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NFPA 231C Standard for Rack Storage of Materials 1995 Edition

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Policy Adopted by NFPA Board of Directors on December 3, 1982

The Board of Directors reaffirms that the National Fire Protection Association recognizes that the toxicity of the products of combustion is an important factor in the loss of life from fire. NFPA has dealt with that subject in its technical committee documents for many years.

There is a concern that the growing use of synthetic materials may produce more or additional toxic products of combustion in a fire environment. The Board has, therefore, asked all NFPA technical committees to review the documents for which they are responsible to be sure that the documents respond to this current concern. To assist the committees in meeting this request, the Board has appointed an advisory committee to provide specific guidance to the technical committees on questions relating to assessing the hazards of the products of combustion.

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Errata

NFPA 231C

Rack Storage

1995 Edition

Reference: Figure 6-9.8, Figures 6-12(a)-(e), Section 7-6, Table 7-10.1 Note 1, Figure 8-2 and 9-1.7

The Committee on Rack Storage notes the following errors in the 1995 edition of NFPA 231C, *Standard for Rack Storage of Materials:*

1. *In Figure 6-9.8, bottom label, replace the term "Original design" with "Reduced design."*

2. *In Figures 6-12(a) through (e), Legend to curve F, replace the term "in-rack" with "ceiling."*

3. *In Section 7-6, remove the term "Pressure" from the section title.*

4. *In Table 7-10.1, Footnote 1, replace the term "pressure" with "discharge" and the term "30 psi" with "30 gpm."*

5. *In Figure 8-2, Part d, the last figure requiring 0.30 gpm per ft^2/2000 ft^2, revise the phrase "See Note 2 and Figure 8-2 part h" to read "See Note 3 and Figure 8-2 part i."*

6. *In 9-1.7 the metric units were reversed. They should read: "80 ft^2 (7.4 m^2)" and "100 ft^2 (9.3m^2)."*

Issue Date: August, 1995

NFPA 231C

Standard for

Rack Storage of Materials

1995 Edition

This edition of NFPA 231C, *Standard for Rack Storage of Materials*, was prepared by the Technical Committee on Rack Storage and acted on by the National Fire Protection Association, Inc., at its Fall Meeting held November 14-16, 1994, in Toronto, Ontario, Canada. It was issued by the Standards Council on January 13, 1995, with an effective date of February 7, 1995, and supersedes all previous editions.

The 1995 edition of this document has been approved by the American National Standards Institute.

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

Origin and Development of NFPA 231C

In August 1967, representatives for rack manufacturers, fire protection equipment manufacturers, the insurance community, and industrial users met and organized the Rack Storage Fire Protection Committee. This committee developed and financially sponsored a program of full-scale fire tests for the storage of combustible materials in racks.

In 1968, the NFPA Committee on Rack Storage of Materials was organized. All of the data developed by the Rack Storage Fire Protection Committee was subsequently turned over to the NFPA committee. Thus, it was possible for the NFPA committee to write a standard supported entirely by actual fire test data. NFPA 231C was first adopted at the Annual Meeting in May 1971.

In 1972, revisions included changing certain recommendations to requirements, and new material was added to the appendix. In 1973, it was revised further to include storage for heights above 25 ft (7.6 m) and to relocate advisory material to Appendix A. In 1974, the entire format was revised, editorial changes were made, and new material was added.

In 1975, new test data resulted in the introduction of additional material. The 1980 edition was a partial revision to the standard, including changes to the tables and figures in Chapter 6. Revisions made in 1986 included expanded protection criteria for plastic commodities.

The 1991 edition incorporated a variety of changes that included editorial improvements as well as numerous substantive changes. Technically important changes in the 1991 edition included permission to utilize intermediate- and high-temperature sprinklers for plastic commodities. In addition, a series of figures were included that show the relative positions of in-rack sprinklers for rack storage of Group A plastics. The previously issued TIA on ESFR sprinklers was incorporated as a new chapter.

The 1995 edition incorporates criteria for miscellaneous storage, extra-large orifice sprinklers, quick response and large orifice sprinklers for in-rack applications, and new large drop and ESFR sprinkler applications. In addition, new definitions were introduced and some chapters were reworded to improve the user friendliness of the document.

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

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

Committee Scope: This Committee shall have primary responsibility for documents on fire prevention and fire protection considerations for the rack storage of materials, including automatic systems. This Committee also shall have primary responsibility for emergency operations, including fire-fighting operations in facilities used for the rack storage of materials.

Contents

NFPA 231C

Standard for

Rack Storage of Materials

1995 Edition

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

A dagger (†) following the number or letter designating a paragraph or section in the text indicates explanatory test data and procedures with regard to that paragraph or section in Appendix B.

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

Chapter 1 Introduction

1-1† Application and Scope. This standard shall apply to storage of materials representing the broad range of commodities stored in racks.

Exception: Miscellaneous storage shall be permitted to be protected in accordance with NFPA 13, Standard for the Installation of Sprinkler Systems.

Storage on plastic pallets or plastic shelves is outside the scope of this standard.

Storage of high hazard materials such as tires, roll paper stored on end, and flammable liquids is outside the scope of this standard. Storage of such commodities shall be protected in accordance with the provisions of NFPA 30, *Flammable and Combustible Liquids Code*; NFPA 40, *Standard for the Storage and Handling of Cellulose Nitrate Motion Picture Film*; NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*; NFPA 81, *Standard for Fur Storage, Fumigation and Cleaning*; NFPA 231, *Standard for General Storage*; NFPA 231D, *Standard for Storage of Rubber Tires*; NFPA 231F, *Standard for the Storage of Roll Paper*; NFPA 232, *Standard for the Protection of Records*, and NFPA 490, *Code for the Storage of Ammonium Nitrate*, as applicable.

NOTE: See also NFPA 231E, *Recommended Practice for the Storage of Baled Cotton*.

Bin storage and shelf storage are outside the scope of this standard.

1-1.1 Nothing in this standard is intended to restrict new technologies or alternate arrangements, provided the level of safety prescribed by the standard is not reduced.

1-2 Retroactivity Clause. The provisions of this document shall be considered necessary to provide a reasonable level of protection from loss of life and property from fire. They reflect situations and the state of the art at the time the standard was issued.

Unless otherwise noted, it is not intended that the provisions of this document be applied to facilities, equipment, structures, or installations that were existing or approved for construction or installation prior to the effective date of this document.

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

1-3 Definitions. Unless specifically stated elsewhere, for the purpose of this standard, the terms in this section shall be defined as follows.

Aisle Width. The horizontal dimension between the face of the loads in racks under consideration. [*See Figure 1-3(a).*]

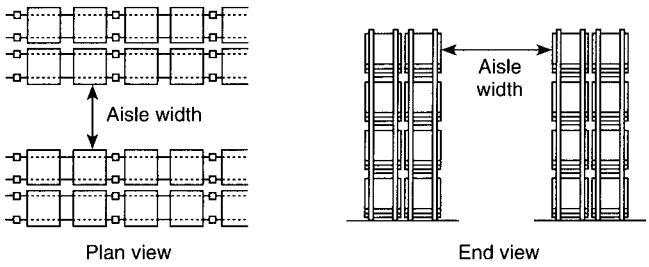


Figure 1-3(a) Illustration of aisle width.

Approved. Acceptable to the authority having jurisdiction.

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

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

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

Bulkhead. A vertical barrier across the rack.

Ceiling Height. The distance between the floor and the underside of the ceiling above (or roof deck) within the storage area.

Commodity. The combinations of product, packing material, and container upon which commodity classification is based.

Conventional Pallets. A material-handling aid designed to support a unit load with openings to provide access for material-handling devices. [*See Figure 1-3(b).*]

Early Suppression Fast Response Sprinklers (ESFR). See NFPA 13, *Standard for the Installation of Sprinkler Systems.*

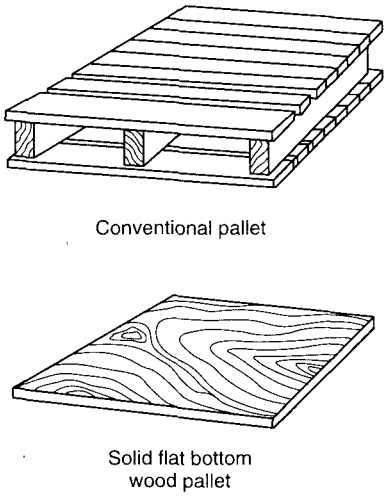


Figure 1-3(b) Typical pallets.

Encapsulated. A method of packaging consisting of a plastic sheet completely enclosing the sides and top of a pallet load containing a combustible commodity or a combustible package or a group of combustible commodities or combustible packages. Combustible commodities individually wrapped in plastic sheeting and stored exposed in a pallet load also are to be considered encapsulated.

Totally noncombustible commodities on wood pallets enclosed only by a plastic sheet as described are not covered under this definition. Banding, i.e., stretch-wrapping around the sides only of a pallet load, is not considered to be encapsulation. Where there are holes or voids in the plastic or waterproof cover on the top of the carton that exceed more than half of the area of the cover, the term "encapsulated" shall not apply. The term encapsulated does not apply to plastic-enclosed product or packages inside a large, nonplastic, enclosed container.

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

Free-Flowing Plastic Materials. Those plastics that fall out of their containers during a fire, fill flue spaces, and create a smothering effect on the fire. Examples: powder, pellets, flakes, or random-packed small objects [razor blade dispensers, 1-oz to 2-oz (28-g to 57-g) bottles, etc.].

Horizontal Barrier. A solid barrier in the horizontal position covering the entire rack, including all flue spaces at certain height increments, to prevent vertical fire spread.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

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

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

Longitudinal Flue Space. The space between rows of storage perpendicular to the direction of loading. [*See Figure 1-3(c).*]

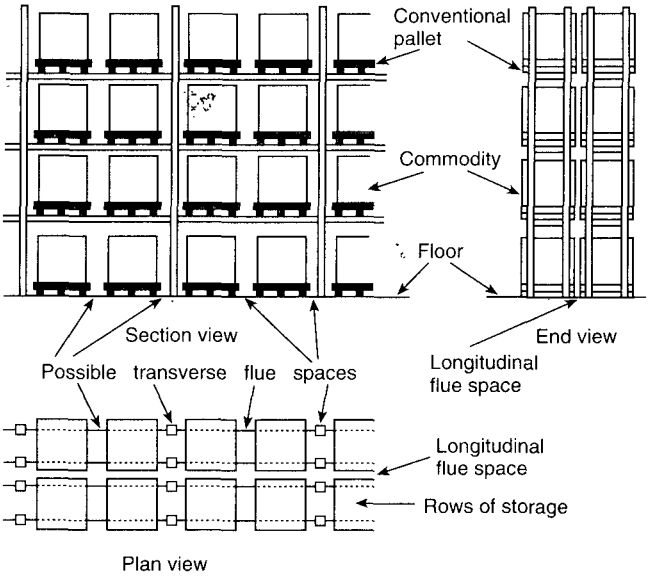


Figure 1-3(c) Typical double-row (back-to-back) rack arrangement.

Miscellaneous Storage. Storage that does not exceed 12 ft (3.7 m) in height and is incidental to another occupancy use group as defined in NFPA 13, *Standard for the Installation of Sprinkler Systems*. Such storage shall not constitute more than 10 percent of the building area or 4000 ft^2 (372 m^2) of the sprinklered area, whichever is greater. Such storage shall not exceed 1000 ft^2 (93 m^2) in one pile or area, and each such pile or area shall be separated from other storage areas by at least 25 ft (7.6 m).

Rack. Any combination of vertical, horizontal, and diagonal members that supports stored materials. Some rack structures use solid shelves. Racks shall be permitted to be fixed, portable, or movable [*see Figures A-4-1(a) through (k)*]. Loading shall be permitted to be either manual, using lift trucks, stacker cranes, or hand placement; or automatic, using machine controlled storage and retrieval systems.

Double-Row Racks. Double-row racks are two single-row racks placed back-to-back having a combined width up to 12 ft (3.7 m) with aisles at least 3.5 ft (1.1 m) on each side.

Movable Racks. Movable racks are racks on fixed rails or guides. They can be moved back and forth only in a horizontal, two-dimensional plane. A moving aisle is created as abutting racks are either loaded or unloaded, then moved across the aisle to abut other racks. Rack arrangements generally result in the same protection requirements as those for multiple-row racks.

Multiple-Row Racks. Multiple-row racks are racks greater than 12 ft (3.7 m) wide or single- or double-row racks separated by aisles less than 3.5 ft (1.1 m) wide having an overall width greater than 12 ft (3.7 m).

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

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

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

Shall. Indicates a mandatory requirement.

Shelf Storage. Storage on structures less than 30 in. (7.62 cm) deep, with shelves usually 2 ft (0.6 m) apart vertically and separated by approximately 30-in. (76.2-cm) aisles.

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

Slave Pallet. A special pallet captive to a material-handling system. [*See Figure 1-3(b).*]

Solid Shelving. Solid shelving is solid, slatted, and other types of shelving located within racks that obstruct sprinkler water penetration down through the racks.

Transverse Flue Space. The space between rows of storage parallel to the direction of loading. [*See Figure 1-3(c).*]

Chapter 2 Classification of Storage

2-1† Commodity Classifications.

2-1.1 Class I commodities are defined as essentially noncombustible products on wood pallets, or in ordinary corrugated cartons with or without single-thickness dividers, or in ordinary paper wrappings, all on wood pallets. Such products shall be permitted to have a negligible amount of plastic trim, such as knobs or handles.

Examples of Class I products include:

Foods. Foods in noncombustible containers; frozen foods; meats; fresh fruits and vegetables in nonplastic trays or containers; dairy products in nonwax-coated paper containers; beer and wine, up to 20 percent alcohol, in metal, glass, or ceramic containers.

Glass Products. Glass bottles, empty or filled with noncombustible liquids; mirrors.

Metal Products. Metal desks with plastic tops and trim; electrical coils; electrical devices in their metal enclosures; pots and pans; electrical motors; dry cell batteries; metal parts; empty cans; stoves; washers; dryers; metal cabinets.

Others. Oil-filled and other types of distribution transformers; cement in bags; electrical insulators; gypsum board; inert pigments; dry insecticides.

2-1.2 Class II commodities are defined as Class I products in slatted wooden crates, solid wooden boxes, multiwall corrugated cartons, or equivalent combustible packaging material on wood pallets.

Examples of Class II products include:

Thinly coated fine wire such as radio coil wire on reels or in cartons; incandescent or fluorescent light bulbs; beer or wine, up to 20 percent alcohol in wood containers; Class I products, if in small cartons or small packages placed in ordinary paperboard cartons.

2-1.3 Class III commodities are defined as wood, paper, natural fiber cloth, and Group C plastics or products thereof on wood pallets. Products shall be permitted to contain a limited amount of Group A or B plastics. Wood dressers with plastic drawer glides, handles, and trim are examples of a commodity containing a limited amount of plastic.

Examples of Class III products include:

Leather Products. Shoes; jackets; gloves; luggage.

Paper Products. Books; magazines; newspapers; stationery; plastic-coated paper food containers; paper or cardboard games; tissue products; rolled paper on side or steel banded on end; regenerated cellulosics (cellophane).

Textiles. Natural fiber upholstered nonplastic furniture; wood or metal furniture with plastic padded and covered armrests; mattresses without expanded plastic or rubber; absorbent cotton in cartons; natural fiber and viscose yarns, thread, and products; natural fiber clothing or textile products.

Wood Products. Doors; windows; door and window frames; combustible fiberboard; wood cabinets; furniture; other wood products.

Others. Tobacco products in paperboard cartons; nonflammable liquids such as soaps, detergents and bleaches, and nonflammable pharmaceuticals in plastic containers; combustible foods and cereal products; non-negative-producing film packs in sealed metal foil wrappers in paperboard packages.

2-1.4 Class IV commodities are defined as Class I, II, and III products containing an appreciable amount of Group A plastics in paperboard cartons or Class I, II, and III products with Group A plastic packing in paperboard cartons on wood pallets. Group B plastics and free-flowing Group A plastics also are included in this class. (*See Section 1-1.*)

Examples of Class IV products include:

Small appliances, typewriters, and cameras with plastic parts; plastic-backed tapes; and synthetic fabrics or clothing. An example of packing material is a metal product in a foamed plastic cocoon in a corrugated carton.

Class IV commodities also include:

Textiles. Synthetic thread and yarn, except viscose; nonviscose synthetic fabrics or clothing.

Others. Vinyl floor tile; wood or metal frame upholstered furniture or mattresses with plastic covering or padding, or both; plastic-padded metal dashboards or metal bumpers.

2-1.5 Classification of Plastics, Elastomers, and Rubber.

NOTE: The following categories are based on unmodified plastic materials. The use of fire- or flame-retarding modifiers or the physical form of the material can change the classification.

2-1.5.1 Group A.

ABS (acrylonitrile-butadiene-styrene copolymer)
Acetal (polyformaldehyde)
Acrylic (polymethyl methacrylate)
Butyl rubber
EPDM (ethylene-propylene rubber)
FRP (fiberglass reinforced polyester)
Natural rubber (if expanded)
Nitrile rubber (acrylonitrile-butadiene rubber)

PET (thermoplastic polyester)
Polybutadiene
Polycarbonate
Polyester elastomer
Polyethylene
Polypropylene
Polystyrene
Polyurethane
PVC (polyvinyl chloride — highly plasticized, e.g., coated fabric, unsupported film)
SAN (styrene acrylonitrile)
SBR (styrene-butadiene rubber)

2-1.5.2 Group B.

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

2-1.5.3 Group C.

Fluoroplastics (PCTFE — polychlorotrifluoroethylene; PTFE — polytetrafluoroethylene)
Melamine (melamine formaldehyde)
Phenolic
PVC (polyvinyl chloride — rigid or lightly plasticized, e.g., pipe, pipe fittings)
PVDC (polyvinylidene chloride)
PVDF (polyvinylidene fluoride)
PVF (polyvinyl fluoride)
Urea (urea formaldehyde)

Chapter 3 Building Construction

3-1 Construction. Buildings used for the rack storage of materials that are protected in accordance with this standard shall be of any of the types described in NFPA 220, *Standard on Types of Building Construction*.

3-2 Fire Protection of Steel.

3-2.1† With sprinkler systems installed in accordance with Chapters 6 through 10, fire protection of roof steel shall not be required.

3-2.2† Where ceiling sprinklers and sprinklers in racks are installed in accordance with Chapters 5 through 8, fire protection of steel building columns shall not be required.

3-2.3† Where storage height exceeds 15 ft (4.6 m) and ceiling sprinklers only are installed, fire protection by one of the following methods shall be required for all types of steel building columns located within the racks or for vertical rack members that support the building:

(a) One-hour fire proofing.

(b) Sidewall sprinklers at the 15-ft (4.6-m) elevation, pointed toward one side of the steel column.

(c) Provision of ceiling sprinkler density for a minimum of 2000 ft^2 (185.9 m^2) with 165°F (74°C) or 286°F (141°C) rated sprinklers as shown in Table 3-2.3(c) for storage heights above 15 ft (4.6 m), up to and including 20 ft (6.1 m).

(d) Provision of large drop or early suppression fast response (ESFR) ceiling sprinkler protection in accordance with Chapters 9 and 10, respectively.

Table 3-2.3(c) Ceiling Sprinkler Densities for Protection of Steel Building Columns

Commodity Class	Aisle Width: 4 ft (1.22 m) gpm/ft^2	Aisle Width: 8 ft (2.44 m) [(L/s)/m^2]
I	0.37	0.33
II	0.44	0.37
III	0.49	0.42
IV and Plastics	0.68	0.57

NOTE: For aisle widths of 4 ft to 8 ft (1.22 m to 2.44 m), a direct linear interpolation between densities may be made.

3-3† Vents and Draft Curtains. Design curves are based on the assumption that roof vents and draft curtains are not being used.

Chapter 4 Storage Arrangement

4-1* Rack Structure. Rack configurations shall be of a generally accepted arrangement.

4-2* Rack Loading. Racks shall not be loaded beyond their design capacity.

4-3 Flue Space.

4-3.1*† In double-row racks with height of storage up to and including 25 ft (7.6 m), and without solid shelves, a longitudinal flue space (back-to-back clearance) is not necessary. Nominal 6-in. (152.4-mm) transverse flue space between loads or at rack uprights shall be maintained. Random variations in the width of the flue spaces or in their vertical alignment shall be permitted. (*See Figure 4-3.1.*)

Exception: A longitudinal flue shall be required where ESFR sprinkler protection is provided.

4-3.2 In double-row racks with height of storage over 25 ft (7.6 m), a minimum longitudinal flue space of (nominal) 6 in. (152.4 mm) shall be provided.

4-4* Aisle Widths.

4-4.1 Aisle widths and depth of racks are determined by material-handling methods. The width of aisles shall be considered in the design of the protection system. (*See Chapters 5 through 7.*)

4-4.2 This standard contemplates aisle widths maintained either by fixed rack structures or control in placing of portable racks. Any decrease in aisle width shall require a review of the adequacy of the protective system.

4-5*† Storage Heights. The distance from the top of storage to the ceiling sprinkler deflectors shall be not less than 18 in. (0.46 m).

Exception: Where large-drop or ESFR sprinkler protection is used, the distance from the top of storage to the ceiling sprinkler deflectors shall be not less than 36 in. (0.91 m).

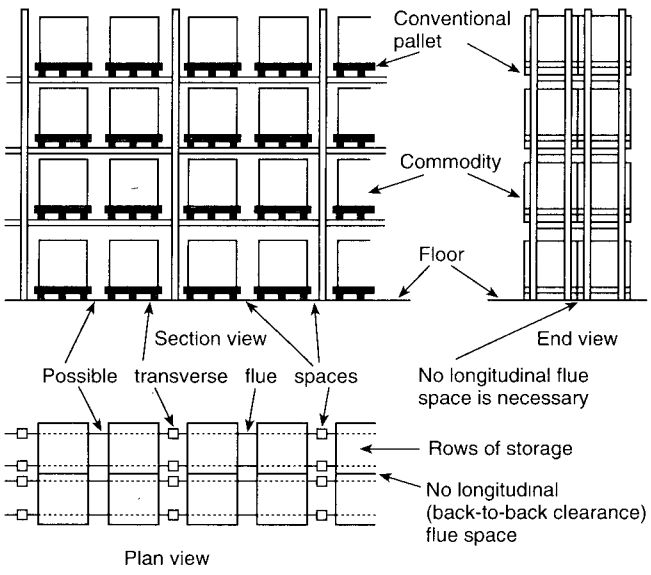


Figure 4-3.1 Typical double-row rack with back-to-back loads.

4-6 Commodity Clearances.

4-6.1* Commodity clearances shall be maintained in accordance with NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials.*

4-6.2* Incandescent Light Fixtures.

4-7*† Storage of Idle Combustible Pallets. Bulk storage of idle combustible pallets shall be in accordance with NFPA 231, *Standard for General Storage.*

Chapter 5 Fire Protection — General

5-1 Protection Systems.

5-1.1 Protection systems that are provided for rack storage facilities shall be in accordance with the provisions of this chapter.

5-1.2 The densities and areas provided in the tables and curves in Chapters 6 through 8 are based on fire tests using standard response standard orifice [1/2 in. (12.7 mm)] and large orifice [17/32 in. (13.5 mm)] sprinklers. For the use of large drop and ESFR sprinklers see Chapters 9 and 10, respectively.

Exception: The use of extra-large orifice (ELO) sprinklers [5/8 in. (15.9 mm)] shall be permitted where listed for such use and where installed at a minimum design pressure of 10 psi (69 kPa).

5-2 Ceiling Sprinklers.

5-2.1* Where automatic sprinkler systems are installed, they shall be in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems.*

Exception: Where modified by this standard.

