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NFPA 231C Rack Storage of Materials 1986

National Fire Protection Association Batterymarch Park, Quincy, MA 02269

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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.

Statement on NFPA Procedures

This material has been developed under the published procedures of the National Fire Protection Association, which are designed to assure the appointment of technically competent Committees having balanced representation. While these procedures assure the highest degree of care, neither the National Fire Protection Association, its members, nor those participating in its activities accepts any liability resulting from compliance or noncompliance with the provisions given herein, for any restrictions imposed on materials or processes, or for the completeness of the text.

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SC FM-85

NFPA 231C

Standard for

Rack Storage of Materials

1986 Edition

This edition of NFPA 231C, *Standard for Rack Storage of Materials*, was prepared by the Technical Committee on Rack Storage of Materials, released by the Correlating Committee on Storage, and acted on by the National Fire Protection Association, Inc. at its Fall Meeting held November 18-20, 1985 in Baltimore, Maryland. It was issued by the Standards Council on December 10, 1985, with an effective date of December 30, 1985, and supersedes all previous editions.

The 1986 edition of this standard 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 of 1967, representatives of the rack manufacturers, the fire protection equipment field, 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 making some former recommendations mandatory and new material was added to the Appendix. In 1973 it was further revised to include storage for heights above 25 feet, and the relocation of advisory material to the appendix. In 1974 the entire format was revised, editorial changes were made, and new material was added.

In 1975, new test data permitted the introduction of new material. The 1980 edition included partial revisions to the standard, in particular the tables and figures in Chapter 6. This 1986 edition includes new chapters on plastics and large-drop sprinklers.

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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.

Contents

NFPA 231C

Standard for

Rack Storage of Materials

1986 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 in regard to that paragraph or section in Appendix B.

Information on referenced publications can be found in Chapter 12 and Appendix C.

Chapter 1 Introduction

1-1† Application and Scope. This standard applies to storage of materials representing the broad range of combustibles stored over 12 ft (3.66 m) in height on racks. For storage height of 12 ft (3.66 m) or less, see NFPA 13, *Standard for 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. See NFPA 30, *Flammable and Combustible Liquids Code*; NFPA 40, *Standard for the Storage and Handling of Cellulose Nitrate Motion Picture Film*; NFPA 490, *Code for the Storage of Ammonium Nitrate*; NFPA 58, *Standard for the Storage and Handling of Liquified 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* and NFPA 232, *Standard for the Protection of Records*, for standards applying to such commodities or to other methods of storage.

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

1-2 Definitions. Unless expressly stated elsewhere, the following terms shall, for the purpose of this standard, have the meanings indicated below.

Aisle Width. The horizontal dimension between the face of the loads in racks under consideration. (*See Figure 1-2.1.*)

Approved. Acceptable to the "authority having jurisdiction."

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

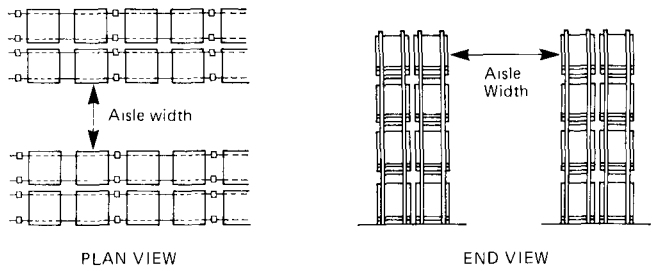


Figure 1-2.1 Illustration of Aisle Width.

Authority Having Jurisdiction. The "authority having jurisdiction" is the organization, office or individual responsible for "approving" equipment, an installation or a procedure.

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

Bulkhead. A vertical barrier across the rack.

Commodity. Designates 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 1-2.2*).

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. Totally noncombustible commodities on wood pallet enclosed only by a plastic sheet as described are not considered to fall under this definition. Banding, i.e., stretch wrapping around the sides only of a pallet load, is not considered to be encapsulated. The term *encapsulated* does not apply to individual plastic-enclosed items 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 to oppose vertical development of fire on the external face of storage.

Free-Flowing Plastic Materials. Those plastics which will fall out of their containers in a fire condition, fill flue spaces, and create a smothering effect on the fire. Example: Powder, pellets, flakes, or random packed small objects [razor blade dispensers, 1-2 oz (22-57 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 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 1-2.3*).

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

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.

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.

Multi-Row Racks. Multi-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 which are not fixed in place. They can be arranged in any number of configurations.

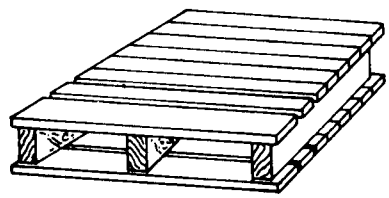
Movable Racks. Movable racks are racks on fixed rails or guides. They can be moved back and forth only in a horizontal two-dimensional plane. A moving aisle is created as abutting racks are either loaded or unloaded, then moved across the aisle to abut other racks. Rack arrangements generally result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

Shall. Indicates a mandatory requirement.

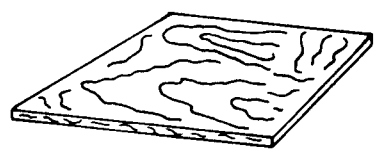
Shelf Storage. Storage in structures usually less than 30 in. (0.76 m) deep, seldom more than 2 ft (0.61 m) between shelves and seldom higher than 12 ft (3.66 m).

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 1-2.2*).



Conventional Pallet



Solid Flat Bottom Wood Pallet

Figure 1-2.2 Typical Pallets.

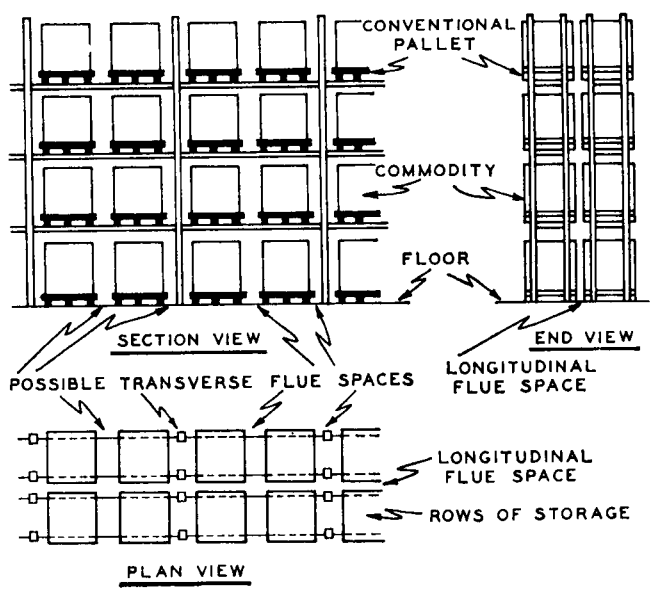


Figure 1-2.3 Typical Double Row (Back-to-Back) Rack Arrangement.

Solid Shelving. Solid shelving is solid, slatted, or other types of shelves located within racks which 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 1-2.3*).

Chapter 2 Classification of Storage

2-1† Commodity Classifications.

2-1.1 Class I commodity is defined as essentially noncombustible product 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 may have a negligible amount of plastic trim, such as knobs or handles.

Examples of Class I products are:

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, and metal cabinets.

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

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

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 commodity is defined as Class I products in slatted wooden crates, solid wooden boxes, multiple-thickness paperboard cartons, or equivalent combustible packaging material on wood pallets.

Examples of Class II products are: 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; and Class I products, if in small cartons or small packages placed in ordinary corrugated cartons.

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

Examples of Class III products are:

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; and regenerated cellulosics (cellophane).

Leather Products. Shoes, jackets, gloves, and luggage.

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

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

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

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

Examples of Class IV products are: 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, and nonviscose synthetic fabrics or clothing.

Others. Vinyl floor tile, wood or metal frame upholstered furniture or mattresses with plastic covering and/or padding, and 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 may change the classification.

Group A

ABS (Acrylonitrile-Butadiene-Styrene Copolymer)
Acetal (Polyformaldehyde)
Acrylic (Polymethyl Methacrylate)
Butyl Rubber
EPDM (Ethylene-Propylene Rubber)
FRP (Fiberglass Reinforced Polyester)
Natural Rubber
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)

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)
Nylon (Nylon 6, Nylon 6/6)
Silicon Rubber

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, which are protected in accordance with this standard, may 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, 7, 8, and 9, fire protection of roof steel is not necessary.

3-2.2† When ceiling sprinklers and sprinklers in racks are installed in accordance with Chapters 5, 6, 7, and 8, fire protection of steel building columns is not necessary.

3-2.3† When storage height exceeds 15 ft (4.57 m), and ceiling sprinklers only are installed, fire protection by one of the following methods is 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) Side wall sprinklers at the 15 ft (4.57 m) elevation, pointed towards one side of the steel column.

(c) For storage heights above 15 ft (4.57 m), up to and including 20 ft (6.1 m), provision of ceiling sprinkler density for a minimum of 2000 sq ft (185.9 m²) with 165°F (74°C) or 286°F (141°C) temperature-rated sprinklers as shown in Table 3-2.3:

Table 3-2.3

	Aisle	
Commodity Class	4 ft (1.22 m)	8 ft (2.44 m)
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 between 4 ft and 8 ft, a direct linear interpolation between densities may be made.

3-3† Vents and Draft Curtains. Design curves are based upon roof vents and draft curtains not being used.

Chapter 4 Storage Arrangements

4-1* Rack Structure. Typical rack configurations are described in Appendix A-4-1.

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 (7.62 m), and without solid shelves, no longitudinal flue space (back-to-back clearance) is necessary. An average 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 are permissible. (*See Figure 4-3.1.*)

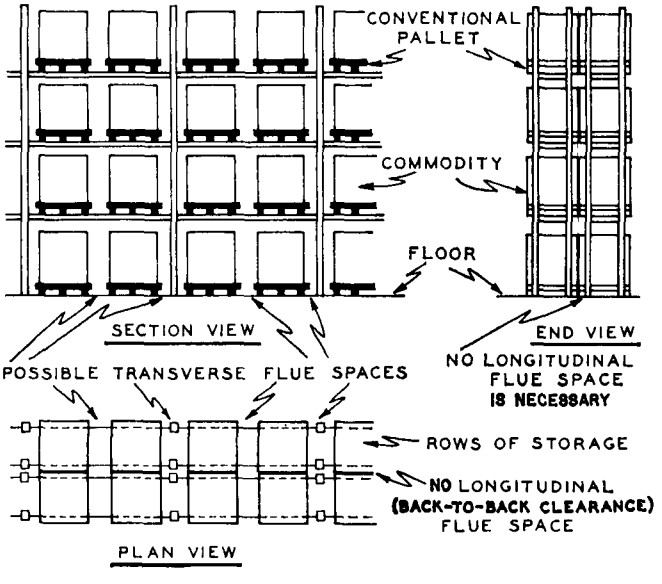


Figure 4-3.1 Typical Double Row Rack with Back-to-Back Loads.

4-3.2 In double row racks with height of storage over 25 ft (7.62 m), a minimum longitudinal flue space of approximately 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. Width of aisles shall be considered in the design of the protection system (*see Chapters 5, 6, and 7*).

4-4.2 This standard contemplates that aisle widths will be 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 the pile to the ceiling sprinkler deflectors shall be not less than 18 in. (0.46 m).

4-6 Commodity Clearances.

4-6.1* Commodity clearances shall be maintained in accordance with NFPA 91, *Standard for the Installation of Blower and Exhaust Systems for Dust, Stock and Vapor Removal or Conveying*.

4-6.2* Incandescent Light Fixtures.

4-7*† Storage of Idle Combustible Pallets. For bulk storage of idle combustible pallets, see NFPA 231, *Standard for General Storage*.

Chapter 5 Fire Protection — General

5-1 Protection Systems.

5-1.1 Protection systems which 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 and 7 are based on fire tests using standard response; standard orifice [½ in. (12.7 mm)] and large orifice [17/32 in. (13.5 mm)] sprinklers. For use of large-drop sprinklers see Chapter 9.

5-2 Ceiling Sprinklers.

5-2.1* Where automatic sprinkler systems are installed, they shall be in accordance with NFPA 13, *Standard for Installation of Sprinkler Systems*, except as 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 (4.57 m) of the racks shall be the same as that provided over the rack storage area.

5-3† Ceiling Sprinkler Spacing. For the purpose of selecting sprinkler spacings in hydraulically designed sprinkler systems, to obtain a stipulated density, 60 psi 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 sq ft (3.7 km²) 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* When sprinklers are installed in racks, separate indicating gate valves and drains shall be provided for ceiling sprinklers and sprinklers in racks, except such drains and valves are not required for small in-rack installations of less than 20 sprinklers.

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

5-7*† Sprinkler Water Flow Alarm.

5-8† Hose Connections. For first aid fire fighting and for mop-up operations, small [1½ in. (38.1 mm)] hose lines shall be available to cover all areas of the rack structure. Such small hose may be supplied from:

(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: When separately controlled, in-rack sprinklers are provided, the ceiling sprinkler system in the same area may 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 sprinkler water demand for Class I, II, III, IV, or 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 sprinkler water demand for Class I, II, III, IV, or plastic commodities.

5-10† Duration of Water Supplies. For double row racks the water supply duration shall be at least 1½ 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* When high expansion foam systems are installed they shall be in accordance with NFPA 11A, *Standard for Medium and High Expansion Foam Systems*, except as modified by this standard and they shall be automatic in operation.

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

5-12 Detectors for High Expansion Foam Systems.

5-12.1 Detectors used shall be listed and shall be installed:

(a) At ceiling only at one-half listed linear spacing [e.g., 15 ft × 15 ft (4.57 m × 4.57 m) instead of 30 ft × 30 ft (9.15 m × 9.15 m)], or

Exception: Ceiling detectors only should not be used when clearance from the top of storage exceeds 10 ft (3.05 m) or height of storage exceeds 25 ft (7.62 m).

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

(c) Listed for rack storage installation and installed in accordance with their listing to provide response within one minute after ignition using ignition source equal to that used on the rack storage testing program.

5-13 Solid and Slatted Shelves.

5-13.1 Slatted shelves shall be considered the same as 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.

5-15.1 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 Feet (7.62 m) in Height

Part A General

NOTE: See also Chapter 5.

