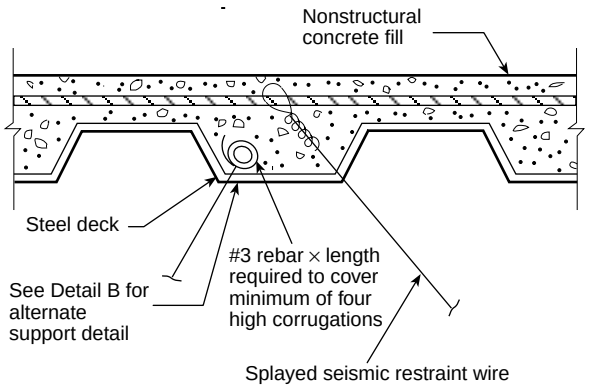
Detail B — At open web steel joist



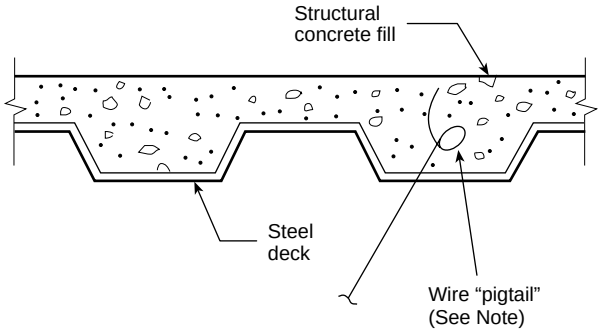
Note: If self-tapping screws are used with concrete fill, set screws before placing concrete.

Detail C — At steel roof deck

Figure A-6-4.6.1(c) Acceptable details — wire connections to steel decking with fill.

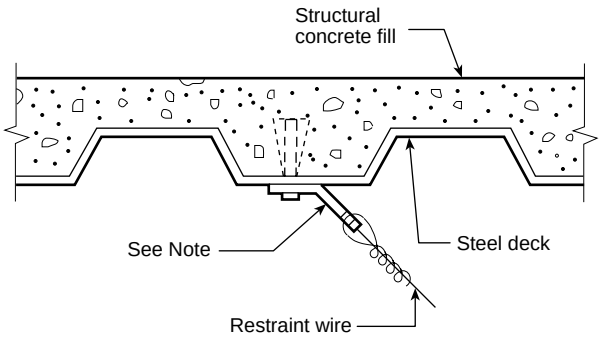


Detail A — At steel deck with insulating fill



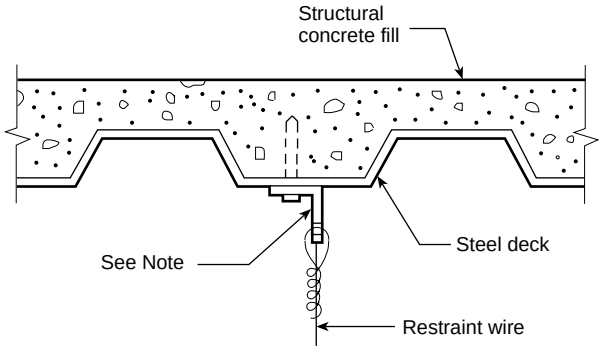
Note: See Figure A-6-4.6.1(a), Detail B.

Detail B — At steel deck with concrete fill



Note: See Figure A-6-4.6.1(a), Detail A.

Detail C — At steel deck with concrete fill

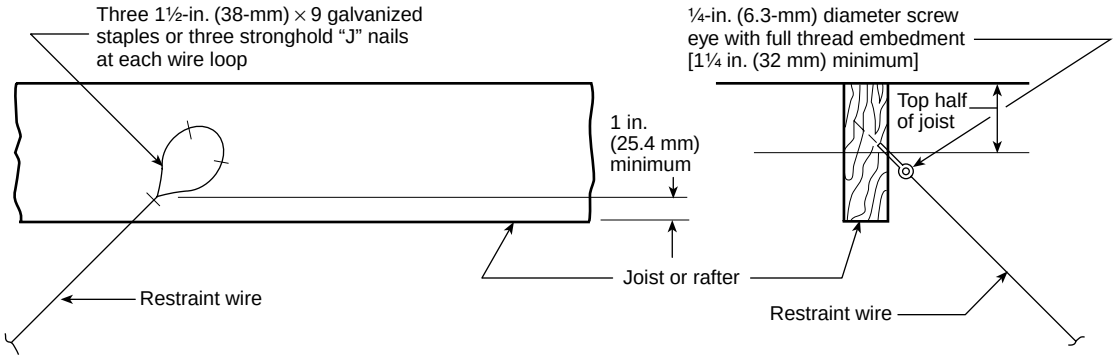


Note: See Figure A-6-4.6.1(a), Detail A.

Detail D — At steel deck with concrete fill

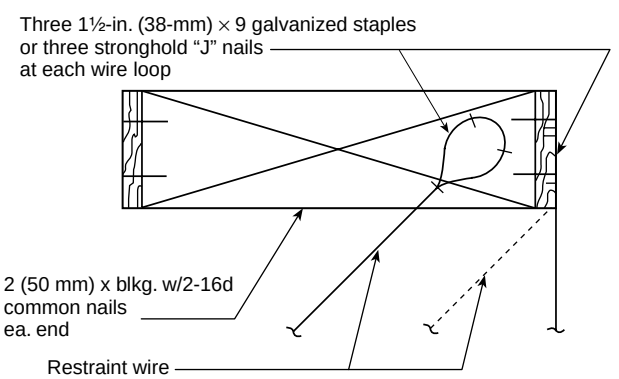
For SI units, 1 in. = 25.4 mm.
Note: If self-tapping screws are used with concrete fill, set screws before placing concrete.

Figure A-6-4.6.1(d) Acceptable details — wire connections to wood framing.

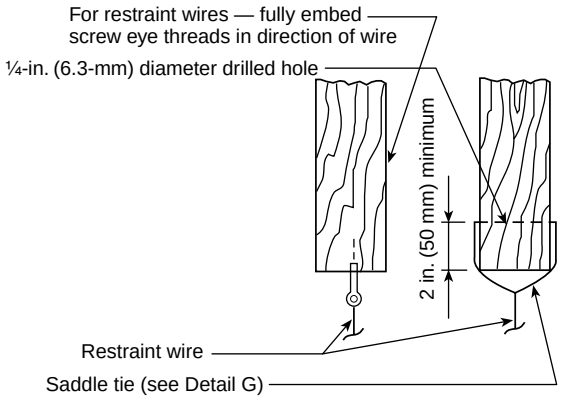


Detail A — Wood joist or rafter

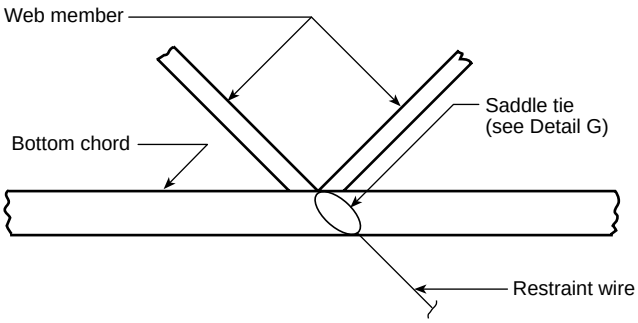
Detail B — At wood joist or rafter



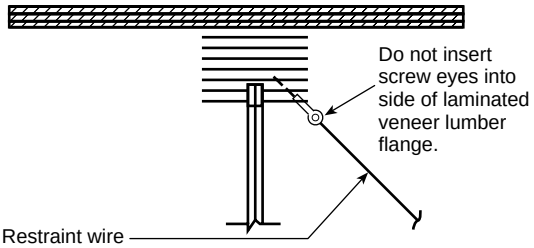
Detail C — At wood joist or block



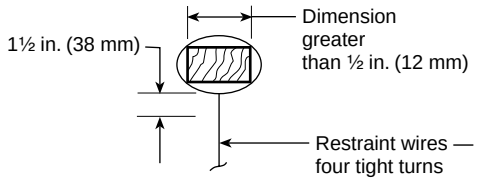
Detail D — To bottom of joist



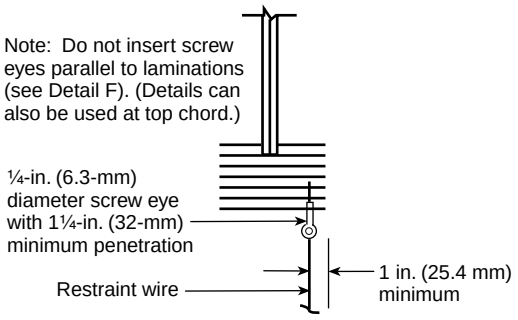
Detail E — Restraint wire parallel to wood truss



Detail F — Laminated veneer lumber upper flange



Detail G — Typical saddle tie



Detail H — Laminated veneer lumber lower flange

A-6-4.6.3 The restraining wire should be provided as close as possible to the hanger.

A-6-4.6.4 Such restraint can be provided by using the restraining wire discussed in 6-4.6.1.

A-7-2.2.3 The additional pressure that is needed at the level of the water supply to account for sprinkler elevation is 0.433 psi/ft (0.098 bar/m) of elevation above the water supply. When backflow prevention valves are installed on pipe schedule systems, the friction losses of the device must be accounted for when determining acceptable residual pressure at the top level of sprinklers. The friction loss [in psi (bar)] should be added to the elevation loss and the residual pressure at the top row of sprinklers to determine the total pressure needed at the water supply.

A-7-2.3.1.1 Appropriate area/density, other design criteria, and water supply requirements should be based on scientifically based engineering analyses that can include submitted fire testing, calculations, or results from appropriate computational models.

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-7-2.3.1.3(b) This section is included to compensate for possible delay in operation of sprinklers from fires in combustible concealed spaces found in wood frame, brick veneer, and ordinary construction.

A-7-2.3.1.3(b) Exception No. 2. Composite wood joists are not considered solid wood joists for the purposes of this section. Their web members are too thin and easily penetrated to adequately compartment a fire in an unsprinklered space.

A-7-2.3.1.3(b) Exception No. 3. This exception is intended to apply only when the exposed materials in the space are limited combustible materials or fire retardant–treated wood as defined in NFPA 703, *Standard for Fire Retardant Impregnated Wood and Fire Retardant Coatings for Building Materials.*

A-7-2.3.2.3 Exception No. 1. It is not the intent of this exception to restrict the use of quick-response sprinklers in extra hazard occupancies but rather to indicate that the areas and densities shown in Figure 7-2.3.1.2 might not be appropriate for use with quick-response sprinklers in those environments due to a concern with water supplies.

A-7-2.3.2.8 *Example 1.* A dry pipe sprinkler system (OH_2) in a building with a ceiling slope exceeding two in 12 in. (16.6 percent slope). The initial area must be increased 30 percent for the dry pipe system and the resulting area an additional 30 percent for the roof slope. If the point 0.2 gpm/ft^2 (8.2 mm/min) over 1500 ft^2 (139 m^2) is chosen from Figure 7-2.3.1.2, the 1500-ft^2 (139-m^2) area is increased 450 ft^2 (42 m^2) to 1950 ft^2 (181 m^2), which is then further increased 585 ft^2 (54 m^2). The final discharge criteria is then 0.2 gpm/ft^2 (8.2 mm/min) over 2535 ft^2 (236 m^2).

Example 2. A wet pipe sprinkler system (light hazard) in a building with a ceiling slope exceeding two in 12 in. (16.6 percent slope) employs quick-response sprinklers qualifying for the 30 percent reduction permitted by 7-2.3.2.4. The initial area must be increased 30 percent for the ceiling slope and the resulting area decreased 30 percent for quick-response sprinklers. It does not matter if the reduction is applied first. If a discharge density of 0.1 gpm/ft^2 (4.1 mm/min) over 1500 ft^2 (139 m^2) is chosen from Figure 7-2.3.1.2, the 1500 ft^2 (139 m^2) is increased 450 ft^2 (42 m^2), resulting in 1950 ft^2 (181 m^2), which is then decreased 585 ft^2 (54 m^2). The final design is 0.1 gpm/ft^2 (4.1 mm/min) over 1365 ft^2 (126.8 m^2).

A-7-2.3.3.1 This subsection allows for calculation of the sprinklers in the largest room, so long as the calculation produces the greatest hydraulic demand among selection of rooms and communicating spaces. For example, in a case where the largest room has four sprinklers and a smaller room has two sprinklers but communicates through unprotected openings with three other rooms, each having two sprinklers, the smaller room and group of communicating spaces should also be calculated.

Corridors are rooms and should be considered as such.

Walls can terminate at a substantial suspended ceiling and need not be extended to a rated floor slab above for this section to be applied.

A-7-3.2.1 The following procedure should be followed in determining the proper density and area as specified in 7-3.2:

(1) Determine the commodity class.
(2) Select the density and area of application from Figure 7-3.2.2.2.1 or Figure 7-3.2.2.2.2.
(3) Adjust the required density for storage height in accordance with Figure 7-3.2.2.2.3.
(4) Increase the operating area by 30 percent in accordance with 7-3.2.2.2.4 where a dry pipe system is used.
(5) Satisfy the minimum densities and areas as indicated in 7-3.1.2.1 and 7-3.1.2.2.

Example:

Storage — greeting cards in boxes in cartons on pallets

Height — 22 ft (6.7 m)

Clearance — 6 ft (1.8 m)

Sprinklers — ordinary temperature

System type — dry

a. Classification — Class III
b. Selection of density/area — 0.225 gpm/ft^2 (9.2 mm/min) over 3000 ft^2 (279 m^2) from Figure 7-3.2.2.2.1.
c. Adjustment for height of storage using Figure 7-3.2.2.2.3 — 1.15 × 0.225 gpm/ft^3 = 0.259 gpm/ft^2 (10.553 mm/min), rounded up to 0.26 gpm/ft^2 (10.6 mm/min)
d. Adjustment of area of operation for dry system — 1.3 × 3000 ft^2 = 3900 ft^2 (363 m^2)
e. Confirmation that minimum densities and areas have been achieved

In 7-3.1.2.1, the minimum design density for a dry sprinkler system is 0.15 gpm/ft^2 over 2600 ft^2 (6.1 mm/min over 242 m^2) [satisfied in A-7-3.2.1(5)b] for Class III.

Paragraph 7-3.1.2.2 refers to ordinary hazard, Group 2. The corresponding minimum density at 3000 ft^2 (279 m^2) is 0.17 gpm/ft^2 (6.9 mm/min) (satisfied); 1.3 × 3000 ft^2 = 3900 ft^2 (363 m^2), 0.17 gpm/ft^2 (6.9 mm/min) over 3900 ft^2 (363 m^2).

The design density and area of application equals 0.26 gpm/ft^2 over 3900 ft^2 (10.6 mm/min over 363 m^2).

A-7-3.2.1.1(3) Full-scale tests show no appreciable difference in the number of sprinklers 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 (6.1 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-7-3.3.1 The densities and area of application have been developed from fire test data. Most of these tests were conducted with K-8 orifice 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 0.4 gpm/ft^2 (16.3 mm/min) and higher, better results are obtained with K-8 orifice and 70-ft^2 to 100-ft^2 (7.4-m^2 to 9.3-m^2) sprinkler spacing than where using K-5.6 orifice sprinklers at 50-ft^2 (4.6-m^2) spacing. A discharge pressure of 100 psi (6.9 bar) 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 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.

Table A-7-3.3.1 explains and provides an example of the method and procedure to follow in using this standard to determine proper protection for Group A plastics.

Table A-7-3.3.1 Metric Conversion Factors for Examples

To Convert from	to	Multiply by
feet (ft)	meters (m)	0.3048
square feet (ft^2)	square meters (m^2)	0.0920
gallons/minute (gpm)	liters/second (L/sec)	0.0631
gallons per minute per square foot (gpm/ft^2)	millimeters per minute (same as liters per minute per square meter) (mm/min)	40.746

Example 1. Storage is expanded, cartoned, stable, 15 ft (4.6 m) high in a 20-ft (6.1-m) building.

Answer 1. Column E — design density is 0.45 gpm/ft^2 (18.3 mm/min).

Example 2. Storage is nonexpanded, unstable, 15 ft (4.6 m) high in a 20-ft (6.1-m) building.

Answer 2. Column A — design density is listed as 0.25 gpm/ft^2 (10.2 mm/min), however, it is also possible that the storage can be 12 ft (3.66 m) in this 20-ft (6.1-m) building, which would require a design density of 0.3 (12.2 mm/min). Unless the owner can guarantee that the storage will always be 15 ft (4.6 m), the design density = 0.3 gpm/ft^2 (12.2 mm/min).

Example 3. Storage is a nonexpanded, stable 15-ft (4.6-m) fixed-height unit load, one high, in an 18-ft (5.5-m) building.

Answer 3. Column A — design density is 0.25 gpm/ft^2 (10.2 mm/min). Note that this design density does not increase to 0.3 gpm/ft^2 (12.2 mm/min) as in the previous example because of the use of a fixed-height unit load. The storage height will never be 12 ft (3.66 m). It will always be 15 ft (4.6 m).

Example 4. Storage is expanded, exposed, unstable, 20 ft (6.1 m) high in a 27-ft (8.2-m) building.

Answer 4. Column C — design density is 0.7 gpm/ft^2 (28.5 mm/min). Note that other lower storage heights should also be checked, but they reveal the same, or lower, densities (0.7 gpm/ft^2 and 0.6 gpm/ft^2) (28.5 mm/min and 24.5 mm/min), so the design density remains at 0.7 gpm/ft^2 (28.5 mm/min).

Example 5. Storage is expanded, cartoned, unstable, 17 ft (5.2 m) high in 32-ft (9.75-m) building.

Answer 5. Column D — 15-ft (4.6 m) storage in a 32-ft (9.75-m) building would be 0.55 gpm/ft^2 (22.4 mm/min); 20-ft (6.1-m) storage in a 32-ft (9.75-m) building would be 0.7 gpm/ft^2 (28.5 mm/min). Interpolation for 17-ft (5.2-m) storage is as follows:

$$0.7 - 0.55 = 0.15$$

$$\frac{0.15}{(20 - 15)} = 0.03$$

$$0.03 \times (17 - 15) = 0.06$$
$$0.55 + 0.06 = 0.61$$

Design density = 0.61 gpm/ft^2 (24.9 mm/min)

Example 6. Storage is expanded, exposed, stable, 22 ft (6.71 m) high in a $23^1/_2$-ft (7.16-m) building.

Answer 6. Column B — could interpolate between 0.6 gpm/ft^2 and 0.75 gpm/ft^2 (24.5 mm/min and 30.6 mm/min); however, this would be a moot point since the density for 15-ft (4.6-m) storage in this $23^1/_2$-ft (7.16-m) building would be 0.8 gpm/ft^2 (32.6 mm/min). Unless the owner can guarantee 22-ft (6.71-m) storage, the design density is 0.8 gpm/ft^2 (32.6 mm/min). If the owner can, in a manner acceptable to the authority having jurisdiction, guarantee 22-ft (6.71-m) storage, the interpolation would yield a design density of 0.66 gpm/ft^2 (26.9 mm/min).

Example 7. Storage is nonexpanded, stable, exposed, $13^1/_2$ ft (4.1 m) high in a 15-ft (4.6-m) building.

Answer 7. Column E — 12-ft (3.66-m) storage in a 15-ft (4.6-m) building would be extra hazard, Group 2 (0.4 gpm/ft^2 over 2500 ft^2) (16.3 mm/min over 230 m^2).

Storage 15 ft (4.6 m) high in a 15-ft (4.6-m) building would be 0.45 gpm/ft^2 (18.3 mm/min). Interpolation for $13^1/_2$-ft (4.1-m) storage is as follows:

$$0.45 - 0.4 = 0.05$$

$$\frac{0.05}{(15 - 12)} = 0.017$$

$$0.017 \times (13.5 - 12) = 0.026$$
$$0.4 + 0.026 = 0.426$$

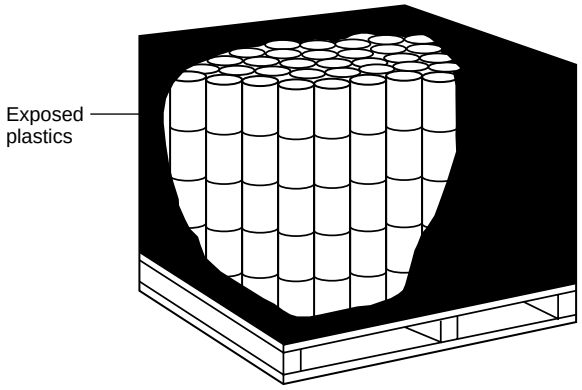
Design density = 0.426 gpm/ft^2 (17.4 mm/min)

A-7-3.3.1.1 Two direct comparisons between ordinary temperature– and high temperature–rated sprinklers are possible, as follows:

(1) 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 (nine at high temperature versus seven at ordinary temperature).
(2) 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 high temperature versus 33 at ordinary temperature).

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-7-3.3.1.1(a).]*

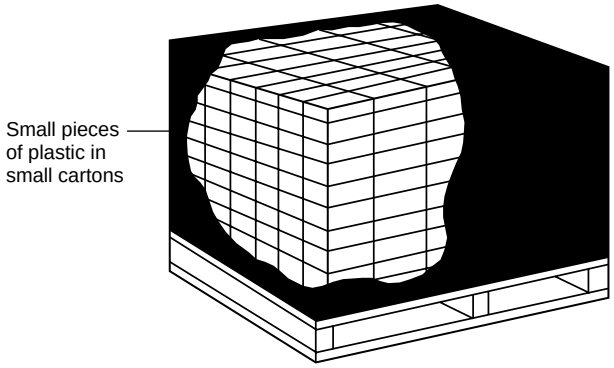
Figure A-7-3.3.1.1(a) Corrugated carton containing individually separated plastic jars.



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-7-3.3.1.1(b).]*

Figure A-7-3.3.1.1(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-7-3.3.1.2 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-7-3.3.2.1 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 (3.1 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 Section 7-3 still apply. The worst applicable height-clearance relationship that can be expected to occur should be found, and protection should be 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-7-3.3.2.2 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 (6.1 m). The protection criteria in this standard for expanded plastics higher than 20 ft (6.1 m) are extrapolated from test data for expanded plastics storage 20 ft (6.1 m) and less in height and test data for unexpanded plastics above 20 ft (6.1 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 (3.1 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 (9.1-m) building [10-ft (3.1-m) clearance] would also protect 15-ft (4.6-m) storage in a 30-ft (9.1-m) building [15-ft (4.6-m) clearance]. Therefore, the protection criteria in Table 7-3.3.2.2 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 (3.1-m) clearance.