5-2.2* In buildings that are occupied in part for rack storage of commodities, the ceiling sprinkler system design within 15 ft (4.6 m) of the racks shall be the same as that provided for the rack storage area.

5-3† Ceiling Sprinkler Spacing. For the purpose of selecting sprinkler spacing in hydraulically designed sprinkler systems to achieve a stipulated density, 60 psi (413.7 kPa) shall be the maximum discharge pressure used at the calculation starting point.

5-4 In-Rack Sprinkler System Size. The area protected by a single system of sprinklers in racks (in-rack sprinklers) shall not exceed 40,000 ft^2 (3716 m^2) of floor area occupied by the racks, including aisles, regardless of the number of intermediate sprinkler levels.

5-5* In-Rack Sprinkler System Control Valves.

5-5.1* Where sprinklers are installed in racks, separate indicating control valves and drains shall be provided and arranged so that ceiling and in-rack sprinklers can be controlled independently.

Exception No. 1: Installation of twenty or fewer in-rack sprinklers supplied by any one ceiling sprinkler system.

Exception No. 2: The separate indicating valves shall be permitted to be arranged as sectional control valves where the racks occupy only a portion of the area protected by ceiling sprinklers. (See 5-2.2.)

5-6 In-Rack Sprinkler Water Demand. The water demand for sprinklers installed in racks shall be added to the ceiling sprinkler water demand at the point of connection. The demand shall be balanced to the higher pressure.

5-7*† Sprinkler Waterflow Alarm.

5-8† Hose Connections. For first aid fire fighting and for mop-up operations, small [1 1/2 in. (38.1 mm)] hose lines shall be available to cover all areas of the rack structure. Such small hose shall be supplied from the following:

(a) Outside hydrants

(b) A separate piping system for small hose stations

(c) Valved hose connections on sprinkler risers where such connections are made upstream of all sprinkler control valves

(d) Adjacent sprinkler systems.

Exception: Where separately controlled in-rack sprinklers are provided, the ceiling sprinkler system in the same area shall be permitted to be used.

5-9 Hose Demand.

5-9.1 For inside hose streams, an allowance of at least 100 gpm (378 L/min) shall be added to the sprinkler water demand for Class I, II, III, IV, and plastic commodities.

5-9.2 For combined inside and outside hose streams, an allowance of at least 500 gpm (1893 L/min) shall be added to the sprinkler water demand for Class I, II, III, IV, and plastic commodities.

5-10† Duration of Water Supplies. For double-row racks, the water supply duration shall be at least 1 1/2 hours for Class I, II, and III commodities and at least 2 hours for Class IV and Group A plastic commodities. For multiple-row racks, the water supply duration shall be at least 2 hours for all classifications of commodities.

5-11 High-Expansion Foam.

5-11.1* Where high-expansion foam systems are installed, they shall be in accordance with NFPA 11A,

Standard for Medium- and High-Expansion Foam Systems, and they shall be automatic in operation.

Exception: Where modified by this standard.

5-11.2 Where high-expansion foam systems are used in combination with ceiling sprinklers, in-rack sprinklers shall not be required.

5-12 Detectors for High-Expansion Foam Systems. Detectors shall be listed and shall be installed as follows:

(a) At the ceiling only where installed at one-half listed linear spacing [e.g., 15 ft × 15 ft (4.6 m × 4.6 m) rather than at 30 ft × 30 ft (9.1 m × 9.1 m)];

Exception: Ceiling detectors alone shall not be used where clearance from the top of storage exceeds 10 ft (3.1 m) or the height of storage exceeds 25 ft (7.6 m); or

(b) At the ceiling at listed spacing and in racks at alternate levels; or

(c) Where listed for rack storage installation and installed in accordance with their listing to provide response within one minute after ignition using an ignition source equivalent to that used in a rack storage testing program.

5-13 Solid and Slatted Shelves.

5-13.1* Slatted shelves shall be considered to be equivalent to solid shelves.

5-13.2† Sprinklers shall be installed at the ceiling and beneath each shelf in double- or multiple-row racks with solid shelves that obstruct both longitudinal and transverse flue spaces. Design curves for combined ceiling and in-rack sprinklers shall be used with this storage configuration.

5-14† Open-Top Combustible Containers.

5-15 Movable Racks. Rack storage in movable racks shall be protected in the same manner as multiple-row racks.

Chapter 6 Fire Protection — Storage up to and Including 25 ft (7.6 m) in Height

Part A General

(See also Chapter 5.)

6-1 General. For the storage of Class I through Class IV commodities stored 12 ft (3.7 m) or less in height, the sprinkler design criteria for miscellaneous storage specified in NFPA 13, *Standard for the Installation of Sprinkler Systems*, shall apply.

6-2 In-Rack Sprinkler Type. Sprinklers in racks shall be ordinary temperature standard response classification with nominal ½-in. (12.7-mm) orifice size, pendent or upright. Sprinklers with 212°F (100°C) and 286°F (141°C) temperature ratings shall be used near heat sources as required by NFPA 13, *Standard for the Installation of Sprinkler Systems*.

Exception: Quick-response sprinklers shall be permitted to be installed in racks.

6-3 In-Rack Sprinkler Pipe Size. The number of sprinklers and the pipe sizing on a line of sprinklers in racks is restricted only by hydraulic calculations and not by any piping schedule.

6-4† In-Rack Sprinkler Water Shields. Water shields shall be provided directly above in-rack sprinklers, or listed sprinklers equipped with water shields shall be used where there is more than one level, if not shielded by horizontal barriers.

6-5 In-Rack Sprinkler Location.

6-5.1*† The elevation of in-rack sprinkler deflectors with respect to storage shall not be a consideration in single- or double-row rack storage up to and including 20 ft (6.1 m) high.

6-5.2* In single- or double-row racks without solid shelves with storage over 20 ft (6.1 m) high, or in multiple-row racks, or in single- or double-row racks with solid shelves and storage height up to and including 25 ft (7.6 m), a minimum of 6 in. (152.4 mm) vertical clear space shall be maintained between the sprinkler deflectors and the top of a tier of storage. Sprinkler discharge shall not be obstructed by horizontal rack members.

6-5.3 In-rack sprinklers at one level only for storage up to and including 25 ft (7.6 m) high in single- or double-row racks shall be located at the first tier level at or above one-half of the storage height.

6-5.4 In-rack sprinklers at two levels only for storage up to and including 25 ft (7.6 m) high shall be located at the first tier level at or above one-third and two-thirds of the storage height.

6-6 In-Rack Sprinkler Spacing.

6-6.1* Maximum horizontal spacing of sprinklers in single- or double-row racks with nonencapsulated storage up to and including 25 ft (7.6 m) in height shall be in accordance with Table 6-6.1:

Table 6-6.1 In-Rack Sprinkler Spacing

Aisle Widths	Commodity Class I and II	Commodity Class III	Commodity Class IV
8 ft	12 ft	12 ft	8 ft
4 ft	12 ft	8 ft	8 ft

For SI units: 1 ft = 0.3048 m

For encapsulated storage, maximum horizontal spacing shall be 8 ft (2.44 m).

6-6.2† Sprinklers installed in racks shall be spaced without regard to rack uprights.

6-7† In-Rack Sprinkler Discharge Pressure. Sprinklers in racks shall discharge at not less than 15 psi (103.4 kPa) for all classes of commodities.

6-8† In-Rack Sprinkler Water Demand. The water demand for sprinklers installed in racks shall be based on simultaneous operation of the most hydraulically remote sprinklers as follows:

(a) Six sprinklers where only one level is installed in racks with Class I, II, or III commodities;

(b) Eight sprinklers where only one level is installed in racks with Class IV commodities;

(c) Ten sprinklers (five on each two top levels) where more than one level is installed in racks with Class I, II, or III commodities;

(d) Fourteen sprinklers (seven on each two top levels) where more than one level is installed in racks with Class IV commodities.

6-9*† Ceiling Sprinkler Water Demand. The design curves in Figures 6-12(a) through (g) shall apply to nominal 20-ft (6.1-m) height of storage.

6-9.1 The design curves indicate water demands for nominal 165°F (74°C) and nominal 286°F (141°C) rated sprinklers at the ceiling. The 165°F (74°C) design curves shall be used for sprinklers with ordinary and intermediate temperature classification but not less than 160°F (71°C) rating. The 286°F (141°C) rating design curve shall be used for sprinklers with high temperature classification.

6-9.2 For storage height up to and including 25 ft (7.6 m) protected with ceiling sprinklers only, and for storage height up to and including 20 ft (6.1 m) protected with ceiling sprinklers and minimum required in-rack sprinklers, densities obtained from design curves shall be adjusted in accordance with Figure 6-9.2.

6-9.3 For storage height over 20 ft (6.1 m) up to and including 25 ft (7.6) protected with ceiling sprinklers and minimum required in-rack sprinklers, densities obtained from design curves shall be used. Densities shall not be adjusted in accordance with Figure 6-9.2.

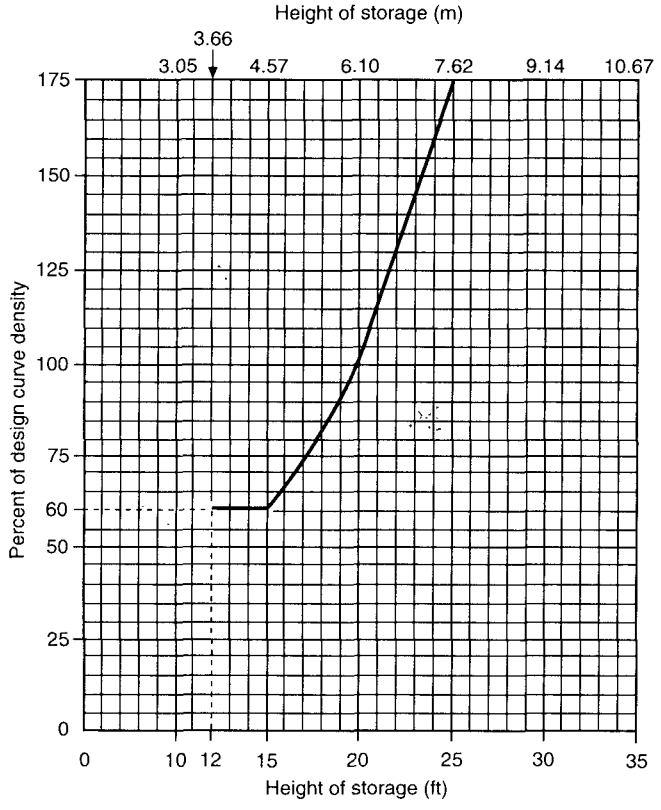


Figure 6-9.2 Ceiling sprinkler density vs storage height.

Table 6-9.2 Adjustment to Ceiling Sprinkler Density for Storage Height and In-Rack Sprinklers

Storage Height (ft)	In-Rack Sprinklers	Apply Fig. 6-9.2	Permitted Ceiling Sprinklers Density Adjustments
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

6-9.4 For storage height up to and including 20 ft (6.1 m) protected with ceiling sprinklers and with more than one level of in-rack sprinklers, but not in every tier, densities obtained from design curves and adjusted in accordance with Figure 6-9.2 shall be permitted to be reduced an additional 20 percent.

6-9.5 For storage height over 20 ft (6.1 m) up to and including 25 ft (7.6 m) protected with ceiling sprinklers, and with more than the minimum required level of in-rack sprinklers, but not in every tier, densities obtained from design curves shall be permitted to be reduced 20 percent. Densities shall not be adjusted in accordance with Figure 6-9.2.

6-9.6 For storage height up to and including 20 ft (6.1 m) protected with ceiling sprinklers and in-rack sprinklers at each tier, densities obtained from design curves and adjusted in accordance with Figure 6-9.2 shall be permitted to be reduced an additional 40 percent.

6-9.7 For storage height over 20 ft (6.1 m) up to and including 25 ft (7.6 m) protected with ceiling sprinklers and in-rack sprinklers at each tier, densities obtained from design curves shall be permitted to be reduced 40 percent. Densities shall not be adjusted in accordance with Figure 6-9.2.

6-9.8† Where clearance from ceiling to top of storage is less than 4½ ft (1.37 m) (*see Section 4-5*), the sprinkler operating area indicated in curves E, F, G, and H in Figures 6-12(a) through (e) shall be permitted to be reduced as indicated in Figure 6-9.8 but to not less than 2000 ft^2 (185.8 m^2). (*See 6-9.9.*)

6-9.9 Where clearance from ceiling to top of Class I or II encapsulated storage is 1½ ft to 3 ft (0.46 m to 0.91 m), the sprinkler operating area indicated in curve F only of Figure 6-12(e) shall be permitted to be reduced by 50 percent but to not less than 2000 sq ft^2 (185.8 m^2).

6-9.10 Where solid, flat-bottom wood pallets are used, with storage height up to and including 25 ft (7.6 m), the

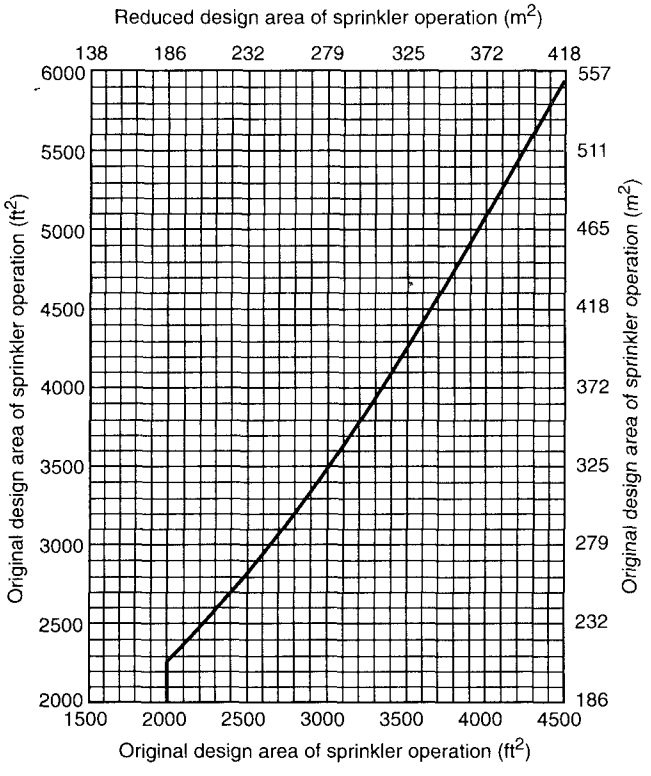


Figure 6-9.8 Adjustment of design area of sprinkler operation for clearance from top of storage to ceiling.

densities indicated in the design curves, based on conventional pallets, shall be increased 20 percent for the given area. This percentage shall be applied to the density determined in accordance with Figure 6-9.2. This increase shall not apply where in-rack sprinklers are installed.

6-10 High-Expansion Foam Submergence.

6-10.1* Where high-expansion foam systems are used without sprinklers, the maximum submergence time shall be 5 minutes for Class I, II, or III commodities and 4 minutes for Class IV commodities.

6-10.2 Where high-expansion foam systems are used in combination with ceiling sprinklers, the maximum submergence time shall be 7 minutes for Class I, II, or III commodities and 5 minutes for Class IV commodities.

6-11 High-Expansion Foam Ceiling Sprinkler Density. Where high-expansion foam systems are used in combination with ceiling sprinklers, the minimum ceiling sprinkler design density shall be 0.2 gpm/ft^2 [(8.15 L/min)/m^2] for Class I, II, or III commodities or 0.25 gpm/ft^2 [(10.2 L/min)/m^2] for Class IV commodities for the most hydraulically remote 2000-ft^2 (185.8-m^2) operating area.

Part B Double- and Single-Row Racks

(See also Chapter 5.)

6-12* Ceiling Sprinkler Water Demand. For Class I, II, III, or IV commodities encapsulated or nonencapsulated in single- or double-row racks, ceiling sprinkler water demand in terms of density (gpm/ft^2) [(L/min)/m^2] and area of sprinkler operation [ft^2 (m^2) of ceiling or roof] shall be selected from the curves in Figures 6-12(a) through (g). The curves in Figures 6-12(a) through (g) also shall apply to portable racks arranged in the same manner as single- or double-row racks or multiple-row racks. The design shall be sufficient to satisfy a single point on the appropriate curve related to the storage configuration and commodity class. It shall not be required to meet all points on the selected curve. Figure 6-9.2 shall be used to adjust the density for storage height unless otherwise specified.

6-12.1† Design curves for single- and double-row racks shall be selected to correspond to aisle width. For aisle widths between 4 ft (1.22 m) and 8 ft (2.44 m), a direct linear interpolation between curves shall be made. The density given for 8-ft (2.44-m) wide aisles shall be applied to aisles wider than 8 ft (2.44 m). The density given for 4-ft (1.22-m) wide aisles shall be applied to aisles narrower than 4 ft (1.22 m) down to 3½ ft (1.07 m). Where aisles are narrower than 3½ ft (1.07 m), racks shall be considered to be multiple-row racks.

6-13 In-Rack Sprinkler Location. In single- or double-row racks without solid shelves, in-rack sprinklers shall be installed in accordance with Table 6-12.

Part C Multiple-Row Racks

(See also Chapter 5.)

6-14† In-Rack Sprinkler Location. For encapsulated or nonencapsulated storage in multiple-row racks no deeper than 16 ft (4.88 m) with aisles no narrower than 8 ft (2.44 m), in-rack sprinklers shall be installed in accordance with Table 6-14.

6-14.1 For encapsulated or nonencapsulated storage in multiple-row racks deeper than 16 ft (4.88 m), or with aisles less than 8 ft (2.44 m) wide, in-rack sprinklers shall be installed in accordance with Table 6-14.1.

6-14.2* Maximum horizontal spacing of sprinklers on branch lines, in multiple-row racks with encapsulated or nonencapsulated storage up to and including 25 ft (7.6 m) in height, shall not exceed 12 ft (3.7 m) for Class I, II, or III commodities and 8 ft (2.44 m) for Class IV commodities, with area limitations of 100 ft^2 (9.29 m^2) per sprinkler for Class I, II, or III commodities and 80 ft^2 (7.43 m^2) per sprinkler for Class IV commodities. The rack plan view shall be considered in determining the area covered by each sprinkler. The aisles shall not be included in area calculations.

6-14.3 A minimum of 6 in. (152.4 mm) shall be maintained between the sprinkler deflector and the top of a tier of storage.

6-15 Ceiling Sprinkler Water Demand.

6-15.1 For nonencapsulated Class I, II, III, or IV commodities, ceiling sprinkler water demand in terms of density (gpm/ft^2) [(L/min)/m^2] and area of sprinkler operation [ft^2 (m^2) of ceiling or roof] shall be selected from the curves in Figures 6-12(a) through (d). The curves in Figures 6-12(a) through (d) also shall apply to portable racks arranged in the same manner as single-, double-, or multiple-row racks.

Table 6-12 Single- or Double-Row Racks. Storage Height up to and Including 25 ft, Aisles Wider than 4 ft, without Solid Shelves.

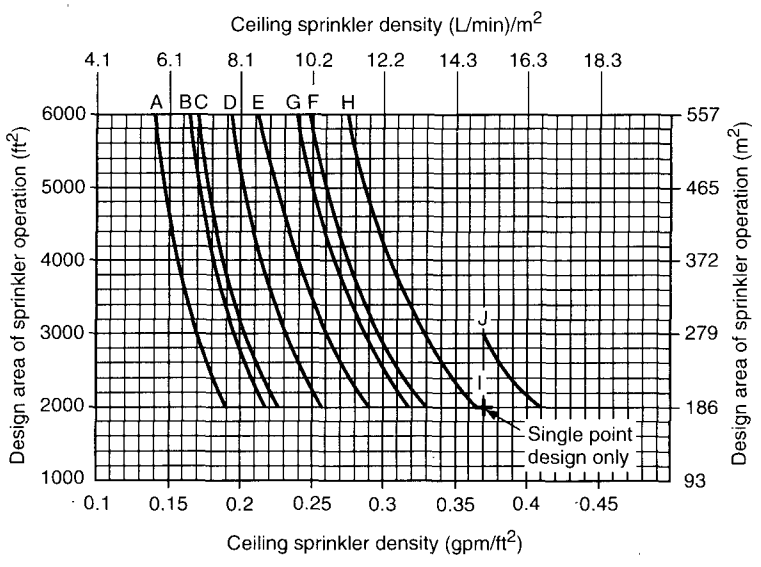
Height	Commodity Class	Encapsulated	Aisles (ft) (4-4.1) (B-6-11.2)	Sprinklers Mandatory In-Rack	Ceiling Sprinkler Water Demand					
					With In-Rack Sprinklers			Without In-Rack Sprinklers		
					Fig.	Curves	Apply Fig. 6-9.2	Fig.	Curves	Apply Fig. 6-9.2
Over 12 ft, Up to and including 20 ft	I	No	4 8	No	6-12(a)	C&D A&B	Yes	6-12(a)	G&H E&F	Yes
		Yes	4 8	No	6-12(e)	C&D A&B		6-12(e)	G&H E&F	Yes
	II	No	4 8	No	6-12(b)	C&D A&B		6-12(b)	G&H E&F	Yes
		Yes	4 8	No	6-12(e)	C&D A&B		6-12(e)	G&H E&F	Yes
	III	No	4 8	No	6-12(c)	C&D A&B		6-12(c)	G&H E&F	Yes
		Yes	4 8	1 Level	6-12(f)	C&D A&B				
	IV	No	4 8	No	6-12(d)	C&D A&B		6-12(d)	G&H E&F	Yes
		Yes	4 8	1 Level	6-12(g)	C&D A&B				
Over 20 ft, Up to and including 22 ft	I	No	4 8	No	6-12(a)	C&D A&B	No	6-12(a)	G&H E&F	Yes
		Yes	4 8	1 Level	6-12(e)	C&D A&B				
	II	No	4 8	No	6-12(b)	C&D A&B		6-12(b)	G&H E&F	Yes
		Yes	4 8	1 Level	6-12(e)	C&D A&B				
	III	No	4 8	No	6-12(c)	C&D A&B		6-12(c)	G&H E&F	Yes
		Yes	4 8	1 Level	6-12(f)	C&D A&B				
	IV	No	4 8	No	6-12(d)	C&D A&B		6-12(d)	G&H E&F	Yes
		Yes	4 8	1 Level	6-12(g)	C&D A&B				
Over 22 ft, Up to and including 25 ft	I	No	4 8	No	6-12(a)	C&D A&B	No	6-12(a)	G&H E&F	Yes
		Yes	4 8	1 Level	6-12(e)	C&D A&B				
	II	No	4 8	No	6-12(b)	C&D A&B		6-12(b)	G&H E&F	Yes
		Yes	4 8	1 Level	6-12(e)	C&D A&B				
	III	No	4 8	No	6-12(c)	C&D A&B		6-12(c)	G&H E&F	Yes
		Yes	4 8	1 Level	6-12(f)	C&D A&B				
	IV	No	4 8	1 Level	6-12(d)	C&D A&B				
		Yes	4 8		6-12(g)	C&D A&B				

For SI units: 1 ft = 0.3048 m

The design shall be sufficient to satisfy a single point on the appropriate curve related to the storage configuration and commodity class. It shall not be required to meet all points on the selected curve. Figure 6-9.2 shall be used to adjust density for storage height unless otherwise specified. (*See A-6-6.1 and A-6-12.*)

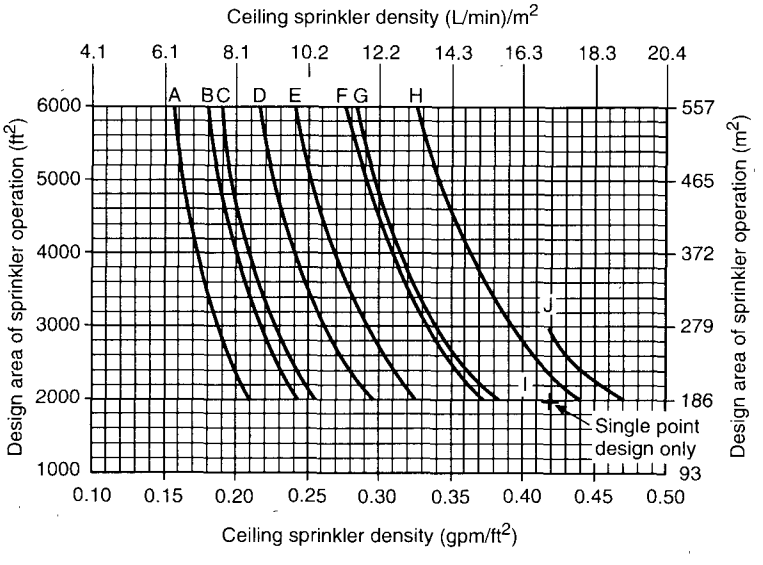
6-15.2 For encapsulated Class I, II, or III commodities with storage height up to and including 25 ft (7.6 m) on multiple-row racks, ceiling sprinkler density shall be 25 percent greater than for nonencapsulated commodities on multiple-row racks.