6-1 In-Rack Sprinkler Size. Sprinklers in racks shall be ordinary temperature classification with nominal ½ in. (12.7 mm) orifice size pendent or upright, except that 212°F (100°C) and 286°F (141°C) classifications shall be used near heat sources as specified in NFPA 13.

6-2 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.

6-3† 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 when there is more than one level, if not shielded by horizontal barriers.

6-4 In-Rack Sprinkler Location.

6-4.1* The elevation of in-rack sprinkler deflectors with respect to storage is not a consideration in double rack storage up to and including 20 ft (6.1 m) high.

6-4.2* In double row racks without solid shelves with height of storage over 20 ft (6.1 m), or in multiple row racks, or in double row racks with solid shelves and height of storage up to and including 25 ft (7.62 m), a minimum of 6 in. (152.4 mm) clear space shall be maintained between the sprinkler deflectors and the top of a tier of storage.

6-4.3† In-rack sprinklers at one level only for storage up to and including 25 ft (7.62 m) high in double row racks shall be located at the first tier level at or above one-half of the storage height.

6-4.4 In-rack sprinklers at two levels only for storage up to and including 25 ft (7.62 m) high shall be located at the first tier level at or above one-third and two-thirds of the storage height.

6-5 In-Rack Sprinkler Spacing.

6-5.1* Maximum horizontal spacing of sprinklers in double row racks with nonencapsulating storage up to and including 25 ft (7.62 m) in height shall be in accordance with the following table:

	Commodity Class		
Aisle Widths	**I & II**	**III**	**IV**
8 ft.	12 ft.	12 ft.	8 ft.
4 ft.	12 ft.	8 ft.	8 ft.

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

For SI Units: 1 ft = 0.3048 m)

6-5.2† Sprinklers installed in racks may be spaced without regard to rack uprights.

6-6† In-Rack Sprinkler Discharge Pressure. Sprinklers in racks shall discharge at not less than 15 psi for all classes of commodity.

6-7† In-Rack Sprinkler Water Demand. Water demand for sprinklers installed in racks shall be based on simultaneous operation of the most hydraulically remote:

(a) Six sprinklers when only one level is installed in racks with Class I, II, or III commodity.

(b) Eight sprinklers when only one level is installed in racks with Class IV commodity.

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

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

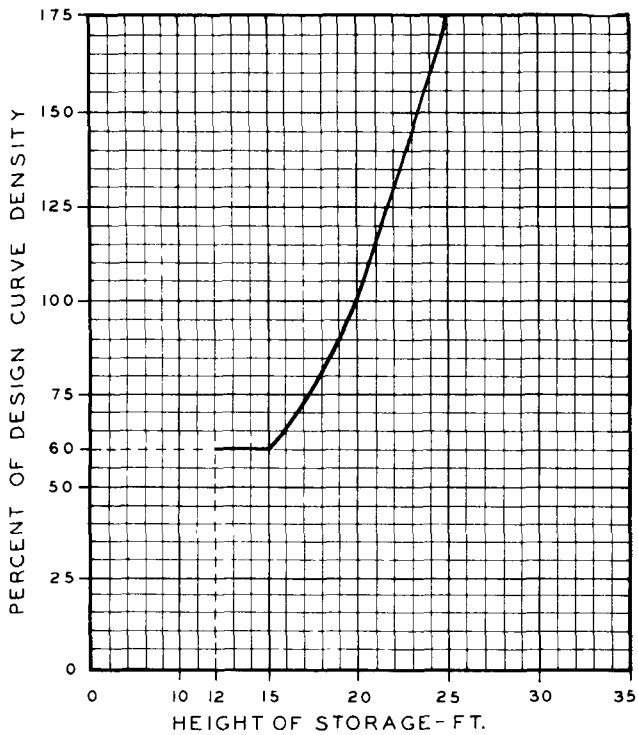
6-8 Ceiling Sprinkler Water Demand.

6-8.1*† Design curves in Figures 6-11.1(a) through (g) apply to nominal 20 ft (6.1 m) height of storage.

6-8.1.1 The design curves indicate water demands for nominal 165°F (74°C) and nominal 286°F (141°C) 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). The 286°F (141°C) design curve shall be used for sprinklers with high temperature classification.

6-8.2 For height of storage up to and including 25 ft (7.62 m) protected with ceiling sprinklers only, and for height of storage up to and including 20 ft (6.1 m) protected with ceiling sprinklers and minimum acceptable in-rack sprinklers, densities given in design curves shall be adjusted according to Figure 6-8.2.

6-8.3 For height of storage over 20 ft (6.1 m) up to and including 25 ft (7.62) protected with ceiling sprinklers and minimum acceptable in-rack sprinklers, densities given in design curves shall be used. Densities shall not be adjusted per Figure 6-8.2.



For SI Units: 1 ft = 0.3048 m

Figure 6-8.2 Ceiling Sprinkler Density versus Storage Height.

6-8.4 For height of storage up to and including 20 ft (6.1 m) protected with ceiling spinklers and with more than one level of in-rack sprinklers, but not in every tier, densities given in design curves and adjusted according to Figure 6-8.2 can be reduced an additional 20 percent.

6-8.5 For height of storage 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 acceptable level of in-rack sprinklers, but not in every tier, densities given in design curves can be reduced 20 percent. Densities shall not be adjusted per Figure 6-8.2.

Table 6-8.2 Adjustment to Ceiling Sprinkler Density for Storage Height and In-Rack Sprinklers

Stge. Height (ft)	In-Rack Sprinklers	Apply Fig. 6-8.2	Permitted Ceiling Sprinklers Density Adjustments
Over 12 Ft Through 25 Ft	None	Yes	None
Over 12 Ft Through 20 Ft	Minimum Acceptable	Yes	None
	More than Minimum but Not In Every Tier.	Yes	Reduce Density 20% from that for Minimum In-Rack Sprinklers
	In Every Tier.	Yes	Reduce Density 40% from that for Minimum In-Rack Sprinklers
Over 20 Ft Through 25 Ft	Minimum Acceptable	No	None
	More than Minimum but Not In Every Tier.	No	Reduce Density 20% from that for Minimum In-Rack Sprinklers
	In Every Tier.	No	Reduce Density 40% from that for Minimum In-Rack Sprinklers

For SI Units: 1 ft = 0.3048 m

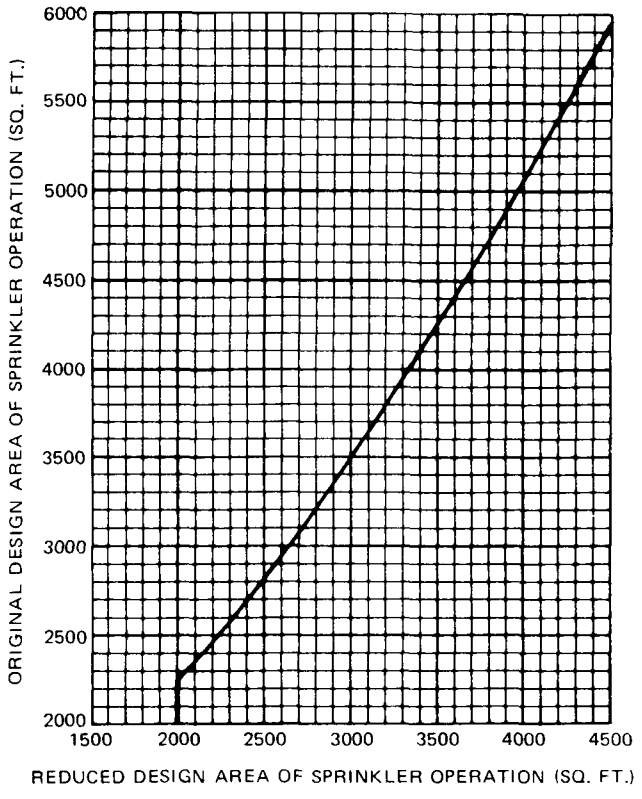
6-8.6 For height of storage up to and including 20 ft (6.1 m) protected with ceiling sprinklers and in-rack sprinklers at each tier, densities given in design curves and adjusted according to Figure 6-8.2 can be reduced an additional 40 percent.

6-8.7 For height of storage over 20 ft (6.1 m) up to and including 25 ft (7.62 m) protected with ceiling sprinklers and in-rack sprinklers at each tier, densities given in design curves can be reduced 40 percent. Densities shall not be adjusted per Figure 6-8.2.

6-8.8† When clearance from top of storage to ceiling 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 6-11.1(a), (b), (c), (d), and (e) can be reduced as indicated in Figure 6-8.8, but not less than 2,000 sq ft (185.8 m²) (*see 6-8.9*).

6-8.9 When clearance from ceiling to top of Class I or II encapsulated storage is 1½ to 3 ft (0.46 m to 0.91 m), sprinkler operating area indicated in curve F only of Figure 6-11.1(e) may be reduced by 50 percent but to not less than 2,000 sq ft (185.8 m²).

6-8.10 Where solid flat bottom wood pallets are used, with height of storage up to and including 25 ft (7.62 m), the densities indicated in the design curves, based on conventional pallets, shall be increased 20 percent for the given area. This percentage shall be applied to the density resulting from the application of Figure 6-8.2. This increase does not apply when in-rack sprinklers are installed.



For SI Units: 1 sq ft = 0.0929 m^2)

Figure 6-8.8 Adjustment of Design Area of Sprinkler Operation for Clearance from Top of Storage to Ceiling

6-9 High Expansion Foam Submergence.

6-9.1* When 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.

6-9.2 When 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.

6-10 High Expansion Foam Ceiling Sprinkler Density. When high expansion foam systems are used in combination with ceiling sprinklers, the minimum ceiling sprinkler design shall be a density of 0.2 gpm per sq ft (8.15 L/min/m^2) for Class I, II, or III commodities or 0.25 gpm per sq ft (10.2 L/min/m^2) for Class IV commodities for the most hydraulically remote 2,000 sq ft (185.8 L/min/m^2) operating area.

Part B Double and Single Row Racks

NOTE: See also Chapter 5.

6-11 Ceiling Sprinkler Water Demand.

6-11.1* For Class I, II, III, or IV commodities encapsulated or nonencapsulated in double row racks, ceiling sprinkler water demand in terms of density (gpm per sq ft) and area of sprinkler operation (sq ft of ceiling or roof) shall be selected from curves given in Figures 6-11.1(a) through (g). The curves in Figures 6-11.1(a) through (g) also apply to portable racks arranged in the same manner as double row racks or multiple row racks. Design is intended to be at a single point on the appropriate curve related to the storage configuration and commodity class. It is not necessary to meet all points on the selected curve. Figure 6-8.2 shall be used to adjust density for storage height unless otherwise specified.

6-11.2† Design curves for single and double row racks shall be selected corresponding to aisle width. For aisle widths between 4 ft (1.22 m) and 8 ft (2.44 m) a direct linear interpolation between curves may be made. Density given for 8 ft (2.44 m) wide aisles shall be applied to aisles wider than 8 ft (2.44 m). 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). When aisles are narrower than 3½ ft (1.07 m), racks shall be considered as multiple row racks.

6-12 In-Rack Sprinkler Location. In double row racks without solid shelves, in-rack sprinklers shall be installed as indicated in Table 6-11.1.

Part C Multiple Row Racks

NOTE: See also Chapter 5.

6-13 In-Rack Sprinkler Location.

6-13.1† 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 as indicated in Table 6-13.1.

6-13.2 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 as indicated in Table 6-13.2.

6-13.3* Maximum horizontal spacing of sprinklers on branch lines, in multiple row racks with encapsulated or nonencapsulated storage up to and including 25 ft (7.62 m) in height, shall not exceed 12 ft (3.66 m) for Class I, II, or III commodities and 8 ft (2.44 m) for Class IV commodities, with area limitations of 100 sq ft (9.29 m^2) per sprinkler for Class I, II, or III commodities and 80 sq ft (7.43 m^2) per sprinkler for Class IV commodities. (Rack plan view shall be considered in determining area covered by each sprinkler. Aisles are not to be included in area calculations.)

6-13.4 A minimum of 6 in. (152.4 mm) shall be maintained between the sprinkler deflector and top of a tier of storage.

6-14 Ceiling Sprinkler Water Demand.

6-14.1 For nonencapsulated Class I, II, III, or IV commodities, ceiling sprinkler water demand in terms of density (gpm per sq ft) and area of sprinkler operation (sq ft of ceiling or roof) shall be selected from curves given in Figures 6-11.1(a) through (d). The curves in Figures 6-11.1(a) through (d) also apply to portable racks arranged in the same manner as double row racks or multi-

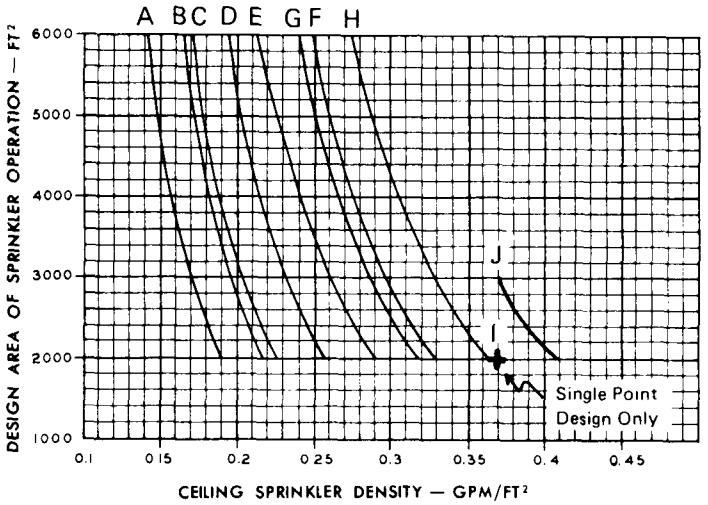
ple row racks. Design is intended to be at a single point on the appropriate curve related to the storage configuration and commodity class. It is not necessary to meet all points on the selected curve. Figure 6-8.2 shall be used to adjust density for storage height unless otherwise specified. (*See A-6-5.1 and A-6-11.1.*)

6-14.2 For encapsulated Class I, II,or III commodities with height of storage up to and including 25 ft (7.62 m) on multiple row racks, ceiling sprinkler density shall be 25 percent greater than for nonencapsulated commodities on multiple row racks.

Table 6-11.1 Double row racks. Height of Storage up to and Including 25 ft, Aisles Wider Than 4 ft, Without Solid Shelves.