Table 7-3.3.2.2 is based on tests that were conducted primarily with high temperature–rated, K-8 orifice sprinklers. Other tests have demonstrated that, where sprinklers are used with orifices greater than K-8, ordinary-temperature sprinklers are acceptable.

A-7-3.3.2.3 Wet systems are recommended for storage occupancies. Dry pipe systems should be permitted only where it is impractical to provide heat.

A-7-4.1.3 The fire protection system design should consider the maximum storage height. For new sprinkler installations, maximum storage height is the usable height at which commodities can be stored above the floor while the minimum required unobstructed space below sprinklers is maintained. Where evaluating existing situations, maximum storage height is the maximum existing storage height if space

between the sprinklers and storage is equal to or greater than that required.

A-7-4.1.3 Exception. Information for the protection of Classes I, II, III, and IV commodities was extrapolated from full-scale fire tests that were performed at different times than the tests that were used to develop the protection for plastic commodities. It is possible that, by selecting certain points from the curves shown in Figures 7-4.2.2.1.1(a) through (g) (and after applying the appropriate modifications), the protection specified by 7-4.2 exceeds the requirements of 7-4.4. In such situations, the protection specified for plastics, although less than that required by the curves shown in Figures 7-4.2.2.1.1(a) through (g), can adequately protect Classes I, II, III, and IV commodities.

This section also allows storage areas that are designed to protect plastics to store Classes I, II, III, and IV commodities without a reevaluation of fire protection systems.

A-7-4.1.5.1 Wet systems are recommended for rack storage occupancies. Dry systems are 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-7-4.1.5.5 Where high temperature–rated sprinklers are installed at the ceiling, high temperature–rated sprinklers also should extend beyond storage in accordance with Table A-7-4.1.5.5.

Table A-7-4.1.5.5 Extension of Installation of High-Temperature Sprinklers over Storage

Design Area for High Temperature–Rated Sprinklers		Distance Beyond Perimeter of High-Hazard Occupancy for High Temperature–Rated 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-7-4.1.7.1 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 7-4.1.4 and illustrated in Figure 7-4.1.4.1.

A-7-4.1.11 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 Classes 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 7-4.3.1.5.1 and Figures 7-4.3.1.5.1(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 7-4.3.1.5.1(a) and (b), provided one line of in-rack sprinklers is installed above the top tier of storage.

A-7-4.1.12.1 Detection systems, concentrate pumps, generators, and other system components that are essential to the operation of the system should have an approved standby power source.

A-7-4.1.12.4.1.1 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 the removal of the foam after discharge.

A-7-4.2.1.1.1 Where possible, it is recommended that in-rack sprinkler deflectors be located at least 6 in. (152.4 mm) above pallet loads.

A-7-4.2.1.1.2 Where possible, it is recommended that in-rack sprinklers be located away from rack uprights.

A-7-4.2.1.2.1 Spacing of sprinklers on branch lines in racks in the various tests demonstrates that maximum spacing as specified is proper.

A-7-4.2.1.6.3 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.

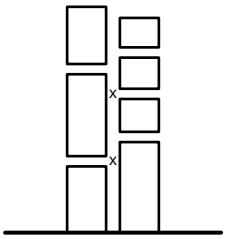
A-7-4.2.2.1.1 Bulkheads are not a substitute for sprinklers in racks. Their installation does not justify reduction in sprinkler densities or design operating areas as specified in the design curves.

A-7-4.2.2.2 Data indicates that the sprinkler protection criteria in Table 7-4.2.1.5 is ineffective, by itself, for rack storage with solid shelves, if the required flue spaces are not maintained. Use of Table 7-4.2.1.5 and the figures it references, along with the additional provisions that are required by this standard, can provide acceptable protection.

A-7-4.2.2.2.2 The aisle width and the depth of racks are determined by material-handling methods. The widths of aisles should be considered in the design of the protection system. Storage in aisles can render protection ineffective and should be discouraged.

A-7-4.3.1.5.1 Where storage tiers are not the same size on each side of the longitudinal flue, one side of the flue should be protected with sprinklers at the proper elevation above the load. The next level of sprinklers should protect the other side of the flue with the sprinklers at the proper elevation above that load as indicated in Figure A-7-4.3.1.5.1. The vertical spacing requirements for in-rack sprinklers specified in Tables 7-4-3.1.5.1 and 7-4.3.1.5.4 and 7-4.4 for plastics should be followed.

Figure A-7-4.3.1.5.1 Placement of in-rack sprinkler where rack levels have varying heights.



A-7-4.3.1.5.3 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-7-4.3.1.5.4 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 7-4.3.1.5.4(a) through (c).

Data indicate that the sprinkler protection criteria in 7-4.3.1.5.4 is ineffective, by itself, for rack storage with solid shelves, if the required flue spaces are not maintained. Use of Table 7-4.3.1.5.4, along with the additional provisions that are required by this standard, can provide acceptable protection.

A-7-4.3.2.1 Water demand for storage height over 25 ft (7.6 m) on racks without solid shelves separated by aisles at least 4 ft (1.2 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 (186-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 mm/min) for Class I commodities, 0.21 gpm/ft^2 (8.56 mm/min) for Classes II and III commodities, and 0.25 gpm/ft^2 (10.2 mm/min) for Class IV commodities for ordinary temperature–rated sprinklers or a minimum of 0.25 gpm/ft^2 (10.2 mm/min) for Class I commodities, 0.28 gpm/ft^2 (11.41 mm/min) for Classes II and III commodities, and 0.32 gpm/ft^2 (13.04 mm/min) for Class IV commodities for high temperature–rated sprinklers. (*See A-7-4.1.11 and A-7-4.3.1.5.4.*)

Where such storage is encapsulated, ceiling sprinkler density should be 25 percent greater than for nonencapsulated storage.

Data indicate that the sprinkler protection criteria in 7-4.3.2.1 is ineffective, by itself, for rack storage with solid shelves, if the required flue spaces are not maintained. Use of 7-4.3.2.1, along with the additional provisions that are required by this standard, can provide acceptable protection.

A-7-4.4.1 All rack fire tests of plastics were run with an approximate 10-ft (3.1-m) maximum clearance between the top of the 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-7-4.4.2.4.4 Figure (a). The protection area per sprinkler under barriers should be no greater than 80 ft^2 (7.44 m^2).

A-7-4.4.2.4.4 Figure (b). The protection area per sprinkler under barriers should be no greater than 80 ft^2 (7.44 m^2).

A-7-4.4.2.4.4 Figure (c). The protection area per sprinkler under barriers should be no greater than 50 ft^2 (4.65 m^2).

A-7-4.4.2.4.4 Figure (d). The protection area per sprinkler under barriers should be no greater than 50 ft^2 (4.65 m^2).

A-7-4.4.2.4.4 Figure (e). The protection area per sprinkler under barriers should be no greater than 50 ft^2 (4.65 m^2).

A-7-4.4.2.4.4 Figure (f). The protection area per sprinkler under barriers should be no greater than 50 ft^2 (4.65 m^2).

A-7-5 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 fire in stacks of idle plastic or 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-7-5.2.1 See Table A-7-5.2.1.

A-7-5.2.2 No additional protection is necessary, provided the requirements of 7-5.2.2(a) and (b) are met.

A-7-6.2.1 The protection criteria in Tables 7-6.2.1(a), (b), and (c) 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 fire testing with densities of 0.45 gpm/ft^2 (18.3 mm/min) 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.

Tables 7-6.2.1(a) and (b) are 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 Tables 7-6.2.1(a), (b), and (c) represent test results from rubber tire fire tests performed at the Factory Mutual Research Center.

Storage heights and configurations, or both, [e.g., automated material-handling systems above 30 ft (9.1 m)] 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.

Table A-7-5.2.1 Recommended Clearance Between Outside Idle Pallet Storage and Building

Wall Construction		Minimum Distance of Wall from Storage of					
		Under 50 Pallets		50 to 200 Pallets		Over 200 Pallets	
Wall Type	Openings	ft	m	ft	m	ft	m
Masonry	None	0	0	0	0	0	0
	Wired glass with outside sprinklers and 1-hour doors	0	0	10	3.1	20	6.1
	Wired or plain glass with outside sprinklers and $^3/_4$-hour doors	10	3.1	20	6.1	30	9.1
Wood or metal with outside sprinklers		10	3.1	20	6.1	30	9.1
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 eaves lines, vent openings, and so forth.
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-7-6.2.1 Table (a), Note 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-7-6.4.3 Wet systems are recommended for tire storage occupancies. Dry systems are permitted only where it is impracticable to provide heat.

A-7-7.2.3 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.

A-7-8 This section 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 in 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 has 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 A-7-8 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:

(1) Firespread to the north end of the storage array
(2) Gas temperatures near the ceiling maintained at high levels for a time judged to be sufficient to endanger exposed structural steel
(3) Fire reaching the target stacks

Table A-7-8 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 the 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 (1 bar, 4.1 bar, and 6.6 bar), 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 (3.5 bar). Two tests were conducted following a scheduled decay from an initial pressure of 138 psi (9.5 bar) to a design point of 59 psi (4.1 bar) 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 (6.6-bar) 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 mm/min) were controlled with an average of 17 sprinklers. The maximum number of wet pipe sprinklers that opened was 45 and the minimum number was

five, versus 88 and 26, respectively, in the constant pressure tests. Seventeen sprinklers 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 0.3-gpm/ft^2 (12.2-mm/min) 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.

A-7-8.2 *Existing Systems.* Sprinkler systems protecting existing roll paper storage facilities should be evaluated in accordance with Tables A-7-8.2(a) and (b). While fire can be controlled by the protection shown in Tables A-7-8.2(a) and (b), greater damage can occur when the densities in Tables A-7-8.2(a) and (b) are used rather than those specified in Tables 7-8.2.2.3(a) and (b).

Figure A-7-8 Plan view of typical tissue storage array.

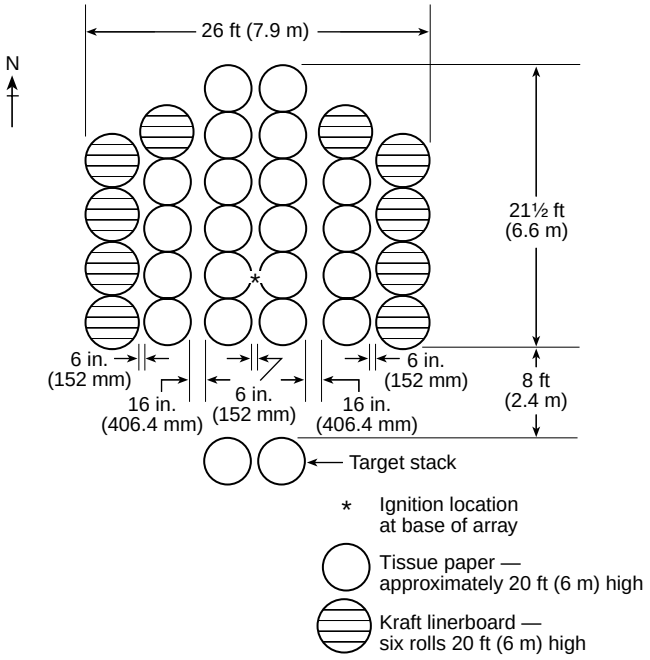


Table A-7-8 Summary of Roll Paper Tissue Tests

Test Specifications	Test Number					
	B1[a]	B2	B3	B4	B5[b]	B6[b]
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	Standard	Standard	Standard	Standard	Standard	Standard
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 (bar)]	14 (0.9)[c]	60 (4.1)	95 (6.6)	50 (3.4)	138 (9.5) initial 102 (7.0) final	138 (9.5) initial 88 (6.1) 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

(continues)

Table A-7-8 Summary of Roll Paper Tissue Tests *(Continued)*

Test Specifications	Test Number					
	B1[a]	B2	B3	B4	B5[b]	B6[b]
Final flow [gpm (L/min)]	2575 (9746)[c]	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)
Average discharge density [gpm/ft² (mm/min)]	0.29 (11.8)[c]	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
Maximum 1-minute average gas temperature over ignition [°F (°C)]	1680 (916)[c]	1463 (795)	1634 (890)	1519 (826)	[d]	[e]
Duration of high temperature within acceptable limits	No	Yes	Yes	Marginal	Yes	Yes
Maximum 1-minute average 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

[a]Phase I test.
[b]Phase III tests decaying pressure.
[c]Pressure increased to 50 psi (3.5 bar) at 10 minutes.
[d]Maximum steel temperature over ignition 341°F (172°C).
[e]Maximum steel temperature over ignition 132°F (56°C).

Table A-7-8.2(a) Automatic Sprinkler System Design Criteria — Spray Sprinklers for Existing Storage Facilities (Discharge densities are gpm/ft² over 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-7-8.2(b) Automatic Sprinkler System Design Criteria — Spray Sprinklers for Existing Storage Facilities (Discharge densities are mm/min over 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

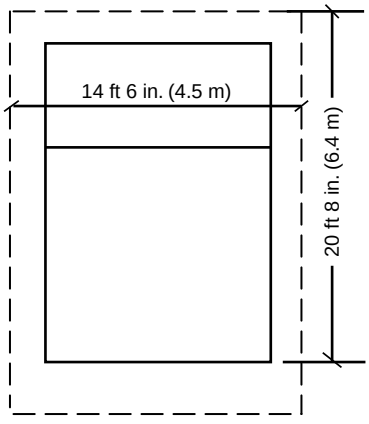
Note: Densities or areas, or both, can be interpolated between any 1.5-m storage height increment.

A-7-8.2.2.4 In a dry pipe system, the area increase of 30 percent should be compounded [e.g., 2000 ft² (186 m²) (1.67 for low-temperature sprinklers and 1.3 for dry pipe systems) = 4343 ft² (403.5 m²) total area]. Where dry pipe systems are used in existing installations, the areas of operation indicated by Tables 7-8.2.2.3(a) and (b) should be increased by 30 percent.

A-7-8.2.2.5 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.

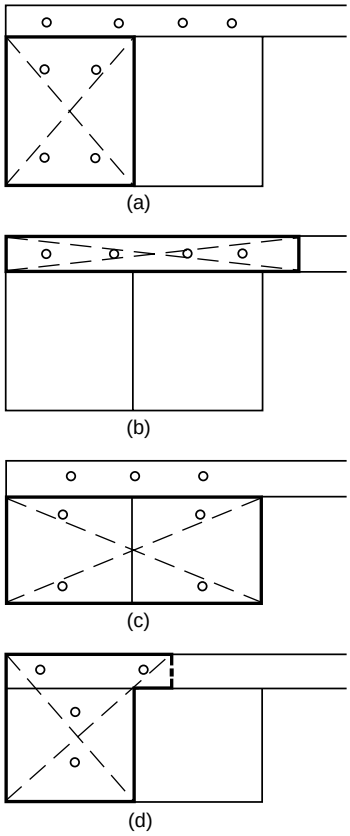
A-7-9.2.1 The protection area for residential sprinklers with extended coverage areas is defined in the listing of the sprinkler as a maximum square or rectangular area. Listing information is presented in even 2-ft (0.61-m) increments from 12 ft to 20 ft (3.6 m to 6.1 m) for residential sprinklers. When a sprinkler is selected for an application, its area of coverage must be equal to or greater than both the length and width of the hazard area. For example, if the hazard to be protected is a room 14 ft 6 in. (4.3 m) wide and 20 ft 8 in. (6.2 m) long, a sprinkler that is listed to protect an area of 16 ft × 22 ft (4.9 m × 6.8 m) must be selected. The flow used in the calculations is then selected as the flow required by the listing for the selected coverage. *(See Figure A-7-9.2.1.)*

Figure A-7-9.2.1 Determination of protection area of coverage for residential sprinklers.



A-7-9.2.2 In Figure A-7-9.2.2, calculate the area indicated by the heavy outline and X. The circle indicates sprinklers.

Figure A-7-9.2.2 Examples of design area for dwelling units.



A-7-9.5 ESFR sprinklers are 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 on to provide suppression if they are used outside the design parameters.

While these sprinklers are intended primarily for use in high-pile storage situations, this section permits their use and extension into adjacent portions of an occupancy that might have a lesser classification.

A-7-9.5.1.1 Storage in single-story or multistory buildings can be permitted, provided the maximum ceiling/roof height as specified in Table 7-9.5.1.1 is satisfied for each storage area.

A-7-9.5.2 Design parameters were determined from a series of full-scale fire tests that were 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-7-9.6.1 If the system is a deluge type, then all the sprinklers need to be calculated even if they are located on different building faces.

A-7-10.3.2 Spray application operations should only be located in buildings that are completely protected by an approved system of automatic sprinklers. If located in unsprinklered buildings, sprinklers should be installed to protect spray application processes where practical. Because of the rapidity and intensity of fires that involve spray operations, the available water should be ample to simultaneously supply all sprinklers likely to open in one fire without depleting the available water for use by hose streams. Noncombustible draft curtains can be used to limit the number of sprinklers that will open.

Even when areas adjacent to coating operations are considered under reasonably positive fire control by adequate automatic sprinkler protection, damage is possible if operations are conducted on floors above those containing contents that are highly susceptible to water damage. Waterproofing and drainage of spray room floors can assist in reducing water damage on floors below. The proper drainage of the large volume of water frequently necessary to extinguish spray finishing room fires often presents considerable difficulty. (**33:** A-7-2)

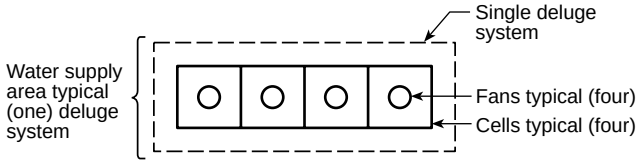
A-7-10.4.2 Water spray systems that are used to protect solvent extraction process equipment or structures should be designed to provide a density of not less than 0.25 gpm per ft^2 (10.2 mm/min) of protected surface area. Deluge systems that are used for the same purposes should be designed to provide a density of not less than 0.16 gpm per ft^2 (6.5 mm/min) of protected surface area. Preparation buildings should be protected with automatic sprinkler systems designed for ordinary hazard, Group 2. (**36:** A-2-9)

A-7-10.14.4 Experience has shown that when water is discharged through conventional sprinklers into a hyperbaric atmosphere, the spray angle is reduced because of increased resistance to water droplet movement in the denser atmosphere. This is so even though the water pressure differential is maintained above chamber pressure. Therefore, it is necessary to compensate by increasing the number of sprinklers. It is recommended that spray coverage tests be conducted at maximum chamber pressure.

Some chamber configurations, such as small-diameter horizontal cylinders, might have a very tiny "floor," or even no floor at all. For horizontal cylinder chambers and spherical chambers, "floor level" shall be taken to mean the level at $^1/_4$ diameter below the chamber centerline or actual "floor level," whichever gives the larger floor area. (**99:** 19-2.5.2.3, Note 1)

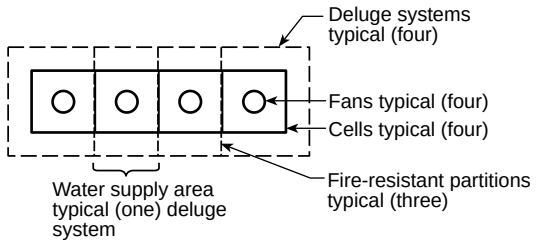
A-7-10.17.8.1.1 Where a single deluge system protects an entire water-cooling tower, regardless of the number of cells, the water supply needs to be based on the entire deluge system coverage. Refer to Figure A-7-10.17.8.1.1. (**214:** A-3-6.1.1)

Figure A-7-10.17.8.1.1 Single deluge system. (214: Figure A-3-6.1.1)



A-7-10.17.8.1.3 Deluge systems separated by fire-resistant partitions can be treated independently as worst-case water supply situations. Refer to Figure A-7-10.17.8.1.3. (**214:** A-3-6.1.3)

Figure A-7-10.17.8.1.3 Multiple deluge systems. (214: Figure A-3-6.1.3)



A-7-10.17.8.2 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-7-10.17.8.2. (**214:** A-3-6.2.1)

A-7-10.17.8.2.2 Without fire-resistant partitions between cells, the worst-case situation involves the most demanding adjoining cells. Refer to Figure A-7-10.17.8.2.2. (**214:** A-3-6.2.2)

Figure A-7-10.17.8.2 Multiple wet, dry, or preaction systems with fire-resistant partitions. (214: Figure A-3-6.2.1)

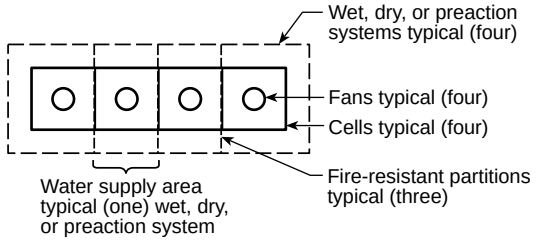
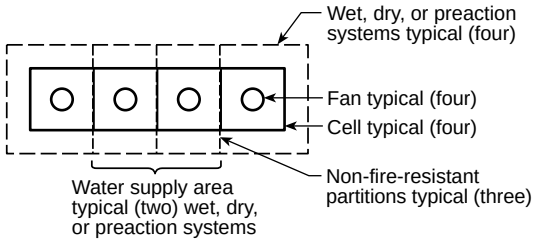


Figure A-7-10.17.8.2.2 Multiple wet, dry, or preaction systems with no fire-resistant partitions. (214: Figure A-3-6.2.2)



A-7-10.18.2 The use of firestops for draft control to bank heat, facilitate the opening of sprinklers, and prevent the overtaxing of the sprinkler system is particularly important in the design of sprinkler protection for combustible substructures. The fire walls and firestops of 3-3.3.6 of NFPA 307, *Standard for the Construction and Fire Protection of Marine Terminals, Piers, and Wharves*, 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 firestops will normally be needed. These additional or supplemental firestops need only have limited fire resistance but should be as deep as possible and be of substantial construction, such as double 3-in. (76.2-mm) planking where exposed to the elements. Where not exposed to physical damage, $^{3}/_{4}$-in. (19.05-mm) treated plywood extending 48 in. (1219.2 mm) below stringers with solid blocking between stringers should provide adequate durability and reasonable effectiveness. [**307:** A-3-3.3.3(a)(5)]

A-7-10.19.2 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. (**318:** A-2-1.2.1)

A-7-10.19.4 Small-orifice sprinklers, $^{3}/_{8}$ in. (9.5 mm) or larger, can be used. (**318:** A-2-1.2.1.6.1)

A-7-10.21.2.2 The exposure to the airport terminal building from the airport ramp is significant. The number of building sprinklers operating from the exposure fire can be greater than from an internal ignition source. (**415:** A-2-5.1.2)

A-7-10.22.2 Because of the nature of the test cell fire potential, deluge systems are considered more appropriate than automatic sprinklers due to their speed of operation and simultaneous discharge of all nozzles; however, automatic sprinklers can be used under the following conditions.