6-15.3 For encapsulated Class IV commodities with storage height up to and including 25 ft (7.6 m) on multiple-row racks, ceiling sprinkler density shall be 50 percent greater than for nonencapsulated commodities on double-row racks.



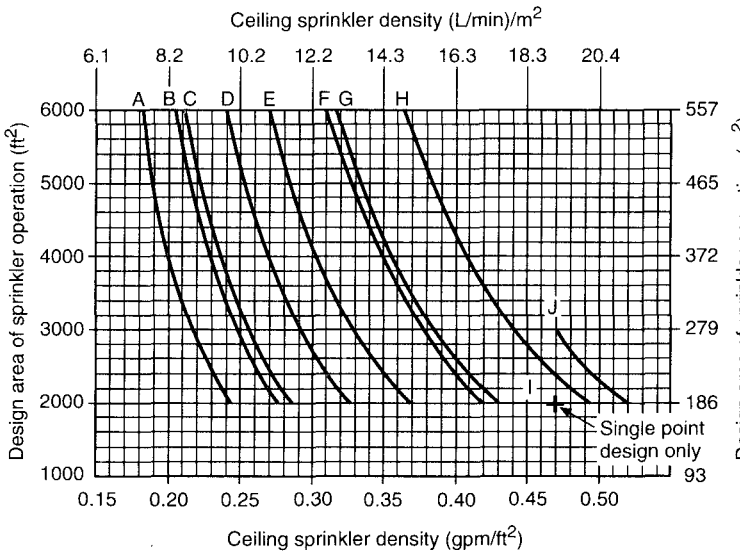
Curve	Legend
A	Single- or double-row racks with 8-ft (2.44-m) aisles with 286°F (141°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers.
B	Single- or double-row racks with 8-ft (2.44-m) aisles with 165°F (74°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers.
C	Single- or double-row racks 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) in-rack 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 6-12(a) Sprinkler system design curves — 20-ft (6.1-m) high rack storage — Class I nonencapsulated commodities — conventional pallets.



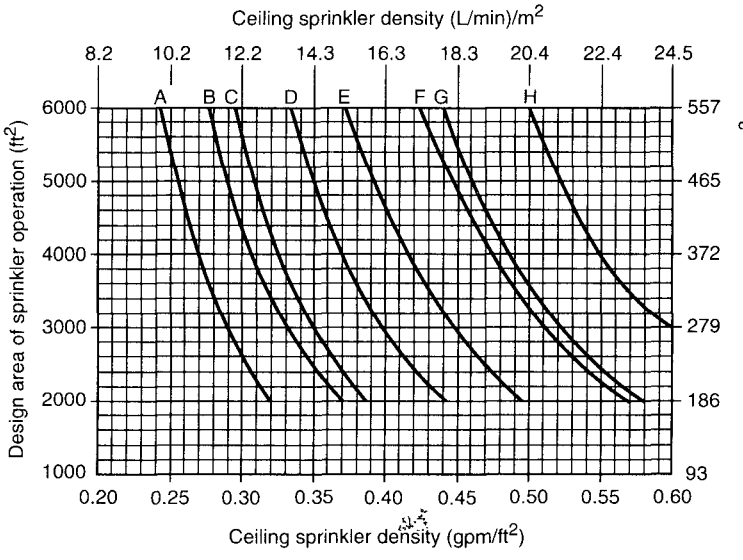
Curve	Legend
A	Single- or double-row racks with 8-ft (2.44-m) aisles with 286°F (141°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers.
B	Single- or double-row racks with 8-ft (2.44-m) aisles with 165°F (74°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers.
C	Single- or double-row racks 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) in-rack 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 6-12(b) Sprinkler system design curves — 20-ft (6.1-m) high rack storage — Class II nonencapsulated commodities — conventional pallets.



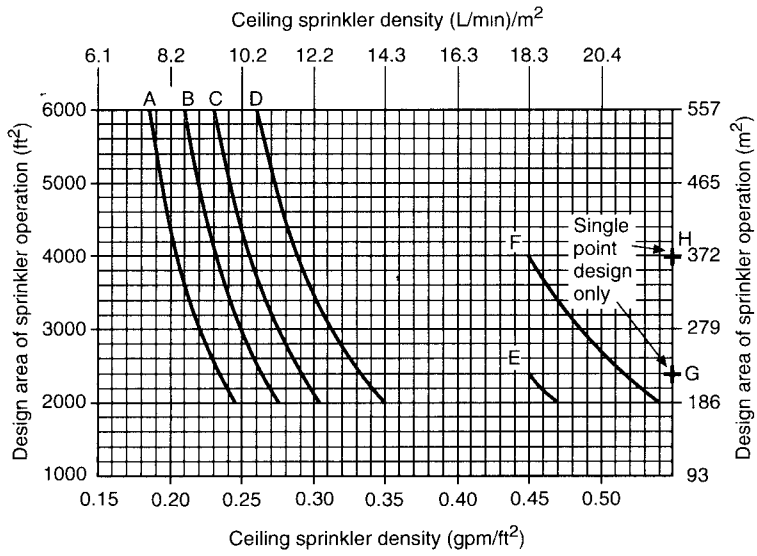
Curve	Legend
A	Single- or double-row racks with 8-ft (2.44-m) aisles with 286°F (141°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers.
B	Single- or double-row racks with 8-ft (2.44-m) aisles with 165°F (74°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers.
C	Single- or double-row racks 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) in-rack 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 6-12(c) Sprinkler system design curves — 20-ft (6.1-m) high rack storage — Class III nonencapsulated commodities — conventional pallets.



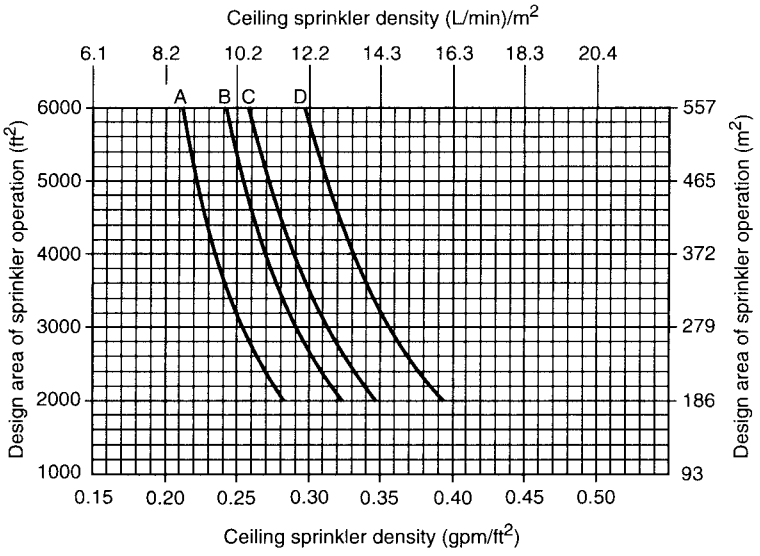
Curve	Legend
A	Single- or double-row racks with 8-ft (2.44-m) aisles with 286°F (141°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers.
B	Single- or double-row racks with 8-ft (2.44-m) aisles with 165°F (74°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers.
C	Single- or double-row racks 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) in-rack 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 6-12(d) Sprinkler system design curves — 20-ft (6.1-m) high rack storage — Class IV nonencapsulated commodities — conventional pallets.



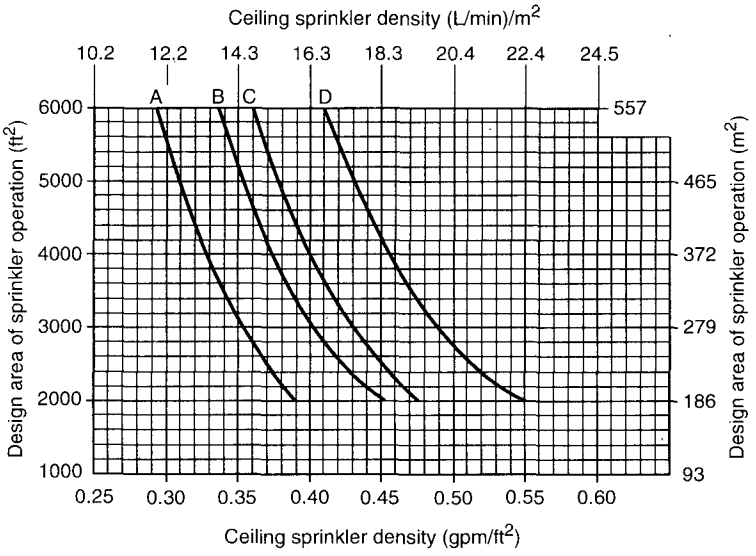
Curve	Legend
A	8-ft (2.44-m) aisles with 286°F (141°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers.
B	8-ft (2.44-m) aisles with 165°F (74°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers.
C	4-ft (1.22-m) aisles with 286°F (141°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers.
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 286°F (141°C) ceiling sprinklers.
F	8-ft (2.44-m) aisles with 165°F (74°C) in-rack 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 6-12(e) Single- or double-row racks — 20-ft (6.1-m) high rack storage — sprinkler system design curves — Class I and II encapsulated commodities — conventional pallets.



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.

Figure 6-12(f) Single- or double-row racks — 20-ft (6.1-m) high rack storage — sprinkler system design curves — Class III encapsulated commodities — conventional pallets.



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.

Figure 6-12(g) Single- or double-row racks — 20-ft (6.1-m) high rack storage — sprinkler system design curves — Class IV encapsulated commodities — conventional pallets.

Table 6-14 Multiple-Row Racks. Rack Depth up to and Including 16 ft, Aisles Wider than 8 ft, Storage Height up to 25 ft.

Height	Commodity Class	Encapsulated	Sprinklers Mandatory In-Racks	Ceiling Sprinkler Water Demand							
				With In-Rack Sprinklers				Without In-Rack Sprinklers			
				Fig. No.	Curves	Apply Fig. 6-9.2	1.25 x Density	Fig. No.	Curves	Apply Fig. 6-9.2	1.25 x Density
Over 12 ft up to and including 15 ft	I	No	No	6-12(a)	C&D	Yes	No	6-12(a)	I&J	Yes	No
		Yes		6-12(a)			Yes	6-12(a)	I&J		Yes
	II	No		6-12(b)			No	6-12(b)	I&J	Yes	No
		Yes		6-12(b)			Yes	6-12(b)	I&J		Yes
	III	No	No	6-12(c)			No	6-12(c)	I&J	Yes	No
		Yes	1 level	6-12(c)			Yes				
	IV	No	No	6-12(d)			No	6-12(d)	C&D	No	No
		Yes	1 level	6-12(d)	A&B		1.50 x density				
Over 15 ft up to and including 20 ft	I	No	No	6-12(a)	C&D	Yes	No	6.12(a)	I&J	Yes	No
		Yes		6-12(a)			Yes	6-12(a)	I&J		Yes
	II	No		6-12(b)			No	6-12(b)	I&J	Yes	No
		Yes		6-12(b)			Yes	6-12(b)	I&J		Yes
	III	No	No	6-12(c)			No	6-12(c)	I&J	Yes	No
		Yes	1 level	6-12(c)			Yes				
	IV	No	1 Level	6-12(d)			No				
		Yes		6-12(d)	A&B		1.50 x density				
Over 20 ft up to and including 25 ft	I	No	No	6-12(a)	C&D	No	No	6-12(a)	I&J	Yes	No
		Yes	1 level	6-12(a)			Yes				
	II	No	1 level	6-12(b)			No				
		Yes		6-12(b)			Yes				
	III	No		6-12(c)			No				
		Yes		6-12(c)			Yes				
	IV	No	2 levels	6-12(d)			No				
		Yes		6-12(d)	A&B		1.50 x density				

For SI units: 1 ft = 0.3048 m

Table 6-14.1 Multiple-Row Racks; Rack Depth Over 16 ft or Aisles Narrower than 8 ft, Storage Height up to and Including 25 ft.

Height	Commodity Class	Encapsulated	Sprinklers Mandatory In-Racks	Ceiling Sprinkler Water Demand							
				With In-Rack Sprinklers				Without In-Rack Sprinklers			
				Fig. No.	Curves	Apply Fig. 6-9.2	1.25 x Density	Fig. No.	Curves	Apply Fig. 6-9.2	1.25 x Density
Over 12 ft up to and including 15 ft	I	No	No	6-12(a)	C&D	Yes	No	6-12(a)	I&J	Yes	No
		Yes		6-12(a)			Yes	6-12(a)	I&J		Yes
	II	No		6-12(b)			No	6-12(b)	I&J	Yes	No
		Yes		6-12(b)			Yes	6-12(b)	I&J		Yes
	III	No		6-12(c)			No	6-12(c)	I&J	Yes	No
		Yes	1 level	6-12(c)			Yes				
	IV	No	No	6-12(d)			No	6-12(d)	C&D	No	No
		Yes	1 level	6-12(d)			1.50 x density				
Over 15 ft up to and including 20 ft	I	No	1 level	6-12(a)	C&D	Yes	No				
		Yes		6-12(a)			Yes				
	II	No		6-12(b)			No				
		Yes		6-12(b)			Yes				
	III	No		6-12(c)			No				
		Yes		6-12(c)			Yes				
	IV	No		6-12(d)			No				
		Yes		6-12(d)			1.50 x density				
Over 20 ft up to and including 25 ft	I	No	1 level	6-12(a)	C&D	No	No				
		Yes		6-12(a)			Yes				
	II	No		6-12(b)			No				
		Yes		6-12(b)			Yes				
	III	No		6-12(c)			No				
		Yes		6-12(c)			Yes				
	IV	No	2 levels	6-12(d)			No				
		Yes		6-12(d)			1.50 x density				

For SI units: 1 ft = 0.3048 m

Chapter 7 Fire Protection — Storage over 25 ft (7.6 m) in Height

Part A General

7-1 In-Rack Sprinkler Type. Sprinklers in racks shall be ordinary temperature standard response classification with nominal 1/2-in. (12.7-mm) or 17/32-in. (13.5-mm) orifice size, pendent or upright. Sprinklers with 212°F (100°C) and 286°F (141°C) temperature ratings shall be used near heat sources as required in NFPA 13, *Standard for the Installation of Sprinkler Systems*.

Exception: Quick-response sprinklers shall be permitted to be installed in racks.

7-2 In-Rack Sprinkler Spacing. In-rack sprinklers shall be staggered horizontally and vertically where installed in accordance with Table 7-10.1, Figures 7-10.1(a) through (j), and Figures 7-10.3(a) through (e).

7-3 In-Rack Sprinkler Pipe Size. The number of sprinklers and the pipe sizing on a line of sprinklers in racks shall be restricted only by hydraulic calculations and not by any piping schedule.

7-4 In-Rack Sprinkler Water Shields. Water shields shall be provided directly above in-rack sprinklers, or listed sprinklers equipped with water shields shall be provided where there is more than one level, if not shielded by horizontal barriers. (*See B-6-4.*)

7-5 In-Rack Sprinkler Location. In single-row, double-row, or multiple-row racks, a minimum 6-in. (152.4-mm) vertical clear space shall be maintained between the sprinkler deflectors and the top of a tier of storage. Face sprinklers in such racks shall be located a minimum of 3 in. (76.2 mm) from rack uprights and no more than 18 in. (0.46 m) from the aisle face of storage. Other sprinklers in racks shall be located a minimum of 2 ft (0.61 m) from rack uprights.

Exception: Where the distance between uprights is less than 4 ft (1.22 m), sprinklers shall be centered between uprights.

7-6 In-Rack Sprinkler Discharge Pressure. Sprinklers in racks shall discharge at not less than 30 gpm (113.6 L/min) for all classes of commodities. (*See B-6-8.*)

7-7 In-Rack Sprinkler Water Demand.

7-7.1 The water demand for sprinklers installed in racks shall be based on simultaneous operation of the most hydraulically remote sprinklers as follows:

(a) Six sprinklers where only one level is installed in racks with Class I, II, or III commodities;

(b) Eight sprinklers where only one level is installed in racks with Class IV commodities;

(c) Ten sprinklers (five on each two top levels) where more than one level is installed in racks with Class I, II, or III commodities;

(d) Fourteen sprinklers (seven on each two top levels) where more than one level is installed in racks with Class IV commodities.

7-8 High-Expansion Foam Submergence. Where high-expansion foam systems are used for storage over 25 ft (7.6 m) high up to and including 35 ft (10.67 m) high, they shall be used in combination with ceiling sprinklers. The maximum submergence time for the high-expansion foam shall be 5 minutes for Class I, II, or III commodities and 4 minutes for Class IV commodities.

7-9 High-Expansion Foam—Ceiling Sprinkler Water Demand. Where high-expansion foam is used in combination with ceiling sprinklers, the minimum ceiling sprinkler design density shall be 0.2 gpm/ft^2 [(8.15 L/min)/m^2] for Class I, II, or III commodities and 0.25 gpm/ft^2 [(10.2 L/min)/m^2] for Class IV commodities for the most hydraulically remote 2000-ft^2 (185.8-m^2) area.

Part B Double- and Single-Row Racks

7-10 In-Rack Sprinkler Location.

7-10.1 In double-row racks without solid shelves and with a maximum of 10 ft (3.1 m) between the top of storageand the ceiling, in-rack sprinklers shall be installed in accordance with Table 7-10.1 and Figures 7-10.1(a) through (j). The highest level of in-rack sprinklers shall be not more than 10 ft (3.1 m) below the top of storage. (*See Section 7-11.*)

7-10.2 In-rack sprinklers for storage higher than 25 ft (7.6 m) in double-row racks shall be spaced horizontally and located in the horizontal space nearest the vertical intervals specified in Table 7-10.1 and Figures 7-10.1(a) through (j).

7-10.3* In single-row racks without solid shelves with storage height over 25 ft (7.6 m) and a maximum of 10 ft (3.1 m) between the top of storage and the ceiling, sprinklers shall be installed in accordance with Figures 7-10.3(a) through (e).

7-11* In-Rack Sprinkler Horizontal Barriers. Horizontal barriers used in conjunction with in-rack sprinklers to impede vertical fire development shall be constructed of sheet metal, wood, or similar material and shall extend the full length and width of the rack. Barriers shall be fitted within 2 in. (50.8 mm) horizontally around rack uprights. [*See Table 7-10.1, Figures 7-10.1(a), (g), and (j), and Figures 7-10.3(c) and (e).*]

7-12 Ceiling Sprinkler Water Demand.

7-12.1*† The water demand for nonencapsulated storage on racks without solid shelves separated by aisles at least 4 ft (1.22 m) wide and with not more than 10 ft (3.1 m) between the top of storage and the sprinklers shall be based on sprinklers in a 2000-ft^2 (185.8-m^2) operating area, discharging a minimum of 0.25 gpm/ft^2 [(10.18 L/min)/m^2] for Class I commodities, 0.3 gpm/ft^2 [(12.2 L/min)/m^2] for Class II and III

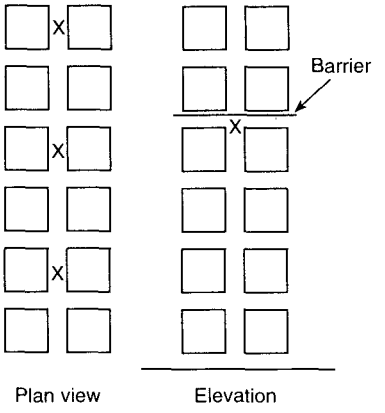
Table 7-10.1 Double-Row Racks without Solid Shelves, Storage Higher than 25 ft, Aisles Wider than 4 ft

Commodity Class	In-rack sprinklers — approximate vertical spacing at tier nearest the vertical distance and maximum horizontal spacing [1,2]		Fig. No.	Maximum Storage Height	Stagger	Ceiling Sprinkler Operating	Ceiling Sprinkler Density (gpm/sq ft)[6] Clearance[5] up to 10 ft[7]	
	Longitudinal Flue[3]	Face [4,8]					165°	286°
I	Vertical 20 ft Horizontal 10 ft under horizontal barriers	None	7-10.1(a)	30 ft	No	2000 ft^2	0.25	0.35
	Vertical 20 ft Horizontal 10 ft	Vertical 20 ft Horizontal 10 ft	7-10.1(b)	Higher than 25 ft	Yes		0.25	0.35
I, II, & III	Vertical 10 ft or at 15 ft & 25 ft Horizontal 10 ft	None	7-10.1(c)	30 ft	Yes	2000 ft^2	0.30	0.40
	Vertical 10 ft Horizontal 10 ft	Vertical 30 ft Horizontal 10 ft	7-10.1(d)	Higher than 25 ft	Yes		0.30	0.40
	Vertical 20 ft Horizontal 10 ft	Vertical 20 ft Horizontal 5 ft	7-10.1(e)		Yes		0.30	0.40
	Vertical 25 ft Horizontal 5 ft	Vertical 25 ft Horizontal 5 ft	7-10.1(f)		No		0.30	0.40
	Horizontal barriers at 20 ft. Vertical intervals—2 lines of sprinklers under barriers—maximum horizontal spacing 10 ft staggered.		7-10.1(g)		Yes		0.30	0.40
I, II, III, & IV	Vertical 15 ft Horizontal 10 ft	Vertical 20 ft Horizontal 10 ft	7-10.1(h)	Higher than 25 ft	Yes	2000 ft^2	0.35	0.45
	Vertical 20 ft Horizontal 5 ft	Vertical 20 ft Horizontal 5 ft	7-10.1(i)		No		0.35	0.45
	Horizontal barriers at 15 ft. Vertical intervals—2 lines of sprinkler under barriers—maximum horizontal spacing 10 ft staggered		7-10.1(j)		Yes		0.35	0.45

For SI Units: 1 ft = 0.3048 m

Footnotes to Table 7-10.1

[1]Minimum in-rack sprinkler pressure, 30 psi (2.1 bar) (Section 7-6).
[2]Water shields required (Section 6-4 and Section 7-4).
[3]Install sprinklers at least 2 ft (0.61 m) from uprights (A-6-5.1).
[4]Install sprinklers at least 3 in. (76.2 mm) from uprights (Section 7-5).
[5]Clearance is distance between top of storage and ceiling.
[6]For encapsulated commodity, increase density 25 percent (7-12.1).
[7]See A-7-10.3, A-7-11, and A-7-12.1 for protection recommendations where clearance is greater than 10 ft (3.05 m).
[8]Face sprinklers shall not be required for a Class I commodity consisting of noncombustible products on wood pallets (without combustible containers) except for arrays shown in Figure 7-10.1(g) and Figure 7-10.1(j).