Height	Commodity Class	Encapsulated	Aisles (Ft) (4-4.1) (B6-11.2)	Sprinklers Mandatory In-Rack	Ceiling Sprinkler Water Demand					
					With In-Rack Sprinklers			Without In-Rack Sprinklers		
					Fig.	Curves	Apply Fig. 6-8.2	Fig.	Curves	Apply Fig. 6-8.2
Over 12 Ft, Up Thru 20 Ft	I	No	4	No	6-11.1a	C & D	Yes	6-11.1a	G & H	Yes
			8			A & B			E & F	
		Yes	4	No	6-11.1e	C & D		6-11.1e	G & H	Yes
			8			A & B			E & F	
	II	No	4	No	6-11.1b	C & D		6-11.1b	G & H	Yes
			8			A & B			E & F	
		Yes	4	No	6-11.1e	C & D		6-11.1e	G & H	Yes
			8			A & B			E & F	
	III	No	4	No	6-11.1c	C & D		6-11.1c	G & H	Yes
			8			A & B			E & F	
		Yes	4	1 Level	6-11.1f	C & D				
			8			A & B				
	IV	No	4	No	6-11.1d	C & D		6-11.1d	G & H	Yes
			8			A & B			E & F	
		Yes	4	1 Level	6-11.1g	C & D				
			8			A & B				
Over 20 Ft, Up Thru 22 Ft	I	No	4	No	6-11.1a	C & D	No	6-11.1a	G & H	Yes
			8			A & B			E & F	
		Yes	4	1 Level	6-11.1e	C & D				
			8			A & B				
	II	No	4	No	6-11.1b	C & D		6-11.1b	G & H	Yes
			8			A & B			E & F	
		Yes	4	1 Level	6-11.1e	C & D				
			8			A & B				
	III	No	4	No	6-11.1c	C & D		6-11.1c	G & H	Yes
			8			A & B			E & F	
		Yes	4	1 Level	6-11.1f	C & D				
			8			A & B				
	IV	No	4	No	6-11.1d	C & D		6-11.1d	G & H	Yes
			8			A & B			E & F	
		Yes	4	1 Level	6-11.1g	C & D				
			8			A & B				
Over 22 Ft, Up Thru 25 Ft	I	No	4	No	6-11.1a	C & D	No	6-11.1a	G & H	Yes
			8			A & B			E & F	
		Yes	4	1 Level	6-11.1e	C & D				
			8			A & B				
	II	No	4	No	6-11.1b	C & D		6-11.1b	G & H	Yes
			8			A & B			E & F	
		Yes	4	1 Level	6-11.1e	C & D				
			8			A & B				
	III	No	4	No	6-11.1c	C & D		6-11.1c	G & H	Yes
			8			A & B			E & F	
		Yes	4	1 Level	6-11.1f	C & D				
			8			A & B				
	IV	No	4	1 Level	6-11.1d	C & D				
			8			A & B				
		Yes	4		6-11.1g	C & D				
			8			A & B				

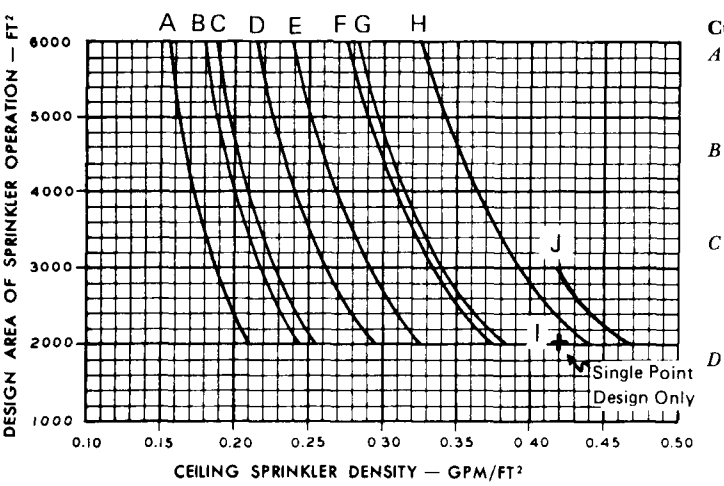
For SI units: 1 ft = 0.3048 m



Curve	Legend
A	*Double row racks with 8 ft aisles with 286°F ceiling sprinklers and 165°F in-rack sprinklers.*
B	*Double row racks with 8 ft aisles with 165°F ceiling sprinklers and 165°F in-rack sprinklers.*
C	*Double row racks with 4 ft aisles or multiple row racks with 286°F ceiling sprinklers and 165°F in-rack sprinklers.*
D	*Double row racks with 4 ft aisles or multiple row racks with 165°F ceiling sprinklers and 165°F in-rack sprinklers.*
E	*Double row racks with 8 ft aisles and 286°F ceiling sprinklers.*
F	*Double row racks with 8 ft aisles and 165°F ceiling sprinklers.*
G	*Double row racks with 4 ft aisles and 286°F ceiling sprinklers.*
H	*Double row racks with 4 ft aisles and 165°F ceiling sprinklers.*
I	*Multiple row racks with 8 ft or wider aisles and 286°F ceiling sprinklers.*
J	*Multiple row racks with 8 ft or wider aisles and 165°F ceiling sprinklers.*

For SI Units: 1 ft = 0.3048 m; C = ⅝ (F-32); 1 gpm/ft² = 40.746 (L/min)/m²

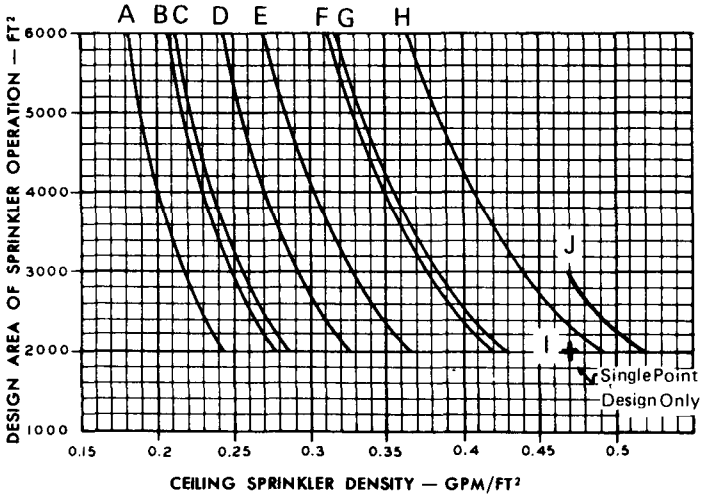
Figure 6-11.1a Sprinkler System Design Curves — 20 Foot High Rack Storage — Class I Nonencapsulated Commodities — Conventional Pallets



Curve	Legend
A	*Double row racks with 8 ft aisles with 286°F ceiling sprinklers and 165°F in-rack sprinklers.*
B	*Double row racks with 8 ft aisles with 165°F ceiling sprinklers and 165°F in-rack sprinklers.*
C	*Double row racks with 4 ft aisles or multiple row racks with 286°F ceiling sprinklers and 165°F in-rack sprinklers.*
D	*Double row racks with 4 ft aisles or multiple row racks with 165°F ceiling sprinklers and 165°F in-rack sprinklers.*
E	*Double row racks with 8 ft aisles and 286°F ceiling sprinklers.*
F	*Double row racks with 8 ft aisles and 165°F ceiling sprinklers.*
G	*Double row racks with 4 ft aisles and 286°F ceiling sprinklers.*
H	*Double row racks with 4 ft aisles and 165°F ceiling sprinklers.*
I	*Multiple row racks with 8 ft or wider aisles and 286°F ceiling sprinklers.*
J	*Multiple row racks with 8 ft or wider aisles and 165°F ceiling sprinklers.*

For SI Units: 1 ft = 0.3048 m; C = ⅝ (F-32); 1 gpm/ft² = 40.746 (L/min)/m²

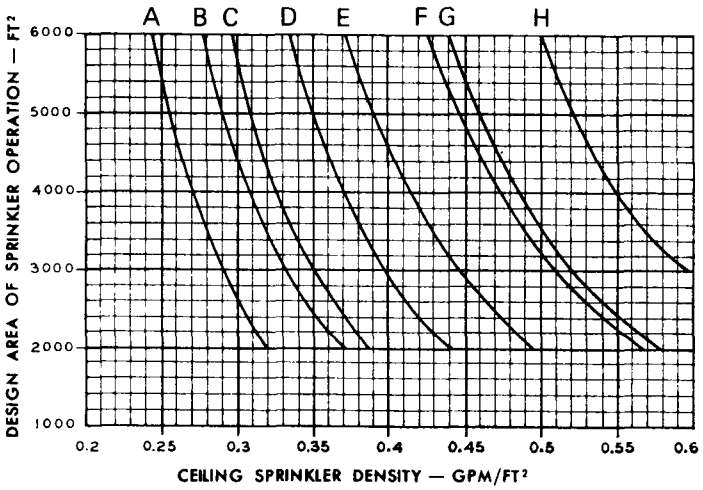
Figure 6-11.1b Sprinkler System Design Curves — 20 Foot High Rack Storage — Class II Nonencapsulated Commodities — Conventional Pallets



Curve	Legend
A	*Double row racks with 8 ft aisles with 286°F ceiling sprinklers and 165°F in-rack sprinklers.*
B	*Double row racks with 8 ft aisles with 165°F ceiling sprinklers and 165°F in-rack sprinklers.*
C	*Double row racks with 4 ft aisles or multiple row racks with 286°F ceiling sprinklers and 165°F in-rack sprinklers.*
D	*Double row racks with 4 ft aisles or multiple row racks with 165°F ceiling sprinklers and 165°F in-rack sprinklers.*
E	*Double row racks with 8 ft aisles and 286°F ceiling sprinklers.*
F	*Double row racks with 8 ft aisles and 165°F ceiling sprinklers.*
G	*Double row racks with 4 ft aisles and 286°F ceiling sprinklers.*
H	*Double row racks with 4 ft aisles and 165°F ceiling sprinklers.*
I	*Multiple row racks with 8 ft or wider aisles and 286°F ceiling sprinklers.*
J	*Multiple row racks with 8 ft or wider aisles and 165°F ceiling sprinklers.*

For SI Units: 1 ft = 0.3048 m; C = ⅝ (F-32); 1 gpm/ft² = 40.746 (L/min)/m²

Figure 6-11.1c Sprinkler System Design Curves — 20 Foot High Rack Storage — Class III Nonencapsulated Commodities — Conventional Pallets

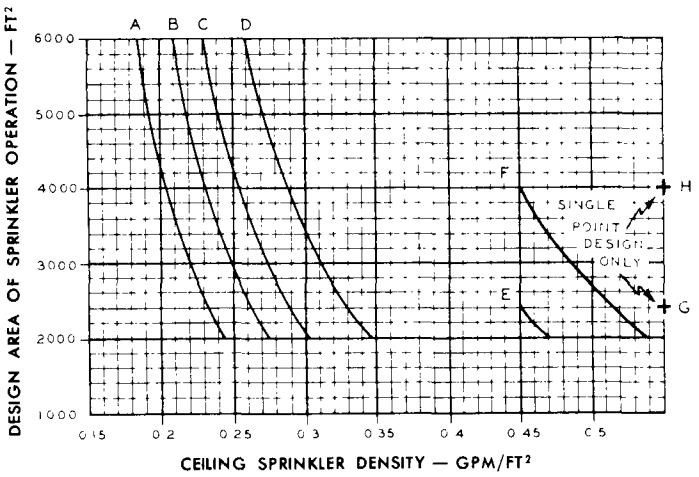


Curve	Legend
A	*Double row racks with 8 ft aisles with 286°F ceiling sprinklers and 165°F in-rack sprinklers.*
B	*Double row racks with 8 ft aisles with 165°F ceiling sprinklers and 165°F in-rack sprinklers.*
C	*Double row racks with 4 ft aisles or multiple row racks with 286°F ceiling sprinklers and 165°F in-rack sprinklers.*
D	*Double row racks with 4 ft aisles or multiple row racks with 165°F ceiling sprinklers and 165°F in-rack sprinklers.*
E	*Double row racks with 8 ft aisles and 286°F ceiling sprinklers.*
F	*Double row racks with 8 ft aisles and 165°F ceiling sprinklers.*
G	*Double row racks with 4 ft aisles and 286°F ceiling sprinklers.*
H	*Double row racks with 4 ft aisles and 165°F ceiling sprinklers.*

NOTE: Curves C and D also apply to ceiling sprinklers only for multiple row racks up to and including 15 ft (4.2 m) high and Figure 6-8.2 shall not be applied.

For SI Units: 1 ft = 0.3048 m; C = ⅝ (F-32); 1 gpm/ft² = 40.746 (L/min)/m²

Figure 6-11.1d Sprinkler System Design Curves — 20 Foot High Rack Storage — Class IV Nonencapsulated Commodities — Conventional Pallets

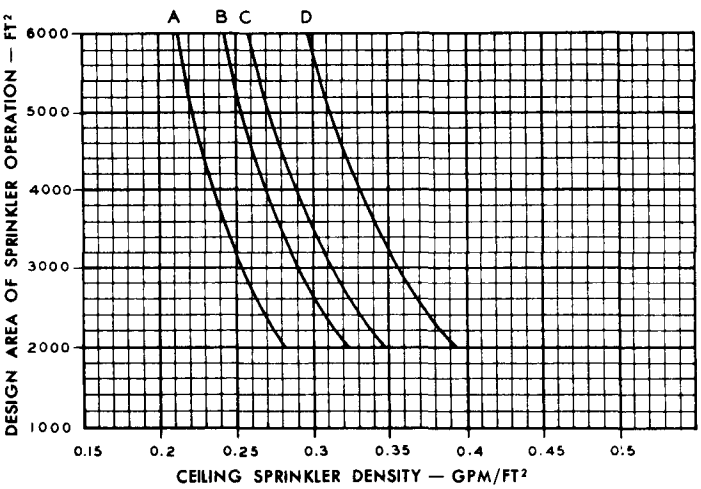


Curve	Legend
A	*8 ft aisles with 286°F ceiling sprinklers and 165°F in-rack sprinklers.*
B	*8 ft aisles with 165°F ceiling sprinklers and 165°F in-rack sprinklers.*
C	*4 ft aisles with 286°F ceiling sprinklers and 165°F in-rack sprinklers.*
D	*4 ft aisles with 165°F ceiling sprinklers and 165°F in-rack sprinklers.*

Curve	Legend
E	*8 ft aisles with 286°F ceiling sprinklers.*
F	*8 ft aisles with 165°F ceiling sprinklers.*
G	*4 ft aisles with 286°F ceiling sprinklers*
H	*4 ft aisles with 165°F ceiling sprinklers.*

For SI Units: 1 ft = 0.3048 m; C = ⅝ (F-32); 1 gpm/ft² = 40.746 (L/min)/m²

Figure 6-11.1e Double Row Racks — 20 Foot High Rack Storage — Sprinkler System Design Curves — Class I & II Encapsulated Commodities — Conventional Pallets.