(1) In small cells [600 ft^2 (56 m^2) or less] where it is likely that all sprinklers would fuse at the same time
(2) As a backup to a manual water spray or other manual system (**423:** A-5-6.3)

A-7-10.23.5.1 For the purposes of Table 7-10.23.5.1, the fire hazard potential of Class 2 oxidizers has been considered as approximately equal to Group A plastic (non-expanded), stable cartoned. (**430:** A-4-4.1)

A-7-10.23.6.1 For the purposes of Table 7-10.23.6.1, the sprinkler density has been derived from fire loss history. (**430:** A-5-4.1)

A-7-10.26.2 Cement-lined pipe 12 in. (304.8 mm) in diameter is recommended. Main sizes should be designed to encompass any anticipated expansion.

The underground main should be arranged such that any one break will not put both a fixed water extinguishing system and hose lines protecting the same area out of service.

A-7-10.27.2 The water supply for the permanent fire protection water system should be based on providing a 2-hour water supply for both items (1) and (2) as follows:

(1) Either of the following items, a or b, whichever is larger:
   a. The largest fixed fire suppression system demand
   b. Any fixed fire suppression system demand that could be reasonably expected to operate simultaneously during a single event (e.g., turbine underfloor protection in conjunction with other fire protection systems in the turbine area)

(2) The hose stream demand of not less than 500 gpm (1892.5 L/min).

(**804:** A-7-2.1)

A-7-10.27.5 To avoid water application to hot parts or other water-sensitive areas and to provide adequate coverage, designs that incorporate items such as fusible element operated spray nozzles might be necessary. (**804:** A-8-8.2.1)

A-7-10.27.6 Additional information concerning turbine generator fire protection can be found in EPRI Research Report 1843-2, "Turbine Generator Fire Protection by Sprinkler System," July 1985. (**804:** A-8-8.3)

A-7-10.28 Sprinkler System Discharge Criteria for Electric Generating Plants and High-Voltage Direct Current Converter Stations. See NFPA 850, *Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations*, for applicable terms not defined in Chapter 1.

(a) *Sprinkler System Water Supply.* The water supply for the permanent fire protection installation should be based on providing a 2-hour supply for both items (1) and (2) as follows:

(1) Either of items a or b below, whichever is larger:
   a. The largest fixed fire suppression system demand
   b. Any fixed fire suppression system demands that could reasonably be expected to operate simultaneously during a single event [e.g., turbine under floor protection in conjunction with other fire protection system(s) in the turbine area; coal conveyor protection in conjunction with protection for related coal handling structures during a conveyor fire; adjacent transformers not adequately separated according to 3-1.3 of NFPA 850].

(2) The hose stream demand of not less than 500 gpm (31.5 L/sec).

(**850:** 4-2.1)

Where an adequate and reliable water supply, such as a lake, cooling pond, river, or municipal water system, is unavailable, at least two separate water supplies should be provided for fire protection purposes with each supply capable of meeting the fire waterflow requirements determined by 4-2.1 of NFPA 850. (**850:** 4-2.2)

(b) *Yard Mains.* The supply mains should be looped around the main power block and should be of sufficient size to supply the flow requirements determined by 4-2.1 of NFPA 850 to any point in the yard loop considering the most direct path to be out of service. Pipe sizes should be designed to encompass any anticipated expansion and future water demands. (**850:** 4-4.1.3)

(c) *Coal Handling Structures.* Sprinkler systems should be designed for a minimum of 0.25 gpm/ft^2 (10.2 mm/min) density over a 2500 ft^2 (232 m^2) area. (**850:** 5-4.6.1)

(d) *Coal Conveyors.* Sprinklers should be designed for a minimum of 0.25 gpm/ft^2 (10.2 mm/min) density over 2000 ft^2 (186 m^2) of enclosed area or the most remote 100 linear ft (30 m) of conveyor structure up to 2000 ft^2 (186 m^2). (**850:** 5-4.6.2)

(e) [In areas over conveyor belts and striker plates within the stacker reclaimer,] the water supply [should] be from a 3000-gal to 5000-gal (11,355-L to 18,925-L) capacity pressure tank located on-board. (**850:** 5-4.6.4)

(f) Sprinklers for bag-type dust collectors should be designed for ordinary hazard systems. Sprinkler systems should be designed for a density of 0.2 gpm (8.2 mm/min) over the projected plan area of the dust collector. (**850:** 5-4.6.5.1)

(g) *Steam Generator.* Boiler front fire protection systems should be designed to cover the fuel oil burners and ignitors, adjacent fuel oil piping and cable, a 20 ft (6.1 m) distance from the burner and ignitor including structural members and walkways at these levels. Additional coverage should include areas where oil may collect. Sprinkler and water spray systems should be designed for a density of 0.25 gpm/ft^2 (10.2 mm/min) over the protected area. (**850:** 5-5.1.2)

(h) *Flue Gas Bag-Type Dust Collectors.* The design density should be 0.2 gpm/ft^2 (8.2 mm/min) over the plan area of the dust collector. (**850:** 5-6.3.3)

(i) *Electrostatic Precipitators.* If mineral oil insulating fluids are used, hydrants or standpipes should be located so that each transformer-rectifier set can be reached by at least one hose stream. In addition the following should be provided:

Automatic sprinkler protection. Automatic sprinkler systems should be designed for a density of 0.25 gpm/ft^2 (10.2 mm/min) over 3500 ft^2 (325 m^2). The drain system should be capable of handling oil spillage plus the largest design waterflow from the fire protection system. (**850:** 5-6.4.3)

(j) *Scrubber Buildings.* Where scrubbers have plastic or rubber linings, one of the following methods of protection for the building should be provided:

Automatic sprinkler protection at ceiling level sized to provide a density 0.2 gpm/ft^2 (8.2 mm/min). The area of operation should be the area of the building or 10,000 ft^2 (930 m^2). Where draft curtains are provided the area of operation can be reduced to the largest area subdivided by draft curtains. (**850:** 5-6.5.2.2)

(k) *Turbine-Generator Area.* The sprinkler system beneath the turbine-generator should take into consideration obstructions from structural members and piping and should be designed to a density of 0.3 gpm/ft^2 (12.2 mm/min) over a minimum application of 5000 ft^2 (464 m^2).

NOTE: To avoid water application to hot parts or other water sensitive areas and to provide adequate coverage, designs that incorporate items such as fusible element operated directional spray nozzles may be necessary. (**850:** 5-7.4.1, 5-7.4.1.1)

The automatic sprinkler system [protecting the lubricating oil lines above the turbine operating floor] should be designed to a density of 0.3 gpm/ft^2 (12.2 mm/min). (**850:** 5-7.4.1.2)

(l) *Turbine-Generator Bearings.* Fire protection systems for turbine-generator bearings should be designed for a density of 0.25 gpm/ft^2 (10.2 mm/min) over the protected area. (**850:** 5-7.4.2.1)

(m) *Cable Spreading Room and Cable Tunnels.* Automatic sprinkler systems should be designed for a density of 0.3 gpm/ft^2 (12.2 mm/min) over 2500 ft^2 (232 m^2) or the most remote 100 linear ft (30 m) of cable tunnels up to 2500 ft^2 (232 m^2). (**850:** 5-8.2.1)

(n) *Emergency Generators.* Sprinkler systems should be designed for a 0.25 gpm/ft^2 (10.2 mm/min) density over the fire area. (**850:** 5-9.1.2.1)

(o) *Fire Pumps.* If sprinkler systems are provided for fire pump houses, they should be designed for a density of 0.25 gpm/ft^2 (10.2 mm/min) over the fire area. (**850:** 5-9.4)

(p) *Oil- or Coal-Fueled Auxiliary Boilers.* If a sprinkler system is provided it should be designed for a density of 0.25 gpm/ft^2 (10.2 mm/min) over the entire room.

(q) *Alternative Fuels.*

(1) *Hydraulic Equipment, Reservoirs, Coolers, and Associated Oil-Filled Equipment.* Sprinklers should be over oil-containing equipment and for 20 ft (6.1 m) beyond in all directions. A density of 0.25 gpm/ft^2 (10.2 mm/min) should be provided. (**850:** 7-3.4.3)

(2) *Tipping/Receiving Building.* Systems should be designed for a minimum of 0.25 gpm/ft^2 (10.2 mm/min) over the most remote 3000 ft^2 (279 m^2) (increase by 30 percent for dry pipe systems) of floor area with the protection area per sprinkler not to exceed 130 ft^2 (120 m^2). High temperature sprinklers [250°F to 300°F (121°C to 149°C)] should be used.

NOTE: The above requirements are based on storage heights not exceeding 20 ft (6.1 m). (**850:** 7-3.4.4)

(3) *The MSW Storage Pit, Charging Floor, and Grapple Laydown Areas.* Systems should be designed for a minimum of 0.2 gpm/ft^2 (8.2 mm/min) over the most remote 3000 ft^2 (279 m^2) (increase by 30 percent for dry pipe systems) of pit/floor area with the protection area per sprinkler not to exceed 100 ft^2 (9.3 m^2). High temperature sprinklers [250°F to 300°F (121°C to 149°C)] should be used. (**850:** 7-3.4.5.1)

(r) *Refuse Derived Fuels.*

(1) *Hydraulic Equipment, Reservoirs, Coolers, and Associated Oil-Filled Equipment.* Sprinklers should be over oil-containing equipment and for 20 ft (6.1 m) beyond in all directions. A density of 0.25 gpm/ft^2 (10.2 mm/min) should be provided. (**850:** 7-4.4.6)

(2) *Tipping/Receiving Building.* Systems should be designed for a minimum of 0.25 gpm/ft^2 (10.2 mm/min) over the most remote 3000 ft^2 (279 m^2) (increase by 30 percent for dry pipe systems) of floor area with the protection area per sprinkler not to exceed 130 ft^2 (12.0 m^2). High temperature sprinklers [250°F to 300°F (121°C to 149°C)] should be used.

NOTE: The above requirements are based on storage heights not exceeding 20 ft (6.1 m).

(**850:** 7-4.4.7)

(3) *Processing Building.* Systems should be designed for a minimum of 0.25 gpm/ft^2 (10.2 mm/min) over the most remote 3000 ft^2 (279 m^2) (increase by 30 percent for dry pipe systems) of floor area with the protection area per sprinkler not to exceed 130 ft^2 (12.0 m^2). (**850:** 7-4.4.8)

(4) *RDF Storage Building.* Systems should be designed for a minimum of 0.35 gpm/ft^2 (14.3 mm/min) over the most remote 3000 ft^2 (279 m^2) (increase by 30 percent for dry pipe systems) of floor area with the protection area per sprinkler not to exceed 100 ft^2 (9.3 m^2). High temperature sprinklers [250°F to 300°F (121°C to 149°C)] should be used. Storage heights in excess of 20 ft (6.1 m) will require higher design densities. (**850:** 7-4.4.9)

(5) *RDF Boiler Feed System Area, Including Bins, Hoppers, Chutes, Conveyors, and So Forth.* Where provided, the systems should be designed for a minimum of 0.2 gpm/ft^2 (8.2 mm/min) over the most remote 2000 ft^2 (186 m^2) (increase by 30 percent for dry pipe systems) of floor area with the protection area per sprinkler not to exceed 130 ft^2 (12.0 m^2). Internal, as well as external, protection also should be considered depending upon specific equipment design, ceiling heights, and accessibility for manual fire fighting. (**850:** 7-4.4.10)

(6) *Shredder Enclosures.* Systems should be designed for a minimum of 0.25 gpm/ft^2 (10.2 mm/min) over the most remote 3000 ft^2 (279 m^2) (increase by 30 percent for dry pipe systems) of floor area with the protection area per sprinkler not to exceed 100 ft^2 (9.3 m^2). (**850:** 7-4.4.11)

(s) *Biomass Fuels.*

(1) *Biomass Storage Buildings.* Systems should be designed for a minimum of 0.25 gpm/ft^2 (10.2 mm/min) over the most remote 3000 ft^2 (279 m^2) (increase by 30 percent for dry pipe systems) of floor area with the protection area per sprinkler not to exceed 130 ft^2 (12.0 m^2).

NOTE: Biomass fuels exhibit a wide range of burning characteristics and upon evaluation can require increased levels of protection.

(**850:** 7-5.4.4)

(2) *Hydraulic Equipment, Reservoirs, Coolers, and Associated Oil-Filled Equipment.* Sprinklers or spray nozzles should be over oil-containing equipment and for 20 ft (6.1 m) beyond in all directions. A density of 0.25 gpm/ft^2 (10.2 mm/min) should be provided. (**850:** 7-5.4.6)

(t) *Rubber Tire Fuel — Hydraulic Equipment, Reservoirs, Coolers, and Associated Oil-Filled Equipment.* Sprinklers should be over oil-containing equipment and for 20 ft (6.1 m) beyond in all directions. A density of 0.25 gpm/ft^2 (10.2 mm/min) should be provided. (**850:** 7-6, 7-6.4.10)

A-7-10.29 Sprinkler System Discharge Criteria for Hydroelectric Generating Plants. See NFPA 851, *Recommended Practice for Fire Protection for Hydroelectric Generating Plants*, for applicable terms not defined in Chapter 1.

(a) *Sprinkler Systems Water Supply.* The water supply for the permanent fire protection installation should be based on the largest fixed fire suppression system demand plus the maximum hose stream demand of not less than 500 gpm (31.5 L/sec) for a 2-hour duration. (**851:** 4-2.2)

(b) If a single water supply is utilized, two independent connections should be provided. If a situation can arise in which the primary water supply can become unavailable (e.g., dewatering of penstocks), an auxiliary supply should be provided. Each supply should be capable of meeting the requirements in 4-2.2 of NFPA 851. (**851:** 4-2.3)

(c) Fixed fire protection for this equipment, where provided, should be automatic wet pipe sprinkler systems utilizing a design density of 0.25 gpm/ft^2 (10.2 mm/min) for the entire hazard area *(see 3-5.3 of NFPA 803).* (**851:** 5-2.4)

(d) Sprinkler or water spray systems should be designed for a density of 0.3 gpm/ft^2 (12.2 mm/min) over 2500 ft^2 (232 m^2). This coverage is for area protection. Individual cable tray tier coverage could be required based on the Fire Risk Evaluation. (**851:** 5-5.3)

(e) *Cable Tunnels.* Automatic sprinkler systems should be designed for a density of 0.3 gpm/ft^2 (12.2 mm/min) over 2500 ft^2 (232 m^2) or the most remote 100 linear ft (30 m) of cable tunnel up to 2500 ft^2 (232 m^2). (**851:** 5-6.1)

(f) *Emergency Generators.* Sprinkler and water spray protection systems should be designed for a 0.25 gpm/ft^2 (10.2 mm/min) density over the fire area. (**851:** 5-11.2)

(g) *Air Compressors.* Automatic sprinkler protection, with a density of 0.25 gpm/ft^2 (10.2 mm/min) over the postulated oil spill, should be considered for air compressors containing a large quantity of oil. *(See 4-8.2 of NFPA 851.)* (**851:** 5-12)

(h) *Hydraulic Systems for Gate and Valve Operators.* Automatic sprinkler protection designed for a density of 0.25 gpm/ft^2 (10.2 mm/min) over the fire area should be considered for hydraulic systems not using a listed fire-resistant fluid. *(See 4-8.2 of NFPA 851.)* (**851:** 5-13)

(i) *Fire Pumps.* If sprinkler systems are provided they should be designed for a density of 0.25 gpm/ft^2 (10.2 mm/min) over the fire area. For automatic foam-water sprinkler systems, a density of 0.16 gpm/ft^2 (6.5 mm/min) should be provided. (**851:** 5-14)

A-7-10.30 Sprinkler systems for specific areas associated with religious facilities should be designed as follows:

(1) All assembly areas, except state — Light Hazard
(2) Stages — Ordinary Hazard (Group 2)
(3) Kitchens — Ordinary Hazard (Group 1)
(4) Storage rooms — Ordinary Hazard (Group 2)
(5) Unused attics/lofts/steeples/concealed spaces — Light Hazard
(6) Schools/day-care centers — Light Hazard
(7) Gift shops — Ordinary Hazard (Group 1)
(8) Special exhibit area — Ordinary Hazard (Group 2)
(9) Libraries — Ordinary Hazard (Group 2)
(10) Offices — Light Hazard

(**909:** A-10-4.2)

A-8-1 Preliminary layouts should be submitted for review to the authority having jurisdiction before any equipment is installed or remodeled in order to avoid error or subsequent misunderstanding *(see Figure A-8-1)*. Any material deviation from approved plans will require permission of the authority having jurisdiction.

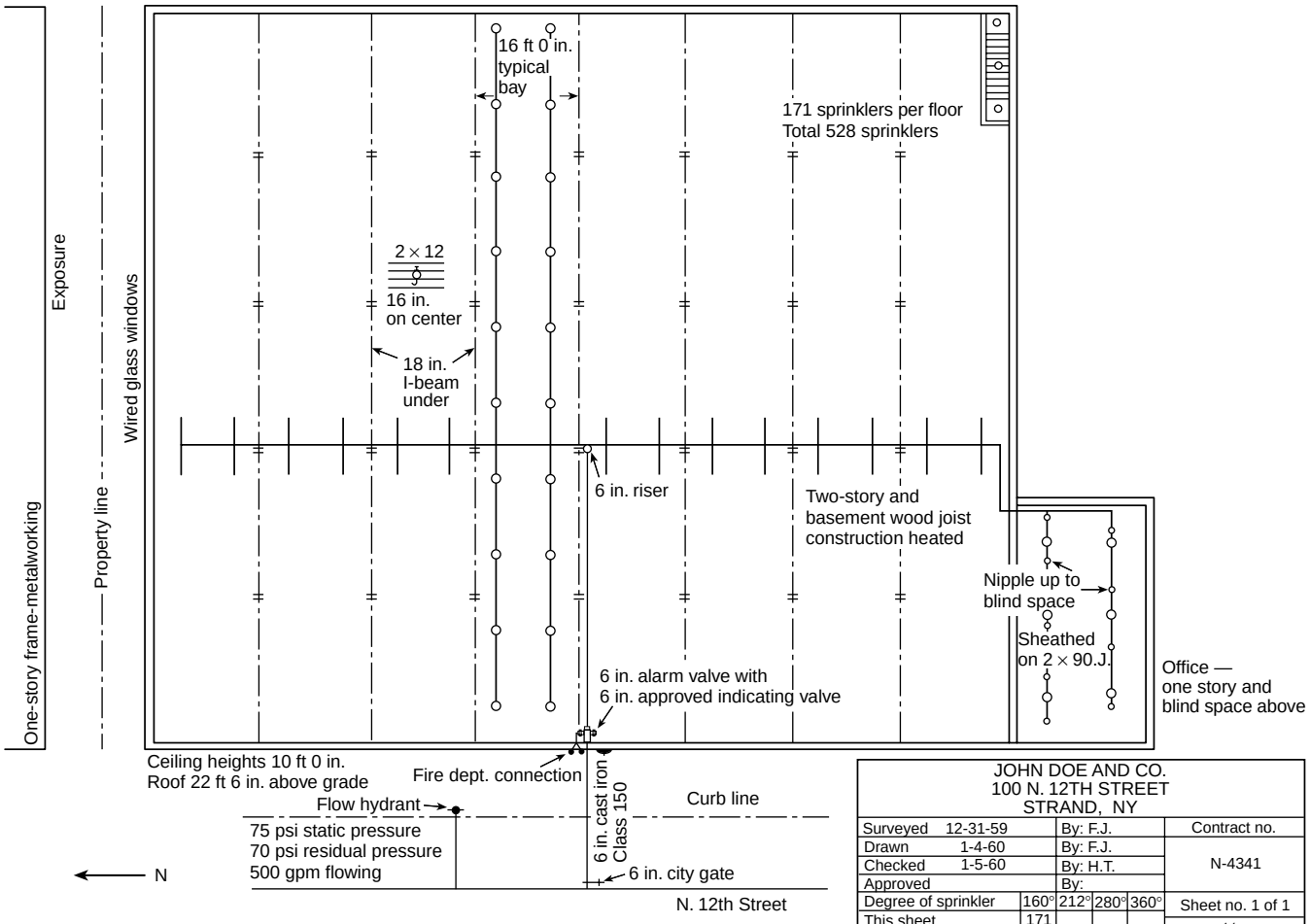
Preliminary layouts should show as much of the following information as is required to provide a clear representation of the system, hazard, and occupancy:

(1) Name of owner and occupant.
(2) Location, including street address.
(3) Point of compass.
(4) Construction and occupancy of each building. Data on special hazards should be submitted as they can require special rulings.
(5) Building height in feet.
(6) If it is proposed to use a city main as a supply, whether the main is dead end or circulating, size of main and pressure in psi, and, if dead end, direction and distance to nearest circulating main.
(7) Distance from nearest pumping station or reservoir.
(8) In cases where reliable, up-to-date information is not available, a waterflow test of the city main should be conducted in accordance with A-9-2.1. The preliminary plans should specify the person who conducted the test, date and time, the location of the hydrants where flow was taken and where static and residual pressure readings were recorded, the size of main supplying these hydrants, and the results of the test, giving size and number of open hydrant butts flowed. Also, data covering minimum pressure in the connection with the city main should be included.
(9) Data covering waterworks systems in small towns in order to expedite the review of plans.
(10) Fire walls, fire doors, unprotected window openings, large unprotected floor openings, and blind spaces.
(11) Distance to and construction and occupancy of exposing buildings — for example, lumber yards, brick mercantiles, and fire-resistive office buildings.
(12) Spacing of sprinklers, number of sprinklers in each story or fire area and total number of sprinklers, number of sprinklers on each riser and on each system by floors, total area protected by each system on each floor, total number of sprinklers on each dry pipe system or preaction or deluge system and if extension to present equipment, sprinklers already installed.
(13) Capacities of dry pipe systems with bulk pipe included *(see Table A-4-2.3)* and, if an extension is made to an existing dry pipe system, the total capacity of the existing and also the extended portion of the system.
(14) Weight or class, size, and material of any proposed underground pipe.
(15) Whether property is located in a flood or earthquake area requiring consideration in the design of sprinkler system.
(16) Name and address of party submitting the layout.

A-8-1.1 See Figure A-8-1.1. Underground mains should be designed so that the system can be extended with a minimum of expense. Possible future plant expansion should also be considered and the piping designed so that it will not be covered by buildings.