NOTES:
1. Symbol X indicates in-rack sprinklers.
2. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-10.1(a) In-rack sprinkler arrangement, Class I commodities, maximum storage height 25 ft to 30 ft (7.6 m to 9.1 m).

commodities, and 0.35 gpm/ft^2 [(14.26 L/min)/m^2] for Class IV commodities, for 165°F (74°C) rated sprinklers; or a minimum of 0.35 gpm/ft^2 [(14.26 L/min)/m^2] for Class I commodities, 0.40 gpm/ft^2 [(16.3 L/min)/m^2] for Class II and III commodities, and 0.45 gpm/ft^2 [(18.3 L/min)/m^2] for Class IV commodities, for 286°F (141°C) rated sprinklers. (*See Table 7-10.1.*)

7-12.2 Where storage as described in 7-12.1 is encapsulated, ceiling sprinkler density shall be 25 percent greater than for nonencapsulated storage.

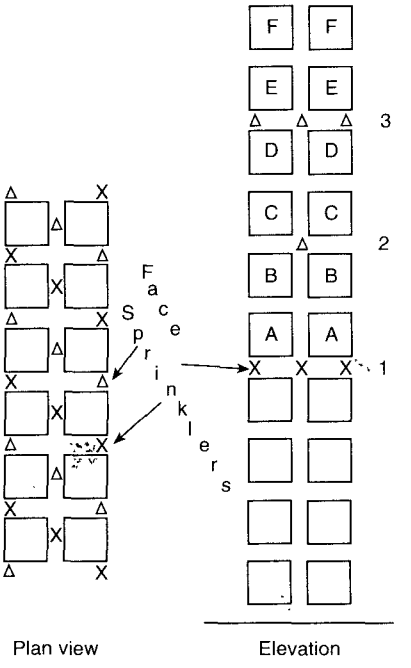
Part C Multiple-Row Racks

7-13* In-Rack Sprinkler Location. In multiple-row racks with a maximum of 10 ft (3.1 m) between the top of storage and the ceiling, in-rack sprinklers shall be installed as indicated in Figures 7-13(a), (b), and (c). The highest level of in-rack sprinklers shall be not more than 10 ft (3.1 m) below maximum storage height for Class I, II, or III commodities or 5 ft (1.52 m) below the top of storage for Class IV commodities. (*See Table 7-13.*)

7-14 In-Rack Sprinkler Spacing. Maximum horizontal spacing of sprinklers in multiple-row racks with storage higher than 25 ft (7.6 m) shall be in accordance with Figures 7-13(a), (b), and (c).

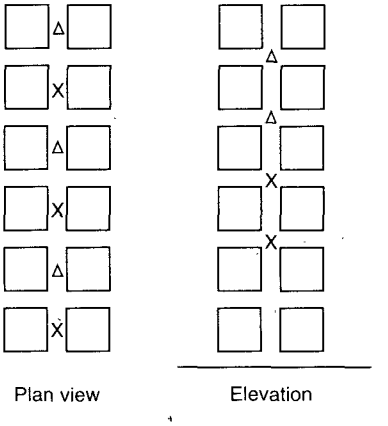
7-15 Ceiling Sprinkler Water Demand.

7-15.1 The water demand for nonencapsulated storage on racks without solid shelves separated by aisles at least 4 ft (1.22 m) wide and with not more than 10 ft (3.1 m) between the top of storage and the sprinklers shall be based on sprinklers in a 2000-ft^2 (185.8-m^2) operating area for multiple-row racks, discharging a minimum of 0.25 gpm/ft^2 [(10.19 L/min)/m^2] for Class I commodities, 0.3 gpm/ft^2 [(12.2 L/min)/m^2] for Class II and III commodities, and 0.35 gpm/ft^2 [(14.26 L/min)/m^2] for Class IV commodities, for 165°F (74°C) rated sprinklers; or a minimum of 0.35 gpm/ft^2 [(14.26 L/min)/m^2] for Class I commodities, 0.40 gpm/ft^2 [(16.8 L/min)/m^2] for Class II and III commodities, and 0.45 gpm/ft^2 [(18.3 L/min)/m^2] for Class IV commodities, for 286°F (141°C) rated sprinklers. (*See Table 7-13.*)



NOTES:
1. Sprinklers labeled 1 (the selected array from Table 7-10.1) shall be required where loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled C or D represent top of storage.
3. Sprinklers labeled 1 and 3 shall be required where loads labeled E or F represent top of storage.
4. For storage higher than represented by loads labeled F, the cycle defined by Notes 2 and 3 is repeated, with stagger as indicated.
5. Symbol Δ or X indicates sprinklers on vertical or horizontal stagger.
6. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

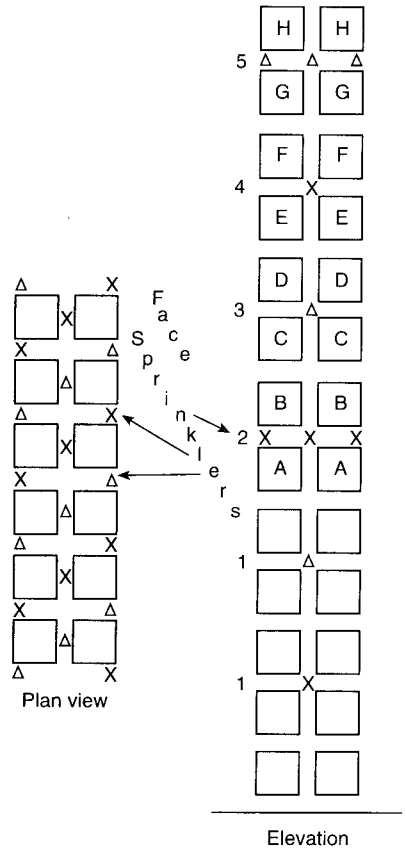
Figure 7-10.1(b) In-rack sprinkler arrangement, Class I commodities, storage height over 25 ft (7.6 m).



NOTES:
1. Alternate location of in-rack sprinklers. Sprinklers may be installed at the second and fourth or the third and fifth tiers.
2. Symbol Δ or X indicates sprinklers on vertical or horizontal stagger.
3. Each square in the figure represents a storage cube measuring 4 ft or 5 ft (1.25 m to 1.56 m) on a side.

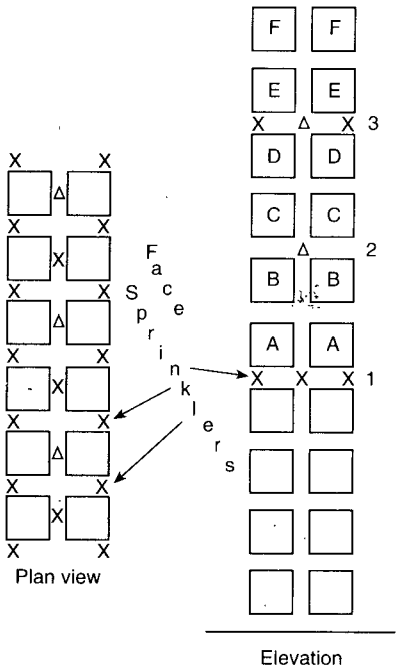
Figure 7-10.1(c) In-rack sprinkler arrangement, Class I, II, or III commodities, maximum storage height 25 ft to 30 ft (7.6 m to 9.1 m).

7-15.2 Where such storage is encapsulated, ceiling sprinkler density shall be 25 percent greater than for nonencapsulated storage.



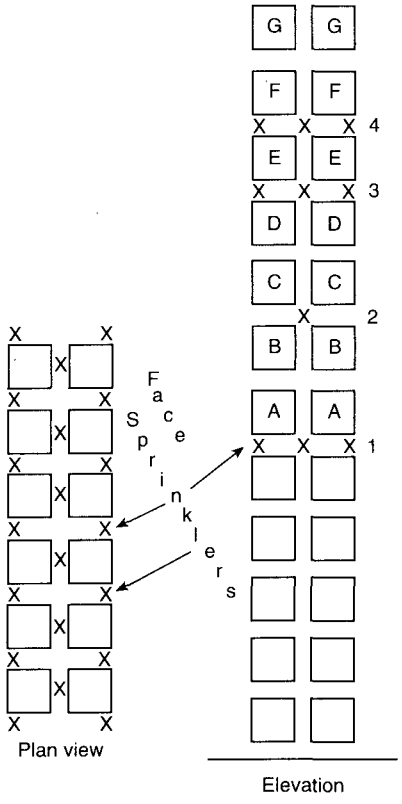
NOTES:
1. Sprinklers labeled 1 shall be required where loads labeled A represent the top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled B or C represent top of storage.
3. Sprinklers labeled 1, 2, and 3 shall be required where loads labeled D or E represent top of storage.
4. Sprinklers labeled 1, 2, 3, and 4 shall be required where loads labeled F or G represent top of storage.
5. Sprinklers labeled 1, 2, 3, 4, and 5 shall be required where loads labeled H represent top of storage.
6. For storage higher than represented by loads labeled H, the cycle defined by Notes 3, 4, and 5 is repeated with stagger as indicated.
7. The indicated face sprinklers shall be permitted to be omitted where commodity consists of unwrapped or unpackaged metal parts on wood pallets.
8. Symbol Δ or X indicates sprinklers on vertical or horizontal stagger.
9. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-10.1(d) In-rack sprinkler arrangement, Class I, II, or III commodities, storage height over 25 ft (7.6 m).



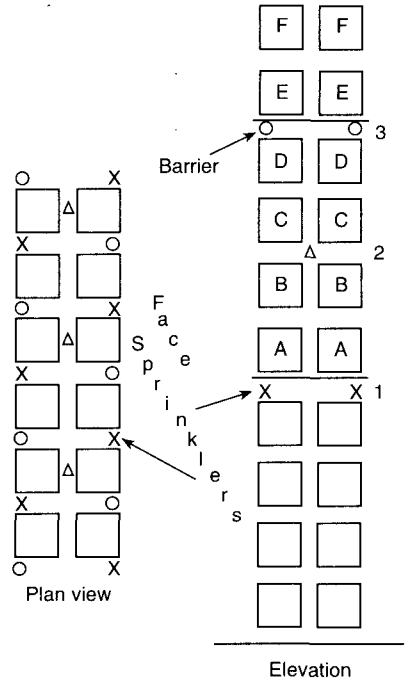
NOTES:
1. Sprinklers labeled 1 (the selected array from Table 7-10.1) shall be required where loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled C or D represent top of storage.
3. Sprinklers labeled 1 and 3 shall be required where loads labeled E or F represent top of storage.
4. For storage higher than represented by loads labeled F, the cycle defined by Notes 2 and 3 is repeated, with stagger as indicated.
5. Symbol Δ or X indicates sprinklers on vertical or horizontal stagger.
6. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-10.1(e) In-rack sprinkler arrangement, Class I, II, or III commodities, storage height over 25 ft (7.6 m).



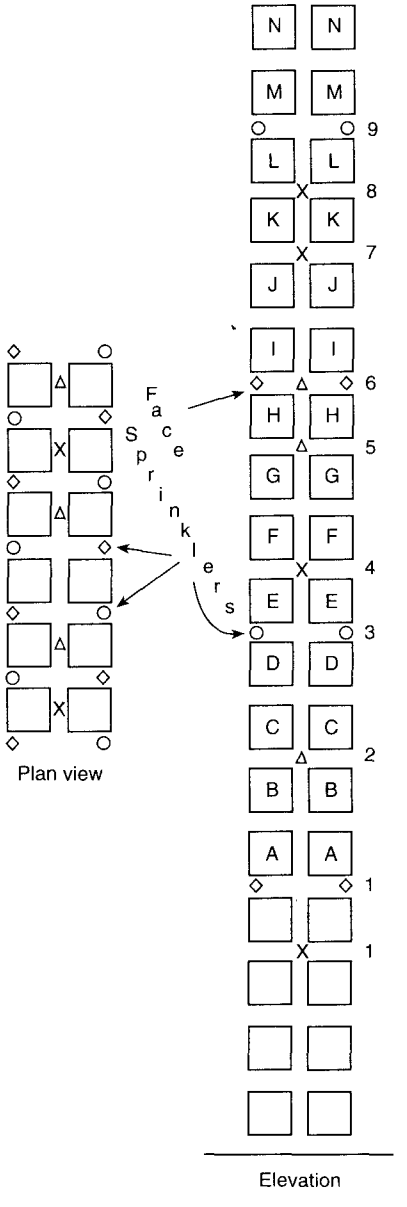
NOTES:
1. Sprinklers labeled 1 (the selected array from Table 7-10.1) shall be required where loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled C or D represent top of storage.
3. Sprinklers labeled 1 and 3 shall be required where loads labeled E represent top of storage.
4. Sprinklers labeled 1 and 4 shall be required where loads labeled F or G represent top of storage.
5. For storage higher than represented by loads labeled G, the cycle defined by Notes 2, 3, and 4 is repeated.
6. Symbol X indicates face and in-rack sprinklers.
7. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-10.1(f) In-rack sprinkler arrangement, Class I, II, or III commodities, storage height over 25 ft (7.6 m).



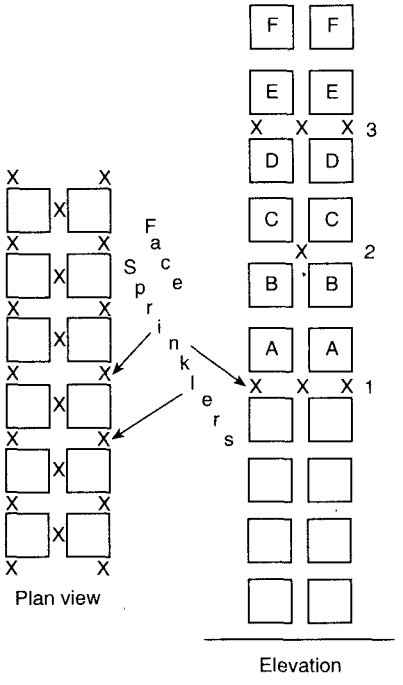
NOTES:
1. Sprinklers labeled 1 (the selected array from Table 7-10.1) shall be required where loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled C or D represent top of storage.
3. Sprinklers labeled 1 and 3 shall be required where loads labeled E or F represent top of storage.
4. For storage higher than represented by loads labeled F, the cycle defined by Notes 2 and 3 is repeated.
5. Symbols O, Δ, and X indicate sprinklers on vertical or horizontal stagger.
6. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-10.1(g) In-rack sprinkler arrangement, Class I, II, or III commodities, storage height over 25 ft (7.6 m).



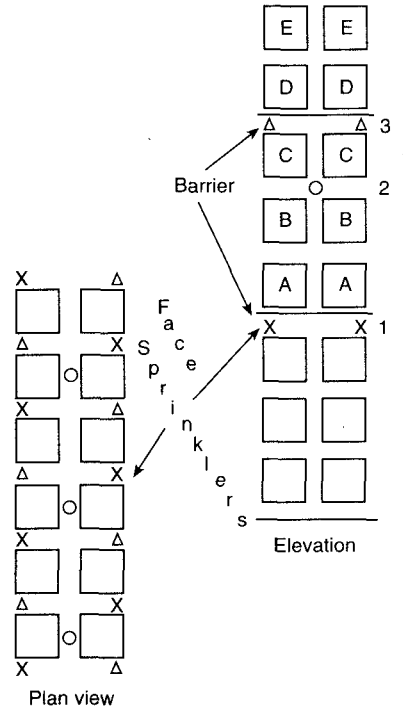
NOTES:
1. Sprinklers labeled 1 (the selected array from Table 7-10.1) shall be required where loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled C or D represent top of storage.
3. Sprinklers labeled 1 and 3 shall be required where loads labeled E or F represent top of storage.
4. Sprinklers labeled 1, 2, 3, and 4 shall be required where loads labeled G represent top of storage.
5. Sprinklers labeled 1, 2, 3, 4, and 5 shall be required where loads labeled H represent top of storage.
6. Sprinklers labeled 1, 2, 3, 4, and 6 (not 5) shall be required where loads labeld I or J represent top of storage.
7. Sprinklers labeled 1, 2, 3, 4, 6, and 7 shall be required where loads labeled K represent top of storage.
8. Sprinklers labeled 1, 2, 3, 4, 6, and 8 shall be required where loads labeled L represent top of storage.
9. Sprinklers labeled 1, 2, 3, 4, 6, 8, and 9 shall be required where loads labeled M or N represent top of storage.
10. For storage higher than represented by loads labeled N, the cycle defined by Notes 1 through 9 is repeated, with stagger as indicated. In the cycle, loads labeled M are equivalent to loads labeled A.
11. Symbols O, X, and Δ indicate sprinklers on vertical or horizontal stagger.
12. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-10.1(h) In-rack sprinkler arrangement, Class I, II, III, or IV commodities, storage height over 25 ft (7.6 m).



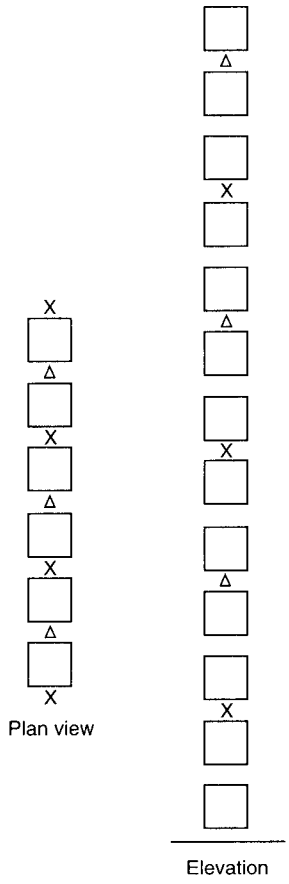
NOTES:
1. Sprinklers labeled 1 (the selected array from Table 7-10.1) shall be required where loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled C or D represent top of storage.
3. Sprinklers labeled 1 and 3 shall be required where loads labeled E or F represent top of storage.
4. For storage higher than represented by loads labeled F, the cycle defined by Notes 2 and 3 is repeated.
5. Symbol X indicates face and in-rack sprinklers.
6. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-10.1(i) In-rack sprinkler arrangement, Class I, II, III, or IV commodities, storage height over 25 ft (7.6 m).



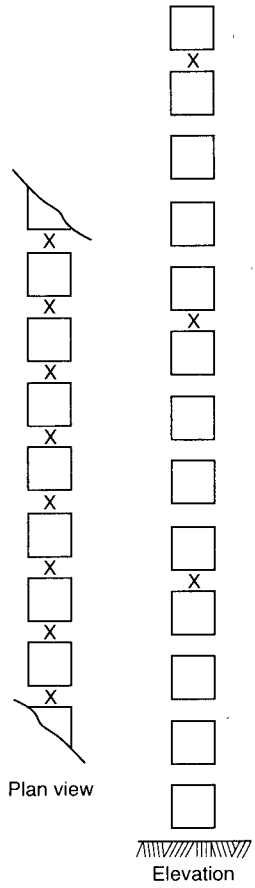
NOTES:
1. Sprinklers labeled 1 (the selected array from Table 7-10.1) shall be required where loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 and barrier labeled 1 shall be required where loads labeled C represent top of storage.
3. Sprinklers and barriers labeled 1 and 3, shall be required where loads labeled D or E represent top of storage.
4. For storage higher than represented by loads labeled E, the cycle defined by Notes 2 and 3 is repeated.
5. Symbol Δ or X indicates sprinklers on vertical or horizontal stagger.
6. Symbol O indicates longitudinal flue space sprinklers.
7. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-10.1(j) In-rack sprinkler arrangement, Class I, II, III, or IV commodities, storage height over 25 ft (7.6 m).



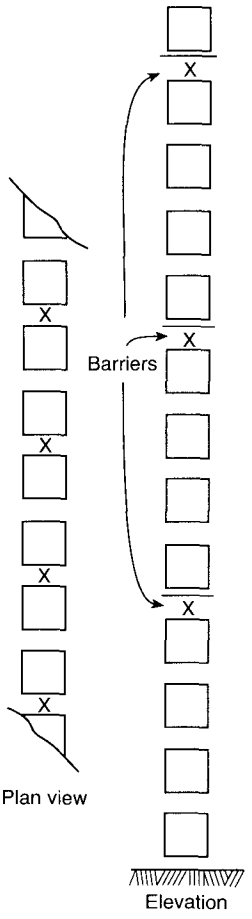
NOTES:
1. For all storage heights, sprinklers shall be installed in every other tier and staggered as indicated.
2. Symbol Δ or X indicates sprinklers on vertical or horizontal stagger.
3. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-10.3(a) Class I, II, III, or IV commodities. In-rack sprinkler arrangement, single-row racks, storage height over 25 ft (7.6 m).



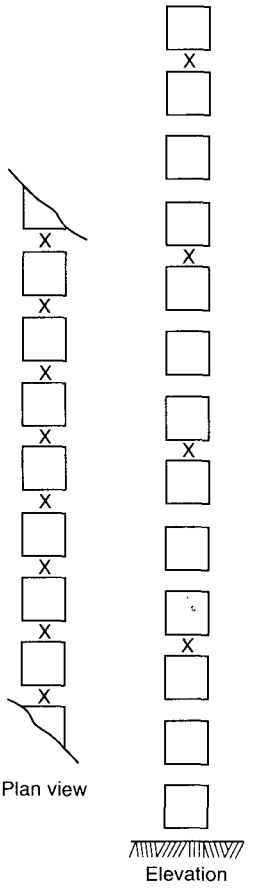
NOTE:
1. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-10.3(b) Class I, II, or III commodities.



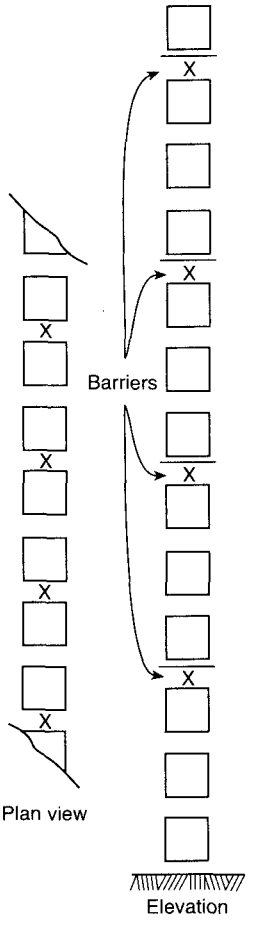
NOTE:
1. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-10.3(c) Class I, II, or III commodities.



NOTE:
1. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-10.3(d) Class I, II, III, or IV commodities.