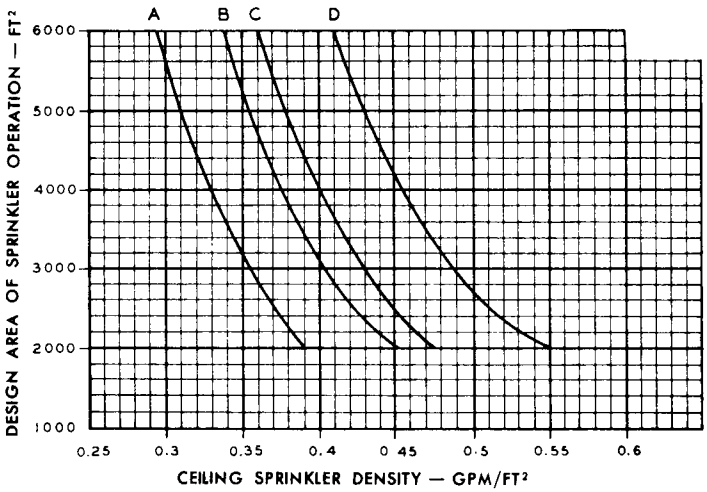


Curve	Legend
A	*8 ft aisles with 286°F ceiling sprinklers and 165°F in-rack sprinklers.*
B	*8 ft aisles with 165°F ceiling sprinklers and 165°F in-rack sprinklers.*

Curve	Legend
C	*4 ft aisles with 286°F ceiling sprinklers and 165°F in-rack sprinklers.*
D	*4 ft aisles with 165°F ceiling sprinklers and 165°F in-rack sprinklers.*

For SI Units: 1 ft = 0.3048 m; C = ⅝ (F-32); 1 gpm/ft² = 40.746 (L/min)/m²

Figure 6-11.1f Double Row Racks — 20 Foot High Rack Storage — Sprinkler System Design Curves — Class III Encapsulated Commodities — Conventional Pallets.



Curve	Legend
A	*8 ft aisles with 286°F ceiling sprinklers and 165°F in-rack sprinklers.*
B	*8 ft aisles with 165°F ceiling sprinklers and 165°F in-rack sprinklers.*
C	*4 ft aisles with 286°F ceiling sprinklers and 165°F in-rack sprinklers.*
D	*4 ft aisles with 165°F ceiling sprinklers and 165°F in-rack sprinklers.*

For SI Units: 1 ft = 0.3048 m; C = ⅝ (F-32); 1 gpm/ft² = 40.746 (L/min)/m²

Figure 6-11.1g Double Row Racks — 20 Foot High Rack Storage — Sprinkler System Design Curves — Class IV Encapsulated Commodities — Conventional Pallets.

Table 6-13.1 Multiple-Row Racks. Rack Depth up to 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. 6-8.2	1.25x Density	Fig. No.	Curves	Apply Fig. 6-8.2	1.25x Density
Over 12 Ft Up Thru 15 Ft	I	No	No	6-11.1a	C&D	Yes	No	6-11.1a	I&J	Yes	No
		Yes		6-11.1a			Yes	6-11.1a	I&J		Yes
	II	No		6-11.1b			No	6-11.1b	I&J	Yes	No
		Yes		6-11.1b			Yes	6-11.1b	I&J		Yes
	III	No	No	6-11.1c			No	6-11.1c	I&J	Yes	No
		Yes	1 Level	6-11.1c			Yes				
	IV	No	No	6-11.1d			No	6-11.1d	C&D	No	No
		Yes	1 Level	6-11.1d	A&B		1.50x Density				
Over 15 Ft Up Thru 20 Ft	I	No	No	6-11.1a	C&D	Yes	No	6-11.1a	I&J	Yes	No
		Yes		6-11.1a			Yes	6-11.1a	I&J		Yes
	II	No		6-11.1b			No	6-11.1b	I&J	Yes	No
		Yes		6-11.1b			Yes	6-11.1b	I&J		Yes
	III	No	No	6-11.1c			No	6-11.1c	I&J	Yes	No
		Yes	1 Level	6-11.1c			Yes				
	IV	No	1 Level	6-11.1d			No				
		Yes		6-11.1d	A&B		1.50x Density				
Over 20 Ft Up Thru 25 Ft	I	No	No	6-11.1a	C&D	No	No	6-11.1a	I&J	Yes	No
		Yes	1 Level	6-11.1a			Yes				
	II	No	1 Level	6-11.1b			No				
		Yes		6-11.1b			Yes				
	III	No		6-11.1c			No				
		Yes		6-11.1c			Yes				
	IV	No	2 Level	6-11.1d			No				
		Yes		6-11.1d	A&B		1.50x Density				

For SI Units: 1 ft = 0.3048 m

Table 6-13.2 Multiple-Row Racks. Rack Depth over 16 Ft or Aisles Narrower 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. 6-8.2	1.25x Density	Fig. No.	Curves	Apply Fig. 6-8.2	1.25x Density
Over 12 Ft Up Thru 15 Ft	I	No	No	6-11.1a	C&D	Yes	No	6-11.1a	I&J	Yes	No
		Yes		6-11.1a			Yes	6-11.1a	I&J		Yes
	II	No		6-11.1b			No	6-11.1b	I&J	Yes	No
		Yes		6-11.1b			Yes	6-11.1b	I&J		Yes
	III	No		6-11.1c			No	6-11.1c	I&J	Yes	No
		Yes	1 Level	6-11.1c			Yes				
	IV	No	No	6-11.1d			No	6-11.1d	C&D	No	No
		Yes	1 Level	6-11.1d			1.50x Density				
Over 15 Ft Up Thru 20 Ft	I	No	1 Level	6-11.1a	C&D	Yes	No				
		Yes		6-11.1a			Yes				
	II	No		6-11 1b			No				
		Yes		6-11.1b			Yes				
	III	No		6-11.1c			No				
		Yes		6-11.1c			Yes				
	IV	No		6-11.1d			No				
		Yes		6-11.1d			1.50x Density				
Over 20 Ft Up Thru 25 Ft	I	No	1 Level	6-11.1a	C&D	No	No				
		Yes		6-11.1a			Yes				
	II	No		6-11.1b			No				
		Yes		6-11.1b			Yes				
	III	No		6-11.1c			No				
		Yes		6-11.1c			Yes				
	IV	No	2 Levels	6-11.1d			No				
		Yes		6-11.1d			1.50x Density				

For SI Units: 1 ft = 0.3048 m

6-14.3 For encapsulated Class IV commodities with height of storage up to and including 25 ft (7.62 m) on multiple row racks, ceiling sprinkler density shall be 50 percent greater than for nonencapsulated commodities on double row racks.

Chapter 7 Fire Protection — Storage over 25 Feet (7.62 m) in Height

Part A General

7-1 In-Rack Sprinkler Size. Sprinklers in racks shall be ordinary temperature classification with nominal ½ in. (12.7 mm) orifice size, pendent or upright, except that 212°F (100°C) and 286°F (141°C) classifications shall be used near heat sources as specified in NFPA 13.

7-2 In-Rack Sprinkler Spacing. In-rack sprinklers shall be staggered horizontally and vertically when installed as indicated in 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 is 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 when there is more than one level, if not shielded by horizontal barriers (*see Appendix B-6-3*).

7-5 In-Rack Sprinkler Location. In double row or multiple row racks, a minimum 6 in. (152.4 mm) 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.

7-6 In-Rack Sprinkler Discharge Pressure. Sprinklers in racks shall discharge at not less than 30 psi (206.8 kPa) for all classes of commodity (*see Appendix B-6-7*).

7-7 In-Rack Sprinkler Water Demand.

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

(a) Six sprinklers when only one level is installed in racks with Class I, II, or III commodity.

(b) Eight sprinklers when only one level is installed in racks with Class IV commodity.

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

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

7-8 High Expansion Foam Submergence. When high expansion foam systems are used for storage over 25 ft (7.62 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. When high expansion foam is used in combination with ceiling sprinklers, the sprinkler design shall be 0.2 gpm per sq ft [(8.15 L/min)/m²] for Class I, II, or III commodities and 0.25 gpm per sq ft [(10.19 L/min)/m²] for Class IV commodities, over the most hydraulically remote 2,000 sq ft (185.8 m²) 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 (3.05 m) between top of storage and ceiling, in-rack sprinklers shall be installed as indicated in Table 7-10.1 and Figures 7-10.1(a) through (j). The highest level of in-rack sprinklers shall not be more than 10 ft (3.05 m) below top of storage (*see 7-11*).

7-10.2 In-rack sprinklers for storage higher than 25 ft (7.62 m) in double row racks shall be spaced horizontally and located in horizontal space nearest the vertical intervals indicated in Table 7-10.1, Figures 7-10.1(a) through (j).

7-10.3* In single row racks without solid shelves with height of storage over 25 ft (7.62 m) and a maximum of 10 ft (3.05 m) between top of storage and ceiling, sprinklers shall be installed as indicated in 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 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 and 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*† 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 (3.05 m) between top of storage and sprinklers shall be based on sprinklers in a 2,000 sq ft (185.8 m²) operating area,

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 Area	Ceiling Sprinkler Density (gpm/sq. ft.) (6) Clearance (5) Up to 10 ft. (7)	
	Longitudinal Flue (3)	Face (4) and (8)					165°	286°
I	Vertical 20 ft. Horizontal 10 ft. under horizontal Barriers	None	7-10.1a	30 ft.	No	2000 sq. ft.	0.25	0.35
	Vertical 20 ft. Horizontal 10 ft.	Vertical 20 ft. Horizontal 10 ft.	7-10.1b	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	7-10.1c	30 ft.	Yes	2000 sq. ft.	0.30	0.40
	Vertical 10 ft. Horizontal 10 ft.	Vertical 30 ft. Horizontal 10 ft.	7-10.1d	Higher than 25 ft.	Yes		0.30	0.40
	Vertical 20 ft. Horizontal 10 ft.	Vertical 20 ft. Horizontal 5 ft.	7-10.1e		Yes		0.30	0.40
	Vertical 25 ft. Horizontal 5 ft.	Vertical 25 ft. Horizontal 5 ft.	7-10.1f		No		0.30	0.40
	Horizontal barriers at 20 ft. Vertical Intervals-2 lines of sprinklers under barriers-maximum horizontal spacing 10 ft. staggered.		7-10.1g		Yes		0.30	0.40
I, II, III, & IV	Vertical 15 ft. Horizontal 10 ft.	Vertical 20 ft. Horizontal 10 ft.	7-10.1h	Higher than 25 ft.	Yes	2000 sq. ft.	0.35	0.45
	Vertical 20 ft. Horizontal 5 ft.	Vertical 20 ft. Horizontal 5 ft.	7-10.1i		No		0.35	0.45
	Horizontal barriers at 15 ft. Vertical intervals-2 lines of sprinkler under barriers-maximum horizontal spacing 10 ft. staggered		7-10.1j		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 (Section 7-6)

[2]Water shields required (Section 6-3 and Section 7-4)

[3]Install sprinklers at least 2 ft (0.61 m) from uprights (A-6-4.1)

[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 suggestions when clearance is greater than 10 ft (3.05 m)

[8]Face sprinklers are not mandatory 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).

discharging a minimum of 0.25 gpm per sq ft [(10.18 L/min)/m²] for Class I commodities, 0.3 gpm per sq ft [(12.2 L/min)/m²] for Class II and III commodities, and 0.35 gpm per sq ft [(14.26 L/min)/m²] for Class IV commodities, for 165°F (74°C) sprinklers; or a minimum of 0.35 gpm per sq ft [(14.26 L/min)/m²]for Class I commodities, 0.40 gpm per sq ft [(16.3 L/min)/m²] for Class II and III commodities, and 0.45 gpm per sq ft [(18.3 L/min)/m²] for Class IV commodities, for 286°F (141°C) 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.

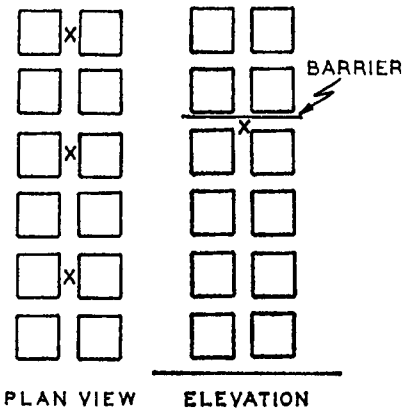


Figure 7-10.1(a) In-Rack Sprinkler Arrangement, Class I Commodity, Maximum Height of Storage 25 Ft (7.62 m) to 30 Ft (9.15 m).

NOTE:
1. Symbol X indicates in-rack sprinklers.

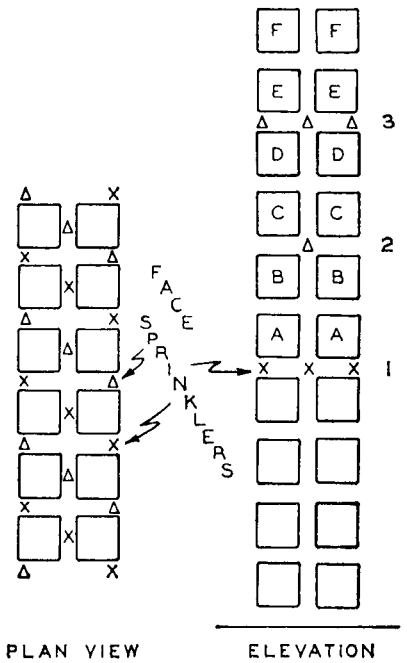


Figure 7-10.1(b) In-Rack Sprinkler Arrangement, Class I Commodity, Height of Storage over 25 Ft (7.62 m).