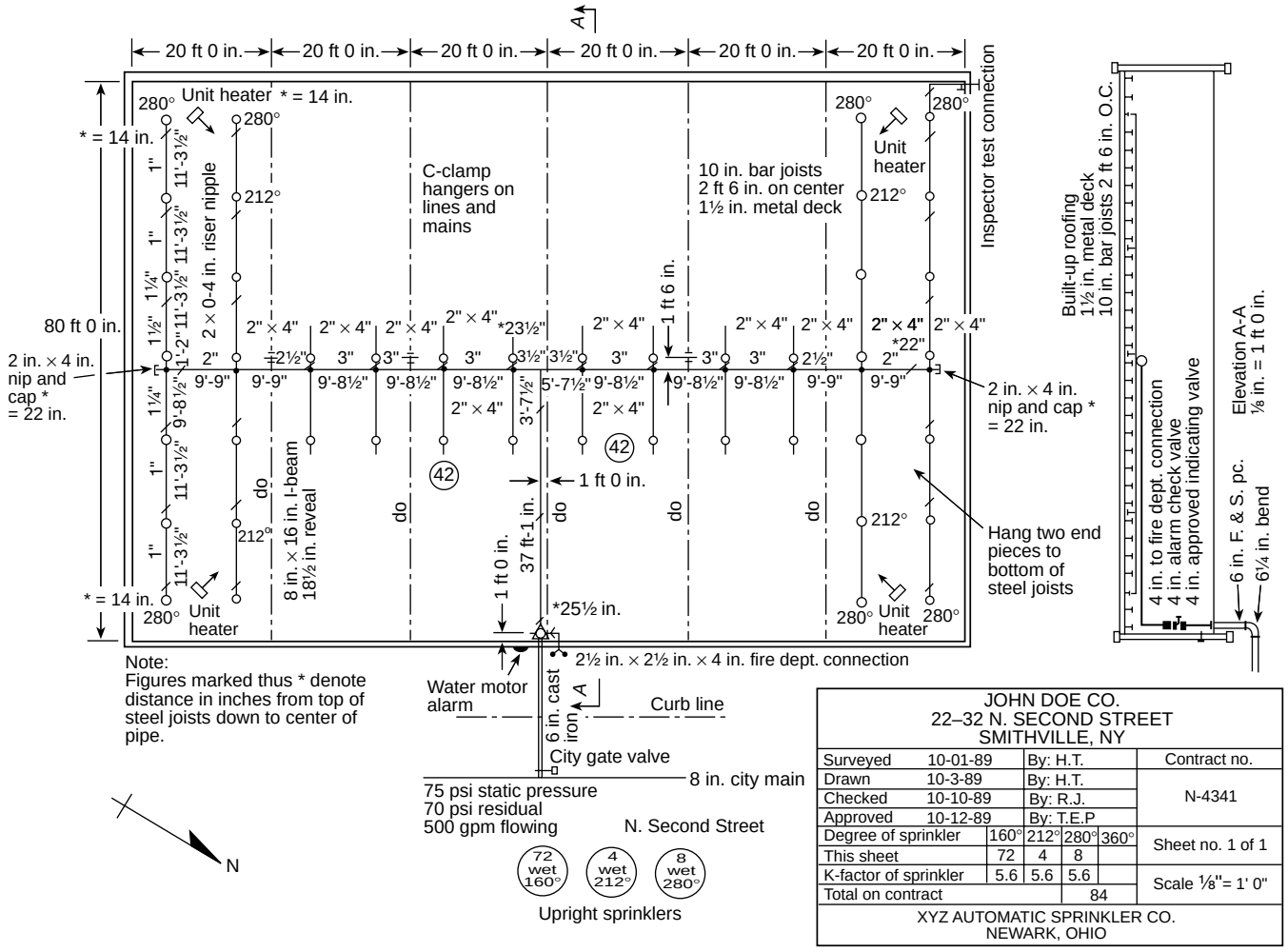
A-8-1.1.3 See Figures A-8-1.1.3(a) and (b).

Figure A-8-1 Typical preliminary plan.



JOHN DOE AND CO. 100 N. 12TH STREET STRAND, NY					
Surveyed 12-31-59		By: F.J.			Contract no.
Drawn 1-4-60		By: F.J.			N-4341
Checked 1-5-60		By: H.T.			
Approved		By:			
Degree of sprinkler	160°	212°	280°	360°	Sheet no. 1 of 1
This sheet	171				Scale ⅛" = 1' 0"
Total on contract			528		
XYZ AUTOMATIC SPRINKLER CO. NEWARK, OHIO					

Figure A-8-1.1 Typical working plans.



JOHN DOE CO. 22–32 N. SECOND STREET SMITHVILLE, NY					
Surveyed	10-01-89	By: H.T.			Contract no.
Drawn	10-3-89	By: H.T.			N-4341
Checked	10-10-89	By: R.J.			
Approved	10-12-89	By: T.E.P			
Degree of sprinkler		160°	212°	280°	360°
This sheet		72	4	8	Sheet no. 1 of 1
K-factor of sprinkler		5.6	5.6	5.6	Scale ⅛"= 1' 0"
Total on contract				84	
XYZ AUTOMATIC SPRINKLER CO. NEWARK, OHIO					

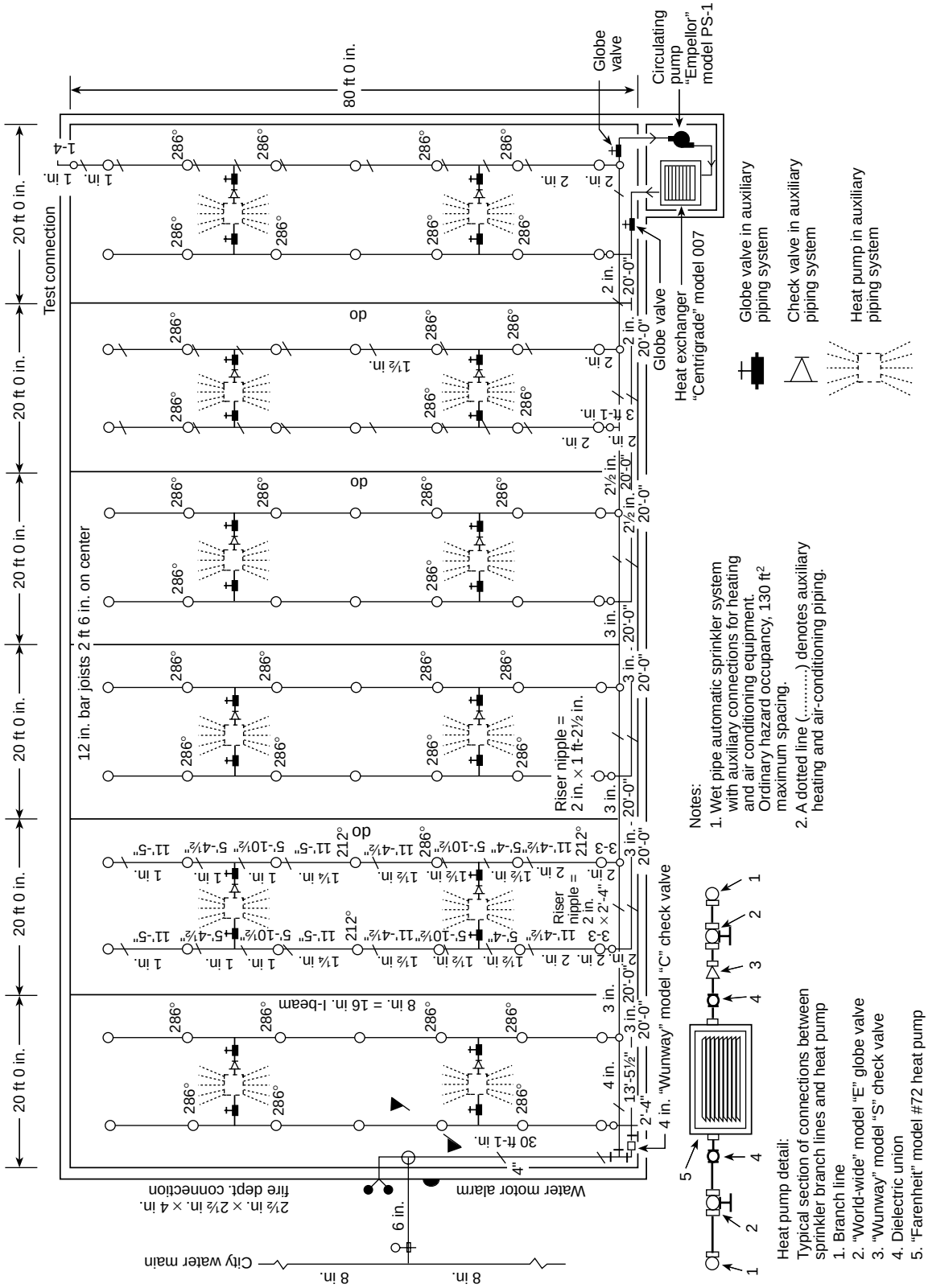


Figure A-8-1.1.3(a) Working plans for circulating closed-loop systems (example 1).

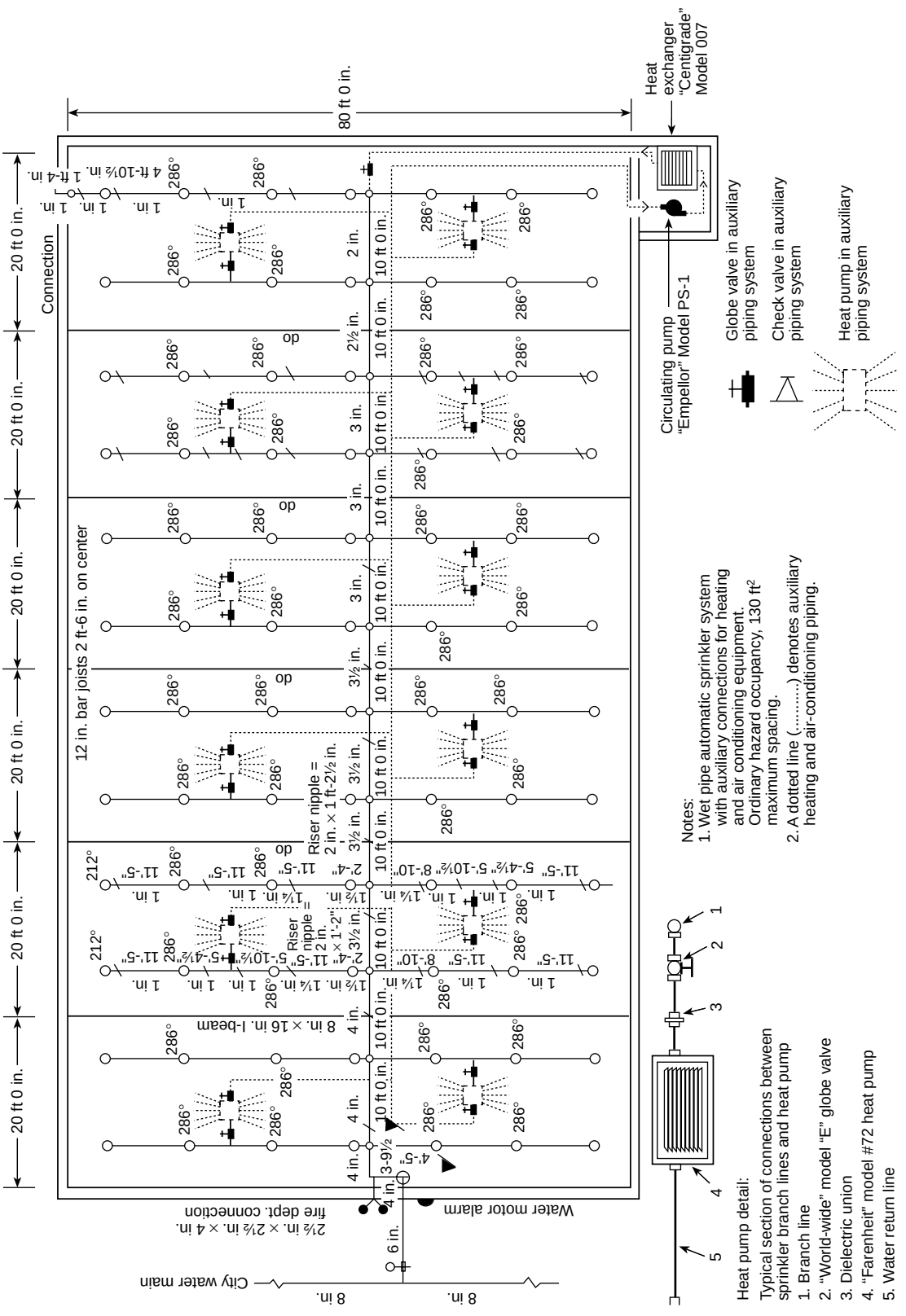


Figure A-8-1.1.3(b) Working plans for circulating closed-loop systems (example 2).

A-8-3.2 See Figures A-8-3.2(a) through (d).

A-8-3.3 See Figure A-8-3.3.

A-8-3.3(15) See Figure A-8-3.3(15).

A-8-3.4 See Figure A-8-3.4.

Figure A-8-3.2(a) Summary sheet.

Hydraulic Calculations

for

ABC Company, employee garage

7499 Franklin Road

Charleston, SC

Contract No. 4001

Date 1 – 7 – 91

Design data:

Occupancy classification ORD. GR. 1

Density 0.15 gpm/ft²

Area of application 1500 ft²

Coverage per sprinkler 130 ft²

Special sprinklers —

No. of sprinklers calculated 12

In-rack demand —

Hose streams 250 gpm

Total water required 510.4 gpm
including hose streams

Name of contractor _____

Name of designer _____

Address _____

Authority having jurisdiction _____

Figure A-8-3.2(b) Hydraulic calculation example (plan view and elevation view).

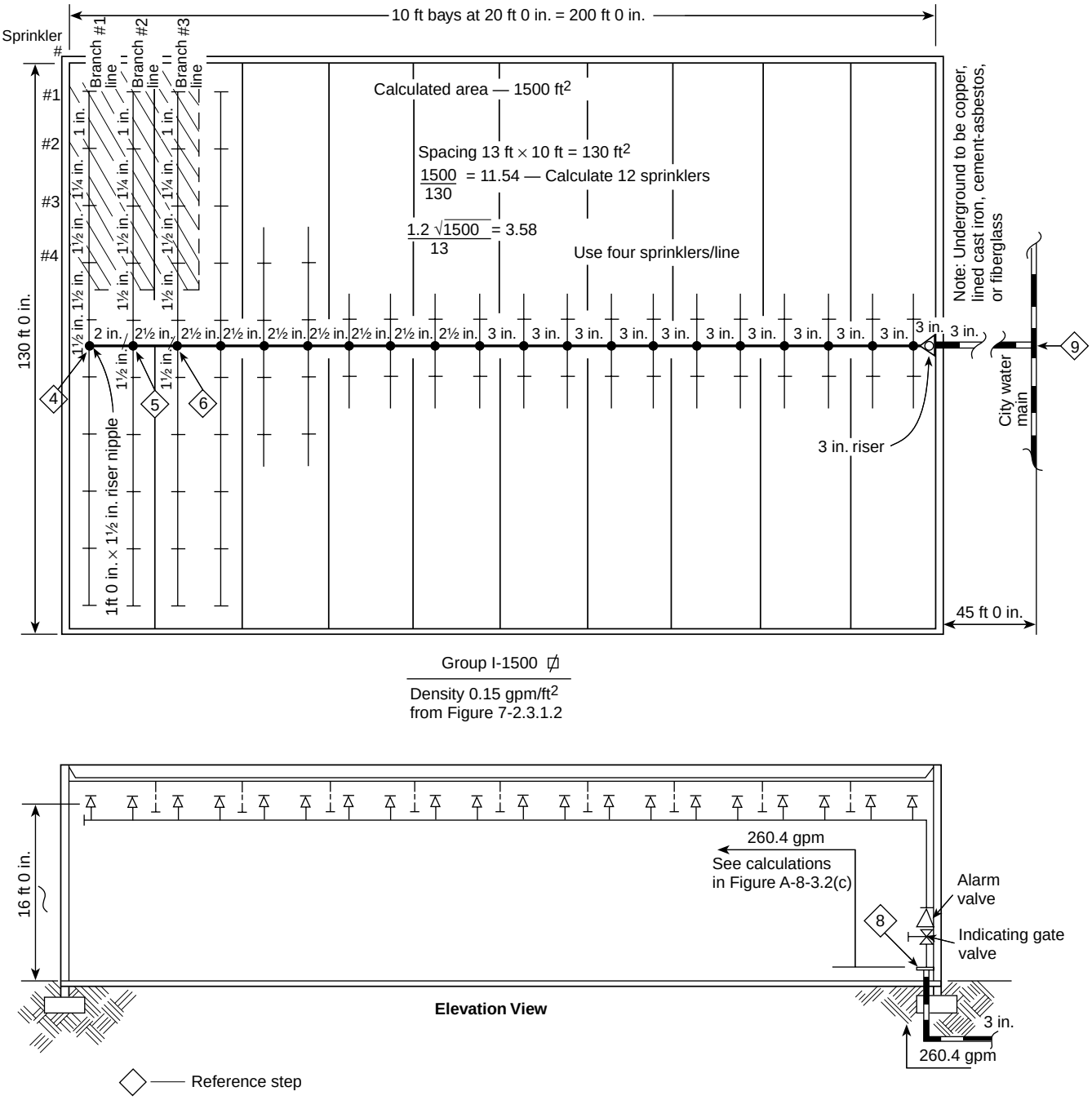


Figure A-8-3.2(c) Hydraulic calculations.

Contract Name GROUP I 1500 ft² Sheet 2 Of 3

Step No.	Nozzle Ident. and Location	Flow in gpm	Pipe Size	Pipe Fittings and Devices	Equiv. Pipe Length	Friction Loss psi Foot	Pressure Summary	Normal Pressure	D = 0.15 GPM/ ft² Notes K = 5.6	Ref. Step
1	1 BL-1	q Q 19.5	1		L 13.0 F T 13.0	C=120 0.124	P_t 12.1 P_e P_f 1.6	P_t P_v P_n	Q = 130 x .15 = 19.5 P = (19.5/5.6)² = 12.1 psi	
2	2	q 20.7 Q 40.2	1¼		L 13.0 F T 13.0	0.125	P_t 13.7 P_e P_f 1.6	P_t P_v P_n	q = 5.65 $\sqrt{13.7}$	
3	3	q 21.9 Q 62.1	1½		L 13.0 F T 13.0	0.131	P_t 15.3 P_e P_f 1.7	P_t P_v P_n	q = 5.65 $\sqrt{15.3}$	4
4	4 DN RN	q 23.1 Q 85.2	1½	2T-16	L 20.5 F 16.0 T 36.5	0.236	P_t 17.0 P_e 0.4 P_f 8.6	P_t P_v P_n	q = 5.65 $\sqrt{17}$ Pe = 1 x 0.433	5
5	CM TO BL-2	q Q 85.2	2		L 10.0 F T 10.0	0.07	P_t 26.0 P_e P_f .7	P_t P_v P_n	K = $\frac{85.2}{\sqrt{26}}$ K = 16.71	
6	BL-2 CM TO BL-3	q 86.3 Q 171.5	2½		L 10.0 F T 10.0	0.107	P_t 26.7 P_e P_f 1.1	P_t P_v P_n	q = 16.71 $\sqrt{26.1}$	6
7	BL-3 CM	q 88.1 Q 259.6	2½		L 70.0 F T 70.0	0.231	P_t 27.8 P_e P_f 16.2	P_t P_v P_n	q = 16.7 $\sqrt{27.8}$	
8	CM TO FIS	q Q 259.6	3	E5 AV15 GV1	L 119.0 F 21 T 140.0	.081	P_t 44.0 P_e 6.5 P_f 11.2	P_t P_v P_n	Pe = 15 x 0.433	8
9	THROUGH UNDER-GROUND TO CITY MAIN	q Q 259.6	3	E5 GV1 T15	L 50.0 F 27.6 T 77.6	C=150 TYPE'M' 0.061	P_t 61.7 P_e P_f 4.7	P_t P_v P_n	F = F_{40} x 1.51 x F_c F_c = [2.981/3.068]^4.87 = 0.869 F = 21 x 1.51 x 0.869 F = 27.6	9
		q Q			L F T		P_t 66.4 P_e P_f	P_t P_v P_n		
		q Q			L F T		P_t P_e P_f	P_t P_v P_n		
							P_t			

Figure A-8-3.2(d) Hydraulic graph.

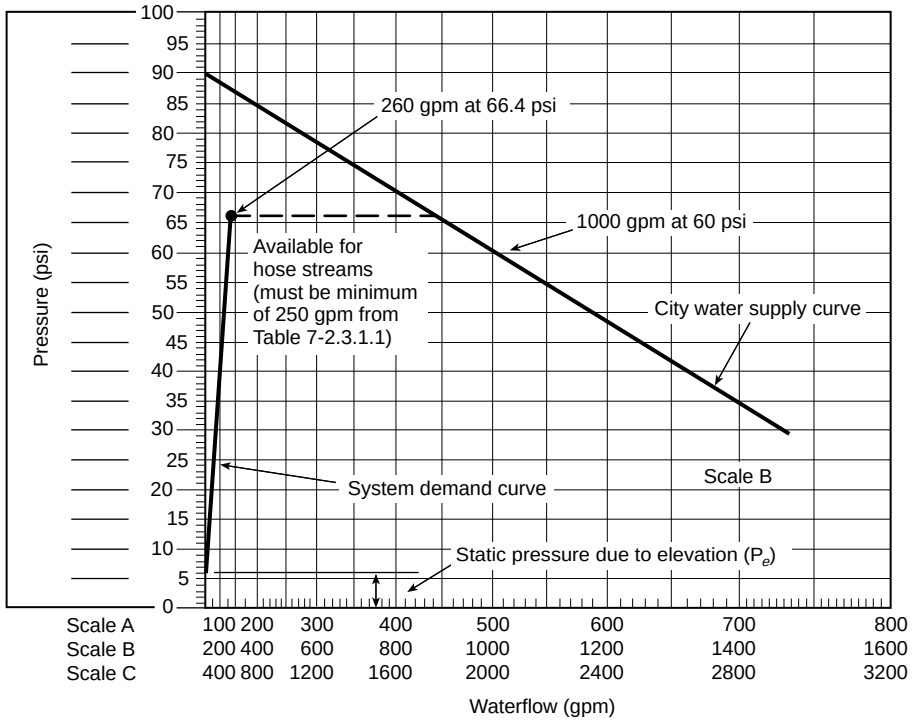


Figure A-8-3.3 Sample worksheet.