NOTE:
1. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

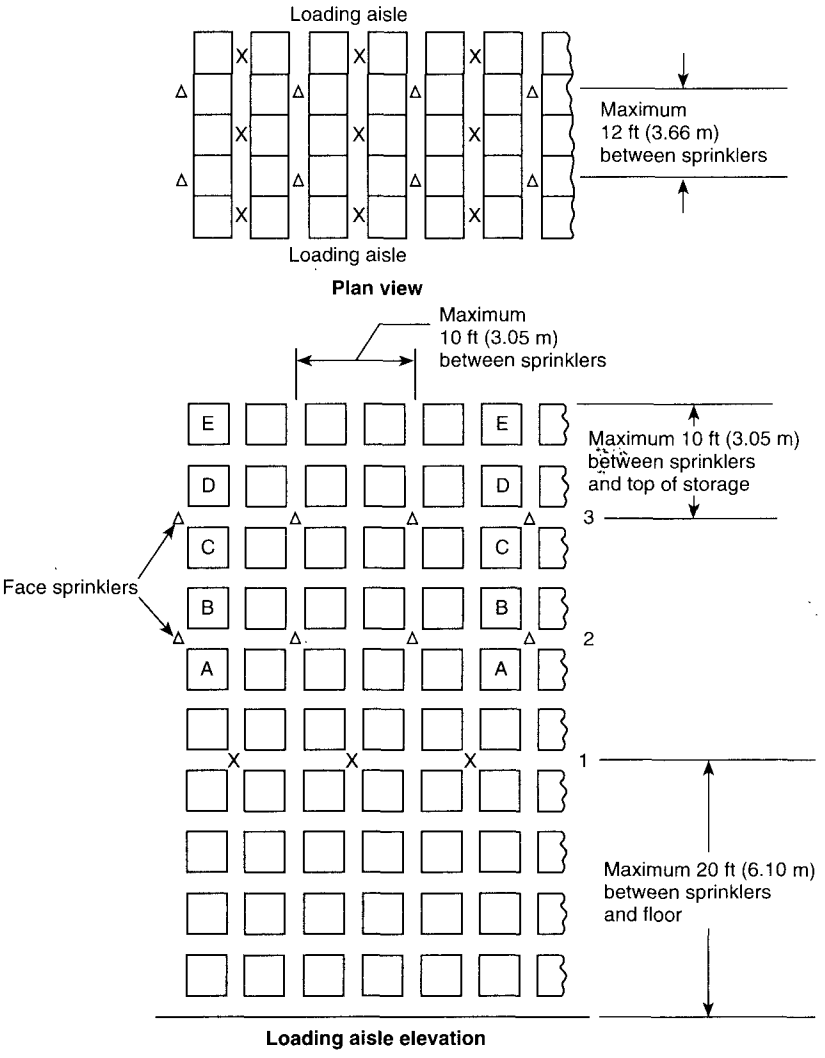
Figure 7-10.3(e) Class I, II, III, or IV commodities.

Table 7-13 Multiple-Row Racks. Storage Heights over 25 ft.

Commodity Class	Encapsulated	In-Rack Sprinklers[1]			Height Limit (ft)	Stagger	Fig. No.	Maximum Spacing from Top of Storage to Highest In-Rack Sprinklers (ft)	Ceiling Sprinkler Operating Area (ft^2)	Ceiling Sprinklers Density (gpm/ft^2)	
		Approximate Vertical Spacing (ft)	Maximum Horizontal Spacing In a Flue (ft)	Maximum Horizontal Spacing Across Flue (ft)						165° Rating	286° Rating
I	No	20	12	10	None	Between adjacent flues	7.13(a)	10	2000	0.25	0.35
	Yes									0.31	0.44
I, II, & III	No	15	10	10			7-13(b)	10		0.30	0.40
	Yes									0.37	0.50
I, II, III, & IV	No	10	10	10			7.13(c)	5		0.35	0.45
	Yes									0.44	0.56

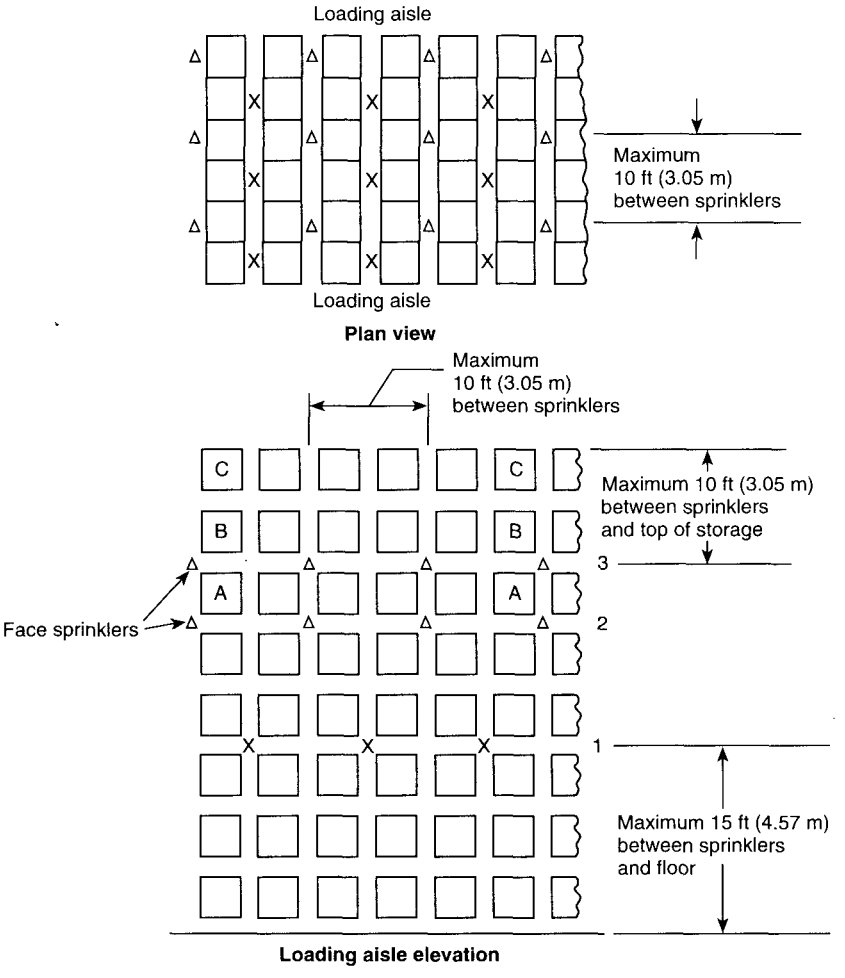
[1]All four rack faces shall be protected by sprinklers located within 18 in. of the faces, as indicated in Figures 7-13(a), (b), and (c). It shall not be required for each sprinkler level to protect all faces. (*See A-7-13.*)

For SI units. 1 ft = 0.3048 m; C = 5/9 (F − 32); 1 gpm/ft^2 = 40.746 $(L/min)/m^2$



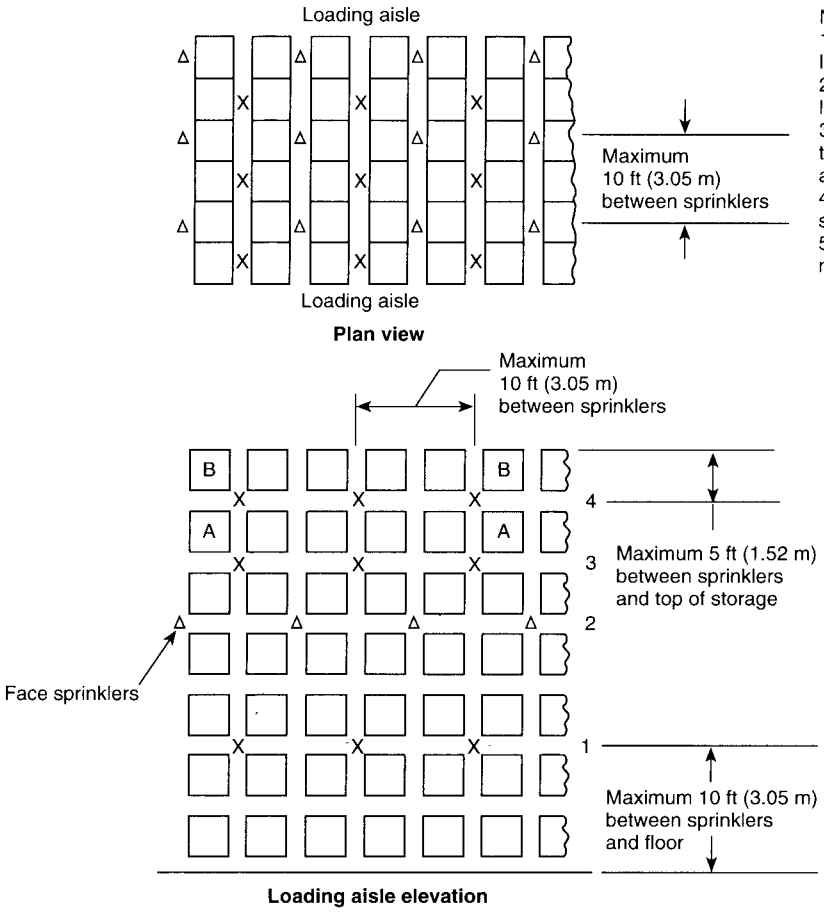
NOTES:
1. Sprinklers labeled 1 shall be required if loads labeled A represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required if loads labeled B or C represent top of storage.
3. Sprinklers labeled 1 and 3 shall be required if loads labeled D or E represent top of storage.
4. For storage higher than represented by loads labeled E, the cycle defined by Notes 2 and 3 is repeated, with stagger as indicated.
5. Symbol Δ or X indicates sprinklers on vertical or horizontal stagger.
6. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-13(a) In-rack sprinkler arrangement — multiple-row racks, Class I commodities, storage height over 25 ft (7.6 m).



NOTES:
1. Sprinklers labeled 1 and 2 shall be required if loads labeled A represent top of storage.
2. Sprinklers labeled 1 and 3 shall be required if loads labeled B or C represent top of storage.
3. For storage higher than represented by loads labeled C, the cycle defined by Notes 2 and 3 is repeated, with stagger as indicated.
4. Symbol Δ or X indicates sprinklers on vertical or horizontal stagger.
5. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-13(b) In-rack sprinkler arrangement — multiple-row racks, Class I, II, or III commodities, storage height over 25 ft (7.6 m).



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, and 4 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.
5. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 7-13(c) In-rack sprinkler arrangement, Class I, II, III, or IV commodities — multiple-row racks, storage height over 25 ft (7.6 m).

Chapter 8* Plastics

8-1 General. For the storage of Group A plastics stored 5 ft (1.5 m) or less in height, the sprinkler design criteria for miscellaneous storage specified in NFPA 13, *Standard for the Installation of Sprinkler Systems*, shall be used.

8-1.1† Plastics in corrugated cartons shall be protected in accordance with Figure 8-1.1. This decision tree also shall be used to determine protection for commodities that are not entirely Group A plastics but contain such quantities and arrangement of Group A plastics that they are deemed more hazardous than Class IV commodities.

8-1.2 Group B plastics and free-flowing Group A plastics shall be protected the same as Class IV commodities.

8-1.3 Group C plastics shall be protected the same as Class III commodities.

8-1.4† Ceiling sprinklers shall be large orifice [$^{17}/_{32}$ in. (13.5 mm)] and rated ordinary to high temperature.

Exception No. 1: Large drop sprinklers in accordance with Chapter 9.

Exception No. 2: ESFR sprinklers in accordance with Chapter 10.

Exception No. 3: For densities of 0.30 gpm/ft² [(12.2 L/mm)/m²] or less, $^1/_2$-in. (12.7-mm) orifice sprinklers shall be permitted.

Exception No. 4: High-temperature sprinklers shall be used where required by NFPA 13, Standard for the Installation of Sprinkler Systems.

8-1.5 In-Rack Sprinklers.

8-1.5.1 In-Rack Sprinkler Classification. Sprinklers in racks shall be ordinary-temperature standard response classification.

Exception No. 1: High-temperature sprinklers shall be used as specified in NFPA 13, Standard for the Installation of Sprinkler Systems.

Exception No. 2: Quick-response sprinklers shall be permitted to be installed in racks.

8-1.5.2 In-Rack Sprinkler Pipe Size. The number of sprinklers and the pipe sizing on a line of sprinklers in racks shall be restricted only by the hydraulic calculations and not by any piping schedule.

8-1.5.3 In-Rack Sprinkler Water Shields. Where in-rack sprinklers are not shielded by horizontal barriers, water shields shall be provided above the sprinklers, or listed sprinklers equipped with water shields shall be used.

8-1.5.4 In-Rack Sprinkler Clearance. The minimum of 6 in. (152.4 mm) vertical clear space shall be maintained between the sprinkler deflectors and the top of a tier of storage.

8-1.5.5 In-Rack Sprinkler Water Demand. The water demand for sprinklers installed in racks shall be based on simultaneous operation of the most hydraulically remote sprinklers as follows:

(a) Eight sprinklers where only one level is installed in racks;

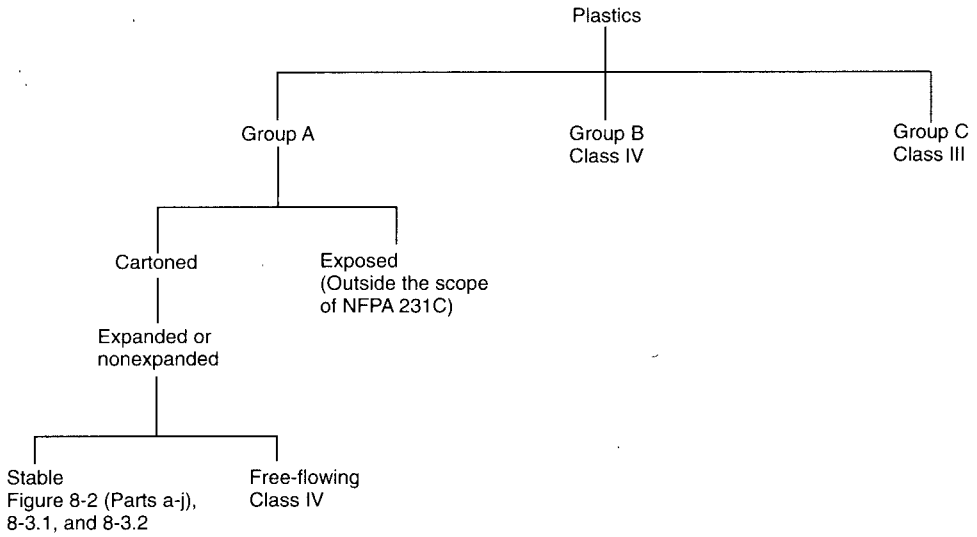


Figure 8-1.1 Decision tree.

(b) Fourteen sprinklers (seven on each top two levels) where more than one level is installed in racks.

8-1.5.6 Chapters 1 through 5 apply to plastics storage.

8-2 Single-, Double-, and Multiple-Row Racks — Storage up to and Including 25 ft (7.6 m) — Clearances up to and Including 10 ft (3.1 m).

8-2.1 Ceiling Sprinkler Water Demand. For Group A plastic commodities in cartons, encapsulated or nonencapsulated in single-, double-, and multiple-row racks, ceiling sprinkler water demand in terms of density (gpm/ft^2) [(L/min)/m^2] and area of operation [ft^2 (m^2)] shall be selected from Figure 8-2 Parts (a) through (g). Linear interpolation of design densities and areas of application shall be permitted between storage heights with the same clearances. No interpolation between clearances shall be permitted.

8-2.1.1 Single-, Double-, and Multiple-Row Racks — 5-ft to 10-ft (1.25-m to 3.1-m) Storage with 1½-ft to 10-ft (0.5-m to 3.1-m) Clearance. The protection strategies utilizing ceiling sprinklers only, as shown in Figure 8-2 Part (a), shall be acceptable for single- and double-row rack storge with 4-ft (1.22-m) or greater aisles and for multiple-row storage.

8-2.1.2 Single- and Double-Row Racks — 15-ft (4.6-m) Storage with Less than 5-ft (1.25-m) Clearance. The protection strategy utilizing ceiling sprinklers only as shown in Figure 8-2 Part (b) shall be acceptable only for single- and double-row rack storage with 8-ft (2.4-m) aisles. For 3½-ft (1-m) aisles, a density of 0.60 gpm/ft^2 [(24.5 L/min)/m^2] and an area of application of 1500 ft^2 (139.5 m^2) shall be used. For aisle widths of 3½ ft to 8 ft (1 m to 2.4 m), a direct linear interpolation shall be permitted between densities and areas of application.

8-2.1.3 Single- and Double-Row Racks — 15-ft (4.6-m) Storage with 10-ft (3.1-m) Clearance; 20-ft (6-m) Storage with Less than 5-ft (1.25-m) Clearance. The protection strategies utilizing ceiling sprinklers only as shown in Figures 8-2 Parts (c) and (d) shall be acceptable only for single- and double-row rack storage with 8-ft (2.4-m) aisles. In-rack sprinkler protection shall be required for aisles less than 8 ft (2.4 m) in width.

Where utilizing the strategies for ceiling sprinklers only, as shown in Figures 8-2 Parts (c) and (d), column steel shall be protected in accordance with 3-2.3(a) or (b). Roof structural steel shall be protected in such a manner as to provide a minimum of 15 minutes fire resistance.

8-2.1.4 Multiple-Row Racks — 15-ft (4.6-m) Storage with Less than 5-ft (1.25-m) Clearance. The protection strategy utilizing ceiling sprinklers only, as shown in Figure 8-2 Part (b), shall not be permitted for multiple-row rack storage. The density to be used shall be 0.60 gpm/ft^2 [(24.5 L/min)/m^2] over 2000 ft^2 (186 m^2). The combination of ceiling and in-rack sprinklers specified in Figure 8-2 Part (b) shall be permitted as an alternative.

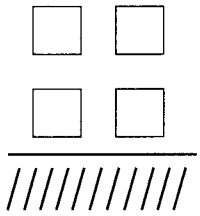
8-2.1.5 Multiple-Row Racks — 15-ft (4.6-m) Storage with 10-ft (3.1-m) Clearance; 20-ft (6-m) Storage with Less than 5-ft (1.25-m) Clearance. The protection strategies utilizing ceiling sprinklers only as shown in Figure 8-2 Parts (c) and (d) shall not be permitted for multiple-row rack storage. Only the specified combinations of ceiling and in-rack sprinklers shall be used.

Strategies for Protection of Rack Storage of Plastics—Single-Row, Double-Row, and Multiple-Row Rack Configurations, Unexposed (Expanded and Unexpanded) Group A Plastics

Part a: 5-ft (1.52-m) to 10-ft (3.05-m) storage

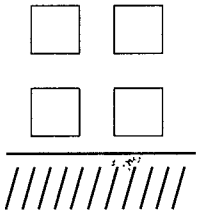
0.30 gpm per ft^2/2000 ft^2 (12.2 L/min per m^2/186 m^2)

< 5-ft (1.52-m) clearance



0.45 gpm per ft^2/2000 ft^2 (18.3 L/min per m^2/186 m^2)

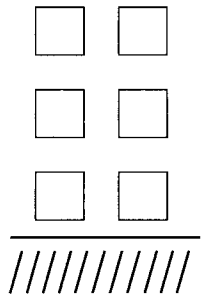
5-ft (1.52-m) to 10-ft (3.05-m) clearance



Part b: 15-ft (4.57-m) storage < 5-ft (1.52-m) ceiling clearance

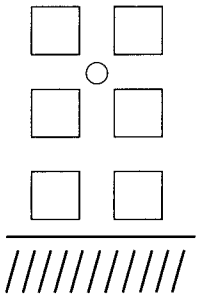
0.45 gpm per ft^2/2000 ft^2 (18.3 L/min per m^2/186 m^2)

See 8-2.1.2 and 8-2.1.4



0.30 gpm per ft^2/2000 ft^2 (12.2 L/min per m^2/186 m^2)

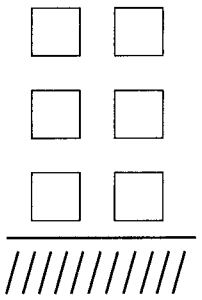
See Note 2 and Figure 8-2 Part h



Part c: 15-ft (4.57-m) storage 5-ft (1.52-m) to 10-ft (3.05-m) ceiling clearance

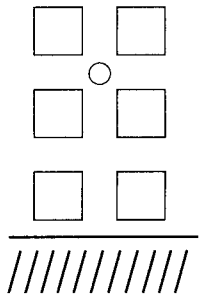
0.60 gpm per ft^2/4000 ft^2 (24.5 L/min per m^2/372 m^2)

See 8-2.1.3 8-2.1.5



0.30 gpm per ft^2/2000 ft^2 (12.2 L/min per m^2/186 m^2)

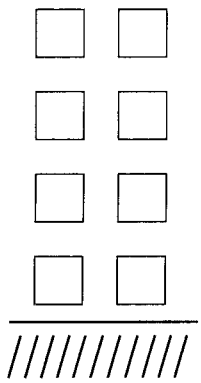
See Note 2 and Figure 8-2 Part h



Part d: 20-ft (6.10-m) storage; < 5-ft (1.52-m) ceiling clearance

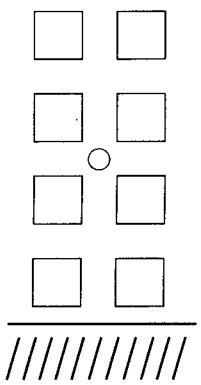
0.60 gpm per ft^2/4000 ft^2 (24.5 L/min per m^2/372 m^2)

See 8-2.1.3 and 8-2.1.5



0.45 gpm per ft^2/2000 ft^2 (18.3 L/min per m^2/186 m^2)

See Note 2 and Figure 8-2 Part h



0.30 gpm per ft^2/2000 ft^2 (12.2 L/min per m^2/186 m^2)

See Note 2 and Figure 8-2 Part h

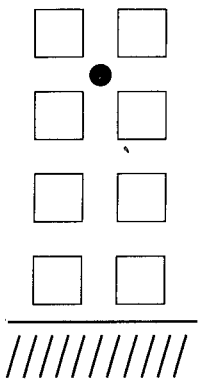
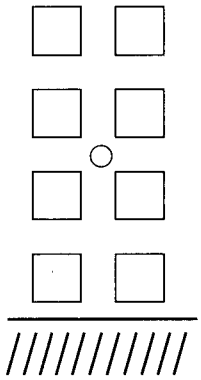


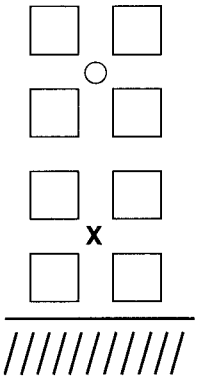
Figure 8-2. (cont'd)

Part e: 20-ft (6.10-m) storage
5-ft (1.52-m) to 10-ft (3.05-m) ceiling clearance (See Note 5)

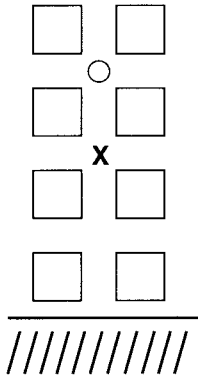
0.45 gpm per ft^2/2000 ft^2 (18.3 L/min per m^2/186 m^2)
See Note 2 and Figure 8-2 Part h



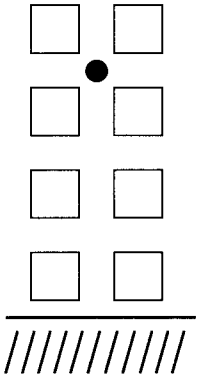
0.30 gpm per ft^2/2000 ft^2 (12.2 L/min per m^2/186 m^2)
See Note 4 and Figure 8-2 Part j



0.30 gpm per ft^2/2000 ft^2 (12.2 L/min per m^2/186 m^2)
See Note 4 and Figure 8-2 Part j

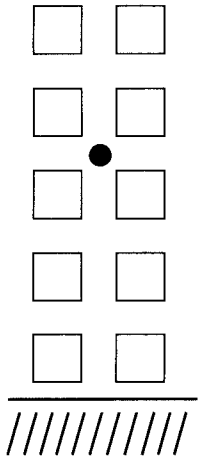


0.30 gpm per ft^2/2000 ft^2 (12.2 L/min per m^2/186 m^2)
See Note 3 and Figure 8-2 Part i

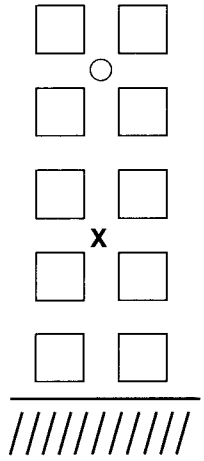


Part f: 25-ft (7.62-m) storage
< 5-ft (1.52-m) ceiling clearance (See Note 5)

0.45 gpm per ft^2/2000 ft^2 (18.3 L/min per m^2/186 m^2)
See Note 3 and Figure 8-2 Part i