NOTES:
1. Sprinklers labeled 1 (the selected array from Table 7-10.1) required when loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 required when loads labeled C or D represent top of storage.
3. Sprinklers labeled 1 and 3 required when 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. Symbols Δ or X indicate sprinklers on vertical or horizontal stagger.

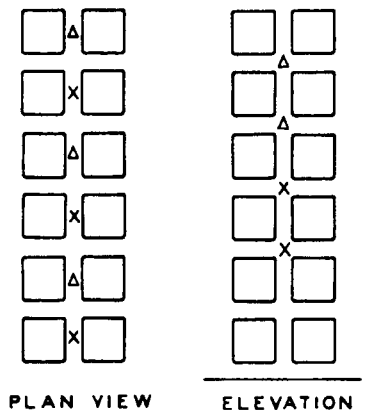


Figure 7-10.1(c) In-Rack Sprinkler Arrangement, Class I, II, or III Commodity, Maximum Height of Storage 25 Ft (7.62 m) to 30 Ft (9.15 m).

NOTES:
1. Alternate location of in-rack sprinklers. Sprinklers may be installed at the second and fourth or the third and fifth tiers.
2. Symbols Δ or X indicate sprinklers on vertical or horizontal stagger.

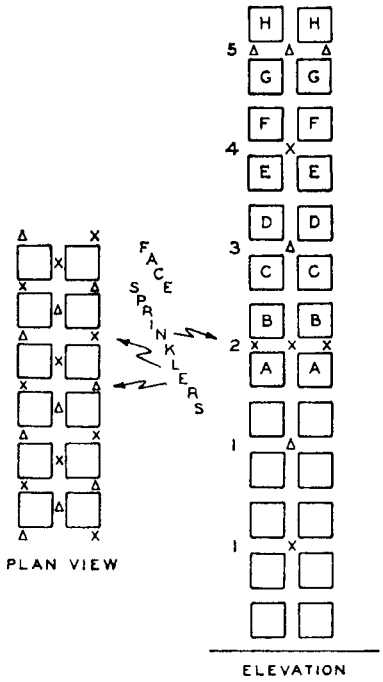


Figure 7-10.1(d) In-Rack Sprinkler Arrangement, Class I, II, or III Commodity, Height of Storage over 25 Ft (7.62 m).

NOTES:

1. Sprinklers labeled 1 required when loads labeled A represent the top of storage.
2. Sprinklers labeled 1 and 2 required when loads labeled B or C represent top of storage.
3. Sprinklers labeled 1, 2 and 3 required when loads labeled D or E represent top of storage.
4. Sprinklers labeled 1, 2, 3 and 4 required when loads labeled F or G represent top of storage.
5. Sprinklers labeled 1, 2, 3, 4 and 5 required when 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 may be omitted when commodity consists of unwrapped or unpackaged metal parts on wood pallets.
8. Symbols Δ or X indicate sprinklers on vertical or horizontal stagger.

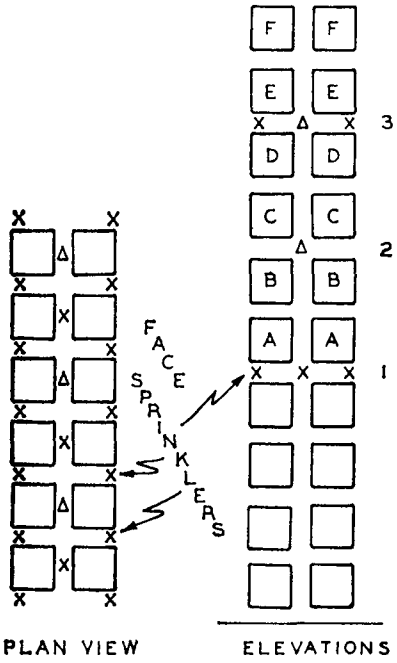


Figure 7-10.1(e) In-Rack Sprinkler Arrangement, Class I, II, or III Commodity, Height of Storage over 25 Ft (7.62 m).

NOTES:

1. Sprinklers labeled 1 (the selected array from Table 7-10.1) required when loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 required when loads labeled C or D represent top of storage.
3. Sprinklers labeled 1 and 3 required when 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. Symbols Δ or X indicate sprinklers on vertical or horizontal stagger.

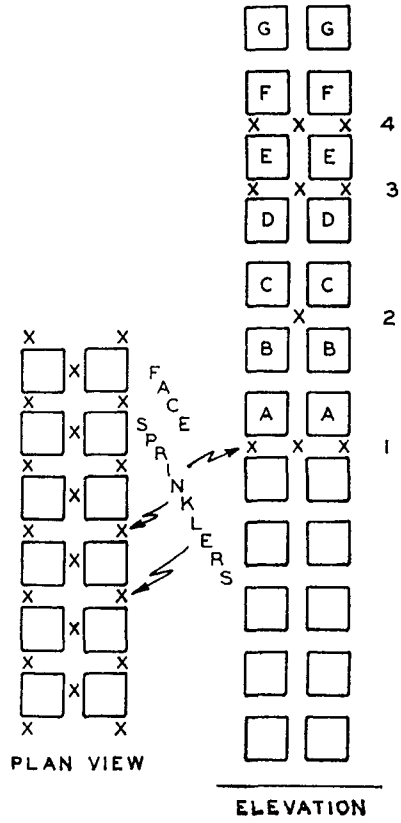


Figure 7-10.1(f) In-Rack Sprinkler Arrangement, Class I, II, or III Commodity, Height of Storage over 25 Ft (7.62 m).

NOTES:

1. Sprinklers labeled 1 (the selected array from Table 7-10.1) required when loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 required when loads labeled C or D represent top of storage.
3. Sprinklers labeled 1 and 3 required when loads labeled E represent top of storage.
4. Sprinklers labeled 1 and 4 required when loads labeled F or G represent top of storage.
5. For storage higher than represented by loads labeled G, the cycle defined by notes 2, 3, and 4 is repeated.
6. Symbol X indicates face and in-rack sprinklers.

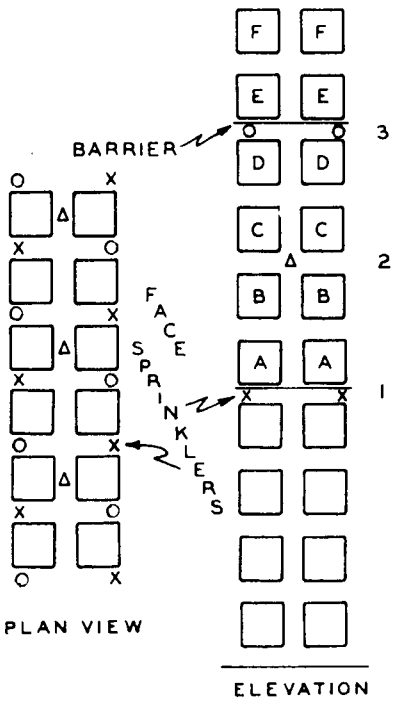


Figure 7-10.1(g) In-Rack Sprinkler Arrangement, Class I, II, or III Commodity, Height of Storage over 25 Ft (7.62 m).

NOTES:

1. Sprinklers labeled 1 (the selected array from Table 7-10.1) required when loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 required when loads labeled C or D represent top of storage.
3. Sprinklers labeled 1 and 3 required when 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 or X indicate sprinklers on vertical or horizontal stagger.

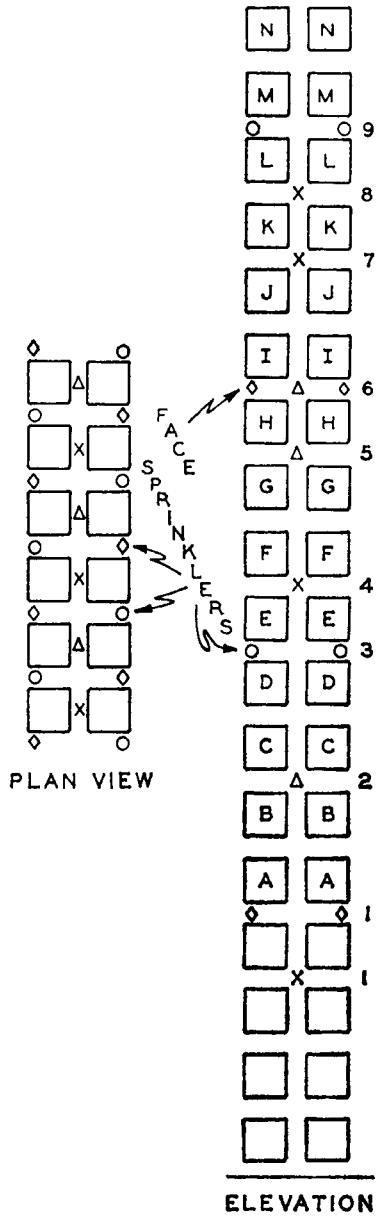


Figure 7-10.1(h) In-Rack Sprinkler Arrangement, Class I, II, III, or IV Commodity, Height of Storage over 25 Ft (7.62 m).

NOTES:

1. Sprinklers labeled 1 (the selected array from Table 7-10.1) required when loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 required when loads labeled C or D represent top of storage.
3. Sprinklers labeled 1, 2 and 3 required when loads labeled E or F represent top of storage.
4. Sprinklers labeled 1, 2, 3 and 4 required when loads labeled G represent top of storage.
5. Sprinklers labeled 1, 2, 3, 4 and 5 required when loads labeled H represent top of storage.
6. Sprinklers labeled 1, 2, 3, 4 and 6 (not 5) required when loads labeled I or J represent top of storage.
7. Sprinklers labeled 1, 2, 3, 4, 6 and 7 required when loads labeled K represent top of storage.
8. Sprinklers labeled 1, 2, 3, 4, 6 and 8 required when loads labeled L represent top of storage.
9. Sprinklers labeled 1, 2, 3, 4, 6, 8 and 9 required when 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, Δ, indicate sprinklers on vertical or horizontal stagger.

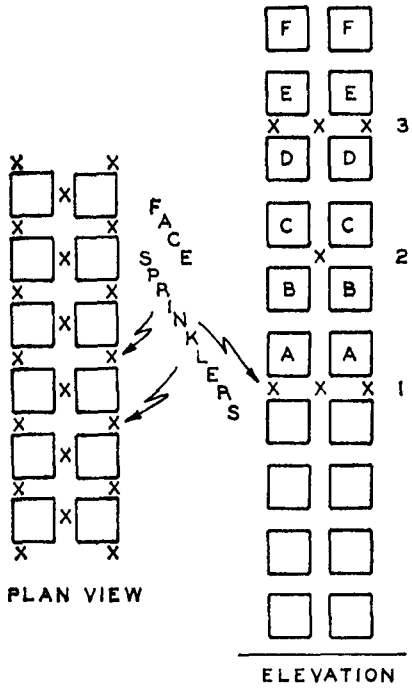


Figure 7-10.1(i) In-Rack Sprinkler Arrangement, Class I, II, III, or IV Commodity, Height of Storage over 25 Ft (7.62 m).

NOTES:

1. Sprinklers labeled 1 (the selected array from Table 7-10.1) required when loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 required when loads labeled C or D represent top of storage.
3. Sprinklers labeled 1 and 3 required when loads labeled E or F represent top of storage.
4. For storage higher than represented by loads labeled F, the cycle defined by notes 2 and 3 is repeated.
5. Symbol X indicates face and in-rack sprinklers.

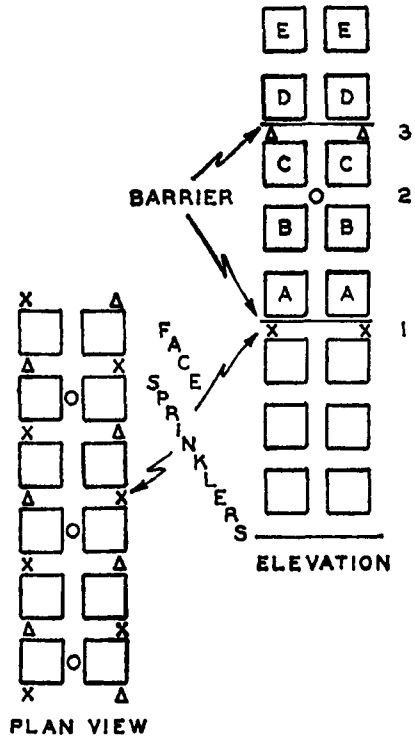


Figure 7-10.1(j) In-Rack Sprinkler Arrangement, Class I, II, III, or IV Commodity. Height of Storage over 25 Ft (7.62 m).

NOTES:

1. Sprinklers and barrier labeled 1 (the selected array from Table 7-10.1) required when loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 and barrier labeled 1 required when loads labeled C represent top of storage.
3. Sprinklers and barriers labeled 1 and 3 required when 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. Symbols Δ or X indicate sprinklers on vertical or horizontal stagger.
6. Symbol O indicates longitudinal flue space sprinklers.

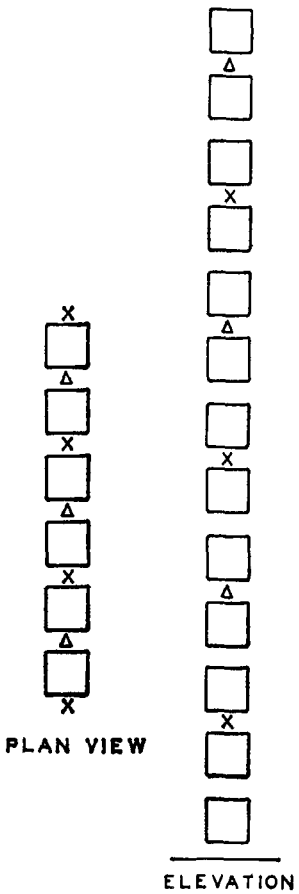


Figure 7-10.3(a) In-Rack Sprinkler Arrangement, Single Row Racks, Height of Storage over 25 Ft (7.62 m).

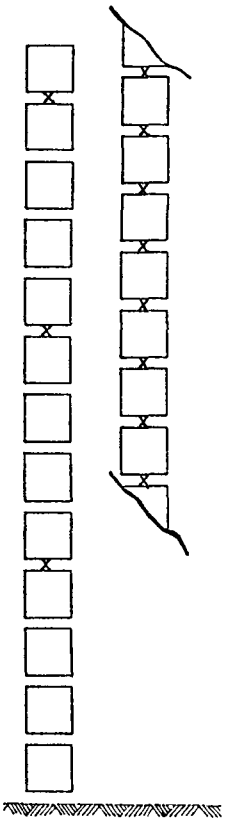


Figure 7-10.3(b) Class I, II, or III Commmodity.