Contract no. ____________ Sheet no. ______ of ______

Name and location ____________________________

Reference	Nozzle type and location	Flow in gpm (L/min)	Pipe size (in.)	Fitting and devices	Pipe equivalent length	Friction loss psi/ft (bar/m)	Required psi (bar)	Normal Pressure	Notes
		q			length		P_t	P_t	
					fitting		P_f	P_v	
		Q			total		P_e	P_n	
		q			length		P_t	P_t	
					fitting		P_f	P_v	
		Q			total		P_e	P_n	
		q			length		P_t	P_t	
					fitting		P_f	P_v	
		Q			total		P_e	P_n	
		q			length		P_t	P_t	
					fitting		P_f	P_v	
		Q			total		P_e	P_n	
		q			length		P_t	P_t	
					fitting		P_f	P_v	
		Q			total		P_e	P_n	
		q			length		P_t	P_t	
					fitting		P_f	P_v	
		Q			total		P_e	P_n	
		q			length		P_t	P_t	
					fitting		P_f	P_v	
		Q			total		P_e	P_n	
		q			length		P_t	P_t	
					fitting		P_f	P_v	
		Q			total		P_e	P_n	
		q			length		P_t	P_t	
					fitting		P_f	P_v	
		Q			total		P_e	P_n	
		q			length		P_t	P_t	
					fitting		P_f	P_v	
		Q			total		P_e	P_n	
		q			length		P_t	P_t	
					fitting		P_f	P_v	
		Q			total		P_e	P_n	
		q			length		P_t	P_t	
					fitting		P_f	P_v	
		Q			total		P_e	P_n	
		q			length		P_t	P_t	
					fitting		P_f	P_v	
		Q			total		P_e	P_n	
		q			length		P_t	P_t	
					fitting		P_f	P_v	
		Q			total		P_e	P_n	
		q			length		P_t	P_t	
					fitting		P_f	P_v	
		Q			total		P_e	P_n	
		q			length		P_t	P_t	
					fitting		P_f	P_v	
		Q			total		P_e	P_n	
		q			length		P_t	P_t	
					fitting		P_f	P_v	
		Q			total		P_e	P_n	
		q			length		P_t	P_t	
					fitting		P_f	P_v	
		Q			total		P_e	P_n	

Pt = total pressure; Pf = friction loss pressure; Pv = velocity pressure; Pe = elevation pressure

Figure A-8-3.3(15) Example of hydraulically remote area — grid system.

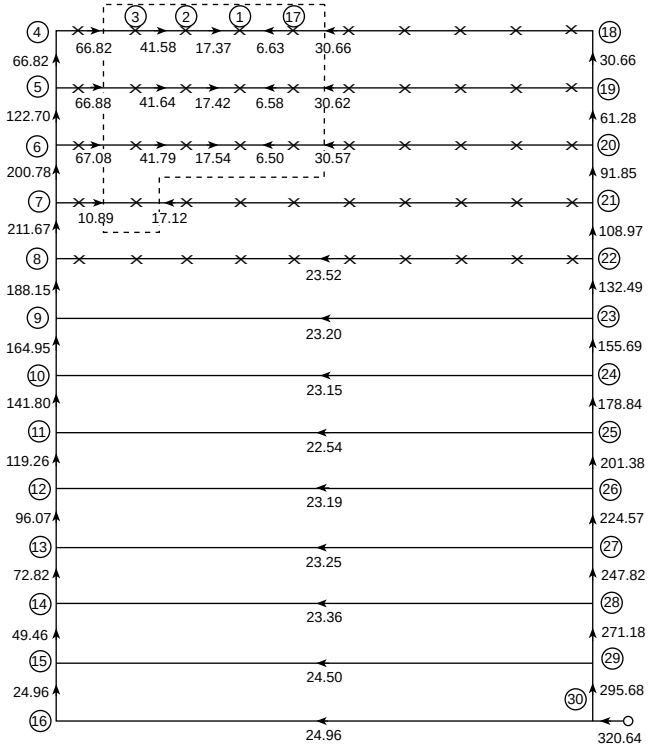
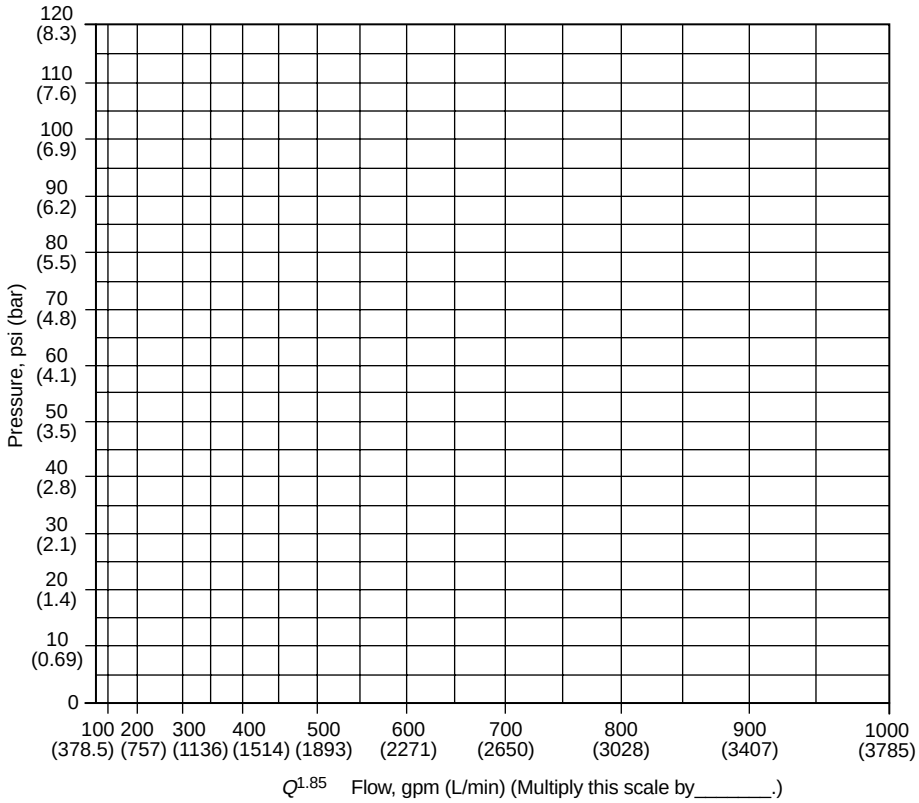


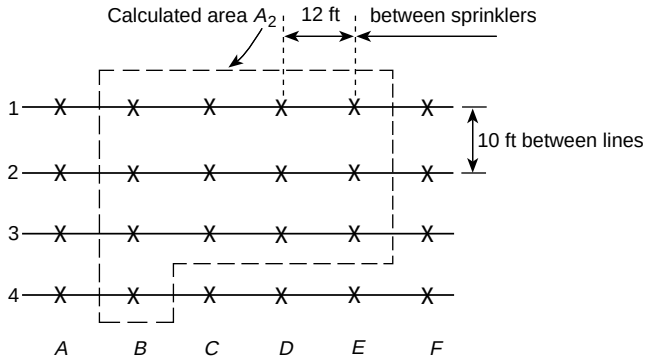
Figure A-8-3.4 Sample graph sheet.



A-8-4.1 When additional sprinkler piping is added to an existing system, the existing piping does not have to be increased in size to compensate for the additional sprinklers, provided the new work is calculated and the calculations include that portion of the existing system that can be required to carry water to the new work. It is not necessary to restrict the water velocity when determining friction losses using the Hazen-Williams formula.

A-8-4.4 See Figure A-8-4.4.

Figure A-8-4.4 Example of determining the number of sprinklers to be calculated.



Notes:
1. For gridded systems, the extra sprinkler (or sprinklers) on branch line 4 can be placed in any adjacent location from *B* to *E* at the designer's option.
2. For tree and looped systems, the extra sprinkler on line 4 should be placed closest to the cross main.

Assume a remote area of 1500 ft^2 with sprinkler coverage of 120 ft^2

$$\text{Total sprinklers to calculate} = \frac{\text{Design area}}{\text{Area per sprinkler}}$$

$$= \frac{1500}{120} = 12.5, \text{ calculate } 13$$

$$\text{Number of sprinklers on branch line} = \frac{1.2\sqrt{A}}{S}$$

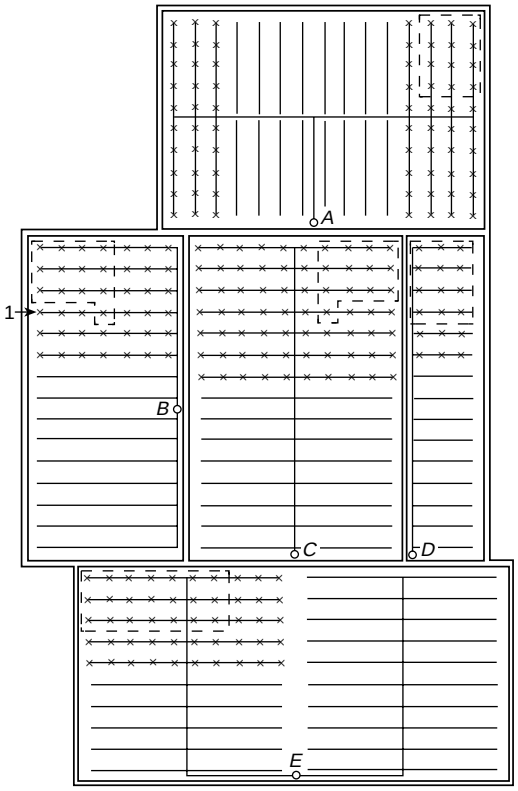
Where:
A = design area
S = distance between sprinklers on branch line

$$\text{Number of sprinklers on branch line} = \frac{1.2\sqrt{1500}}{12} = 3.87$$

For SI units, 1 ft = 0.3048 m; 1 ft^2 = 0.0929 m^2.

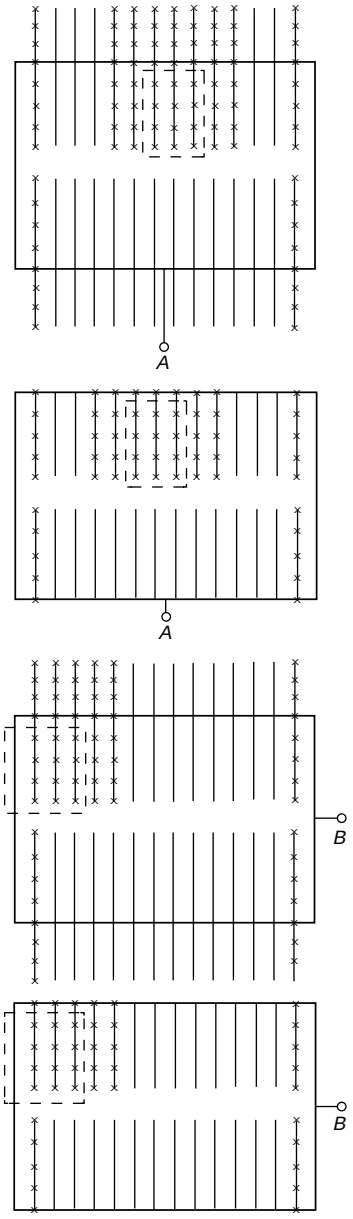
A-8-4.4.1 See Figures A-8-4.4.1(a) and (b).

Figure A-8-4.4.1(a) Example of hydraulically most demanding area.



1 This sprinkler is not in the selected area of operation.

Figure A-8-4.4.1(b) Example of hydraulically most demanding area.



A-8-4.4.2 See Figure A-8-4.4.2.

A-8-4.4.3.1 See Figure A-8-4.4.3.1.

A-8-4.4.3.2 This subsection assumes a ceiling constructed so as to reasonably assure that a fire on one side of the ceiling will operate sprinklers on one side only. Where a ceiling is sufficiently open, or of such construction that operation of sprinklers above and below the ceiling can be anticipated, the operation of such additional sprinklers should be considered in the calculations.

A-8-4.4.4 When it is not obvious by comparison that the design selected is the hydraulically most remote, additional calculations should be submitted. The most distant area is not necessarily the hydraulically most remote.

A-8-4.4.6 The use of sprinklers with differing orifice sizes in situations where different protection areas are needed is not considered balancing. An example would be a room that could be protected with sprinklers having different orifice size in closet, foyer, and room areas. However, this procedure introduces difficulties when restoring a system to service after operation since it is not always clear which sprinklers go where.

Figure A-8-4.4.2 Example of determining the most remote area for a gridded system.

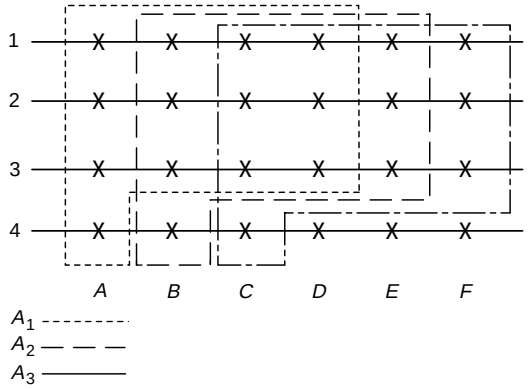
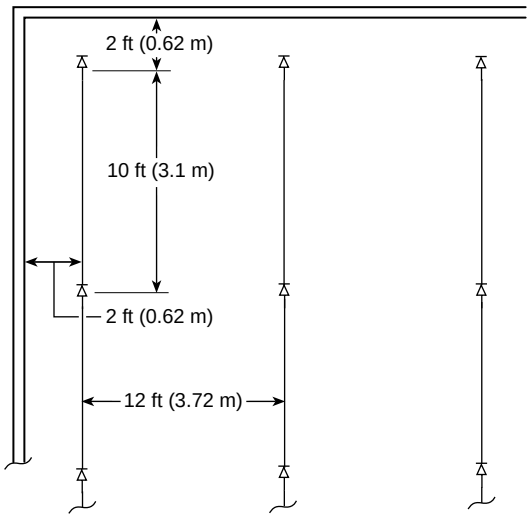


Figure A-8-4.4.3.1 Sprinkler design area.



A-8-4.4.7 Where the normal pressure (P_n) is used to calculate the flow from an orifice, the following assumptions should be used.

(a) At any flowing outlet along a pipe, except the end outlet, only the normal pressure (P_n) can act on the outlet. At the end outlet the total pressure (P_t) can act. The following should be considered end outlets:

(1) The last flowing sprinkler on a dead-end branch line
(2) The last flowing branch line on a dead-end cross main
(3) Any sprinkler where a flow split occurs on a gridded branch line
(4) Any branch line where a flow split occurs on a looped system

(b) At any flowing outlet along a pipe, except the end outlet, the pressure acting to cause flow from the outlet is equal to the total pressure (P_t) minus the velocity pressure (P_v) on the upstream (supply) side.

(c) To find the normal pressure (P_n) at any flowing outlet, except the end outlet, assume a flow from the outlet in question and determine the velocity pressure (P_v) for the total flow on the upstream side. Because normal pressure (P_n) equals total pressure (P_t) minus velocity pressure (P_v), the value of the normal pressure (P_n) so found should result in an outlet flow approximately equal to the assumed flow; if not, a new value should be assumed, and the calculations should be repeated.

A-8-5.1 The demonstrated effectiveness of pipe schedule systems is limited to their use with $^1/_2$-in. (13-mm) orifice sprinklers. The use of other size orifices can require hydraulic calculations to prove their ability to deliver the required amount of water within the available water supply.

A-8-5.1.2 Where the construction or conditions introduce unusually long runs of pipe or many angles in risers or feed or cross mains, an increase in pipe size over that called for in the schedules can be required to compensate for increased friction losses.

A-8-5.2.3.1 For example, a $2^1/_2$-in. (64-mm) steel pipe, which is permitted to supply 30 sprinklers, can supply a total of 50 sprinklers where not more than 30 sprinklers are above or below a ceiling.

A-8-5.3.3.1 For example, a 3-in. (76-mm) steel pipe, which is permitted to supply 40 sprinklers in an ordinary hazard area, can supply a total of 60 sprinklers where not more than 40 sprinklers protect the occupied space below the ceiling.

A-8-5.4 The piping schedule shown in Table A-8-5.4 is reprinted only as a guide for existing systems. New systems for extra hazard occupancies should be hydraulically calculated as required in 8-5.4.

Table A-8-5.4 Extra Hazard Pipe Schedule

Steel		Copper	
1 in.	1 sprinkler	1 in.	1 sprinkler
$1^1/_4$ in.	2 sprinklers	$1^1/_4$ in.	2 sprinklers
$1^1/_2$ in.	5 sprinklers	$1^1/_2$ in.	5 sprinklers
2 in.	8 sprinklers	2 in.	8 sprinklers
$2^1/_2$ in.	15 sprinklers	$2^1/_2$ in.	20 sprinklers
3 in.	27 sprinklers	3 in.	30 sprinklers
$3^1/_2$ in.	40 sprinklers	$3^1/_2$ in.	45 sprinklers
4 in.	55 sprinklers	4 in.	65 sprinklers
5 in.	90 sprinklers	5 in.	100 sprinklers
6 in.	150 sprinklers	6 in.	170 sprinklers

For SI units, 1 in. = 25.4 mm.

A-8-7 In the design of an exposure protection system, the flow rate from window and cornice sprinklers is shown in Table 8-7. The flow rates are based on the guide numbers selected from Table 2-3 of NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures.*

Section A of the table is for window sprinklers. The orifice size is selected according to the level on which the sprinkler is located. Section B of the table is for cornice sprinklers.

A-9-1.6.2 Where the system riser is close to an outside wall, underground fittings of proper length should be used in order to avoid pipe joints located in or under the wall. Where the connection passes through the foundation wall below grade, a 1-in. to 3-in. (25-mm to 76-mm) clearance should be provided around the pipe and the clear space filled with asphalt mastic or similar flexible waterproofing material.

A-9-1.7 Where water meters are in the supply lines to a sprinkler system, they should be rated to deliver the proper system demand. The amount of water supplied through a water meter varies with its size and type and might not provide the required demand, regardless of the water supply available.

A-9-1.8 Where connections are made from public waterworks systems, such systems should be guarded against possible contamination as follows *(see AWWA M14, Backflow Prevention and Cross Connection Control).*

(a) For private fire service mains with direct connections from public waterworks mains only or with booster pumps installed in the connections from the street mains, no tanks or reservoirs, no physical connection from other water supplies, no antifreeze or other additives of any kind, and with all drains discharging to atmosphere, dry well, or other safe outlets, no backflow protection is recommended at the service connection.

(b) For private fire service mains with direct connection from the public water supply main plus one or more of the following: elevated storage tanks or fire pumps taking suction from aboveground covered reservoirs or tanks (all storage facilities are filled or connected to public water only and the water in the tanks is to be maintained in a potable condition), an approved double check valve assembly is recommended.

(c) For private fire service mains directly supplied from public mains with an auxiliary water supply such as a pond or river on or available to the premises and dedicated to fire department use; or for systems supplied from public mains and interconnected with auxiliary supplies, such as pumps taking suction from reservoirs exposed to contamination or rivers and ponds; driven wells, mills, or other industrial water systems; or for systems or portions of systems where antifreeze or other solutions are used, an approved reduced pressure zone–type backflow preventer is recommended.

A-9-2.1 Care should be taken in making water tests to be used in designing or evaluating the capability of sprinkler systems. The water supply tested should be representative of the supply that might be available at the time of a fire. For example, testing of public water supplies should be done at times of normal demand on the system. Public water supplies are likely to fluctuate widely from season to season and even within a 24-hour period. Allowance should be made for seasonal or daily fluctuations, for drought conditions, for possibility of interruption by flood, or for ice conditions in winter. Testing of water supplies also normally used for industrial use should be done while water is being drawn for industrial use. The range of industrial-use demand should be taken into account. In special situations where the domestic water demand could significantly reduce the sprinkler water supply, an increase in the size of the pipe supplying both the domestic and sprinkler water can be justified.

Future changes in water supplies should be considered. For example, a large, established, urban supply is not likely to change greatly within a few years. However, the supply in a growing suburban industrial park might deteriorate quite rapidly as greater numbers of plants draw more water.

Dead-end mains should be avoided, if possible, by arranging for mains supplied from both directions. When private fire service mains are connected to dead-end public mains, each situation should be examined to determine if it is practical to request the water utility to loop the mains in order to obtain a more reliable supply.

Testing of Water Supply. To determine the value of public water as a supply for automatic sprinkler systems, it is generally necessary to make a flow test to determine how much water can be discharged at a residual pressure at a rate sufficient to give the required residual pressure under the roof (with the volume flow hydraulically translated to the base of the riser) — that is, a pressure head represented by the height of the building plus the required residual pressure.

The proper method of conducting this test is to use two hydrants in the vicinity of the property. The static pressure should be measured on the hydrant in front of or nearest to the property and the water allowed to flow from the hydrant next nearest the property, preferably the one farthest from the source of supply if the main is fed only one way. The residual pressure will be that indicated at the hydrant where water is not flowing.

Referring to Figure A-9-2.1, the method of conducting the flow tests is as follows:

(1) Attach the gauge to the hydrant *(A)* and obtain static pressure.

(2) Either attach a second gauge to the hydrant *(B)* or use the pitot tube at the outlet. Have hydrant *(B)* opened wide and read pressure at both hydrants.

(3) Use the pressure at *(B)* to compute the gallons flowing and read the gauge on *(A)* to determine the residual pressure or that which will be available on the top line of sprinklers in the property.

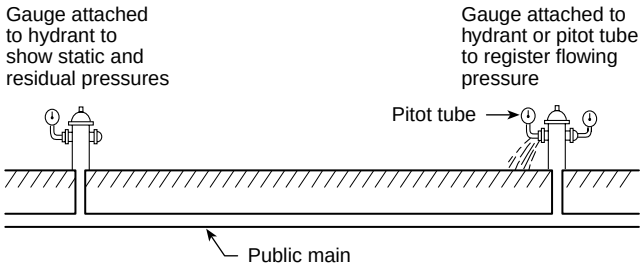
Water pressure in psi for a given height in feet equals height multiplied by 0.434.

In making flow tests, whether from hydrants or from nozzles attached to hose, always measure the size of the orifice. While hydrant outlets are usually $2^1/_2$ in. (64 mm), they are sometimes smaller and occasionally larger. The Underwriters Laboratories play pipe is $1^1/_8$ in. (29 mm) and $1^3/_4$ in. (44 mm) with the tip removed, but occasionally nozzles will be 1 in. (25.4 mm) or $1^1/_4$ in. (33 mm), and with the tip removed the opening can be only $1^1/_2$ in. (38 mm).