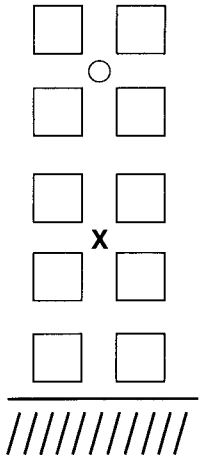


0.30 gpm per ft^2/2000 ft^2 (12.2 L/min per m^2/186 m^2)
See Note 4 and Figure 8-2 Part j



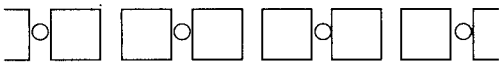
Part g: 25-ft (7.62-m) storage
5-ft (1.52-m) to 10-ft (3.05-m) ceiling clearance (See Note 5)

0.30 gpm per ft^2/2000 ft^2 (12.2 L/min per m^2/186 m^2)
See Note 4 and Figure 8-2 Part j

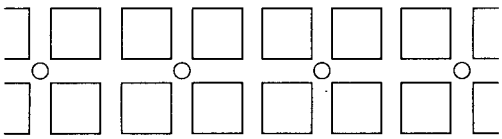


Part h: One level of in-rack sprinklers – plan view
ordinary spacing (See Note 2)

Single-row rack storage



Double-row rack storage



Multiple-row rack storage

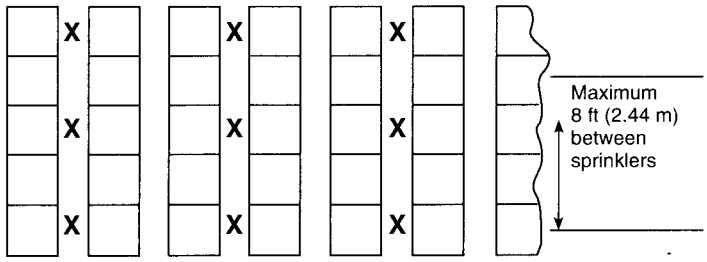
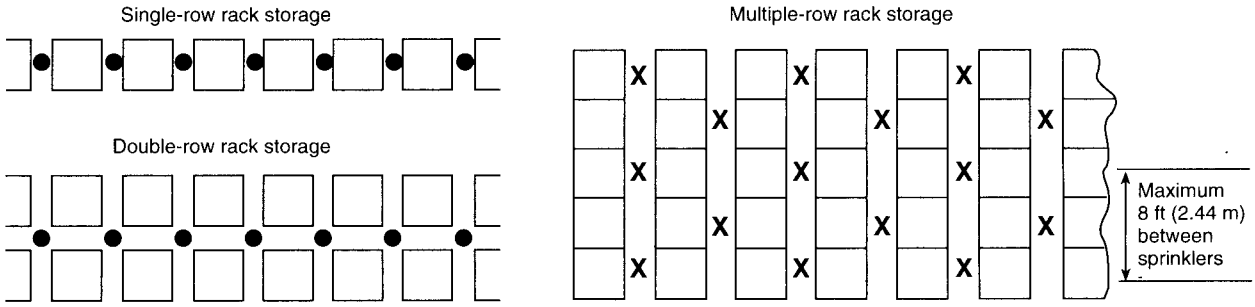
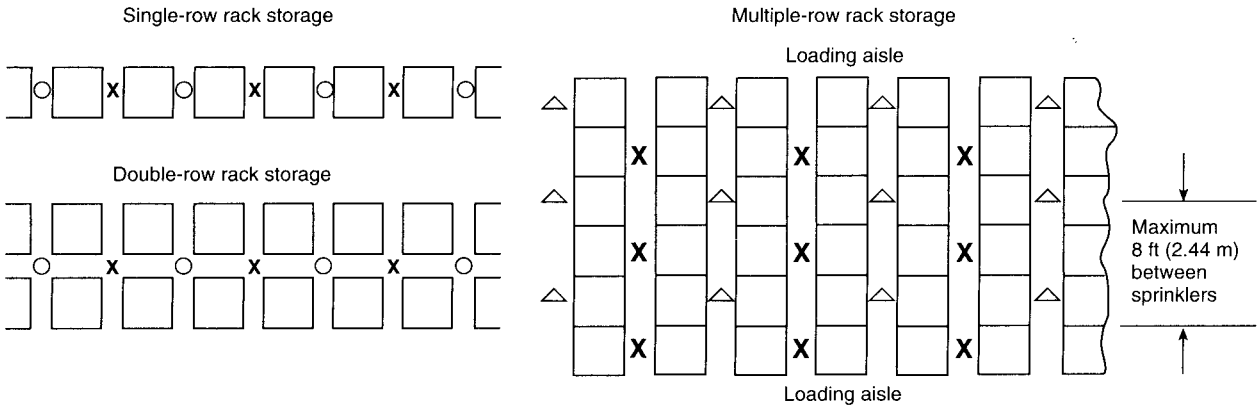


Figure 8-2. (cont'd)

Part i: One level of in-rack sprinklers – plan view close spacing (See Note 3)



Part j: Two levels of in-rack sprinklers – plan view ordinary spacing (See Note 4)



Notes to parts a through j:
1. Each square in the figures represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.
2. Single level of in-rack sprinklers (½ in. or 17/32 in. operating at 15 psi [1.03 bar] minimum) installed on 8 ft to 10 ft (2.5 m to 3.12 m) spacings located, as indicated, in the transverse flue spaces.
3. Single level of in-rack sprinklers (17/32 in. operating at 15 psi [1.03 bar] minimum or ½ in. operating at 30 psi [2.07 bar] minimum) installed on 4 ft to 5 ft (1.25 m to 1.56 m) spacings located, as indicated, in the longitudinal flue space at the intersection of every transverse flue space.
4. Two levels of in-rack sprinklers (½ in. or 17/32 in. operating at 15 psi [1.03 bar] minimum) installed on 8 ft to 10 ft (2.5 m to 3.12 m) spacings located as indicated and staggered in the transverse flue spaces.
5. Ceiling only protection shall not be permitted for this storage configuration.

Figure 8-2. (cont'd)

8-2.2 In-Rack Sprinklers. In-rack sprinklers shall be installed in accordance with Figure 8-2 Parts (b) through (j).

8-3 Single- and Double-Row Racks — Storage over 25 ft (7.6 m) in Height.

8-3.1 Ceiling Sprinkler Water Demand. For Group A plastic commodities in cartons, encapsulated or nonencapsulated in single- and double-row racks, ceiling sprinkler water demand in terms of density (gpm/ft^2) [(L/min)/m^2] and area of operation [ft^2 (m^2)] shall be selected from Table 8-3.1.

Table 8-3.1 Single- and Double-Row Racks. Storage Height over 25 ft.

Storage Height above Top Level In-Rack Sprinklers	Ceiling Sprinklers Density (gpm/ft^2)/Area of Application (ft^2)
5 ft or less	0.30/2000
Over 5 ft up to 10 ft	0.45/2000

For SI units 1 ft = 0.3048 m; 1 gpm = 3.785 L/min; 1 gpm/ft^2 = 40.74 (L/min)/m^2

NOTE: Provide in-rack sprinkler protection per Figures 8-3.2.1(a) and (b) and Figures 8-3.2.3(a) through (c).

8-3.2 In-Rack Sprinkler Location.

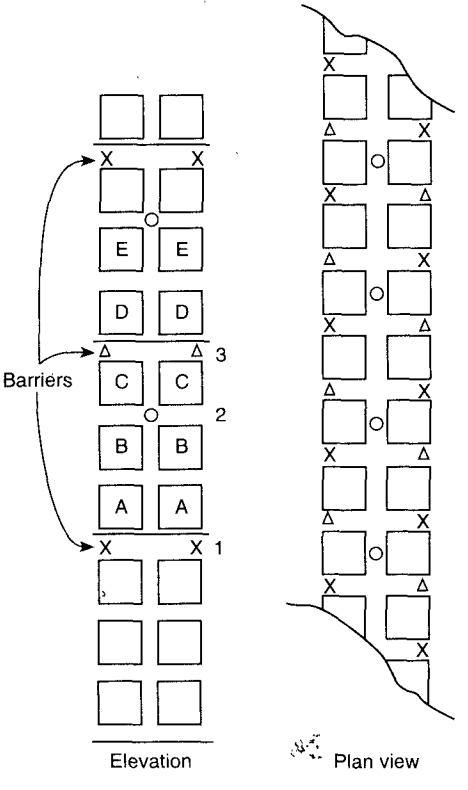
8-3.2.1 In double-row racks without solid shelves and with a maximum of 10 ft (3.1 m) between the top of storage and the ceiling, in-rack sprinklers shall be installed in accordance with Figures 8-3.2.1(a) or (b). The highest level of in-rack sprinklers shall be not more than 10 ft (3.1 m) below the top of storage.

8-3.2.2 In-rack sprinklers for storage higher than 25 ft (7.6 m) in double-row racks shall be spaced horizontally and located in the horizontal space nearest the vertical intervals specified in Figures 8-3.2.1(a) or (b).

8-3.2.3 In single-row racks without solid shelves with storage height over 25 ft (7.6 m) and a maximum of 10 ft (3.1 m) between the top of storage and the ceiling, sprinklers shall be installed as indicated in Figures 8-3.2.3(a), (b), or (c).

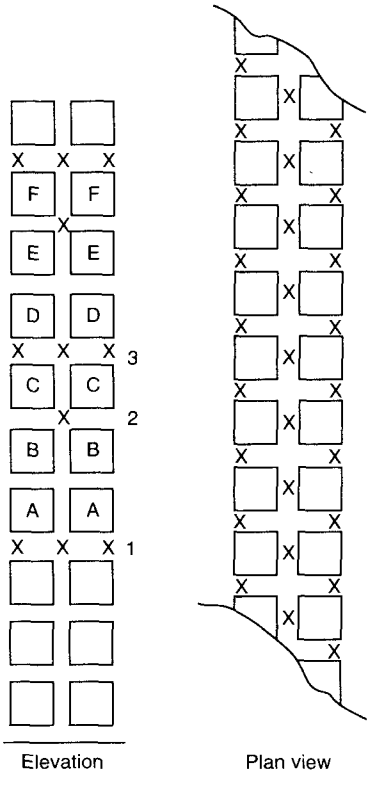
8-3.3 In-Rack Sprinkler Size. Sprinklers in racks shall be $\frac{1}{2}$-in. (12.7-mm) or $\frac{17}{32}$-in. (13.5-mm) orifice size, pendent or upright.

8-3.4 In-Rack Sprinkler Discharge Pressure. Sprinklers in racks shall discharge at not less than 30 gpm (113.6 L/min).



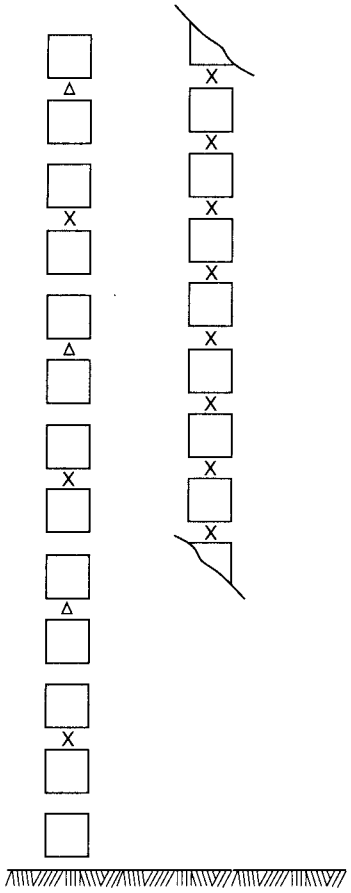
NOTES:
1. Sprinklers and barriers labeled 1 shall be required where loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 and barriers labeled 1 shall be required where loads labeled C represent top of storage.
3. Sprinklers and barriers labeled 1 and 3 shall be required where loads labeled D or E represent top of storage.
4. For storage higher than represented by loads labeled, E the cycle defined by Notes 2 and 3 is repeated.
5. Symbol Δ or X indicates face sprinklers on vertical or horizontal stagger.
6. Symbol O indicates longitudinal flue space sprinklers.
7. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 8-3.2.1(a) In-rack sprinkler arrangement, Group A plastic commodities, storage height over 25 ft (7.6 m).



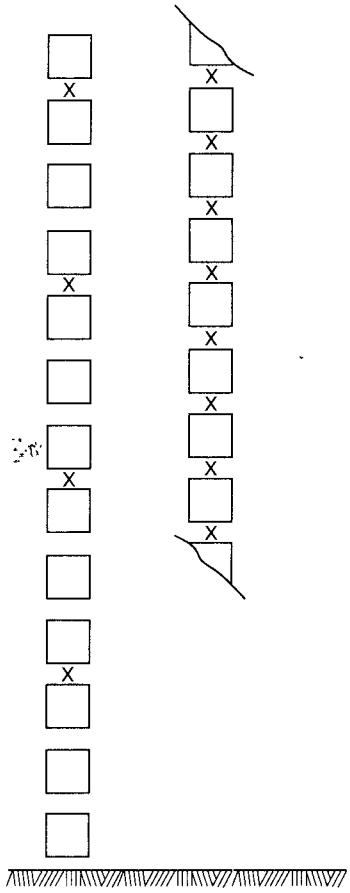
NOTES:
1. Sprinklers labeled 1 shall be required where loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled C represent top of storage.
3. sprinklers labeled 1 and 3 shall be required where loads labeled D or E represent top of storage.
4. For storage higher than loads labeled F, the cycle defined by Notes 2 and 3 is repeated.
5. Symbol X indicates face and in-rack sprinklers.
6. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 8-3.2.1(b) In-rack sprinkler arrangement, Group A plastic commodities, storage height over 25 ft (7.6 m).



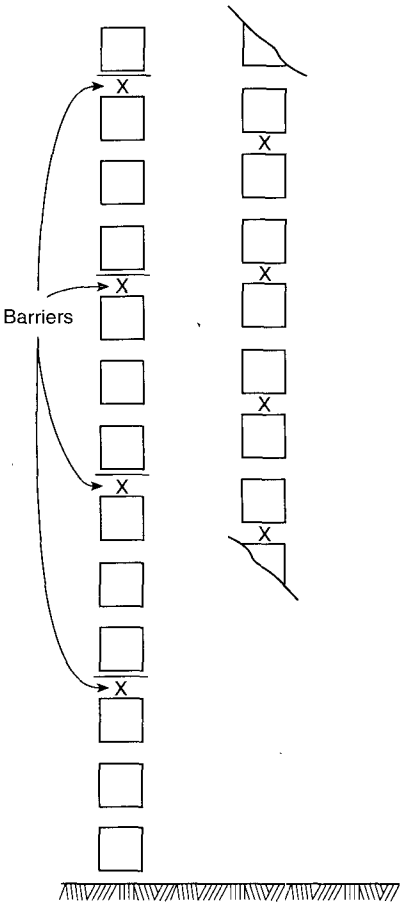
NOTE:
1. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 8-3.2.3(a) In-rack sprinkler arrangement, Group A plastic commodities, single-row racks, storage height over 25 ft (7.6 m).



NOTE:
1. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 8-3.2.3(b) In-rack sprinkler arrangement, Group A plastic commodities, single-row racks, storage height over 25 ft (7.6 m).



NOTE:
1. Each square in the figure represents a storage cube measuring 4 ft to 5 ft (1.25 m to 1.56 m) on a side.

Figure 8-3.2.3(c) In-rack sprinkler arrangement, Group A plastic commodities, single-row racks, storage height over 25 ft (7.6 m).

Chapter 9 Large Drop Sprinklers

9-1 General.

9-1.1 Large drop sprinklers shall be suitable for use with the hazards specified in Table 9-1.1.

9-1.2 Each joist channel of open, wood joist construction shall be fully firestopped to its full depth at intervals not exceeding 20 ft (6 m).

Exception: Unfirestopped, open, wood joist construction or firestops at intervals exceeding 20 ft (6 m) shall be permitted where the minimum operating pressure is increased by 40 percent.

9-1.3 Building steel shall not require special protection where Table 9-1.1 is applied.

9-1.4 Protection requirements are based on rack storage having no solid shelves or slave pallets.

9-1.5 A minimum of 6 in. (152.4 mm) longitudinal flue spaces shall be maintained in addition to transverse flue spaces.

9-1.6 For dry-pipe systems, high-temperature sprinklers shall be used; for wet-pipe systems, ordinary- or high-temperature sprinklers shall be permitted.

9-1.7 Sprinkler spacing shall be not less than 80 ft^2 (9.3 m^2) or more than 100 ft^2 (7.4 m^2).

9-1.8 All requirements contained in NFPA 13, *Standard for the Installation of Sprinkler Systems*, shall apply.

Exception: Where modified by this standard.

Table 9-1.1 Large Drop Sprinkler Data
Pressure and Number of Design Sprinklers Required for Various Hazards for Large Drop Sprinklers

Hazard	Type of System	Minimum Operating Pressure, psi (bar) 25 (1.7)	50 (3.4)	75 (5.2)	Hose Stream Demand gal/min (dm³/min)	Water Supply Duration (hr)
		Number of Design Sprinklers				
Double-Row Storage with Minimum 5.5-ft (1.7-m) Aisle Width and Multiple-Row Rack Storage with Minimum 8.0-ft (2.5-m) Aisle Width (Note 1)						
Class I and II commodities up to 25 ft (7.6 m) with maximum 5-ft (1.5-m) clearance to ceiling	Wet	20	Note 2	Note 2	500 (1900)	1½
	Dry	30	Note 2	Note 2		
Class I and II commodities up to 30 ft (9.1 m) with maximum 5-ft (1.5-m) clearance to ceiling	Wet	20 plus one level of in-rack sprinklers	Note 2	Note 2		
	Dry	30 plus one level of in-rack sprinklers	Note 2	Note 2	500 (1900)	1½
Class I, II, and III commodities up to 20 ft (6.1 m) with maximum 10-ft (3.1-m) clearance to ceiling	Wet	15	Note 2	Note 2	500 (1900)	1½
	Dry	25	Note 2	Note 2		
Class I, II, and III commodities up to 25 ft (7.6 m) with maximum 10-ft (3.1-m) clearance to ceiling	Wet	15 plus one level of in-rack sprinklers	Note 2	Note 2		
	Dry	25 plus one level of in-rack sprinklers	Note 2	Note 2	500 (1900)	1½
Class IV commodities up to 20 ft (6.1 m) with maximum 10-ft (3.1-m) clearance to ceiling	Wet	NA	20	15	500 (1900)	2
	Dry	NA	NA	NA		
Class IV commodities up to 25 ft (7.6 m) with maximum 10-ft (3.1-m) clearance to ceiling	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		
Unexpanded plastics up to 20 ft (6.1 m) with maximum 10-ft (3.1-m) clearance to ceiling	Wet	NA	30	20	500 (1900)	2
	Dry	NA	NA	NA		
Unexpanded plastics up to 25 ft (7.6 m) with maximum 10-ft (3.1-m) clearance to ceiling	Wet	NA	30 plus one level of in-rack sprinklers	20 plus one level of in-rack sprinklers	500 (1900)	2
	Dry	NA	NA	NA		
Class IV commodities and unexpanded plastics up to 20 ft (6.1 m) with maximum 5-ft (1.5-m) clearance to ceiling	Wet	NA	15	Note 2	500 (1900)	2
	Dry	NA	NA	NA		
Class IV commodities and unexpanded plastics up to 25 ft (7.6 m) with maximum 5-ft (1.5-m) clearance to ceiling	Wet	NA	15 plus one level of in-rack sprinklers	Note 2	500 (1900)	2
	Dry	NA	NA	NA		

NOTE 1: Conventional wood pallets only shall be used; no slave pallets shall be permitted to be used.
NOTE 2: The high pressure shall be permitted to be used, but the required number of design sprinklers shall not be reduced from that required for the lower pressure.
N/A: Not applicable.

Table 10-1 Early Suppression Fast Response (ESFR) Sprinkler Data

Type of Storage	Commodity	Maximum Height of Storage ft (m)	Maximum Height of Building (ft) (m) (Note 1)	Nominal K Factor	Sprinkler Design Pressure psi (bars)	Commodity Limitation
Single-, double-, and multiple-row rack storage (No open-top containers or solid shelves)	Cartoned unexpanded plastic; cartoned expanded plastic; uncartoned unexpanded plastic; and Class I, II, III, or IV commodities, encapsulated or unencapsulated	25 (7.6)	30 (9.1)	13.5–14.5	50 (3.4)	—
	Cartoned unexpanded plastic; and class I, II, III, or IV commodities, encapsulated or unencapsulated	35 (10.7)	40 (12.2)	13.5–14.5	75 (5.2)	Note 2
		20 (6.1)	25 (7.6)	11.0–11.5	50 (3.4)	

NOTE 1: Maximum building height shall be measured to the underside of the roof deck or ceiling.
NOTE 2: Only ESFR sprinklers specifically listed for 40-ft (12.2-m) high buildings shall be used in buildings higher than 30 ft (9.1 m) up to 40 ft (12.2 m).

Chapter 10 Early Suppression Fast Response (ESFR) Sprinklers

10-1* General. Early suppression fast response (ESFR) sprinklers shall be permitted for the protection of rack storage in accordance with Table 10-1 and shall be used only in buildings equal to, or less than, the height of the building for which they have been listed.

Exception: ESFR protection as defined shall not apply to:

1. Rack storage involving solid shelves

2. Rack storage involving combustible, open-top cartons or containers.

10-2 Sprinkler System Design.

10-2.1* ESFR sprinkler systems shall be designed to provide the minimum operating pressure, in accordance with Table 10-1 for the commodity, storage height, and building height involved, to the twelve most hydraulically remote sprinklers based on flowing four sprinklers on each of three branch lines.

10-2.2 The distance between branch lines and sprinklers on branch lines shall not be more than 10 ft (3.1 m) nor less than 8 ft (2.4 m) for buildings higher than 30 ft (9.1 m) up to 40 ft (12.2 m), and not more than 12 ft (3.7 m) nor less than 8 ft (2.4 m) for buildings up to 30 ft (9.1 m) high.

10-2.3 Only wet-pipe systems are acceptable for use with ESFR sprinklers.

10-2.4 All requirements contained in NFPA 13, *Standard for the Installation of Sprinkler Systems*, shall apply.

Exception: Where modified by this standard.

10-2.5 ESFR sprinklers shall be ordinary-temperature rated sprinklers.

Exception No. 1: ESFR sprinklers located in proximity to heat sources.

Exception No. 2: ESFR sprinklers located under skylights.

10-3 Water Demand.

10-3.1 A minimum of 250 gpm (16 L/s) shall be added to the sprinkler demand for combined large and small hose streams.

10-3.2 Water supply duration shall be at least 1 hour.

Chapter 11 Equipment

11-1 Mechanical Handling Equipment—Industrial Trucks.

11-1.1 Power-operated industrial trucks shall be of the type designated in NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance, and Operation*, and their maintenance and operation shall be in accordance with Chapters 2 and 3 of that standard.

11-1.2† Industrial trucks using LP-Gas or liquid fuel shall be refueled outside of the storage building at a location designated for that purpose.

Chapter 12 Building Maintenance and Operation

12-1* Building Operations Other than Storage. Welding, soldering, brazing, and cutting shall be permitted to be performed on rack or building components that cannot be removed, provided no storage is located below and within 25 ft (7.6 m) of the working area and flameproof tarpaulins enclose this section. During any of these operations, the sprinkler system shall be in service. Water-type extinguishers with a capacity of 2½ gal (9.45 L) and charged inside hose lines shall be located in the working area. A fire watch shall be maintained during these operations and for at least 30 additional minutes.

12-2* Waste Disposal. Approved containers for rubbish and other trash materials shall be provided.

12-3 Smoking. Smoking shall be strictly prohibited. "No Smoking" signs shall be posted in prohibited areas.