NOTES:

1. For all storage heights, install sprinklers in every other tier and stagger as indicated.
2. Symbols Δ or X indicate sprinklers on vertical or horizontal stagger.

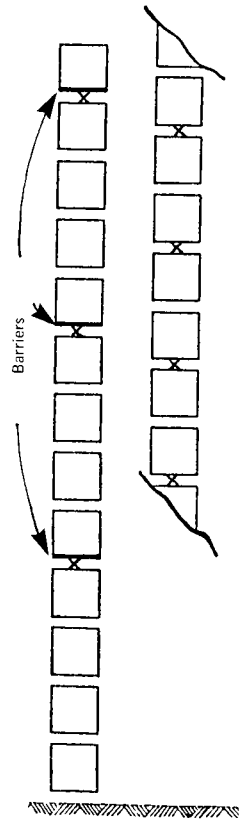


Figure 7-10.3(c) Class I, II, or III Commodity.

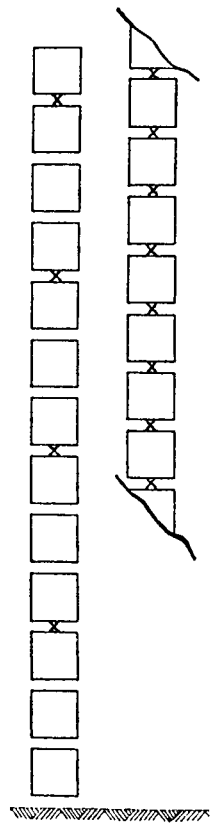


Figure 7-10.3(d) Class I, II, III, or IV Commodity.

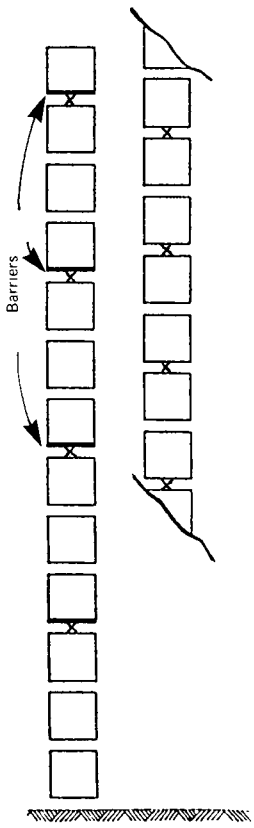


Figure 7-10.3(e) Class I, II, III, or IV Commodity.

Part C Multiple Row Racks

7-13* In-Rack Sprinkler Location. In multiple row racks with a maximum of 10 ft (3.05 m) between top of storage and 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 (3.05 m) below maximum height of storage for Class I, II, or III commodities or 5 ft (1.52 m) below 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 (7.62 m) shall conform to Figures 7-13(a), (b), and (c).

7-15 Ceiling Sprinkler Water Demand.

7-15.1 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 (3.05 m) between top of storage and sprinklers shall be based on sprinklers in a 2,000 sq ft (185.8 m^2) operating area for multiple row racks, discharging a minimum of 0.25 gpm per sq ft [(10.19 L/min)/m^2] for Class I commodities, 0.3 gpm per sq ft [(12.2 L/min)/m^2] for Class II and III commodities, and 0.35 gpm per sq ft [(14.26 L/min)/m^2] for Class IV commodities, for 165°F (74°C) sprinklers; or a minimum of 0.35 gpm per sq ft [(14.26 L/min)/m^2] for Class I commodities, 0.40 gpm per sq ft [(16.8 L/min)/m^2] for Class II and III commodities, and 0.45 gpm per sq ft [(18.3 L/min)/m^2] for Class IV commodities, for 286°F (141°C) sprinklers (*see Table 7-13*).

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

Table 7-13 Multiple-Row Racks. Storage Height 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 Sprinkler 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	7-13.1a	10	2000	.25	.35
	Yes									.31	.44
I, II & III	No	15	10	10			7-13.1b	10		.30	.40
	Yes									.37	.50
I, II, III & IV	No	10	10	10			7-13.1c	5		.35	.45
	Yes									.44	.56

[1]All four rack faces should be protected by sprinklers located within 18 in. of the faces, as indicated in Figs. 7-13.1a, b and c. It is not necessary 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

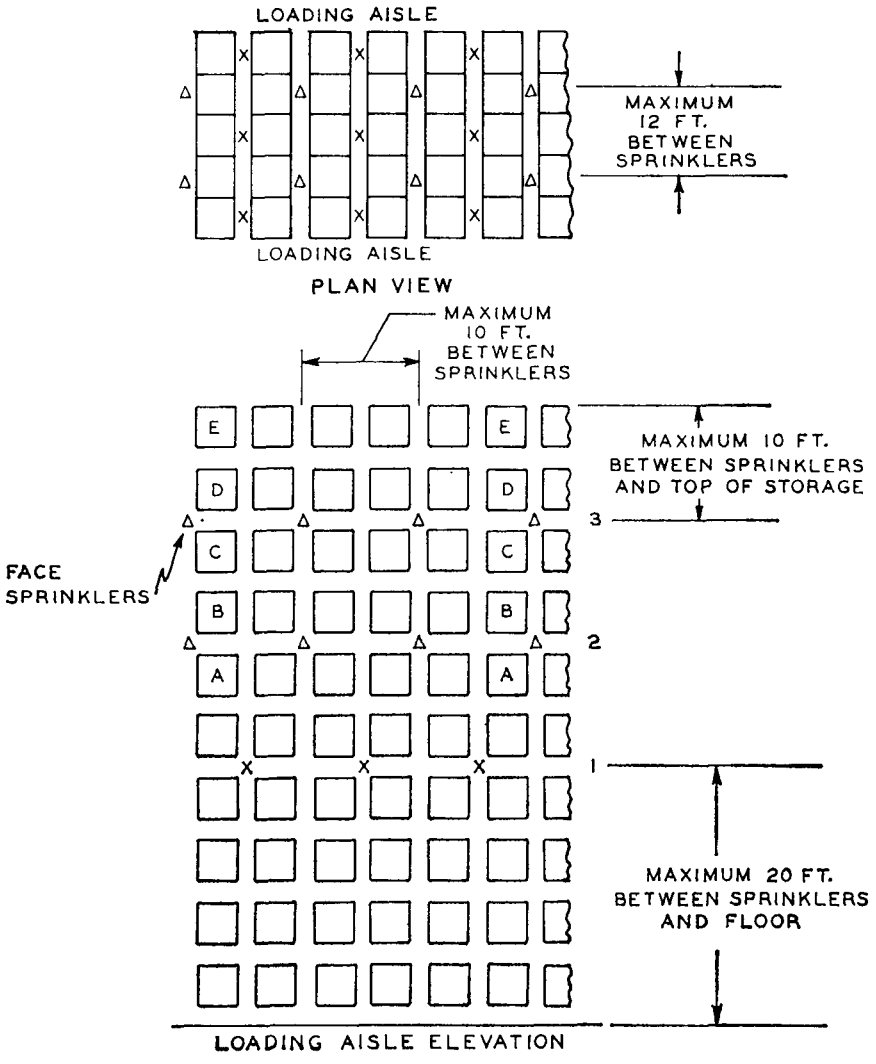


Figure 7-13(a) In-Rack Sprinkler Arrangement — Multiple-Row Racks, Class I Commodity. Height of Storage over 25 Ft.

For SI Units: 1 ft = 0.3048 m

NOTES:

1. Sprinklers labeled 1 required if loads labeled A represent top of storage.
2. Sprinklers labeled 1 and 2 required if loads labeled B or C represent top of storage.
3. Sprinklers labeled 1 and 3 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. Symbols Δ or X indicate sprinklers on vertical or horizontal stagger.

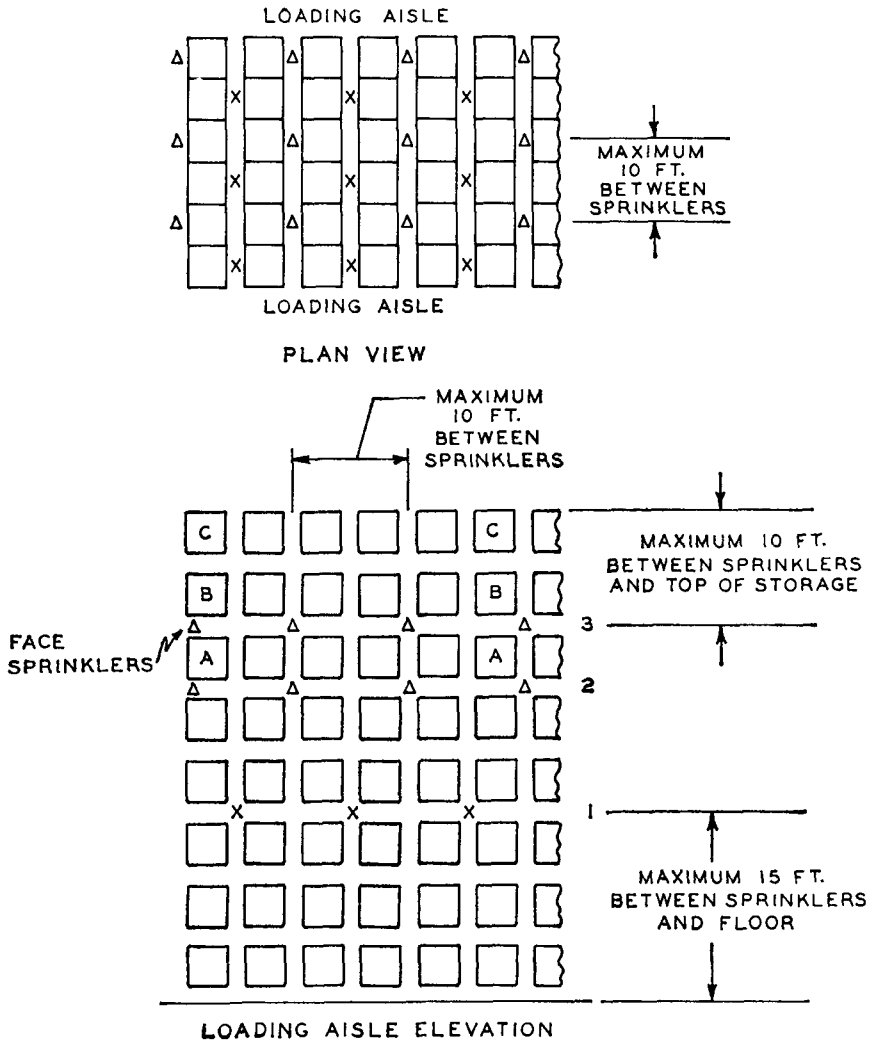


Figure 7-13(b) In-Rack Sprinkler Arrangement — Multiple-Row Racks, Class I, II, or III Commodity. Height of Storage over 25 Ft.

For SI Units: 1 ft = 0.3048 m

NOTES:

1. Sprinklers labeled 1 and 2 required if loads labeled A represent top of storage.
2. Sprinklers labeled 1 and 3 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 1 and 2 is repeated, with stagger as indicated.
4. Symbols Δ or X indicate sprinklers on vertical or horizontal stagger.

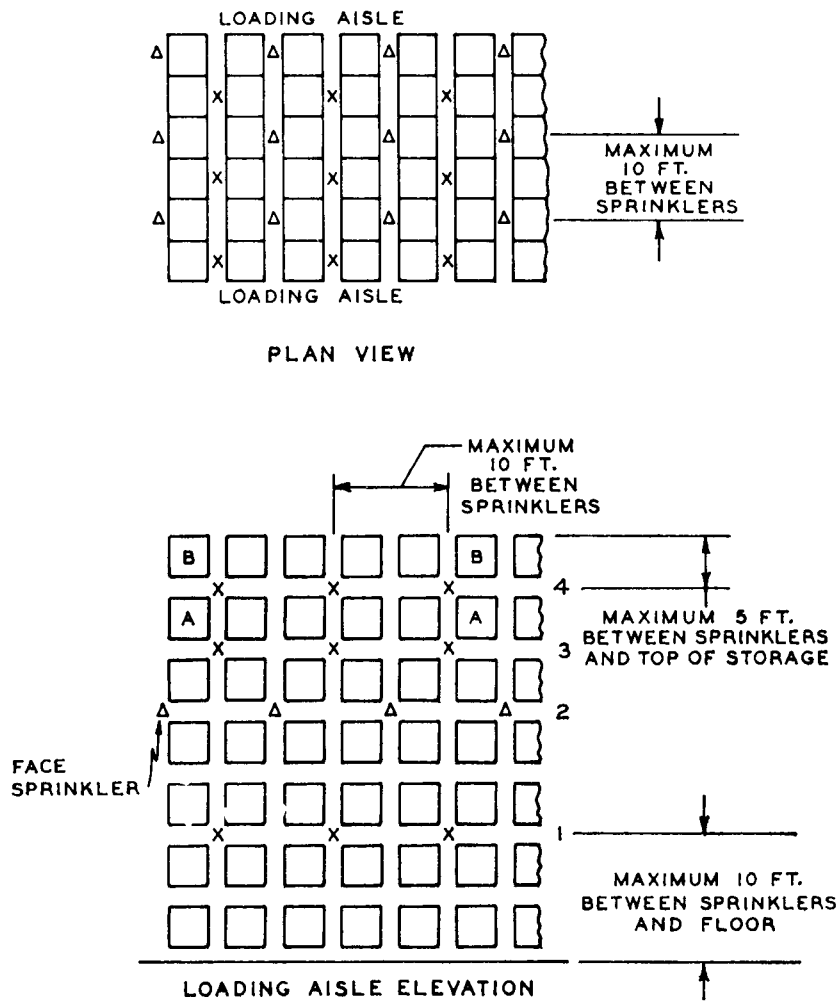


Figure 7-13(c) In-Rack Sprinkler Arrangement, Class I, II, III & IV Commodity, Multiple-Row Racks. Height of Storage over 25 Ft.

For SI Units: 1 ft = 0.3048 m

NOTES:

1. Sprinklers labeled 1, 2 and 3 required if loads labeled A represent top of storage.
2. Sprinklers labeled 1, 2 and 4 required if loads labeled B represent top of storage.
3. For storage higher than represented by loads labeled B, the cycle defined by notes 1 and 2 is repeated, with stagger as indicated.
4. Symbols Δ or X indicate sprinklers on vertical or horizontal stagger.