The pitot tube should be held approximately one-half the diameter of the hydrant or nozzle opening away from the opening. It should be held in the center of the stream, except that in using hydrant outlets the stream should be explored to ascertain the average pressure.

For further information on water supply testing, see NFPA 291, *Recommended Practice for Fire Flow Testing and Marking of Hydrants.*

Figure A-9-2.1 Method of conducting flow tests.



A-9-2.2 An automatically controlled vertical turbine pump taking suction from a reservoir, pond, lake, river, or well complies with 9-2.2.

See sections dealing with sprinkler equipment supervisory and waterflow alarm services in NFPA 72, *National Fire Alarm Code.*

A-9-2.3.3 For pipe schedule systems, the air pressure to be carried and the proper proportion of air in the tank can be determined from the following formulas where:

P = air pressure carried in pressure tank
A = proportion of air in tank
H = height of highest sprinkler above tank bottom

When the tank is placed above the highest sprinkler, use the following formula:

$$P = \frac{30}{A} - 15$$

If $A = {}^1/_3$, then $P = 90 - 15 = 75$ lb psi
If $A = {}^1/_2$, then $P = 60 - 15 = 45$ lb psi
If $A = {}^2/_3$, then $P = 45 - 15 = 30$ lb psi

When the tank is below the level of the highest sprinkler, use the following formula:

$$P = \frac{30}{A} - 15 + \frac{0.434H}{A}$$

If $A = {}^1/_3$, then $P = 75 + 1.30H$
If $A = {}^1/_2$, then $P = 45 + 0.87H$
If $A = {}^2/_3$, then $P = 30 + 0.65H$

The respective air pressures above are calculated to ensure that the last water will leave the tank at a pressure of 15 psi (1 bar) when the base of the tank is on a level with the highest sprinkler or at such additional pressure as is equivalent to a head corresponding to the distance between the base of the tank and the highest sprinkler when the latter is above the tank.

For hydraulically calculated systems, the following formula should be used to determine the tank pressure and ratio of air to water:

$$P_i = \frac{P_f + 15}{A} - 15$$

where:

P_i = tank pressure
P_f = pressure required from hydraulic calculations
A = proportion of air

Example: Hydraulic calculations indicate 75 psi (5.2 bar) is required to supply the system. What tank pressure will be required?

$$P_i = \frac{75 + 15}{0.5} - 15$$

$$P_i = 180 - 15 = 165 \text{ psi}$$

For SI units, 1 ft = 0.3048 m; 1 psi = 0.0689 bar.

In this case, the tank would be filled with 50 percent air and 50 percent water, and the tank pressure would be 165 psi (11.4 bar). If the pressure is too high, the amount of air carried in the tank will have to be increased.

Pressure tanks should be located above the top level of sprinklers but can be located in the basement or elsewhere.

A-10-2.1 Underground mains and lead-in connections to system risers should be flushed through hydrants at dead ends of the system or through accessible aboveground flushing outlets allowing the water to run until clear. Figure A-10-2.1 shows acceptable examples of flushing the system. If water is supplied from more than one source or from a looped system, divisional valves should be closed to produce a high-velocity flow through each single line. The flows specified in Table 10-2.1(2) will produce a velocity of at least 10 ft/sec (3 m/sec), which is necessary for cleaning the pipe and for lifting foreign material to an aboveground flushing outlet.

A-10-2.2.1 A sprinkler system has for its water supply a connection to a public water service main. A 100-psi (6.9-bar) rated pump is installed in the connection. With a maximum normal public water supply of 70 psi (4.8 bar) at the low elevation point of the individual system or portion of the system being tested and a 120-psi (8.3-bar) pump (churn) pressure, the hydrostatic test pressure is 70 psi + 120 psi + 50 psi or 240 psi (16.5 bar).

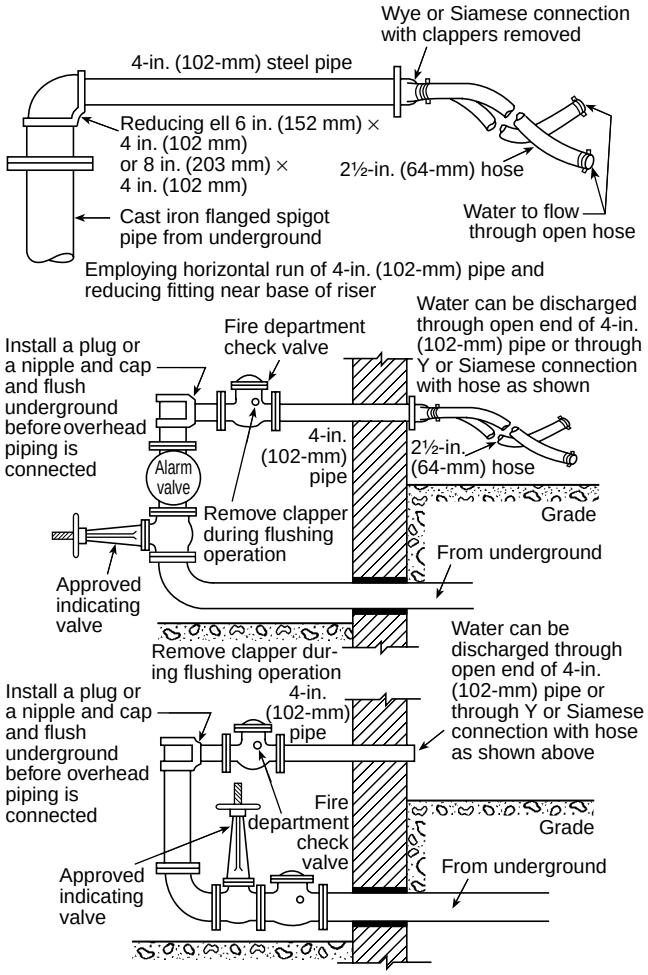
To reduce the possibility of serious water damage in case of a break, pressure can be maintained by a small pump, the main controlling gate meanwhile being kept shut during the test.

Polybutylene pipe will undergo expansion during initial pressurization. In this case, a reduction in gauge pressure might not necessarily indicate a leak. The pressure reduction should not exceed the manufacturer's specifications and listing criteria.

When systems having rigid thermoplastic piping such as CPVC are pressure tested, the sprinkler system should be filled with water. The air should be bled from the highest and farthest sprinklers. Compressed air or compressed gas should never be used to test systems with rigid thermoplastic pipe.

A recommended test procedure is as follows: The water pressure is to be increased in 50-psi (3.4-bar) increments until the test pressure described in 10-2.2.1 is attained. After each increase in pressure, observations are to be made of the stability of the joints. These observations are to include such items as protrusion or extrusion of the gasket, leakage, or other factors likely to affect the continued use of a pipe in service. During the test, the pressure is not to be increased by the next increment until the joint has become stable. This applies particularly to movement of the gasket. After the pressure has been increased to the required maximum value and held for 1 hour, the pressure is to be decreased to 0 psi while observations are made for leakage. The pressure is again to be slowly increased to the value specified in 10-2.2.1 and held for 1 more hour while observations are made for leakage and the leakage measurement is made.

Figure A-10-2.1 Methods of flushing water supply connections.



A-10-2.2.1 Exception No. 6(a). New pipe laid with rubber gasketed joints should, if the workmanship is satisfactory, have no leakage at the joints. Unsatisfactory amounts of leakage usually result from twisted, pinched, or cut gaskets. However, some leakage might result from small amounts of grit or small imperfections in the surfaces of the pipe joints.

A-10-2.2.1 Exception No. 6(b). The use of a blind flange or skillet is preferred for use when hydrostatically testing segments of new work. Metal seated valves are susceptible to developing slight imperfections during transport, installation, and operation and thus can be likely to leak more than 1 fluid ounce (30 ml) per inch of valve diameter per hour. For this reason, the blind flange should be used when hydrostatically testing.

A-10-2.2.5 Hydrostatic tests should be made before the joints are covered so that any leaks can be readily detected. Thrust blocks should be sufficiently hardened before hydrostatic testing is begun. If the joints are covered with backfill prior to testing, the contractor remains responsible for locating and correcting any leakage in excess of that permitted in 10-2.2.1, Exception No. 6.

The pipeline should be prepared 24 hours prior to testing by filling it with water in such a manner as to remove all air. The test pressure should be applied to stabilize the system, which should minimize losses due to entrapped air, changes in water temperature, distention of components under pressure, movement of gaskets, and absorption of air by the water and water by the pipe wall.

A-10-2.2.7 Valves isolating the section to be tested might not be "drop-tight." When such leakage is suspected, test blanks of the type required in 10-2.2.7 should be used in a manner that includes the valve in the section being tested.

A-10-5 See Figure A-10-5.

Figure A-10-5 Sample nameplate.

This system as shown on . . . . . company

print no . . . . . dated . . . . . .

for . . . . . .

at . . . . . contract no . . . . . .

is designed to discharge at a rate of . . . . . gpm/ft^2

(L/min/m^2) of floor area over a maximum area of . . . . . .

ft^2 (m^2) when supplied with water at a rate of . . . . . .

gpm (L/min) at . . . . . psi (bar) at the base of the riser.

Hose stream allowance of . . . . . gpm (L/min)

is included in the above.

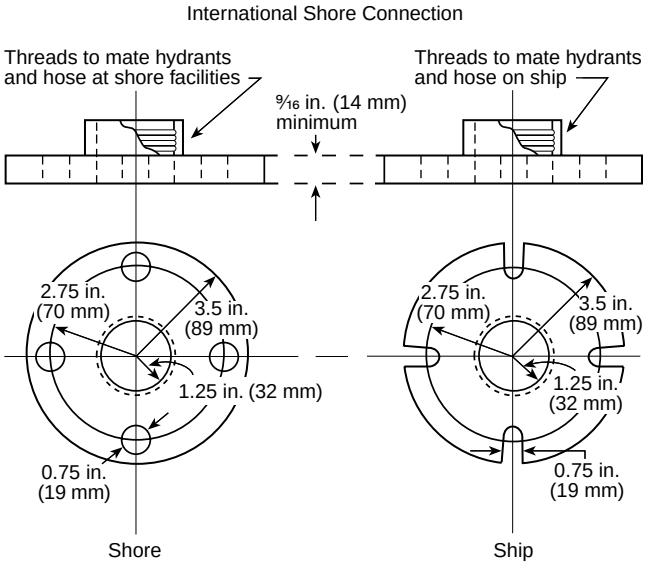
Occupancy classification . . . . . .

Commodity classification . . . . . .

Maximum storage height . . . . . .

A-11-1.1 Heat-Sensitive Material. The backbone of the fire protection philosophy for U.S. flagged vessels and passenger vessels that trade internationally is limiting a fire to the compartment of origin by passive means. Materials that do not withstand a 1-hour fire exposure when tested in accordance with ASTM E 119, *Standard Test Methods for Fire Tests of Building Construction and Materials,* are considered "heat sensitive." *(See Figure A-11-1.1.)*

Figure A-11-1.1 International Shore Fire Connection.



Material: Any suitable for 150 psi (10.3 bar) service (shore)
Flange surface: Flat face
Gasket material: Any suitable for 150 psi (10.3 bar) service
Bolts: Four 5/8-in. (16-mm) minimum diameter, 2-in. (51-mm) long, threaded to within 1 in. (25.4 mm) of bolt head
Nuts: Four, to fit bolts
Washers: Four, to fit bolts

Material: Brass or bronze suitable for 150 psi (10.3 bar) service (ship)

A-11-1.1 Marine System. Some types of sprinkler systems can closely resemble marine systems, such as a system installed on a floating structure that has a permanent water supply connection to a public main. For these types of systems, judgment should be used in determining if certain aspects of Chapter 11 are applicable.

A-11-1.1 Marine Thermal Barrier. A marine thermal barrier is typically referred to as a B-15 boundary.

A-11-1.2 In addition to the examples provided in A-2-1, Table A-11-1.2 provides additional examples of occupancy definitions of typical shipboard spaces.

Table A-11-1.2 Examples of Shipboard Space Occupancy Classification

Occupancy Type	Space Types Included		Examples
	CFR[1]	SOLAS[2]	
Light hazard	1[3], 2, 3, 4, 5, 6, 7, 8[4], 13	1[3], 2, 3, 4, 5, 6, 7, 8, 9	Accommodation spaces Small pantries
Ordinary hazard (Group 1)	8[4], 9[4]	12, 13[4]	Galleys Storage areas Sales shops Laundries Pantries with significant storage
Ordinary hazard (Group 2)	9[4], 11[4]	12[4], 13[4]	Sales shops Storage areas Stages (with sets) Machine shops
Extra hazard (Group 1)	1, 9[4], 10, 11[4]	1, 12[4], 13[4]	Auxiliary machinery — limited combustible liquids[5] Steering rooms — combustible hydraulic fluid in use[5]
Extra hazard (Group 2)	1, 9[4], 10, 11[4]	1, 12[4], 13[4]	Auxiliary machinery — with combustible liquids[5] Machinery spaces[5]

[1]Space type designations are given in 46 CFR 72.05-5.
[2]Space type designations are given in the *International Convention for the Safety of Life at Sea*, 1974 (SOLAS 74), as amended, regulations II-2/3 and II-2/26.
[3]Primarily for accommodation-type control stations, such as the wheel house, which would not include generator rooms or similar-type spaces.
[4]Depends on storage type, quantity, and height and distance below sprinkler.
[5]Automatic sprinklers typically will not be the primary means of protection in these areas; total flooding systems are usually used.

The classifications in Table A-11-1.2 are not meant to be applied without giving consideration to the definition of each occupancy hazard given in the standard. Table A-11-1.2 is general guidance for classification of typical spaces. Where a space is outfitted such that the occupancy definitions indicate that another classification would be more appropriate, the most representative and most demanding occupancy classification should be used. For example, it would certainly be possible to outfit a stateroom to require upgrading the occupancy to ordinary hazard, Group 1.

When a vessel undergoes modifications, alterations, or service changes that significantly affect the fire risk of the occupancy of one or more compartments, the occupancy classification should be reevaluated to determine if it has changed.

A-11-1.3 Experience has shown that structures that are partially sprinklered can be overrun by well-developed fires originating in unsprinklered areas. Therefore, the entire vessel should be sprinklered whenever sprinkler systems are considered.

A-11-2.1 Sprinklers with a nominal K-factor of 2.8 or less coupled with a system strainer minimize the potential for clogging.

A-11-2.2 Where a marine thermal barrier is penetrated, limiting the opening around the sprinkler pipe to $^1/_{16}$ in. (1.6 mm) is considered as meeting this requirement.

A-11-2.4.1 When nonferrous materials are used, consideration should be given to protecting against galvanic corrosion where the non-ferrous materials connect to steel pipe. Consideration should also be given to protection against galvanic corrosion from pipe hangers in areas of high humidity.

The piping between the sea chest and the sprinkler zone valves are likely to see the frequent flow of salt water when testing. Sprinkler zone piping will rarely, if ever, be exposed to salt water. In such an event, NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, requires flushing of the piping. Even if the piping is not flushed, the salt water will not be replenished and will lose oxygen content in fairly short order.

Even if galvanized, the failure from corrosion from the interior of the pipe is likely to be at all threaded connections, welded assembly connections, and where brass sprinklers thread into ferrous pipe. Only hot dipped galvanized after fabrication of assembly (as opposed to simply hot dipped galvanized pipe and fittings) will protect against some of those failures. Hot dipped galvanized after fabrication of assembly is practical from the sea chest to the sprinkler manifold where spaces are open and pipe is relatively large and uses flanged takedown joints instead of threaded unions. Hot dipped galvanized after fabrication of assembly is not practical in the sprinkler zone pipe where it is mainly field fit.

A-11-2.5.1 When designing supports, the selection and spacing of pipe supports should take into account the pipe dimensions, mechanical and physical properties of piping materials and supports, operating temperature, thermal expansion effects, external loads, thrust forces, vibration, maximum accelerations, differential motions to which the system might be subjected, and the type of support.

The route of the vessel is intended to be descriptive of its usual operating area. For example, expected motion of the system on an ocean vessel is expected to be considerably greater than the motion of a vessel that operates on a river. A vessel that operates within the confines of any of the Great Lakes is expected to subject the system pipe to greater motion than would a vessel that operates on a lake such as Lake Tahoe.

It is recommended that the designer review the requirements for automatic sprinkler systems that are subject to earthquakes. While it is obvious that shipboard motions and accelerations differ from those that occur during an earthquake, the general principle of protecting the piping system against damage applies. Individual hanger design, however, will be very similar. *(See Section 6-4.)*

Earthquake protection does not apply to ships; however, motions are similar to those that a ship will experience in a seaway. The design principles discussed in this section should be used as a guide for shipboard system design. See 6-1.1.

A-11-2.5.3 Use of heat-sensitive materials for pipe hangers and supports might be desirable in some cases. Where heat-sensitive materials are used, the hangers and supports should be adequately protected by either the direct application of insulation or installation behind a marine thermal barrier. Insulation materials applied directly to hangers should be insulated in accordance with the method provided in Society of Naval Architects and Marine Engineers Technical Research Bulletin 2-21, "Aluminum Fire Protection Guidelines."

A-11-2.5.4 Consideration should be given to increasing the size of rods and U-hooks as necessary, to account for service and operational loading, including ship motion and vibrations.

A-11-2.6.1 Shipboard installations will normally require more than one valve per water supply. Locking valves in the open position is not an acceptable substitute for the requirement of 11-2.6.1 but can be done in addition to the supervision requirement.

A-11-2.7.1 International Shore Connections are portable universal couplings that permit connections of shipboard sprinkler or firemain systems between one ship and another or between a shore facility and a ship. Both the ship and the shore facility are expected to have an International Shore Connection fitting such that in an emergency they can be attached to their respective fire hoses and bolted together to permit charging the ship's system. It must be portable to accommodate hose-to-hose connection and allow assistance from any position.

Installation of an additional fire boat connection might be required on-board vessels whose route is such that regular access to fire boats is possible. An additional fire boat connection might not be necessary where fire boats are equipped to connect to the regular fire department connection. *(See A-11-2.7.3).*

A-11-2.7.3 Selection of the pipe thread for the fire department connection should be done very carefully. It is recommended that a $2^1/_2$-in. (63.5-mm) siamese connection with National Standard Hose Thread be used since a majority of fire department hose lines will be compatible with this thread. However, it must be noted that some fire jurisdictions might not be compatible with a connection of this type. Serious consideration should be given to the vessel's typical operating area. Precautions and planning should avert the possibility of the vessel being forced ashore by fire at a location where the fire department equipment is not compatible with this connection. Carriage of extra fittings and pre-voyage arrangements with all applicable jurisdictions should be considered. The International Shore Connection is required to ensure that all vessels fitted with sprinkler systems have at least one type of common connection.

A-11-3.1 Special consideration should be given to the installation of relief valves in all wet pipe systems. Ambient ship temperatures can vary greatly depending on operating environment, duration of voyage, and failure of climate control systems.

A-11-4.2 Areas fitted primarily with multiple staterooms and corridors should be considered sleeping accommodation areas.

A-11-4.4 If combustibles are present such that they constitute a threat, the space should be sprinklered. One example would be the presence of large bundles of unsheathed computer or electrical cable. Typical amounts of lighting or control cabling should not be considered to constitute a fire threat.

A-11-4.10.1 Exception to (3). Because of its melting point, brazing would be considered heat sensitive. The criteria of this paragraph is intended to permit brazed joints without requiring that they be installed behind a marine thermal barrier, while maintaining the fire endurance performance as stated in 11-4.10.1 under reasonably foreseeable failure modes.

A-11-4.12.1 While not required, a dual annunciator alarm panel system is recommended. One panel should show the piping system layout and indicate status of zone valves, tank pressures, water supply valves, pump operation, and so forth. The second panel should show the vessel's general arrangement and indicate status of waterflow (i.e., fire location) alarms.

A-11-5.2 For example, a design area of 1500 ft^2 (139.3 m^2) is used to design a sprinkler system for an unobstructed light hazard occupancy. In this case, the system must supply at least seven sprinklers that are installed within that area. If eight sprinklers are installed to protect windows within this design area, the water demand of these sprinklers is added to the total water demand. Thus, 15 sprinklers must be supplied by this system.

A-11-5.3 Hose stream flow need not be added to the water demand. The water supply for fire streams is supplied by separate fire pump(s) that supply the vessel's fire main.

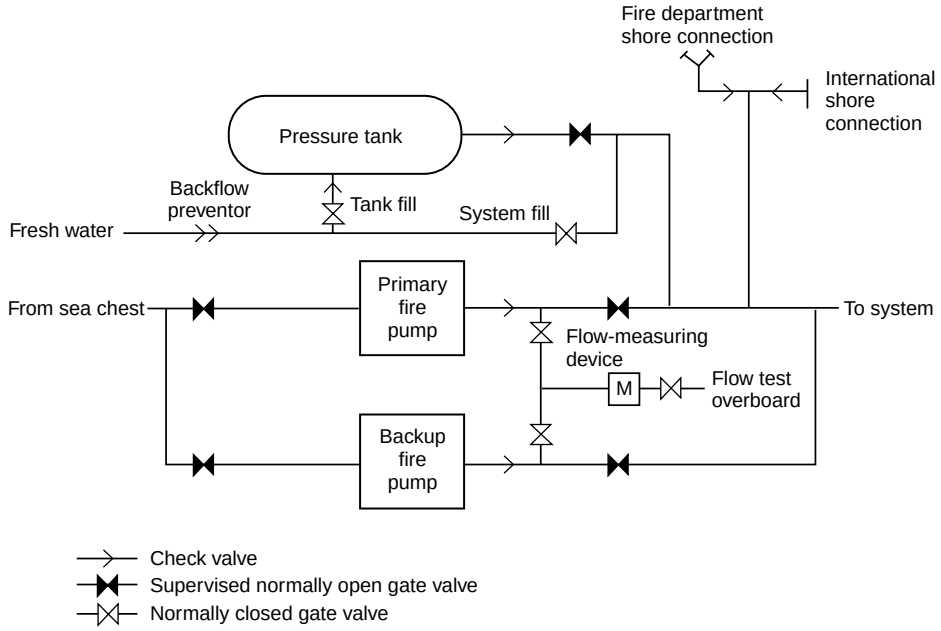
A-11-6.3 In vessels, the elevation of sprinklers with respect to the water supply varies as the vessel heels to either side or trims by the bow or stern. The water demand requirements can be increased or decreased under these conditions. This requirement aligns the operational parameters of this safety system with that required for other machinery vital to the safety of the vessel.