Exception: Smoking shall be permitted in locations prominently designated as smoking areas.

12-4* Maintenance. Fire walls, fire doors, and floors shall be maintained in good repair at all times.

12-5* Plant Emergency Organization. A fire watch shall be maintained when the sprinkler system is not in service.

12-6* General Fire Protection. The sprinkler system and the water supplies shall be inspected, tested, and maintained in accordance with NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems.*

Chapter 13 Referenced Publications

13-1 The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

13-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*, 1994 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1994 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, 1995 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 1993 edition.

NFPA 40, *Standard for the Storage and Handling of Cellulose Nitrate Motion Picture Film*, 1994 edition.

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, 1995 edition.

NFPA 81, *Standard for Fur Storage, Fumigation and Cleaning*, 1986 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*, 1995 edition.

NFPA 220, *Standard on Types of Building Construction*, 1992 edition.

NFPA 231, *Standard for General Storage*, 1995 edition.

NFPA 231D, *Standard for Storage of Rubber Tires*, 1994 edition.

NFPA 231F, *Standard for the Storage of Roll Paper*, 1987 edition.

NFPA 232, *Standard for the Protection of Records*, 1991 edition.

NFPA 490, *Code for the Storage of Ammonium Nitrate*, 1993 edition.

NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance, and Operation*, 1992 edition.

Appendix A Explanatory Material

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

A-4-1 Rack storage as referred to in this standard contemplates commodities in a rack structure, usually steel. Many variations of dimensions are found. Racks can be single-row, double-row, or multiple-row, with or without solid shelves. The standard commodity used in most of the tests was 42 in. (1.07 m) on a side. The types of racks covered in this standard are as follows:

Double-Row Racks. Pallets rest on two beams parallel to the aisle. Any number of pallets can be supported by one pair of beams. [*See Figures A-4-1(a) through (d).*]

Automatic Storage-Type Rack. The pallet is supported by two rails running perpendicular to the aisle. [*See Figure A-4-1(e).*]

Multiple-Row Racks More than Two Pallets Deep, Measured Aisle to Aisle. These include drive-in racks, drive-through racks, flow-through racks, portable racks arranged in the same manner, and conventional or automatic racks with aisles less than 42 in. (1.07 m) wide. [*See Figures A-4-1(f) through (i).*]

Movable Racks. Movable racks are racks on fixed rails or guides. They can be moved back and forth only in a horizontal two-dimensional plane. A moving aisle is created as abutting racks are either loaded or unloaded, then moved across the aisle to abut other racks. [*See Figure A-4-1(k).*]

Solid Shelving. Conventional pallet racks with plywood shelves on the shelf beams [*see Figures A-4-1(c) and (d)*]. These are used in special cases. (*See Chapter 5.*)

Cantilever Rack. The load is supported on arms that extend horizontally from columns. The load can rest on the arms or on shelves supported by the arms. [*See Figure A-4-1(j).*]

Load depth in conventional or automatic racks should be considered a nominal 4 ft (1.22 m). [*See Figure A-4-1(b).*]

A-4-2 Fixed rack structures should be designed to facilitate removal or repair of damaged sections without resorting to flame cutting or welding in the storage area. Where sprinklers are to be installed in racks, rack design should anticipate the additional clearances necessary to facilitate installation of sprinklers. The rack structure should be anchored to prevent damage to sprinkler lines and supply piping in racks.

Rack structures should be designed for seismic conditions in areas where seismic resistance of building structure is required.

A-4-3.1 Nominal 6-in. (152.4-mm) transverse flues should be provided in multiple-row racks.

A-4-4 Storage in aisles can render protection ineffective and should be discouraged.

A-4-5 The fire protection system design should contemplate the maximum storage height. For new sprinkler installations, maximum storage height is the usable height at which commodities can be stored above the floor when the minimum required unobstructed space below sprinklers is maintained. For the evaluation of existing situations, maximum storage height is the maximum existing if space between the sprinklers and storage is equal to or greater than that required.

A-4-6.1 A horizontal clearance of at least 1 ft (0.30 m) should be maintained between storage and major unprotected roof structural members where storage is stored above the bottom of such members.

A-4-6.2 Incandescent light fixtures should have shades or guards to prevent ignition of commodities from hot bulbs where possibility of contact with storage exists.

A-4-7 Idle combustible pallets should not be stored in racks.

A-5-2.1 Ceiling Sprinklers. Wet systems are recommended for rack storage occupancies.

Dry systems may be permitted only where it is impractical to provide heat.

Preaction systems should be considered for rack storage occupancies that are unheated, particularly where in-rack sprinklers are installed or for those occupancies that are highly susceptible to water damage.

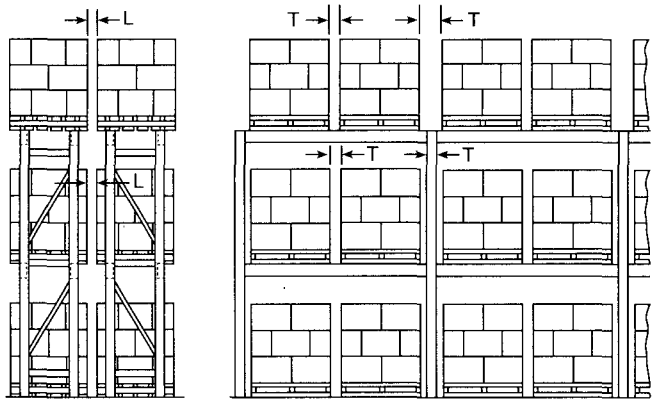


Figure A-4-1(a) Conventional pallet rack.

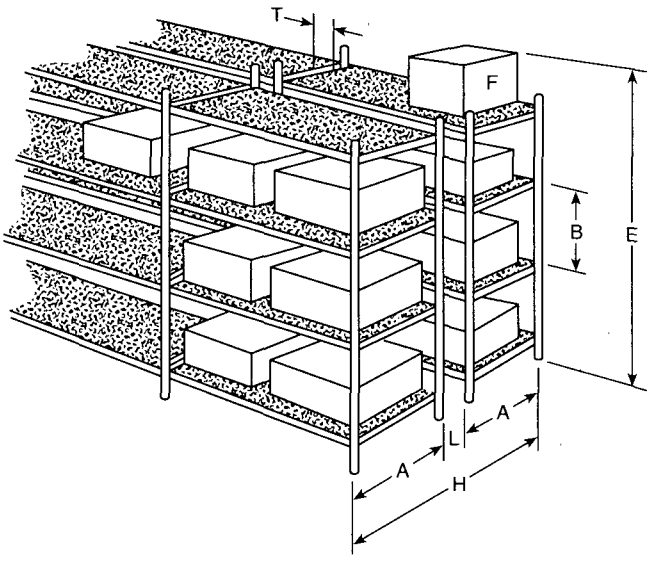


Figure A-4-1(c) Double-row racks with solid shelves.

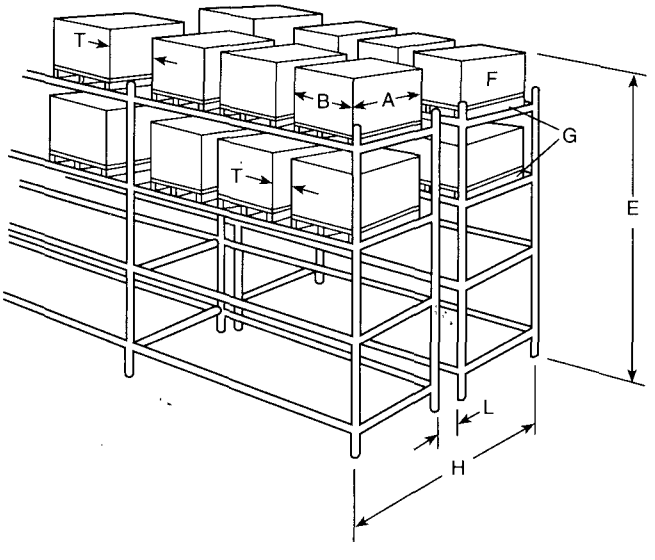


Figure A-4-1(b) Double-row racks without solid or slatted shelves.

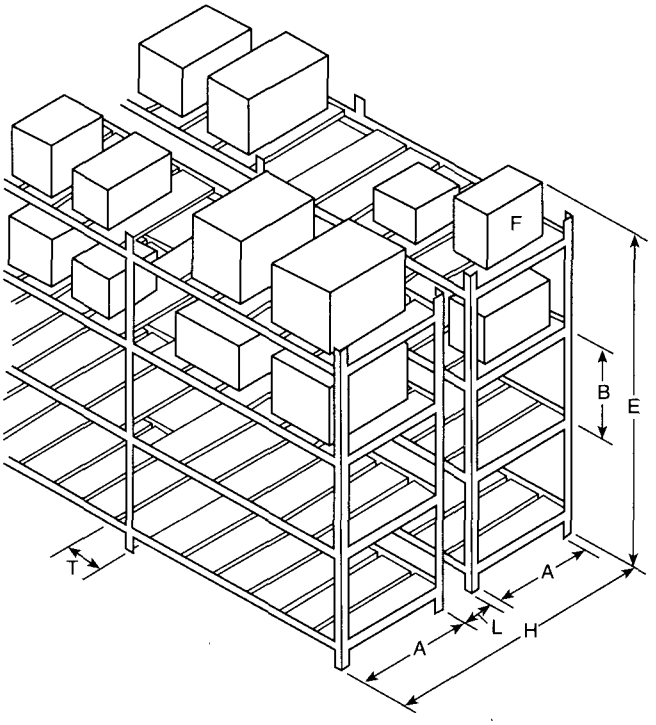
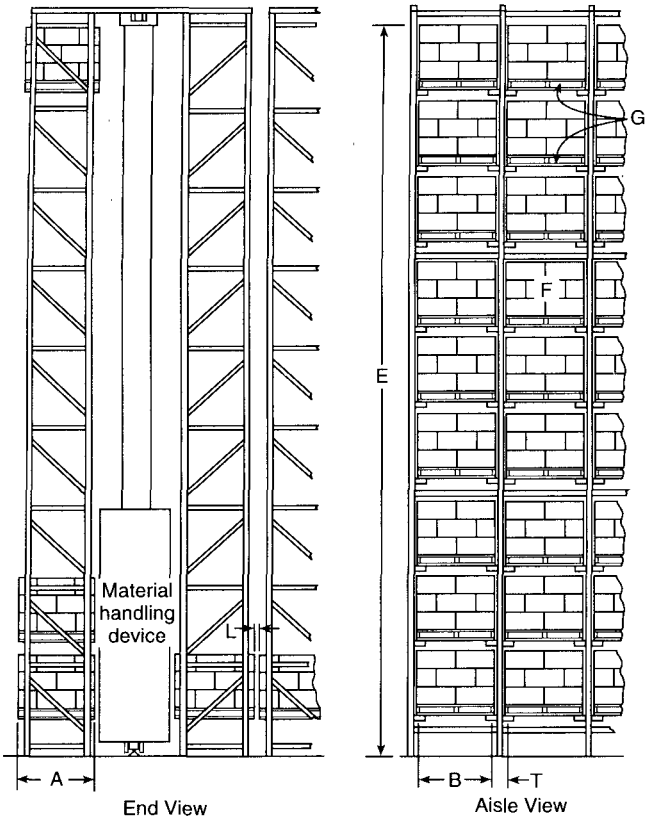


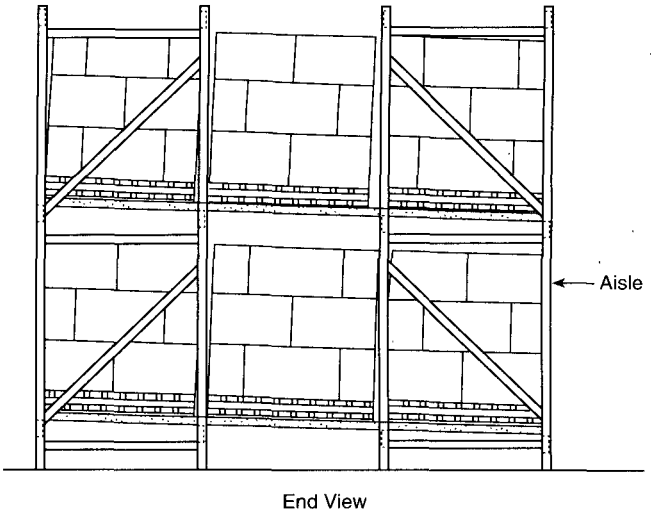
Figure A-4-1(d) Double-row racks with slatted shelves.

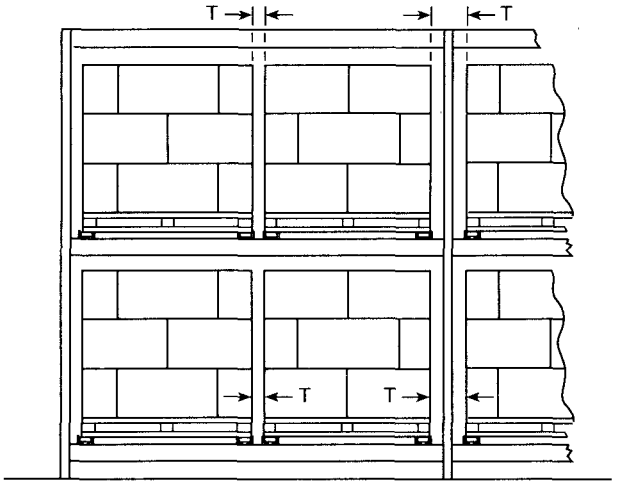


Legend

A – Load depth
B – Load width
E – Storage height
F – Commodity
G – Pallet
L – Longitudinal flue space
T – Transverse flue space

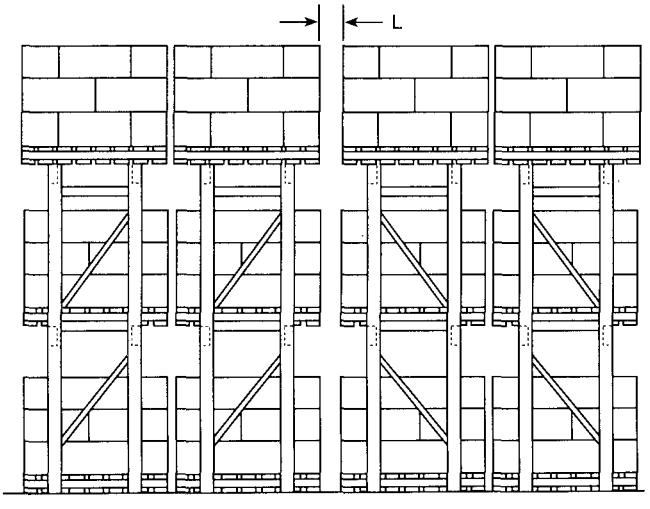
Figure A-4-1(e) Automatic storage-type rack.





T – Transverse flue space

Figure A-4-1(g) Flow-through pallet rack.



L – Longitudinal flue space

Figure A-4-1(f) Multiple-row rack to be served by a reach truck.

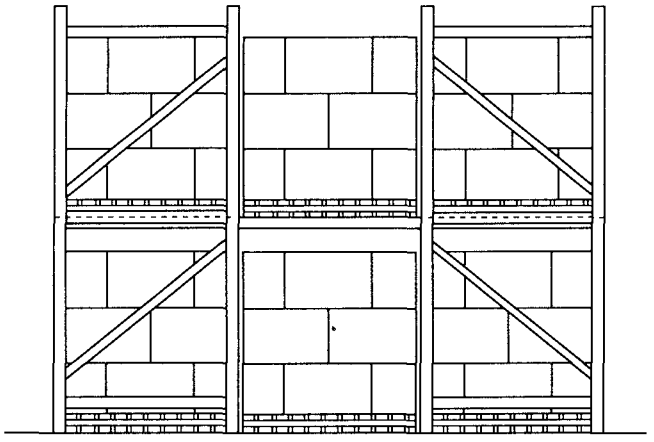


Figure A-4-1(h) Drive-in rack — two or more pallets deep (fork truck drives into the rack to deposit and withdraw loads in the depth of the rack).

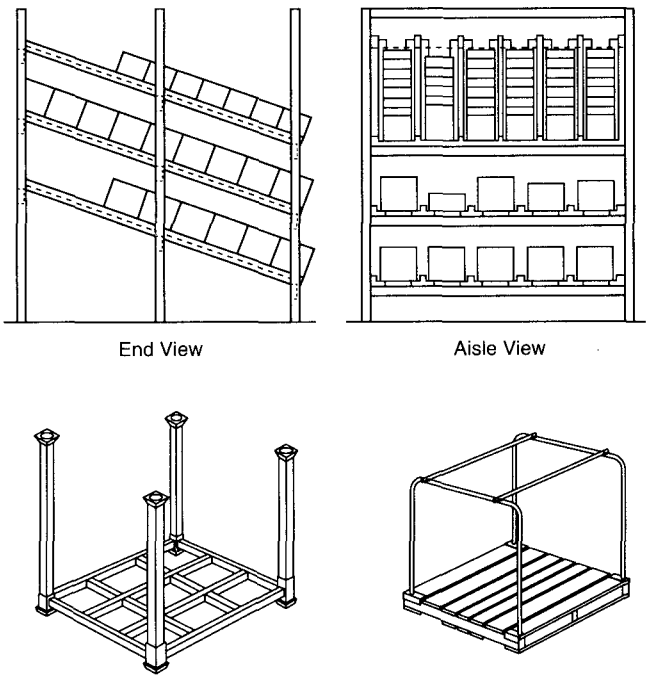
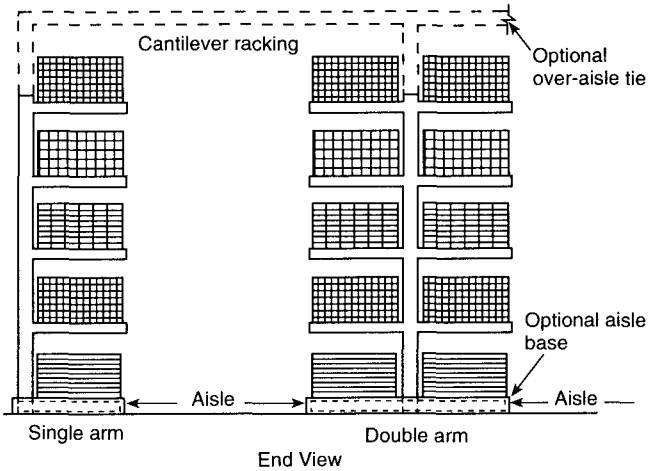


Figure A-4-1(i) Flow-through racks (top) and portable racks (bottom).



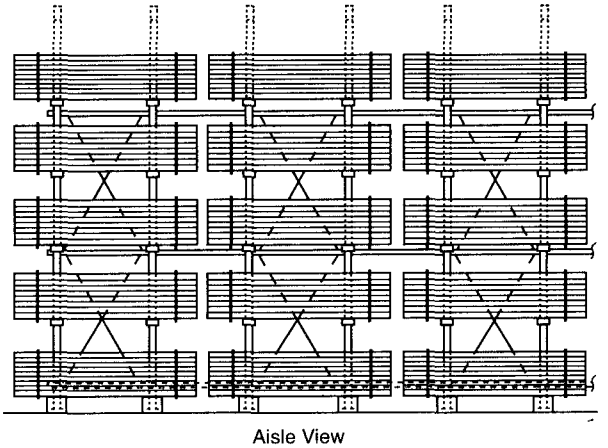


Figure A-4-1(j) Cantilever rack.

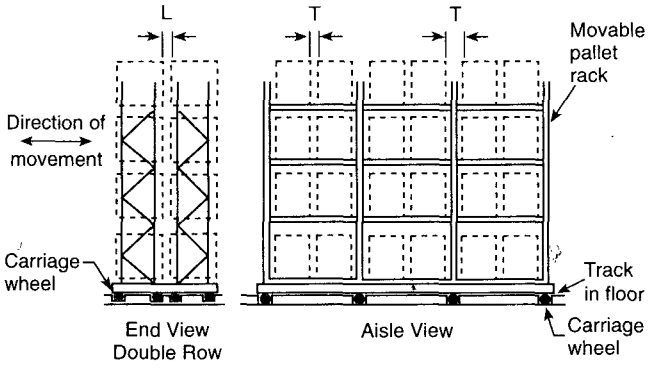


Figure A-4-1(k) Movable rack.

A-5-2.2 Where 286°F (141°C) rated sprinklers are installed at the ceiling, 286°F (141°C) rated sprinklers also should extend beyond storage in accordance with Table A-5-2.2.

A-5-5 In-rack sprinklers and ceiling sprinklers selected for protection should be controlled by at least two separate indicating valves and drains.

A-5-5.1 In higher rack arrangements, consideration should be given to providing more than one in-rack control valve in order to limit the extent of any single impairment.

A-5-7 Approved supervisory alarm service should be provided for all fire detection and extinguishing systems.

A central station, auxiliary, remote station, or proprietary sprinkler waterflow alarm should be provided, except that local waterflow alarm may be permitted where approved guard service is provided. (*See NFPA 72, National Fire Alarm Code.*)

A-5-11.1 Detection systems, concentrate pumps, generators, and other system components essential to the operation of the system should have an approved standby power source.

A-5-13.1 In NFPA 13, *Standard for the Installation of Sprinkler Systems*, A-4-4.1.3.2.1 states: "Slatting of decks or walkways or the use of open grating as a substitute for automatic sprinkler thereunder is not acceptable."

In addition, where shelving of any type is employed, it is for the basic purpose of providing an intermediate support between the structural members of the rack. As a result, it becomes almost impossible to define and maintain transverse flue spaces across the rack as required in 4-3.1 and illustrated in Figure 4-3.1.

A-6-5.1 Where possible, it is preferable to locate in-rack sprinkler deflectors at least 6 in. (152.4 mm) above pallet loads.

Table A-5-2.2

Design Area for 286°F (141°C) Sprinklers		Distance Beyond Perimeter of High-Hazard Occupancy for High-Temp. Sprinklers	
(ft^2)	(m^2)	(ft)	(m)
2000	185.8	30	9.14
3000	278.7	40	12.2
4000	371.6	45	13.72
5000	464.5	50	15.24
6000	557.4	55	16.76

A-6-5.2 Where possible, it is preferable to locate in-rack sprinklers away from rack uprights.

A-6-6.1 Spacing of sprinklers on branch lines in racks in the various tests demonstrates that maximum spacing as specified is proper.

A-6-9 Bulkheads are not a substitute for sprinklers in racks. Their installation does not justify reduction in sprinkler densities or design operating areas as specified in the design curves.

A-6-10.1 Where high-expansion foam is contemplated as the protection media, consideration should be given to possible damage to the commodity from soaking and corrosion. Consideration also should be given to the problems associated with removal of foam after discharge.

A-6-12 Where dry-pipe systems are used, the areas of operation specified in the design curves should be increased by 30 percent. Densities should be selected so that areas of operation, after the 30 percent increase, do not exceed 6000 ft^2 (557.4 m^2).

A-6-14.2 In-rack sprinklers at one level only for storage up to and including 25 ft (7.6 m) in multiple-row racks should be located at the tier level nearest one-half to two-thirds of the storage height.

A-7-10.3 In single-row racks with more than 10 ft (3.1 m) between the top of storage and the ceiling, a horizontal barrier should be installed above storage with one line of sprinklers under the barrier.

A-7-11 Where the ceiling is more than 10 ft (3.1 m) above the maximum height of storage, a horizontal barrier should be installed above storage with one line of sprinklers under the barrier for Class I, II, and III commodities and two lines of sprinklers under the barrier for Class IV commodities. In-rack sprinkler arrays should be installed as indicated in Table 7-10.1 and Figures 7-10.1(a) through (j).