Chapter 8 Plastics

8-1† General.

8-1.1 Plastics in corrugated cartons shall be protected as indicated by Figure 8-1.1. This decision tree shall also be used to determine protection for commodities that are not wholly Group A plastics, but contain such quantities and arrangement of the same 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 ordinary temperature rated.

Exception No. 1: Large-drop sprinklers as indicated in Chapter 9.

Exception No. 2: Higher temperature sprinklers shall be used where required by NFPA 13, Standard for Installation of Sprinkler Systems.

8-2 In-Rack Sprinklers.

8-2.1 In-Rack Sprinkler Classification. Sprinklers in racks shall be ordinary temperature classification except higher temperature sprinklers shall be used as specified in NFPA 13, Standard for Installation of Sprinkler Systems.

8-2.2 In-Rack Sprinkler Pipe Size. The number of sprinklers and the pipe sizing on a line of sprinklers in racks are restricted only by the hydraulic calculations and not by any piping schedule.

8-2.3 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 when there is more than one level, if not shielded by horizontal barriers.

8-2.4 In-Rack Sprinkler Location.

8-2.4.1 The minimum of 6 in. (152.4 mm) clear space shall be maintained between the sprinkler deflectors and the top of a tier of storage.

8-2.4.2 In-rack sprinklers at one level only, for storage up to and including 25 ft (7.62 m) high in double row racks, shall be located at the first tier level at or above one-half of the storage height.

8-2.4.3 In-rack sprinklers at two levels only, for storage up to and including 25 ft (7.62 m) high, shall be located at the first tier level at or above one-third and two-thirds of the storage height.

8-2.5 In-Rack Sprinkler Water Demand. Water demand for sprinklers installed in racks shall be based on simultaneous operation of the most hydraulically remote:

(a) Eight sprinklers when only one level is installed in racks.

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

8-3 Single and Double Row Racks — Storage up to and Including 25 Ft.

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/ft²) and area of operation (ft²) shall be selected from Table 8-3.1.

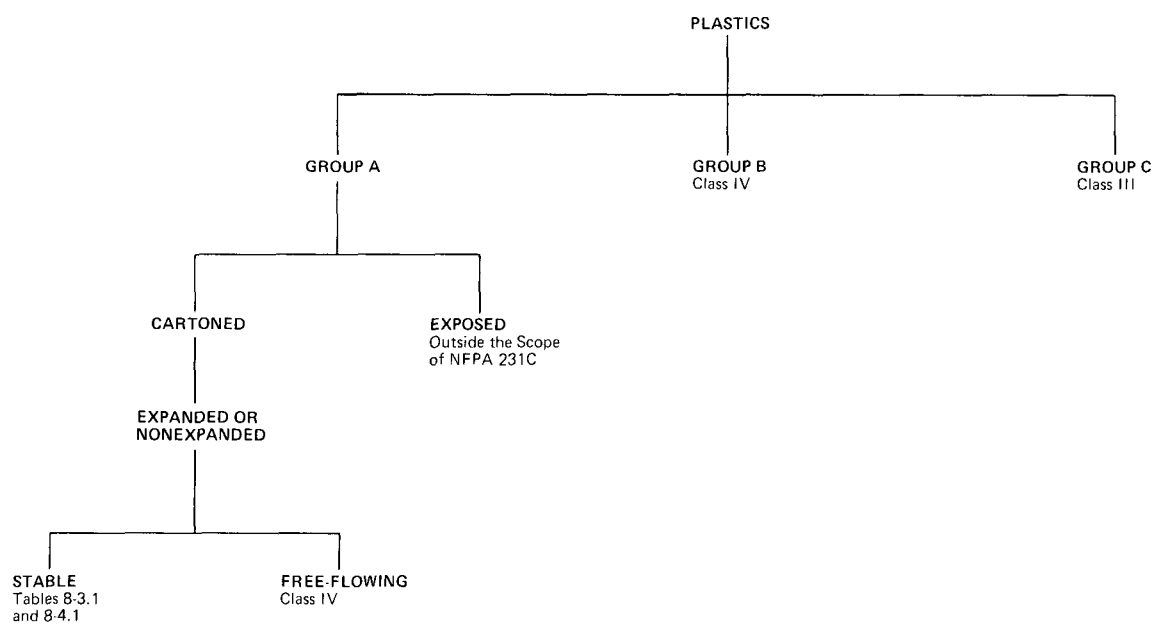


Figure 8-1.1 Decision Tree.

Linear interpolation for storage height is permitted at the same clearance.

Table 8-3.1
Single and Double Row Racks with 8 Ft Aisles, Height of Storage up through 25 Ft — 165°F Sprinklers.

Storage Height (ft)/ Clearance (ft)	Ceiling Density (gpm/ft²)/ Area of Application (ft²)	In-Rack Sprinklers Needed (Note 2)
15 3	0.45 2000 (Note 1)	None
	0.30 2000 (Note 3)	1 Level
15 10	0.60 3000	None
	0.30 2000 (Note 3)	1 Level
20 3	0.60 3000	None
	0.45 2000	1 Level
20 10 or 25 3	0.45 2000	One Level
	0.30 2000 (Note 3)	2 Levels
25 10	0.30 2000 (Note 3)	2 Levels

NOTES:

1. For 4 ft aisles a density of 0.60 gpm/ft² and an area of application of 1500 ft² shall be used. For aisle widths between 4 ft and 8 ft a direct linear interpolation may be made between densities and areas of application.

2. Based on maximum of 5 ft of storage above the top level of in-rack sprinklers. For storage greater than 5 ft up to a maximum of 10 ft, increase density to 0.45 gpm/ft².

3. Clearance is distance between top of storage and ceiling.

For SI Units:

1 in = 25.4 mm
1 ft = 0.3048 m
1 psi = 0.0689 bars = 6 895 kPa
1 gpm = 3 785 L/min
1 gpm/ft² = 40.74 L/min·m²

8-3.2 In-Rack Sprinkler Spacing. Maximum horizontal spacing of sprinklers in single and double row racks shall not exceed 8 ft (2.44 m).

8-3.3 In-Rack Sprinkler Size. Sprinklers in racks shall be ½ in. (12.7 mm) or 17/32 in. (13.5 mm) orifice size, pendent or upright.

8-3.4 In-Rack Sprinkler Discharge Pressure. Sprinklers in racks shall discharge at not less than 15 psi (1.03 bars).

8-4 Single and Double Row Racks — Storage over 25 Ft in Height.

8-4.1 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/ft²) and area of operation (ft²) shall be selected from Table 8-4.1.

8-4.2 In-Rack Sprinkler Location.

8-4.2.1 In double row racks without solid shelves and with a maximum of 10 ft (3.05 m) between the top of storage and ceiling, in-rack sprinklers shall be installed as indicated in Figures 8-4.2.1(a) and (b). The highest level of in-rack sprinklers shall not be more than 10 ft (3.05 m) below the top of storage.

Table 8-4.1
Single and Double Row Racks.
Height of Storage over 25 Ft.

Storage Height Above Top Level In-Rack Sprinklers	Ceiling Sprinklers Density (gpm/ft²)/Area of Application (ft²)
5 ft or less	0.30 2000
Over 5 ft up to 10 ft	0.45 2000

NOTE: Provide in-rack sprinkler protection as per Figures 8-4.2.1(a) and (b) and Figures 8-4.2.3(a) through (c).

For SI Units:

1 ft = 0.3048 m
1 gpm = 3 785 L/min
1 gpm/ft² = 40.74 L/min·m²

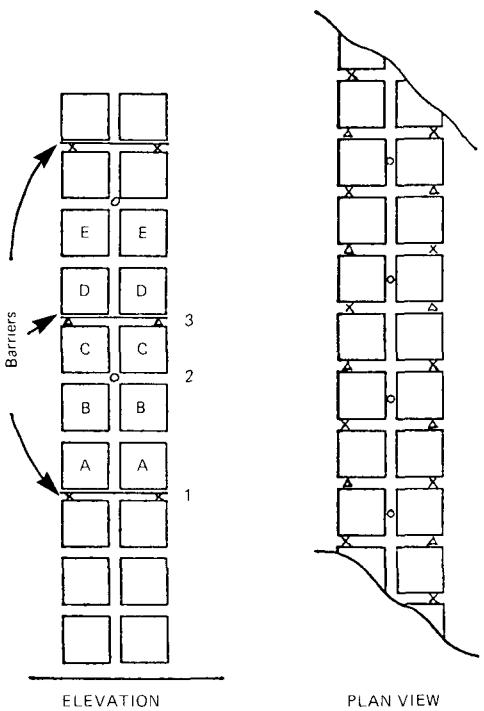


Figure 8-4.2.1(a) In-Rack Sprinkler Arrangement, Group A Plastic Commodity, Height of Storage over 25 Ft.

NOTES:

1. Sprinklers and barrier labeled 1 required when loads labeled A or B represent top of storage.

2. Sprinklers labeled 1 and 2 and barrier labeled 1 required when loads labeled C represent top of storage.

3. Sprinklers and barriers labeled 1 and 3 required when 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. Symbols Δ or × indicate face sprinklers on vertical or horizontal stagger.

6. Symbol 0 indicates longitudinal flue space sprinklers.

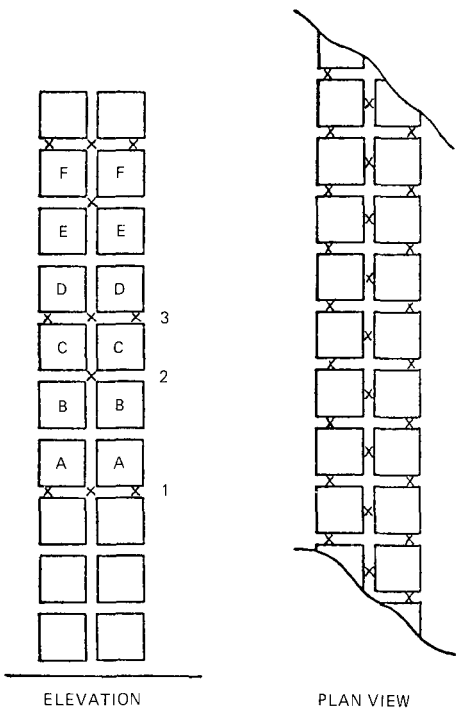


Figure 8-4.2.1(b) In-Rack Sprinkler Arrangement, Group A Plastic Commodity, Height of Storage over 25 Ft.

NOTES

1. Sprinklers labeled 1 required when loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 required when loads C represent top of storage.
3. Sprinklers labeled 1 and 3 required when loads D or E represent top of storage.
4. For storage higher than loads F, the cycle defined by Notes 2 and 3 is repeated.
5. Symbol X indicates face and in-rack sprinklers.

8-4.2.2 In-rack sprinklers for storage higher than 25 ft (7.62 m) in double row racks shall be spaced horizontally and located in the horizontal space nearest the vertical intervals indicated in Figures 8-4.2.1(a) and (b).

8-4.2.3 In single row racks without solid shelves with height of storage over 25 ft (7.62 m) and a maximum of 10 ft (3.05 m) between the top of storage and ceiling, sprinklers shall be installed as indicated in Figures 8-4.2.3(a) through (c).

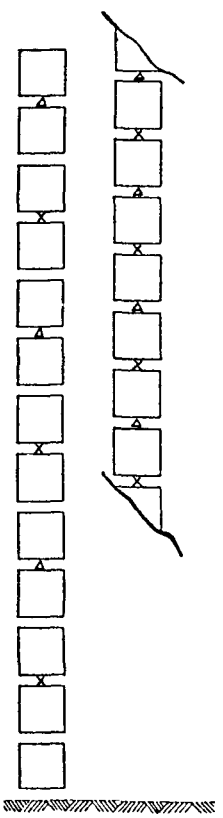


Figure 8-4.2.3(a) In-Rack Sprinkler Arrangement, Group A Plastic Commodity, Single Row Racks, Height of Storage over 25 Ft.

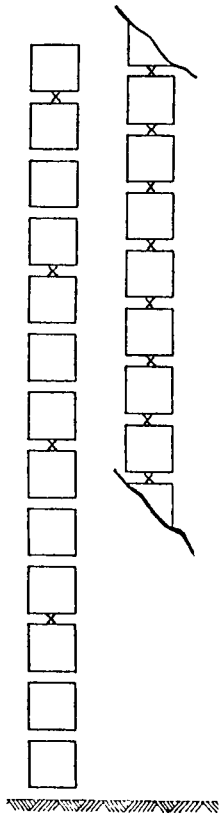


Figure 8-4.2.3(b) In-Rack Sprinkler Arrangement, Group A Plastic Commodity, Single Row Racks, Height of Storage over 25 Ft.

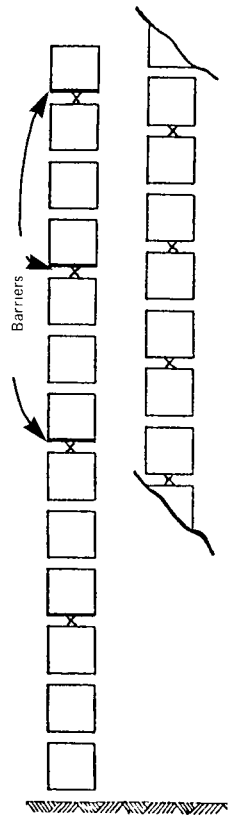


Figure 8-4.2.3(c) In-Rack Sprinkler Arrangement, Group A Plastic Commodity, Single Row Racks, Height of Storage over 25 Ft.

8-4.3 In-Rack Sprinkler Size. Sprinklers in racks shall be ½ in. (12.7 mm) or $^{17}/_{32}$ in. (13.5 mm) orifice size, pendent or upright.

8-4.4 In-Rack Sprinkler Discharge Pressure. Sprinklers in racks shall discharge at not less than 30 psi (2.07 bars).

Chapter 9 Large-Drop Sprinklers

9-1 General.

9-1.1 Large-drop sprinklers are suitable for use with the hazards listed in Table 9-1.

9-1.2 All requirements contained in NFPA 13, Installation of Sprinkler Systems, particularly Chapter 9, shall apply.

Table 9-1
Pressure and Number of Design Sprinklers For Various Hazards.