A-11-7.2.6 The purpose of this is to ensure that the pressure tank air supply will not keep the tank "fully" pressurized while water is expelled, thus preventing pump actuation.

A-11-7.3.2 NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, requires that fire pumps furnish not less than 150 percent of their rated capacity at not less than 65 percent of their rated heat. The intention of the requirement of 11-7.3.2 is to limit designers to 120 percent of the rated capacity of the pump to provide an additional factor of safety for marine systems.

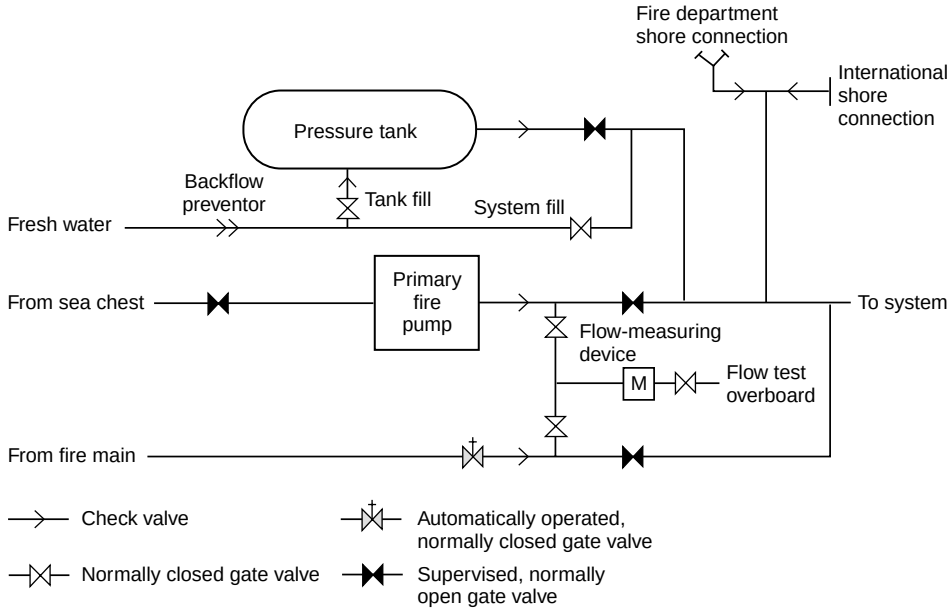
A-11-7.3.6(a) Pumps should not be located within the same compartment. However, where this is not reasonable or practical, special attention should be given to protecting pumps such that a single failure will not render the sprinkler system inoperative. *[See Figure A-11-7.3.6(a).]*

Figure A-11-7.3.6(a) Abbreviated example of a dual fire pump water supply.



A-11-7.3.7 See Figure A-11-7.3.7.

Figure A-11-7.3.7 Abbreviated example of a water supply with fire pump backup.



A-11-7.4.6 This procedure should be used to qualify each water supply to which the vessel is to be attached. For example, this might require testing of multiple hydrants or connections in the same mooring area. The pressure loss effect of the hose or piping leading from the water supply to the ship should also be considered when qualifying each hydrant.

A-12-1 *Impairments.* Before shutting off a section of the fire service system to make sprinkler system connections, notify the authority having jurisdiction, plan the work carefully, and assemble all materials to enable completion in the shortest possible time. Work started on connections should be completed without interruption, and protection should be restored as promptly as possible. During the impairment, provide emergency hose lines and extinguishers and maintain extra watch service in the areas affected.

When changes involve shutting off water from any considerable number of sprinklers for more than a few hours, temporary water supply connections should be made to sprinkler systems so that reasonable protection can be maintained. In adding to old systems or revamping them, protection should be restored each night so far as possible. The members of the private fire brigade as well as public fire departments should be notified as to conditions.

Maintenance Schedule. The items shown in Table A-12-1 should be checked on a routine basis.

Table A-12-1 Maintenance Schedule

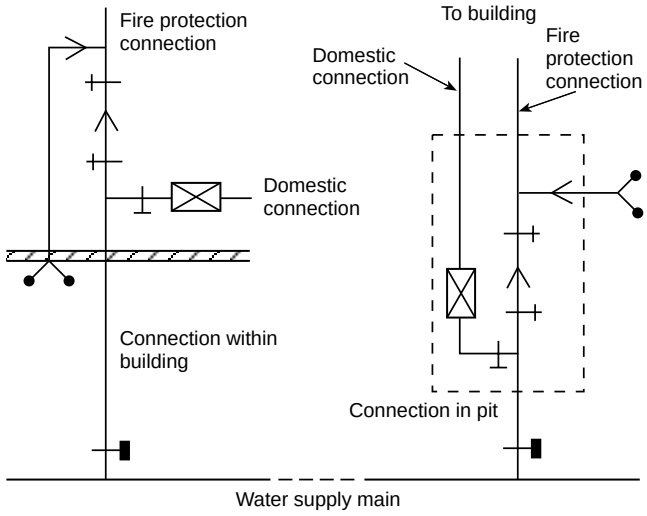
Parts	Activity	Frequency
Flushing piping	Test	5 years
Fire department connections	Inspection	Monthly
Control valves	Inspection	Weekly — sealed
	Inspection	Monthly — locked
	Inspection	Monthly — tamper switch
	Maintenance	Yearly
Main drain	Flow test	Quarterly — Annual
Open sprinklers	Test	Annual
Pressure gauge	Calibration test	
Sprinklers	Test	50 years
Sprinklers — high temperature	Test	5 years
Sprinklers — residential	Test	20 years
Waterflow alarms	Test	Quarterly
Preaction/deluge detection system	Test	Semiannually
Preaction/deluge systems	Test	Annually
Antifreeze solution	Test	Annually
Cold weather valves	Open and close valves	Fall, close; spring, open
Dry/preaction/deluge systems		
Air pressure and water pressure	Inspection	Weekly
Enclosure	Inspection	Daily — cold weather
Priming water level	Inspection	Quarterly
Low-point drains	Test	Fall
Dry pipe valves	Trip test	Annual — spring
Dry pipe valves	Full flow trip	3 years — spring
Quick-opening devices	Test	Semiannually

Appendix B Miscellaneous Topics

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

B-1 Figure B-1 shows acceptable methods for interconnection of the fire protection and domestic water supply.

Figure B-1 Permitted arrangements between the fire protection water supply and the domestic water supply.



B-2 Sprinkler System Performance Criteria.

B-2.1 Sprinkler system performance criteria have been based on test data. The factors of safety are generally small, are not definitive, and can depend on expected (but not guaranteed) inherent characteristics of the sprinkler systems involved. These inherent factors of safety consist of the following:

(1) The flow-declining pressure characteristic of sprinkler systems whereby the initial operating sprinklers discharge at a higher flow than with all sprinklers operating within the designated area.
(2) The flow-declining pressure characteristic of water supplies, which is particularly steep where fire pumps are the water source. This characteristic similarly produces higher than design discharge at the initially operating sprinklers.

The user of these standards can elect an additional factor of safety if the inherent factors are not considered adequate.

B-2.1.1 Performance-specified sprinkler systems, as opposed to scheduled systems, can be designed to take advantage of multiple loops or gridded configurations. Such configurations result in minimum line losses at expanded sprinkler spacing, in contrast to the older tree-type configurations, where advantage cannot be taken of multiple path flows.

Where the water supply characteristics are relatively flat with pressures being only slightly above the required sprinkler pressure at the spacing selected, gridded systems with piping designed for minimal economic line losses can all but eliminate the inherent flow-declining pressure characteristic generally assumed to exist in sprinkler systems. In contrast, the economic design of a tree-type system would likely favor a system design with closer sprinkler spacing and greater line losses, demonstrating the inherent flow-declining pressure characteristic of the piping system.

Elements that enter into the design of sprinkler systems include the following:

(1) Selection of density and area of application
(2) Geometry of the area of application (remote area)
(3) Permitted pressure range at sprinklers
(4) Determination of the water supply available
(5) Ability to predict expected performance from calculated performance
(6) Future upgrading of system performance
(7) Size of sprinkler systems

In developing sprinkler specifications, each of these elements needs to be considered individually. The most conservative design should be based on the application of the most stringent conditions for each of the elements.

B-2.1.2 Selection of Density and Area of Application. Specifications for density and area of application are developed from NFPA standards and other standards. It is desirable to specify densities rounded upward to the nearest 0.005 gpm/ft^2 (0.2 mm/min).

Prudent design should consider reasonable-to-expect variations in occupancy. This design would include not only variations in type of occupancy, but also, in the case of warehousing, the anticipated future range of materials to be stored, clearances, types of arrays, packaging, pile height, and pile stability, as well as other factors.

Design should also consider some degree of adversity at the time of a fire. To take this into account, the density and/or area of application can be increased. Another way is to use a dual-performance specification where, in addition to the normal primary specifications, a secondary density and area of application is specified. The objective of such a selection is to control the declining pressure-flow characteristic of the sprinkler system beyond the primary design flow.

A case can be made for designing feed and cross mains to lower velocities than branch lines to achieve the same result as specifying a second density and area of application.

B-2.1.3 Geometry of the Area of Application (Remote Area). It is expected that, over any portion of the sprinkler system equivalent in size to the area of application, the system will achieve the minimum specified density for each sprinkler within that area.

Where a system is computer-designed, ideally the program should verify the entire system by shifting the area of application the equivalent of one sprinkler at a time so as to cover all portions of the system. Such a complete computer verification of performance of the system is most desirable, but unfortunately not all available computer verification programs currently do this.

This selection of the proper Hazen-Williams coefficient is important. New unlined steel pipe has a Hazen-Williams coefficient close to 140. However, it quickly deteriorates to 130 and, after a few years of use, to 120. Hence, the basis for normal design is a Hazen-Williams coefficient of 120 for steel-piped wet systems. A Hazen-Williams coefficient of 100 is generally used for dry pipe systems because of the increased tendency for deposits and corrosion in these systems. However, it should be realized that a new system will have fewer line losses than calculated, and the distribution pattern will be affected accordingly.

Conservatism can also be built into systems by intentionally designing to a lower Hazen-Williams coefficient than that indicated.

B-2.1.4 Ability to Predict Expected Performance from Calculated Performance. Ability to accurately predict the performance of a complex array of sprinklers on piping is basically a function of the pipe line velocity. The greater the velocity, the greater is the impact on difficult-to-assess pressure losses. These pressure losses are presently determined by empirical means that lose validity as velocities increase. This is especially true for fittings with unequal and more than two flowing ports.

The inclusion of velocity pressures in hydraulic calculations improves the predictability of the actual sprinkler system performance. Calculations should come as close as practicable to predicting actual performance. Conservatism in design should be arrived at intentionally by known and deliberate means. It should not be left to chance.

B-2.1.5 Future Upgrading of System Performance. It is desirable in some cases to build into the system the capability to achieve a higher level of sprinkler performance than needed at present. If this is to be a consideration in conservatism, consideration needs to be given to maintaining sprinkler operating pressures on the lower side of the optimum operating range and/or designing for low pipe line velocities, particularly on feed and cross mains, to facilitate future reinforcement.

Appendix C Explanation of Test Data and Procedures for Rack Storage

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

Appendix C provides an explanation of the test data and procedures that led to the development of sprinkler system discharge criteria for rack storage applications. The paragraphs are identified by the same number as the text in this standard to which they apply.

C-2-2 A review of full-scale fire tests run on the standard commodity (double tri-wall carton with metal liner), of Hallmark products and 3M 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. Such guidance 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.

C-5-12.3.1 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.

C-5-15.1.8 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.

C-5-15.5.1 In most tests conducted, it was necessary to use small hose for mop-up operations. Small hose 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.

C-7-2.3.1.1 Table. 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.

C-7-4 The discharge criteria of Section 7-4 uses as a basis the large-scale fire test series conducted at the Factory Mutual Research Center, West Gloucester, 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 that is 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, which 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 (2.4 m) on center for conventional racks and 4 ft (1.2 m) on center 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 (1.2-m) aisle tests. Conventional racks and conventional pallets were used in the main central rack in the 8-ft (2.4-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 (e.g., water damage).

Table C-7-4 illustrates these points. The information shown in the table is taken from the test series for storage height of 20 ft (6.1 m) using the standard commodity.

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 mm/min) 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 (18.3-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, which minimized the effect of exterior wind conditions.

The purpose of the tests for storage height over 25 ft (7.6 m) was to accomplish the following:

(1) Determine the arrangement of in-rack sprinklers that can be repeated as pile height increases and that provide control of the fire
(2) 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 failed to exhibit the following characteristics:

(1) Jump the 4-ft (1.2-m) aisles to adjoining racks
(2) 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 tests for storage over 25 ft (7.6 m). Hallmark products and 3M products described in the 20-ft (6.1-m) test series report also were used as representative of Class III or Class 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 tests for storage over 25 ft (7.6 m). 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.

Table C-7-4 Summary of Relationship Between Sprinkler Discharge Density and the Extent of Fire Damage and Sprinkler Operation

Density gpm/ft^2		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 mm/min.

C-7-4.1.3.1 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.

C-7-4.1.4.1 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. (0.3 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.

C-7-4.1.7.1 A full-scale test program was conducted with various double-row rack storage arrangements of a cartoned Group A unexpanded plastic commodity at the Factory Mutual Research Corporation (FMRC) test facility. The series of nine tests included several variations, one of which involved the use of the following four distinct shelving arrangements: slatted wood, solid wood, wire mesh, and no shelving. The results of the testing program, specifically Tests 1, 2, 3, and 5, clearly demonstrate the acceptable performance of sprinkler systems protecting storage configurations that involve the use of slated shelving as described in 5-10.1. As a result of the test program, Factory Mutual has amended FM Loss Prevention Data Sheet 8-9 to allow slatted shelving to be protected in the same manner as an open rack arrangement.

Complete details of the test program are documented in the FMRC technical report FMRC J. I. 0X1R0.RR, "Large-Scale Fire Tests of Rack Storage Group A Plastics in Retail Operation Scenarios Protected by Extra Large Orifice (ELO) Sprinklers."

C-7-4.1.7.2 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 (12.2 mm/min) 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 (15.3 mm/min), and rack sprinklers discharged at 15 psi (1 bar).

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 (18.3 mm/min) 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 (7.3 m) on center or 22 ft (6.7 m) on each side of the ignition flue. Ceiling sprinkler discharge density was 0.375 gpm/ft^2 (15.3 mm/min). In-rack sprinkler discharge pressure was 30 psi (2.1 bar). A total of 46 ceiling sprinklers and three 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.

C-7-4.1.8 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.

C-7-4.2.1.1.1 In one 20-ft (6.1-m) high test, sprinklers were buried in the flue space 1 ft (0.3 m) above the bottom of the pallet load, and 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.

C-7-4.2.1.2.2 In all tests with in-rack sprinklers, obstructions measuring 3 in. × 3 ft (7.62 mm × 0.3 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.

C-7-4.2.1.3 Operating pressures were 15 psi (1 bar) on all tests of sprinklers in racks with storage 20 ft (6.1 m) high and 30 psi (2.1 bar) 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 (2.1 bar to 5.2 bar). 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 (1 bar) 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 (2.1 bar), except in Test 124, where it was 75 psi (5.2 bar).

C-7-4.2.1.4 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.

C-7-4.2.1.6 Test 107, a multiple-row rack test conducted with pallet loads butted against each other, was 12 rows long. Each row was four boxes deep. With 0.45 gpm/ft^2 (18.3 mm/min) 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.

C-7-4.2.2 Most tests for storage heights of 25 ft (7.6 m) and under 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 7-4.2.2.1.1(a) through (g) reflect this condition.

Tests 140 and 141 were conducted with a 3-ft (0.9-m) clearance between the top of storage and the ceiling sprinkler deflectors. In Test 140, using a density of 0.3 gpm/ft^2 (12.2 mm/min), 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. Firespread 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 a density of 0.3 gpm/ft^2 (12.2 mm/min). Thirty-seven sprinklers operated compared with 36 sprinklers in Test 140 with a 3-ft (0.9-m) clearance and 45 and 48 sprinklers in Tests 65 and 76 with a 10-ft (3.1-m) clearance. Firespread 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 (0.9-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 (0.9-m) clearance, and 10 sprinklers operating with an 18-in. (0.46-m) clearance. Firespread was less in the test with the 18-in. (0.46-m) clearance than the 3-ft (0.9-m) clearance and also was less with the 3-ft (0.9-m) clearance than with the 10-ft (3.1-m) clearance.

C-7-4.2.2.1.1 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 high temperature–rated sprinklers as compared with ordinary temperature–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 high-temperature curves above 3600 ft^2 (334.6 m^2) of application, therefore, represent 40 percent reductions in area of application of the ordinary-temperature 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 intermediate temperature–rated sprinklers operating is essentially the same as ordinary temperature–rated sprinklers.

C-7-4.2.2.1.9 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-mm to 6-mm thick polyethylene film stapled in place at the bottom. Test 77, at a density of 0.3 gpm/ft^2 (12.2 mm/min), with ceiling sprinklers only, went beyond the parameters for validity. Subsequent privately sponsored tests indicated control at a density of 0.45 gpm/ft^2 (18.3 mm/min). 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 (18.3 mm/min), 40 sprinklers operated. Firespread was slightly greater than in Test 65 with 0.3 gpm/ft^2 (12.2 mm/min) 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 0.9 m) with 0.45 gpm/ft^2 (18.3 mm/min) density, 11 sprinklers operated. Firespread 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. (SPI) tests. Both SPI Tests 1 and 2 are considered valid and indicate that Classes I and II commodities can be protected by ceiling sprinklers only, using densities as indicated in design curves. Tests 1 and 2 also compare the results of a 3-ft (0.9-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 (0.9-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 (0.9 m). With 0.3 gpm/ft^2 (12.2 mm/min) density, 36 sprinklers operated, and with 0.2 gpm/ft^2 (8.2 mm/min) density, 89 sprinklers operated. Firespread 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.

C-7-4.2.2.2.2 Tests were not conducted with aisles wider than 8 ft (2.4 m) or narrower than 4 ft (1.2 m). It is, therefore, not possible to determine whether lower ceiling densities should be used for aisle widths greater than 8 ft (2.4 m) or if higher densities should be used for aisle widths less than 4 ft (1.2 m).

C-7-4.3.2.1 The recommended use of ordinary temperature–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 high temperature–rated sprinklers and 0.45 gpm/ft^2 (18.3 mm/min) 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 (18.3 mm/min) density and ordinary temperature–rated sprinklers produced a dramatic reduction in fire damage with four ceiling sprinklers operating.

The four ordinary temperature–rated ceiling sprinklers operated before the first of the three high temperature–rated ceiling sprinklers. In both tests, two in-rack sprinklers at two levels operated at approximately the same time. The high temperature–rated sprinklers were at all times fighting a larger fire with less water than the ordinary temperature–rated ceiling sprinklers.

Tests 115 and 119 compare ceiling sprinkler density of 0.3 gpm/ft^2 (12.2 mm/min) with 0.45 gpm/ft^2 (18.3 mm/min). 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 ceiling sprinkler temperature ratings of 286°F (141°C) and 165°F (74°C). A review of the number of boxes damaged and the firespread patterns indicates that the use of ordinary temperature–rated ceiling sprinklers on a rack configuration that incorporates in-rack sprinklers dramatically reduces the amount of firespread. Considering that in-rack sprinklers in the tests for storage over 25 ft (7.6 m) 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.

The results of these tests 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.

C-7-4.4.1.1 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 0.6 gpm/ft^2 (24.5 mm/min) density, 8-ft (2.4-m) aisles, and a 10-ft (3.1-m) ceiling clearance, 29 sprinklers opened. In Tests RSP-4 with polystyrene 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 (2.4-m) aisles, and 0.6 gpm/ft^2 (24.5 mm/min) density, only four sprinklers opened.

However, Test RSP-11, with expanded polystyrene plates and 6-ft (1.8-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 (2.4-m) aisles, but protected only by 0.45 gpm/ft^2 (18.3 mm/min) 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 (2.4-m) aisles, a 3-ft (0.9-m) ceiling clearance, and a 0.6 gpm/ft^2 (24.5 mm/min) density opened four 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 (0.9-m) ceiling clearance, 8-ft (2.4-m) aisles, and 0.6 gpm/ft^2 (24.5 mm/min) ceiling sprinkler density in combination with one level of in-rack sprinklers, resulted in four ceiling sprinklers and two in-rack sprinklers operating. Test RSP-9, with the same configuration but with polystyrene plates, opened 12 ceiling sprinklers and three 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.

C-7-4.4.1.4 All tests in the RSP series were conducted utilizing ordinary temperature–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.

C-7-4.4.2.3 Notes 1 and 2 to Figure 7-4.4.2.3(c) and Note 1 to Figure 7-4.4.2.3(d). The protection of Group A plastics by extra-large-orifice (ELO) sprinklers designed to provided 0.6 gpm/ft^2/2000 ft^2 (24.5 mm/min/186 m^2) or 0.45 gpm/ft^2/2000 ft^2 (18.3 mm/min/186 m^2) without the installation of in-rack sprinklers was developed from full-scale testing conducted with various double-row rack storage arrangements of a cartoned Group A unexpanded plastic commodity at the Factory Mutual Research Corporation (FMRC) test facility. The results of this test program are documented in the FMRC technical report, FMRC J.I. 0X1R0.RR, "Large Scale Fire Tests of Rack Stored Group A Plastics in Retail Operation Scenarios Protected by Extra Large Orifice (ELO) Sprinklers." The test program was initiated to address the fire protection issues presented by warehouse-type retail stores with regard to the display and storage of Group A plastic commodities including, but not limited to, acrylonitrile-butadiene-styrene copolymer (ABS) piping, polyvinyl chloride (PVC) hose and hose racks, tool boxes, polypropylene trash and storage containers, and patio furniture. Tests 1 and 2 of this series included protection of the Group A plastic commodity stored to 20 ft (6.1 m) under a 27-ft (8.2-m) ceiling by a design density of 0.6 gpm/ft^2 (24.5 mm/min) utilizing ELO sprinklers. The results of the testing program clearly demonstrate the acceptable performance of sprinkler systems that protect storage configurations involving Group A plastics up to 20 ft (6.1 m) in height under a 27-ft (8.2-m) ceiling where using ELO sprinklers to deliver a design density of 0.6 gpm/ft^2 (24.5 mm/min) and Group A plastics up to 14 ft (4.3 m) in height under a 22-ft (6.7-m) ceiling where using ELO sprinklers to deliver a design density of 0.45 gpm/ft^2 (18.3 mm/min). The tabulation of the pertinent tests shown in Table C-7-4.4.2.3 demonstrates acceptable performance.