Barriers should be of sufficient strength to avoid sagging that interferes with loading and unloading operations.

Horizontal barriers are not required to be provided above a Class I or Class II commodity with in-rack sprinkler arrays in accordance with Figures 7-10.1(a) and (b), provided one line of in-rack sprinklers is installed above the top tier of storage.

A-7-12.1 Water demand for storage height over 25 ft (7.6 m) on racks without solid shelves separated by aisles at least 4 ft (1.22 m) wide and with more than 10 ft (3.1 m) between the top of storage and the sprinklers should be based on sprinklers in a 2000-ft^2 (185.8-m^2) operating area for double-row racks and a 3000-ft^2 (278.7-m^2) operating area for multiple-row racks discharging a minimum of 0.18 gpm/ft^2 [(7.33 L/min)/m^2] for Class I commodities, 0.21 gpm/ft^2 [(8.56 L/min)/m^2] for Class II and III commodities, and 0.25 gpm/ft^2 [(10.19 L/min)/m^2] for Class IV commodities, for 165°F (74°C) rated sprinklers; or a minimum of 0.25 gpm/ft^2 [(10.19 L/min)/m^2] for Class I commodities, 0.28 gpm/ft^2 [(11.41 L/min)/m^2] for Class II and III commodities, and 0.32 gpm/ft^2 [(13.04 L/min)/m^2] for Class IV commodities, for 286°F (141°C) rated sprinklers. (*See A-7-11 and A-7-13.*)

Where such storage is encapsulated, ceiling sprinkler density should be 25 percent greater than for nonencapsulated storage.

A-7-13 In multiple-row racks with more than 10 ft (3.1 m) between the maximum height of storage and ceiling, a horizontal barrier should be installed above storage with a level of sprinklers, spaced as stipulated for in-rack sprinklers, installed directly beneath the barrier. In-rack sprinklers should be installed as indicated in Figures 7-13(a) through (c).

A-8 All rack fire tests of plastics were run with an approximate 10-ft (3.1-m) maximum clearance between the top of storage and the ceiling sprinklers. Within 30-ft (9.1-m) high buildings, greater clearances above storage configurations should be compensated for by the addition of more in-rack sprinklers or the provision of greater areas of application, or both.

A-10-1 ESFR sprinklers were designed to respond quickly to growing fires and deliver heavy discharge to suppress fires rather than to control them. ESFR sprinklers should not be relied upon to provide suppression if they are used outside these design parameters.

A-10-2.1 Design parameters were determined from a series of full-scale fire tests conducted as a joint effort between Factory Mutual Research Corporation and the National Fire Protection Research Foundation. (Copies of the test reports are available from the National Fire Protection Research Foundation.)

A-12-1 The use of welding, cutting, soldering, or brazing torches in the storage areas introduces a severe fire hazard. The use of mechanical fastenings and mechanical saws or cutting wheels is recommended. Where welding or cutting operations are absolutely necessary, the requirements of NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, should apply.

Locomotives should not be allowed to enter the storage area.

A-12-2 Containers should be emptied and their contents removed from the premises at frequent intervals. (*See NFPA 82, Standard on Incinerators and Waste and Linen Handling Systems and Equipment.*)

A-12-4 Periodic inspections of all fire protection equipment should be made in conjunction with regular inspections of the premises. Unsatisfactory conditions should be reported immediately and necessary corrective measures taken promptly.

The sprinkler system and the water supplies should be checked and maintained in accordance with NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems.*

A-12-5 Plant Emergency Organization. Arrangements should be made, in case of fire or other emergency, to permit rapid entry into the premises of the municipal fire department, police department, or other personnel that could be summoned to deal with any emergency. A well-trained plant emergency organization should be provided to control emergency conditions that arise.

The plant emergency organization should be instructed and trained in the following procedures:

(a) Maintenance of the security of the premises

(b) Means of summoning outside aid immediately in an emergency

(c) Use of hand extinguishers and hose lines on small fires and mop-up operations

(d) Operation of the sprinkler system and water supply equipment

(e) Use of material-handling equipment while sprinklers are operating to effect final extinguishment

(f) Supervision of sprinkler valves after system is turned off so that system can be reactivated if rekindling occurs

(g) Need for breathing apparatus.

Attention should be given to advance planning and training with respect to fire department response, access, and fire fighting.

A-12-6 General Fire Protection. All fire-fighting and safety personnel should realize the great danger in shutting off sprinklers once opened by heat from fire. Shutting off sprinklers to locate fire could cause a disaster. Ventilation, use of smoke masks, smoke removal equipment, and removal of material are safer. (*See NFPA 1420, Recommended Practice for Pre-Incident Planning for Warehouse Occupancies, for additional information.*)

Sprinkler water should be shut off only after the fire is extinguished or completely under the control of hose streams. Even then, rekindling is a possibility. To be ready for prompt valve reopening if fire rekindles, a person stationed at the valve, a fire watch, and dependable communications between them are needed until automatic sprinkler protection is restored.

(a) **Pre-Fire Emergency Planning.** It is important that such planning be done by management and fire protection personnel and the action to be taken discussed and correlated with the local fire department personnel.

The critical time during any fire is in the incipient stage, and the action taken by fire protection personnel upon notification of fire can allow the fire to be contained in its early stages.

Pre-emergency planning should contemplate the following:

1. Availability of hand fire-fighting equipment for the height and type of commodity involved;

2. Availability of fire-fighting equipment and personnel properly trained for the type of storage arrangement involved;

3. Assurance that all automatic fire protection equipment, such as sprinkler systems, water supplies, fire pumps and hand hose, is in service at all times.

(b) **Fire Department Operations.** Sprinkler protection installed as required in this standard is expected to protect the building occupancy without supplemental fire department activity. Fires that occur in rack storage occupancies protected in accordance with this standard are likely to be controlled within the limits outlined in B-1-1, since no significant building damage is expected. Fire department activity can, however, minimize the extent of loss. The first fire department pumper arriving at a rack storage-type fire should connect immediately to the sprinkler siamese fire department connection and start pumping operations.

In the test series for storage up to 25 ft (7.6 m), the average time from ignition to smoke obscuration in the test building was about 13 minutes. The first sprinkler operating time in these same fires averaged about 3 minutes. Considering response time for the waterflow device to transmit a waterflow signal, approximately 9 minutes remains between the time of receipt of a waterflow alarm signal at fire department

headquarters and the time of smoke obscuration within the building as an overall average.

In the test series for storage over 25 ft (7.6 m), the visibility time was extended. If the fire department or plant protection department arrives at the building in time to have sufficient visibility to locate the fire, suppression activities with small hose lines should be started. (Self-contained breathing apparatus is recommended.) If, on the other hand, the fire is not readily visible, hose should be laid to exterior doors or exterior openings in the building and charged lines provided to these points, ready for ultimate mop-up operations. Manual fire-fighting operations in such a warehouse should not be considered a substitute for sprinkler protection.

IMPORTANT: The sprinkler system should be kept in operation during manual fire-fighting and mop-up operations.

During the testing program, the installed automatic extinguishing system was capable of controlling the fire and reducing all temperatures to ambient within 30 minutes of ignition. Ventilation operations and mop-up were not started until this point. The use of smoke removal equipment is important.

Smoke removal capability should be provided. Examples of smoke removal equipment include:

(a) Mechanical air-handling systems
(b) Powered exhaust fans
(c) Roof-mounted gravity vents
(d) Perimeter gravity vents.

Whichever system is selected, it should be designed for manual actuation by the fire department, thus allowing personnel to coordinate the smoke removal (ventilation) with mop-up operations.

Appendix B Explanation of Test Data and Procedures

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

Appendix B provides and explanation of the test data and procedures that led to the development of this standard. The paragraphs are identified by the same number as the text in this standard to which they apply.

B-1-1 Application and Scope. This standard uses as a basis the large-scale fire test series conducted at the Factory Mutual Research Center, West Glocester, Rhode Island.

The test building is approximately 200 ft × 250 ft (61 m × 76 m) [50,000 ft^2 (4.65 km^2) in area], of fire-resistive construction, and contains a volume of approximately 2.25 million ft^3 (63 761.86 m^3), the equivalent of a 100,000-ft^2 (9.29-km^2) building 22.5 ft (6.86 m) high. The test building has two primary heights beneath a single large ceiling. The east section is 30 ft (9.1 m) high, and the west section is 60 ft (18.29 m) high.

The test series for storage height of 20 ft (6.1 m) was conducted in the 30-ft (9.1-m) section with clearances from the top of storage to the ceiling nominally 10 ft (3.1 m).

Doors at the lower and intermediate levels and ventilation louvers at the tops of walls were kept closed during the majority of the fire tests. This minimized the effect of exterior conditions.

The entire test series was fully instrumented with thermocouples attached to rack members, simulated building columns, bar joists, and the ceiling.

Racks were constructed of steel vertical and horizontal members designed for 4000-lb (1814-kg) loads. Vertical members were 8 ft (2.44 m) O.C. for conventional racks and 4 ft (1.22 m) O.C. for simulated automated racks. Racks were 3½ ft (1.07 m) wide with 6-in. (152.4-mm) longitudinal flue space for an overall width of 7½ ft (2.29 m). Simulated automated racks and slave pallets were used in the main central rack in the 4-ft (1.22-m) aisle tests. Conventional racks and conventional pallets were used in the main central rack in the 8-ft (2.44-mm) aisle tests. The majority of the tests were conducted with 100-ft^2 (9.29-m^2) sprinkler spacing.

The test configuration for storage heights of 15 ft (4.6 m), 20 ft (6.1 m), and 25 ft (7.6 m) covered an 1800-ft^2 (167.2-m^2) floor area, including aisles between racks. Tests that were used in producing this standard limited fire damage to this area. The maximum water damage area anticipated in the standard is 6000 ft^2 (557.4 m^2), the upper limit of the design curves.

The test data shows that, as density is increased, both the extent of fire damage and sprinkler operation are reduced. The data also indicates that, with sprinklers installed in the racks, a reduction is gained in the area of fire damage and sprinkler operations (i.e., water damage).

Table B-1-1 illustrates these points. The information shown is taken from the test series for storage height of 20 ft (6.1 m) using the standard commodity.

Table B-1-1

Density gpm/ft^2		Fire Damage in Test Array (%)	Fire Damage in Test Array (ft^2)	Sprinkler Operation (165°F) Area (ft^2)
0.30	(Ceiling only)	22	395	4500-4800
0.375	(Ceiling only)	17	306	1800
0.45	(Ceiling only)	9	162	700
0.20	(Ceiling only)	28-36	504-648	13,100-14,000
0.20	(Sprinklers at ceiling and in racks)	8	144	4100
0.30	(Sprinklers at ceiling and in racks)	7	126	700

For SI units: 1 ft = 0.3048 m, °C = 5/9 (°F − 32);
1 gpm/ft^2 = 40.746 (L/min)/m^2

The fact that there is a reduction in both fire damage and area of water application as sprinkler densities are increased or where sprinklers are installed in racks should be considered carefully by those responsible for applying this standard to the rack storage situation.

In the test for storage height of 25 ft (7.6 m), a density of 0.55 gpm/ft^2 [(22.4 L/min)/m^2] produced 42 percent, or 756 ft^2 (70.26 m^2), fire damage in the test array and a sprinkler-wetted area of 1400 ft^2 (130.1 m^2). Lesser densities would not be expected to achieve the same limited degree of control. Therefore, if the goal of smaller areas of fire damage is to be achieved, sprinklers in racks should be considered.

The test series for storage height over 25 ft (7.6 m) was conducted in the 60-ft (18.29-m) section of the test building with nominal clearances from the top of storage to the ceiling of either 30 ft (9.1 m) or 10 ft (3.1 m).

Doors at the lower and intermediate levels and ventilation louvers at the top of walls were kept closed during the fire tests. This minimized the effect of exterior wind conditions.

The purpose of the over-25-ft (7.6-m) series was to:

(a) Determine the arrangement of in-rack sprinklers that can be repeated as pile height increases and that provide control of the fire.

(b) Determine other protective arrangements, such as high-expansion foam, that provide control of the fire.

Control was considered to have been accomplished if the fire was unlikely to spread from the rack of origin to adjacent racks or spread beyond the length of the 25-ft (7.6-m) test rack. To aid in this judgment, control was considered to have been achieved if the fire did not:

(a) Jump the 4-ft (1.22-m) aisles to adjoining racks.

(b) Reach the end face of the end stacks (north or south ends) of the main rack.

Control is defined as holding the fire in check through the extinguishing system until the commodities initially involved are consumed or until the fire is extinguished by the extinguishing system or manual aid.

The standard commodity as selected in the 20-ft (6.1-m) test series was used in the majority of over-25-ft (7.6-m) tests. Hallmark products and 3-M products described in the 20-ft (6.1-m) test series report also were used as representative of Class III or IV commodities, or both, in several tests. The results of privately sponsored tests on Hallmark products and plastic encapsulated standard commodities also were made available to the committee.

A 25-ft (7.6-m) long test array was used for the majority of the over-25-ft (7.6-m) high test series. The decision to use such an array was made because it was believed that a fire in racks over 25 ft (7.6 m) high that extended the full length of a 50-ft (15.24-m) long rack could not be considered controlled, particularly as storage heights increased.

One of the purposes of the tests was to determine arrangements of in-rack sprinklers that can be repeated as pile height increases and that provide control of the fire. The tests for storage height of 30 ft (9.1 m) explored the effect of such arrays. Many of these tests, however, produced appreciable fire spread in storage in tiers above the top level of protection within the racks. (In some cases, a total burnout of the top tiers of both the main rack and the target rack occurred.) In the case of the 30-ft (9.1-m) Hallmark Test 134 on the 60-ft (18.3-m) site, the material in the top tiers of storage burned vigorously, and the fire jumped the aisle above the fourth tier. The fire then burned downward into the south end of the fourth tier. In the test on the floor, a nominal 30-ft (9.1-m) clearance occurred between the top of storage and the ceiling sprinklers, whereas on the platform this clearance was reduced to nominal 10 ft (3.1 m). In most cases, the in-rack sprinklers were effective in controlling fire below the top level of protection within the racks. It has been assumed by the Test Planning Committee that, in an actual case with a clearance of 10 ft (3.1 m) or less above storage, ceiling sprinklers would be expected to control damage above the top level of protection within the racks. Tests have been planned to investigate lesser clearances.

Tests 114 and 128 explore the effect of changing the ignition point from the in-rack standard ignition point to a face ignition location. It should be noted, however, that both of these tests were conducted with 30-ft (9.1-m) clearance from the ceiling sprinklers to the top of storage and, as such, ceiling sprinklers had little effect on the fire in the top two tiers of storage. Fire spread in the three lower tiers is essentially the same. A similar change in the fire spread where the ignition point is changed was noted in Tests 126 and 127. Once again, 30-ft (9.1-m) clearance occurred between the top of storage and the ceiling sprinklers, and, as such, the ceiling sprinklers had little effect on the face fire. Comparisons of Tests 129, 130, and 131 in the test series for storage height of 50 ft (15.24 m) indicate little effect of point of ignition in the particular configuration tested.

Test 125, when compared with Test 133, indicates no significant difference in result between approved low profile sprinklers and standard sprinklers in the racks.

B-2-1 A review of full-scale fire tests run on the standard commodity (double tri-wall carton with metal liner); of Hallmark products and 3-M products (e.g., abrasives, pressure-sensitive tapes of plastic fiber, and paper); and of the considerable number of commodity tests conducted provides a guide for commodity classifications. This guide is not related to any other method of classification of materials; therefore, sound engineering judgment and analysis of the commodity and the packaging should be used when selecting a commodity classification.

B-3-2.1 None of the tests that were conducted with densities in accordance with the design curves produced critical temperatures in bar joists 12½ ft (3.81 m) from the ignition source. Therefore, with sprinkler systems designed in accordance with the curves, fireproofing of roof steel should not be necessary.

B-3-2.2 Temperatures in the test column were maintained below 1000°F (538°C) in all tests where sprinklers in racks were used.

B-3-2.3 Temperatures in the test column were maintained below 1000°F (538°C) with densities, of roof ceiling sprinklers only, of 0.375 gpm/ft^2 [(15.3 L/min)/m^2] with 8-ft (2.44-m) aisles and 0.45 gpm/ft^2 [(18.34 L/min)/m^2] with 4-ft (1.22-m) aisles using the standard commodity.

B-3-3 Tests were conducted as a part of this program with eave line windows or louvers open to simulate smoke and heat venting. These tests opened 87.5 percent and 91 percent more sprinklers than did comparative tests without windows or louvers open. Venting tests that have been conducted in other programs were without the benefit of sprinkler protection and, as such, are not considered in this report, which covers only buildings protected by sprinklers. The design curves are based upon the absence of roof vents or draft curtains in the building. During mop-up operations, ventilating systems, where installed, should be capable of manual exhaust operations.

B-4-3.1 Test 80 was conducted to determine the effect of closing back-to-back longitudinal 6-in. (152.4-mm) flue spaces in conventional pallet racks. Test results indicated fewer sprinklers operating than with the flue space open, and, as such, no minimum back-to-back clearance is necessary if the transverse flue space is kept open.

Tests 145 and 146 were conducted to investigate the influence of longitudinal and transverse flue dimensions in

double-row racks without solid shelves. Results were compared with Tests 65 and 66. Flue dimensions in Tests 65, 66, 145, and 146 were 6 in. (152.4 mm), 6 in. (152.4 mm), 3 in. (76.2 mm), and 12 in. (0.30 m), respectively. All other conditions were the same.

In Tests 65 and 66, 45 and 48 sprinklers operated compared with 59 and 58 for Tests 145 and 146, respectively. Fire damage in Tests 145 and 146 was somewhat less than in Tests 65 and 66: 2100 ft^3 (59.51 m^3) and 1800 ft^3 (51 m^3) in Tests 145 and 146, respectively, versus 2300 ft^3 (65.13 m^3) and 2300 ft^3 (65.13 m^3) in Tests 65 and 66, respectively, of combustible material were consumed.

Test results indicate narrow flue spaces of about 3 in. (76.2 mm) allow reasonable passage of sprinkler water down through the racks.

Tests 96 and 107, on multiple-row racks, used 6-in. (152.4-mm) transverse flue spaces. The water demand recommended in the standard is limited to those cases with nominal 6-in. (152.4-mm) transverse flues in vertical alignment.

B-4-5 Most tests in the 25-ft (7.6-m) and under test series were conducted with a clearance of 10 ft (3.1 m) from the top of storage to the sprinkler deflectors, and the basic design curves in Figures 6-12(a) through (g) reflect this condition.

Tests 140 and 141 were conducted with a 3-ft (0.91-m) clearance between the top of storage and the ceiling sprinkler deflectors. In Test 140, using a density of 0.30, 36 sprinklers operated compared with 45 and 48 sprinklers in Tests 65 and 66 with a 10-ft (3.1-m) clearance. In Test 141, 89 sprinklers operated compared with 140 sprinklers in Test 70 with a 10-ft (3.1-m) clearance. Fire spread in Tests 140 and 141 was somewhat less than in Tests 65, 66, and 70.

Test 143 was conducted with an 18-in. (0.46-m) clearance between the top of storage and the ceiling sprinkler deflectors, and with 0.30 density. Thirty-seven sprinklers operated compared with 36 sprinklers in Test 140 with a 3-ft (0.91-m) clearance and 45 and 48 sprinklers in Tests 65 and 76 with a 10-ft (3.1-m) clearance. Fire spread in Test 143 with an 18-in. (0.46-m) clearance was somewhat less than in Tests 65 and 66 with a 10-ft (3.1-m) clearance and Test 140 with a 3-ft (0.91-m) clearance.

Privately sponsored tests, using a 0.45 ceiling sprinkler density and an encapsulated commodity, indicated 40 sprinklers operating with a 10-ft (3.1-m) clearance, 11 sprinklers operating with a 3-ft (0.91-m) clearance, and 10 sprinklers operating with an 18-in. (0.46-m) clearance. Fire spread was less in the test with the 18-in. (0.46-m) clearance than the 3-ft (0.91-m) clearance and also was less with the 3-ft (0.46-m) clearance than with the 10-ft (3.1-m) clearance.

B-4-7 No tests were conducted with idle pallets in racks. Such storage conceivably would introduce fire severity in excess of that contemplated by protection criteria for an individual commodity classification.

B-5-3 The highest operating pressure at any sprinkler in the test program was 62.5 psi (430.93 kPa).

Tests in the 20-ft (6.10-m) high test series were conducted using wood and metal bulkheads to determine whether bulkheads could be a substitute for either higher ceiling sprinkler densities or for intermediate sprinklers. Bulkheads of either type had no appreciable beneficial effect on the overall sprinkler performance in double-row rack tests.

Tests 125 and 134 were conducted to compare the effect of a different commodity in the 30-ft (9.1-m) high test array. If the degree of damage above the top level of protection (fifth and sixth tiers) is ignored, the Class III commodity represented by Hallmark cards would appear to be protected to the same degree as a Class II commodity.

Tests 132 and 135 were conducted to determine the effect of a different commodity in the test series for storage height of 50 ft (15.24 m). The degree of control achieved with the 3-M products in Test 135 closely approximates that achieved with the standard commodity in Test 132. The results of the Hallmark Test 134 and the private Hallmark test with geometric, in-rack sprinkler array, and in-rack sprinkler flow rate that differs from other tests, conducted as a separate program, suggests that in storage height over 25 ft (7.6 m), Class III commodities can be protected in the same fashion as Class II commodities.

Tests 112 and 115 compare a 10-ft (3.1-m) clearance above storage to sprinklers with a 30-ft (9.1-m) clearance.

B-5-7 The time of operation of the first sprinkler varied from 52 seconds to 3 minutes and 55 seconds, with most tests under 3 minutes, except in Test 64 (Class III), where the first sprinkler operated in 7 minutes and 44 seconds. Fire detection more sensitive than waterflow is, therefore, considered necessary only in exceptional cases.

B-5-8 In most tests conducted, it was necessary to use small hose for mop-up operations. Small hoses were not used in the high-expansion foam test.

Test 97 was conducted to evaluate the effect of dry-pipe sprinkler operation. Test results were approximately the same as the base test with a wet-pipe system. A study of NFPA records, however, indicates an increase in area of operation of 30 percent to be in order for dry-pipe systems as compared with wet-pipe systems.

B-5-10 In all valid tests, with double-row racks, sprinkler water supplies were shut off at approximately 60 minutes. In only one test did the last sprinkler operate in excess of 30 minutes after ignition; the last sprinkler operated in excess of 25 minutes in three tests, with the majority of tests involving the last sprinkler operating within 20 minutes.

B-5-13.2 Test 98 with solid shelves 24 ft (7.3 m) long and 7½ ft (2.3 m) deep at each level produced total destruction of the commodity in the main rack and jumped the aisle. Density was 0.3 gpm/ft^2 [(12.22 L/min)/m^2] from the ceiling sprinklers only. Test 108 with shelves 24 ft (7.3 m) long and 3½ ft (1.07 m) deep and with a 6-in. (152.4-mm) longitudinal flue space and one level of sprinklers in the rack resulted in damage to most of the commodity in the main rack, but did not jump the aisle. Density from ceiling sprinklers was 0.375 gpm/ft^2 [(15.28 L/min)/m^2], and rack sprinklers discharged at 15 psi (103.41 kPa).

These tests did not yield sufficient information to develop a comprehensive protection standard for solid shelf racks. Items such as increased ceiling density, use of bulkheads, other configurations of sprinklers in racks, and limitation of shelf length and width should be considered.

Where such rack installations exist or are contemplated, the damage potential should be considered, and sound engineering judgment should be used in designing the protection system.

Test 98, with solid shelving obstructing both the longitudinal and transverse flue space, produced unsatisfactory results and indicates a need for sprinklers at each level in such a rack structure.