Table C-7-4.4.2.3 Summary of Test Results for Plastic Commodities Using $^5/_8$-in. (15.9-mm) Orifice Sprinklers

Test Parameters	Date of Test						
	8/20/93	8/25/93	9/2/93	10/7/93	2/17/94	2/25/94	4/27/94
Type of shelving	Slatted wood	Slatted wood	Slatted wood	Slatted wood	Slatted wood	Slatted wood	Wire mesh
Other conditions/inclusions	—	—	—	—	Draft curtains	Draft curtains	—
Storage height (ft-in.)	19-11	19-11	15-4	15-4	19-11	19-11	13-11
Number of tiers	6[a]	6[a]	5[b]	5[b]	6[a]	6[b]	3
Clearance to ceiling/sprinklers (ft-in.)	6-10/6-3	6-10/6-3	11-5/10-10	11-5/10-10	6-10/6-3	6-10/6-3	8-4/7-9
Longitudinal/transverse flues (in.)	6/6 to $7^1/_2$	6/6 to $7^1/_2$	6/6 to 7	6/6 to $7^1/_2$	6/6 to $7^1/_2$	6/6 to $7^1/_2$	6/3[c]
Aisle width (ft)	$7^1/_2$	$7^1/_2$	$7^1/_2$	$7^1/_2$	$7^1/_2$	$7^1/_2$	$7^1/_2$
Ignition centered below (number of sprinklers)	2	2	1	1	2	2	1
Sprinkler orifice size (in.)	0.64	0.64	0.64	0.64	0.64	0.64	0.64
Sprinkler temperature rating (°F)	165	286	286	165	165	286	286
Sprinkler RTI (ft-sec)$^{1/2}$	300	300	300	300	300	300	300
Sprinkler spacing (ft × ft)	8 × 10	8 × 10	8 × 10	8 × 10	8 × 10	8 × 10	10 × 10
Sprinkler identification	ELO-231	ELO-231	ELO-231	ELO-231	ELO-231	ELO-231	ELO-231
Constant water pressure (psi)	19	19	19	19	19	19	15.5
Minimum density (gpm/ft^2)	0.6	0.6	0.6	0.6	0.6	0.6	0.45
Test Results							
First sprinkler operation (min:sec)	2:03	2:25	1:12	0:44	1:25	0:52	0:49
Last sprinkler operation (min:sec)	2:12	15:19	6:34	7:34	15:54	14:08	10:58
Total sprinklers opened	4	9	7	13	35	18	12
Total sprinkler discharge (gpm)	205	450	363	613	1651	945	600
Average discharge per sprinkler (gpm)	51	50	52	47	47	52	50
Peak/maximum 1-min average gas temperature (°F)	1107/566	1412/868	965/308	662/184	1575/883	1162/767	1464/895
Peak/maximum 1-min average steel temperature (°F)	185/172	197/196	233/232	146/145	226/225	255/254	502/500
Peak/maximum 1-min average plume velocity (ft/sec)	27/15	25/18	18/15[d]	14/10[d]	26/23	20/18[d]	33/20
Peak/maximum 1-min heat flux (Btu/ft^2/sec)	0.6/0.5	2.0/1.9	2.8/2.5	1.1/0.8	1.0/0.9	4.8/3.0	1.6/1.4
Aisle jump, east/west target ignition (min:sec)	None	8:24/None	5:35/10:10	None	None	[e]/8:18	[e]/None
Equivalent number of pallet loads consumed	3	9	6	5	12	13	12
Test duration (min)	30	30	30	30	30	30	30
Results acceptable	Yes	Yes	Yes	Yes	No[f]	No[g]	Yes

For SI units, 1 ft = 0.305 m; 1 in. = 25.4 mm; °F = (1.8 × °C) +32; °C = (°F − 32)/1.8; 1 psi = 0.069 bar; 1 gpm = 3.8 L/min; 1 ft/sec = 0.31 m/sec; 1 gpm/ft^2 = 40.746 mm/min.

[a]Main (ignition) racks divided into five or six tiers; bottom tiers each approximately 2 ft (0.6 m) high and upper tiers each about 5 ft (1.5 m) high; wood shelving below commodity at second through fifth tiers.

[b]Main (ignition) racks divided into five or six tiers; bottom tiers each approximately 2 ft (0.6 m) high and upper tiers each about 5 ft (1.5 m) high; wood shelving below commodity at second through fifth tiers; wire mesh shelving below commodity at sixth tier or below fifth (top) tier commodity.

[c]Transverse flues spaced 8 ft (2.4 m) apart [versus $3^1/_2$ ft (1.1 m) apart in all other tests].

[d]Instrumentation located 5 ft (1.5 m) north of ignition.

[e]Minor surface damage to cartons.

[f]High water demand.

[g]Excessive firespread; marginally high water demand.

C-7-5.2.3 No tests were conducted with idle pallets in racks using standard spray sprinklers. However, tests were conducted using ESFR and large drop sprinklers. Such storage conceivably would introduce fire severity in excess of that contemplated by protection criteria for an individual commodity classification.

C-7-9.8.1 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 mm/min) with 8-ft (2.4-m) aisles and 0.45 gpm/ft^2 (18.3 mm/min) with 4-ft (1.2-m) aisles using the standard commodity.

Appendix D Sprinkler System Information from the 1997 Edition of the *Life Safety Code*

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 as an aid to the user of NFPA 13 by identifying those portions of the 1997 edition of NFPA *101*, *Life Safety Code*, that pertain to sprinkler system design and installation. It is not intended that this appendix provide complete information regarding all aspects of fire protection addressed by NFPA *101*. It is important to note that this information was not copied from NFPA *101* using NFPA's extract policy and is not intended to be a part of the requirements of NFPA 13. While the 1997 edition of the *Life Safety Code* was the most current at the time of the publication of the 1999 edition of NFPA 13, a 2000 edition of the *Life Safety Code* is in preparation.

D-2 Definitions. See NFPA *101*, *Life Safety Code*, for terms not defined in Chapter 1.

D-3 Atriums. Glass walls and inoperable windows shall be permitted in lieu of the fire barriers where automatic sprinklers are spaced 6 ft (1.8 m) apart or less along both sides of the glass wall and inoperable windows, not more than 1 ft (0.3 m) from the glass, and with the automatic sprinklers located so that the entire surface of the glass is wet upon operation of the sprinklers. The glass shall be tempered, wired, or laminated glass held in place by a gasket system that permits the glass framing system to deflect without breaking (loading) the glass before the sprinklers operate. Automatic sprinklers shall not be required on the atrium side of the glass wall and inoperable windows where there is no walkway or other floor area on the atrium side above the main floor level. Doors in such walls shall be glass or other material that will resist the passage of smoke. Doors shall be self-closing or automatic-closing upon detection of smoke. [**101:** 6-2.4.6, Exception No. 2 to (a)]

D-4 Connection to Domestic Water Supply. Sprinkler piping serving not more than six sprinklers for any isolated hazardous area shall be permitted to be connected directly to a domestic water supply system having a capacity sufficient to provide 0.15 gpm/sq ft (6.1 L/min/sq m) of floor area throughout the entire enclosed area. An indicating shut-off valve shall be installed in an accessible location between the sprinklers and the connection to the domestic water supply. (**101:** 7-7.1.2)

D-5 Supervision. (**101:** 7-7.2)

D-5.1 Supervisory Signals. Where supervised, automatic sprinkler systems are required by another section of NFPA *101*, supervisory attachments shall be installed and monitored for integrity in accordance with NFPA 72, *National Fire Alarm Code*, and a distinctive supervisory signal shall be provided to indicate a condition that would impair the satisfactory operation of the sprinkler system. This shall include, but not be limited to, monitoring of control valves, fire pump power supplies and running conditions, water tank levels and temperatures, pressure of tanks, and air pressure on dry-pipe valves. Supervisory signals shall sound and shall be displayed either at a location within the protected building that is constantly attended by qualified personnel or at an approved, remotely located receiving facility. (**101:** 7-7.2.1)

D-5.2 Alarm Signal Transmission. Where supervision of automatic sprinkler systems is provided in accordance with another provision of NFPA *101*, waterflow alarms shall be transmitted to an approved, proprietary alarm receiving facility, a remote station, a central station, or the fire department. Such connection shall be installed in accordance with 7-6.1.4 of NFPA *101*. (**101:** 7-7.2.2)

D-6 Stages.

D-6.1 Sprinklers shall not be required for stages 1000 sq ft (93 sq m) or less in area and 50 ft (15 m) or less in height where curtains, scenery, or other combustible hangings are not retractable vertically. Combustible hangings shall be limited to a single main curtain, borders, legs, and a single backdrop. (**101:** 8-4.5.10, Exception No. 1)

D-6.2 Sprinklers shall not be required under stage areas less than 4 ft (1.2 m) in clear height used exclusively for chair or table storage and lined on the inside with $^5/_8$-in. (1.6-cm) Type X gypsum wallboard or the approved equivalent. (**101:** 8-4.5.10, Exception No. 2)

D-7 Exhibition Booths. The following shall be protected by automatic extinguishing systems:

(a) Single-level exhibit booths greater than 300 sq ft (27.9 sq m) and covered with a ceiling.

(b) Throughout each level of multilevel exhibit booths, including the uppermost level if the uppermost level is covered with a ceiling.

(c) A single exhibit or group of exhibits with ceilings that do not require sprinklers shall be separated by a minimum of 10 ft (3 m) where the aggregate ceiling exceeds 300 sq ft (27.9 sq m).

The water supply and piping for the sprinkler system shall be permitted to be of approved temporary means taken from an existing domestic water supply, an existing standpipe system, or an existing sprinkler system.

Exception No. 1: Ceilings that are constructed of open grate design or listed dropout ceilings in accordance with NFPA 13, Standard for the Installation of Sprinkler Systems, shall not be considered ceilings within the context of this section.

Exception No. 2: Vehicles, boats, and similar exhibited products having over 100 sq ft (9.3 sq m) of roofed area shall be provided with smoke detectors acceptable to the authority having jurisdiction.

Exception No. 3: Where fire protection of multilevel exhibit booths is consistent with the criteria developed through a life safety evaluation of the exhibition hall in accordance with 8-4.1 of NFPA 101, subject to approval of the authority having jurisdiction. (See A-8-2.3.2 of NFPA 101.)

(**101:** 8-7.5.3.7)

D-8 Proscenium Curtain. The proscenium opening of every legitimate stage shall be provided with a curtain constructed and mounted so as to intercept hot gases, flames, and smoke

and to prevent flame from a fire on the stage from becoming visible from the auditorium side for a 5-min period where the curtain is of asbestos. Other materials shall be permitted if they have passed a 30-min fire test in a small scale 3 ft × 3 ft (0.9 m × 0.9 m) furnace with the sample mounted in the horizontal plane at the top of the furnace and subjected to the standard time-temperature curve.

The curtain shall be automatic-closing without the use of applied power.

All proscenium curtains shall be in the closed position except during performances, rehearsals, or similar activities.

Exception No. 1: In lieu of the protection required herein, all the following shall be provided:

(a) A noncombustible opaque fabric curtain shall be arranged so that it will close automatically; and

(b) An automatic, fixed waterspray deluge system shall be located on the auditorium side of the proscenium opening and shall be arranged so that the entire face of the curtain will be wetted. The system shall be activated by combination of rate-of-rise and fixed-temperature detectors located on the ceiling of the stage. Detectors shall be spaced in accordance with their listing. The water supply shall be controlled by a deluge valve and shall be sufficient to keep the curtain completely wet for 30 min or until the valve is closed by fire department personnel; and

(c) The curtain shall be automatically operated in case of fire by a combination of rate-of-rise and fixed-temperature detectors that also activates the deluge spray system. Stage sprinklers and vents shall be automatically operated by fusible elements in case of fire; and

(d) Operation of the stage sprinkler system or spray deluge valve shall automatically activate the emergency ventilating system and close the curtain; and

(e) The curtain, vents, and spray deluge system valve shall also be capable of manual operation.

Exception No. 2: Proscenium fire curtains or water curtains complying with 8-4.5.7 of NFPA 101.

(**101:** 9-4.5.7)

D-9 Listed quick response or listed residential sprinklers shall be used throughout smoke compartments containing patient sleeping rooms. (**101:** 12-3.5.2)

The requirements for use of quick response sprinklers intends that quick response sprinklers be the predominant type of sprinkler installed in the smoke compartment. It is recognized, however, that quick response sprinklers may not be approved for installation in all areas such as those where NFPA 13, *Standard for the Installation of Sprinkler Systems,* requires sprinklers of the intermediate- or high-temperature classification. It is not the intent of the 12-3.5.2 of NFPA *101* requirements to prohibit the use of standard sprinklers in limited areas of a smoke compartment where intermediate- or high-temperature sprinklers are required.

Where the installation of quick response sprinklers is impracticable in patient sleeping room areas, appropriate equivalent protection features acceptable to the authority having jurisdiction should be provided. It is recognized that the use of quick response sprinklers may be limited in facilities housing certain types of patients, or due to the installation limitations of quick response sprinklers. (**101:** A-12-3.5.2)

D-10 Where an automatic sprinkler system is installed, either for total or partial building coverage, the system shall be installed in accordance with Section 7-7 of NFPA *101.* In buildings up to and including four stories in height, systems installed in accordance with NFPA 13R, *Standard for the Installation of Sprinkler Systems in Residential Occupancies up to and Including Four Stories in Height,* shall be permitted.

Exception No. 1: In individual dwelling units, sprinkler installation shall not be required in closets not over 12 sq ft (1.1 sq m). Closets that contain equipment such as washers, dryers, furnaces, or water heaters shall be sprinklered regardless of size.

Exception No. 2: The draft stop and closely spaced sprinkler requirements of NFPA 13, Standard for the Installation of Sprinkler Systems, shall not be required for convenience openings complying with 6-2.4.8 of NFPA 101 where the convenience opening is within the dwelling unit.

(**101:** 18-3.5.1)

Appendix E Referenced Publications

E-1 The following documents or portions thereof are referenced within this standard for informational purposes only and are thus not considered part of the requirements of this standard unless also listed in Chapter 13. The edition indicated here for each reference is the current edition as of the date of the NFPA issuance of this standard.

E-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 13R, *Standard for the Installation of Sprinkler Systems in Residential Occupancies up to and Including Four Stories in Height*, 1996 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1996 edition.

NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, 1999 edition.

NFPA 22, *Standard for Water Tanks for Private Fire Protection*, 1998 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, 1998 edition.

NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials*, 1995 edition.

NFPA 36, *Standard for Solvent Extraction Plants*, 1997 edition.

NFPA 72, *National Fire Alarm Code®*, 1996 edition.

NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*, 1996 edition.

NFPA 99, *Standard for Health Care Facilities*, 1999 edition.

NFPA *101®*, *Life Safety Code®*, 1997 edition.

NFPA 214, *Standard on Water-Cooling Towers*, 1996 edition.

NFPA 220, *Standard on Types of Building Construction*, 1999 edition.

NFPA 291, *Recommended Practice for Fire Flow Testing and Marking of Hydrants*, 1995 edition.

NFPA 307, *Standard for the Construction and Fire Protection of Marine Terminals, Piers, and Wharves*, 1995 edition.

NFPA 318, *Standard for the Protection of Cleanrooms*, 1998 edition.

NFPA 409, *Standard on Aircraft Hangars*, 1995 edition.

NFPA 415, *Standard on Airport Terminal Buildings, Fueling Ramp Drainage, and Loading Walkways*, 1997 edition.

NFPA 423, *Standard for Construction and Protection of Aircraft Engine Test Facilities*, 1999 edition.

NFPA 430, *Code for the Storage of Liquid and Solid Oxidizers*, 1995 edition.

NFPA 703, *Standard for Fire Retardant Impregnated Wood and Fire Retardant Coatings for Building Materials*, 1995 edition.

NFPA 803, *Standard for Fire Protection for Light Water Nuclear Power Plants*, 1998 edition.

NFPA 804, *Standard for Fire Protection for Advanced Light Water Reactor Generating Plants*, 1995 edition.

NFPA 850, *Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations*, 1996 edition.

NFPA 851, *Recommended Practice for Fire Protection for Hydroelectric Generating Plants*, 1996 edition.

NFPA 909, *Standard for the Protection of Cultural Resources, Including Museums, Libraries, Places of Worship, and Historic Properties*, 1997 edition.

E-1.2 Other Publications.

E-1.2.1 ACPA Publication. American Concrete Pipe Association, 222 W. Las Collinas Boulevard, Suite 641, Irving, TX 75039.

Concrete Pipe Handbook.

E-1.2.2 ASCE Publication. American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, VA 20191-4400.

Standard Guidelines for the Structural Applications of Steel Cables for Buildings, 1996.

E-1.2.3 ASME Publications. American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

ASME B16.1, *Cast-Iron Pipe Flanges and Flanged Fittings for 25, 125, 250 and 800 lb*, 1989.

ASME A17.1, *Safety Code for Elevators and Escalators*, 1996.

ASME B1.20.1, *Pipe Threads, General Purpose (Inch)*, 1983.

E-1.2.4 ASTM Publications. American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM A 126, *Standard Specification for Gray Iron Casting for Valves, Flanges, and Pipe Fittings*, 1995.

ASTM A 135, *Standard Specification for Electric-Resistance-Welded Steel Pipe*, 1997.

ASTM A 197, *Standard Specification for Cupola Malleable Iron*, 1987.

ASTM A 307, *Standard Specification for Carbon Steel Bolts and Studs*, 1997.

ASTM D 3309, *Standard Specification for Polybutylene (PB) Plastic and Hot- and Cold-Water Distribution Systems*, 1996.

ASTM E 119, *Standard Test Methods for Fire Tests of Building Construction and Materials*, 1998.

ASTM F 437, *Standard Specification for Threaded Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80*, 1996.

ASTM F 438, *Standard Specification for Socket-Type Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 40*, 1997.

ASTM F 439, *Standard Specification for Socket-Type Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80*, 1997.

ASTM F 442, *Standard Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe (SDR-PR)*, 1997.

E-1.2.5 AWWA Publications. American Water Works Association, 6666 West Quincy Avenue, Denver, CO 80235.

AWWA C104, *Cement Mortar Lining for Ductile Iron Pipe and Fittings for Water*, 1995.

AWWA C105, *Polyethylene Encasement for Ductile Iron Pipe Systems*, 1993.

AWWA C110, *Ductile Iron and Gray Iron Fittings, 3-in. Through 48-in., for Water and Other Liquids*, 1993.

AWWA C115, *Flanged Ductile Iron Pipe with Ductile Iron or Gray Iron Threaded Flanges*, 1994.

AWWA C150, *Thickness Design of Ductile Iron Pipe*, 1996.

AWWA C151, *Ductile Iron Pipe, Centrifugally Cast for Water*, 1996.

AWWA C153, *Ductile Iron Compact Fittings, 3 in. through 24 in. and 54 in. through 64 in. for Water Service*, 1994.

AWWA C203, *Coal-Tar Protective Coatings and Linings for Steel Water Pipelines Enamel and Tape — Hot Applied*, 1997.

AWWA C205, *Cement-Mortar Protective Lining and Coating for Steel Water Pipe 4 in. and Larger — Shop Applied*, 1995.

AWWA C206, *Field Welding of Steel Water Pipe*, 1997.

AWWA C208, *Dimensions for Fabricated Steel Water Pipe Fittings*, 1996.

AWWA C300, *Reinforced Concrete Pressure Pipe, Steel-Cylinder Type for Water and Other Liquids*, 1997.

AWWA C301, *Prestressed Concrete Pressure Pipe, Steel-Cylinder Type, for Water and Other Liquids*, 1992.

AWWA C302, *Reinforced Concrete Pressure Pipe, Non-Cylinder Type, for Water and Other Liquids*, 1995.

AWWA C303, *Reinforced Concrete Pressure Pipe, Steel-Cylinder Type, Pretensioned, for Water and Other Liquids*, 1995.

AWWA C400, *Standard for Asbestos-Cement Distribution Pipe, 4 in. Through 16 in., for Water and Other Liquids*, 1993.

AWWA C401, *Standard Practice for the Selection of Asbestos-Cement Water Pipe*, 1993.

AWWA C600, *Standard for the Installation of Ductile-Iron Water Mains and Their Appurtenances*, 1993.

AWWA C602, *Cement-Mortar Lining of Water Pipe Lines 4 in. and Larger — in Place*, 1995.

AWWA C603, *Standard for the Installation of Asbestos-Cement Water Pipe*, 1996.

AWWA C606, *Grooved and Shouldered Joints*, 1997.

AWWA C900, *Polyvinyl Chloride (PVC) Pressure Pipe, 4 in. Through 12 in., for Water and Other Liquids*, 1997.

AWWA M11, *A Guide for Steel Pipe-Design and Installation*, 3rd edition, 1989.

AWWA M14, *Recommended Practice for Backflow Prevention and Cross Connection Control*, 2nd edition, 1990.

AWWA M41, *Ductile Iron and Pipe Fittings.*

E-1.2.6 DIRPA Publication. Ductile Iron Pipe Research Association, 245 Riverchase Parkway, East, Suite 0, Birmingham, AL 35244.

Installation Guide for Ductile Iron Pipe.

Thrust Restraint Design for Ductile Iron Pipe.

E-1.2.7 EPRI Publication.

1843-2, "Turbine Generator Fire Protection by Sprinkler System," July 1985.

E-1.2.8 FMRC Publication. Factory Mutual Research Corporation, 1151 Boston-Providence Turnpike, Norwood, MA 02061.

FMRC J. I. 0X1R0.RR, "Large Scale Fire Tests of Rack Storage Group A Plastics in Retail Operation Scenarios Protected by Extra Large Orifice (ELO) Sprinklers."

E-1.2.9 IMO Publication. International Maritime Organization, 4 Albert Embankment, London, SEI 7SR, United Kingdom.

International Convention for the Safety of Life at Sea, 1974 (SOLAS 74), as amended, regulations II-2/3 and II-2/26.

E-1.2.10 SNAME Publication. Society of Naval Architects and Marine Engineers, 601 Pavonia Ave., Suite 400, Jersey City, NJ 07306.

Technical Research Bulletin 2-21, "Aluminum Fire Protection Guidelines."

E-1.2.11 UL Publication. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

"Fact Finding Report on Automatic Sprinkler Protection for Fur Storage Vaults," November 25, 1947.

E-1.2.12 Uni-Bell Plastic Pipe Association.

Handbook of PVC Pipe.

E-1.2.13 U.S. Government Publications. U.S. Government Printing Office, Washington, DC 20402.

Title 46, *Code of Federal Regulations*, Part 72.05-5.

U.S. Federal Standard No. 66C, *Standard for Steel Chemical Composition and Harden Ability*, April 18, 1967, change notice No. 2, April 16, 1970.

Index