Minimum Operating Pressure (Note 1)	Number Design Sprinklers @ 25 psi	@ 50 psi	@ 75 psi	Sprinkler Temperature Rating
Hazard (Note 2)				
Double Row Rack Storage with Minimum 5.5 ft aisle width (Note 4) having:				
Class I and II Commodities up to 25 ft with maximum 5 ft clearance to ceiling	20	Note 3	Note 3	High
Class I, II, and III Commodities up to 20 ft with maximum 10 ft clearance to ceiling	15	Note 3	Note 3	High
Class IV Commodities up to 20 ft with maximum 10 ft clearance to ceiling	Does Not Apply	20	15	High
Non-expanded Group A plastics in corrugated cartons up to 20 ft with maximum 10 ft clearance to ceiling	Does Not Apply	30	20	High
Non-expanded Group A plastics in corrugated cartons up to 20 ft with maximum 10 ft clearance to ceiling	Does Not Apply	20	Note 3	Ordinary
Non-expanded Group A plastics in corrugated cartons up to 20 ft with maximum 5 ft clearance to ceiling	Does Not Apply	15	Note 3	High

NOTES:

1. Open Wood Joist Construction. Testing with open wood joist construction showed that each joist channel shall be fully firestopped to its full depth at intervals not exceeding 20 ft. In unfirestopped open wood joist construction, or if firestops are installed at intervals exceeding 20 ft, the minimum operating pressures shall be increased by 40 percent.

2. Building steel required no special protection for the occupancies listed. Protection requirements are based on rack storage with no solid shelves nor slave pallets.

3. The required number of design sprinklers shall not be reduced from that required for the lower pressure.

4. In addition to the transverse flue spaces required by NFPA 231C, minimum 6 inch longitudinal flue spaces shall be maintained.

For SI Units:
1 ft = 0.3048 m
1 in = 25.4 mm
1 psi = 0.0689 bars = 6.895 kPa

Chapter 10 Equipment

10-1 Mechanical Handling Equipment.

10-1.1 Industrial Trucks.

10-1.1.1 Power-operated industrial trucks shall be of the type designated in NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Area of Use, Maintenance and Operation*, and their maintenance and operation shall be in accordance with Chapters 2 and 3.

10-1.1.2† Industrial trucks using LP-Gas or liquid fuel shall be refueled outside of the storage building at a location designated for that purpose.

Chapter 11 Building Maintenance and Operation

11-1* Building Operations Other than Storage. Welding, soldering, brazing, and cutting may be performed on rack or building components which cannot be removed, provided no storage is located below and within 25 ft (7.62 m) of the working area, and flameproof tarpaulins enclose this section. During any of these operations the sprinkler system shall be in service. Two and one-half gal (9.45 L) water type extinguishers 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.

11-2* Waste Disposal. Approved type containers for rubbish and other trash materials shall be provided.

11-3 Smoking. Smoking shall be strictly prohibited, except in locations prominently designated as smoking areas, and "No Smoking" signs shall be posted in prohibited areas.

11-4* Maintenance. Fire walls, fire doors, and floors shall be maintained in good repair at all times.

11-5* Plant Emergency Organization. A fire watch shall be maintained when the sprinkler system is not in service.

11-6* General Fire Protection.

Chapter 12 Referenced Publications

12-1 The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is current as of the date of the NFPA issuance of this document. These references are listed separately to facilitate updating to the latest edition by the user.

12-1.1 NFPA Publications. National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

NFPA 11A-1983, *Standard for Medium and High Expansion Foam Systems*

NFPA 13-1985, *Standard for Installation of Sprinkler Systems*

NFPA 30-1984, *Flammable and Combustible Liquids Code*

NFPA 40-1982, *Standard for the Storage and Handling of Cellulose Nitrate Motion Picture Film*

NFPA 58-1986, *Standard for the Storage and Handling of Liquefied Petroleum Gases*

NFPA 81, *Standard for Fur Storage, Fumigation and Cleaning*

NFPA 91-1983, *Standard for the Installation of Blower and Exhaust Systems for Dust, Stock and Vapor Removal or Conveying*

NFPA 220-1985, *Standard on Types of Building Construction*

NFPA 231-1985, *Standard for General Storage*

NFPA 231D-1986, *Standard for Storage of Rubber Tires*

NFPA 231F-1984, *Standard for the Storage of Roll Paper*

NFPA 232-1986, *Standard for the Protection of Records*

NFPA 490-1986, *Code for the Storage of Ammonium Nitrate*

NFPA 505-1982, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Area of Use, Maintenance and Operation*

Appendix A

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

Chapter 4 Storage Arrangements

A-4-1 Rack storage as referred to in this standard contemplates commodity in a rack structure, usually steel. Many variations of dimensions are found. Racks may be single row, double row, or multiple row, with or without soild 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:

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), (b), (c), and (d)*].

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

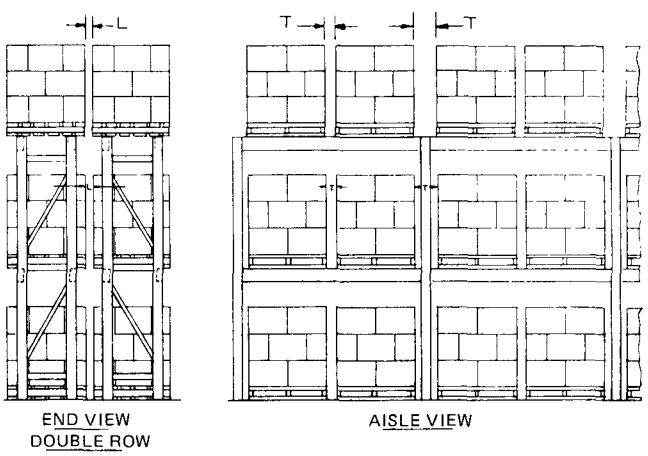
Multiple Row Racks are More than Two Pallets Deep, Measured Aisle to Aisle. This includes drive-in racks, drive-through racks, flow-through racks, portable racks arranged in the same manner, and conventional or automatic racks with aisles less than 42 in. (1.07 m) [*see Figures A-4-1(f) through (i)*].

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 rack with plywood shelves on the shelf beams [*see Figures A-4-1(c) and (d)*]. This is a special case (*see Chapter 5*).

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

Load depth in conventional or automatic racks is considered a nominal 48 in. (1.22 m) [*see Figure A-4-1(b)*].

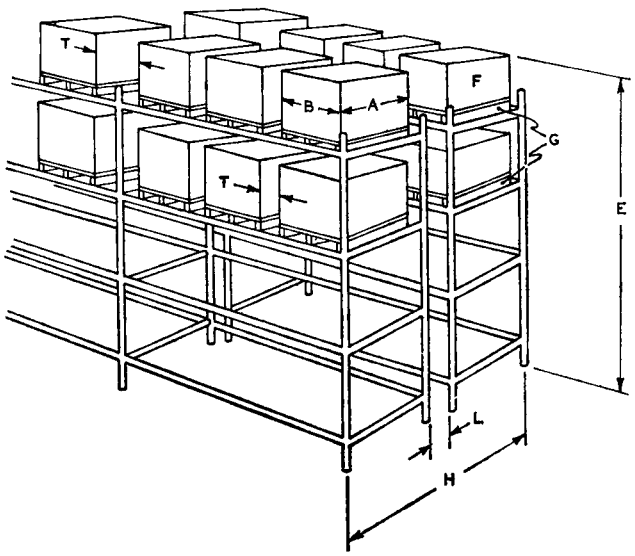


Legend

L — Longitudinal Flue Space

T — Transverse Flue Space

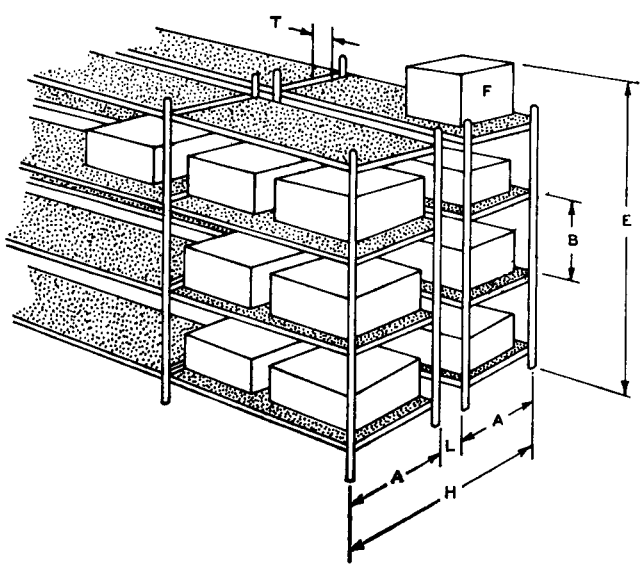
Figure A-4-1(a) Conventional Pallet Rack.



Legend

A — Load Depth
B — Load Width
T — Tranverse Flue Space
L — Longitudinal Flue Space
E — Storage Height
F — Commodity
G — Pallet
H — Rack Depth

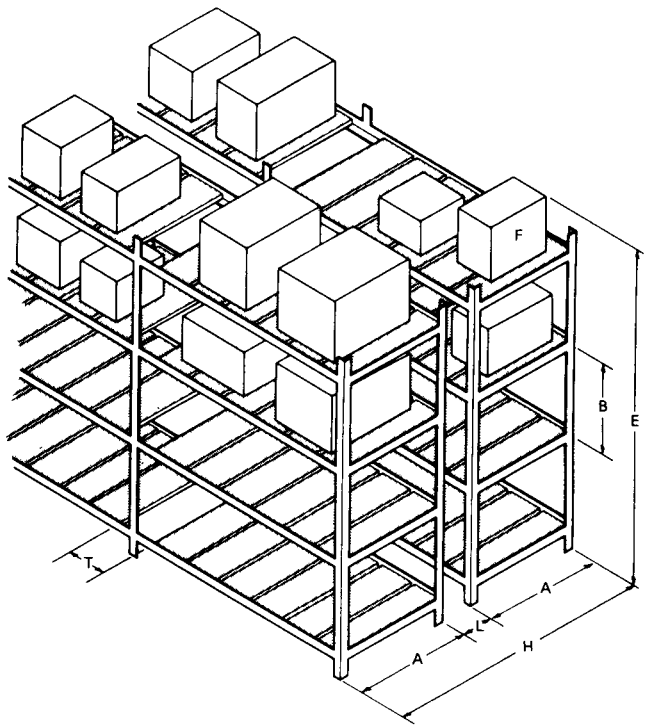
Figure A-4-1(b) Double Row Racks Without Solid or Slatted Shelves.



Legend

A — Shelf Depth
B — Shelf Height
T — Transverse Flue Space
L — Longitudinal Flue Space
E — Storage Height
F — Commodity
H — Rack Depth

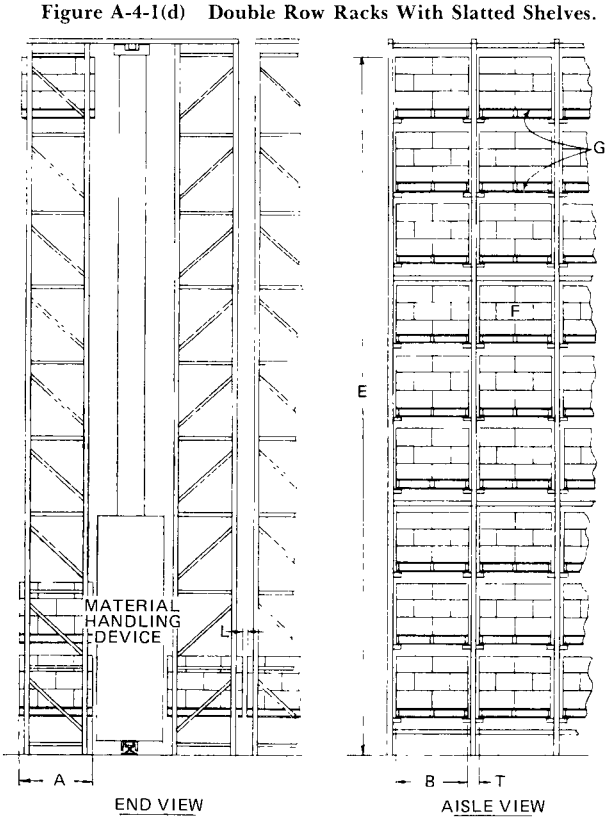
Figure A-4-1(c) Double Row Racks With Solid Shelves.



Legend

A — Shelf Depth
B — Shelf Height
H — Rack Depth
L — Longitudinal Flue Space
E — Storage Height
F — Commodity
T — Transverse Flue Space

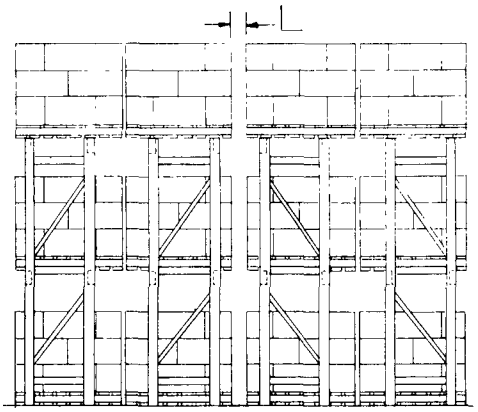
Figure A-4-1(d) Double Row Racks With Slatted Shelves.



Legend

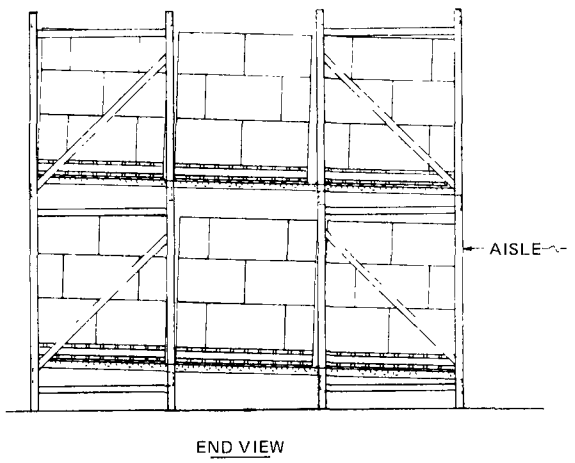
A — Load Depth
B — Load Width
T — Transverse Flue Space
L — Longitudinal Flue Space
E — Storage Height
F — Commodity
G — Pallet

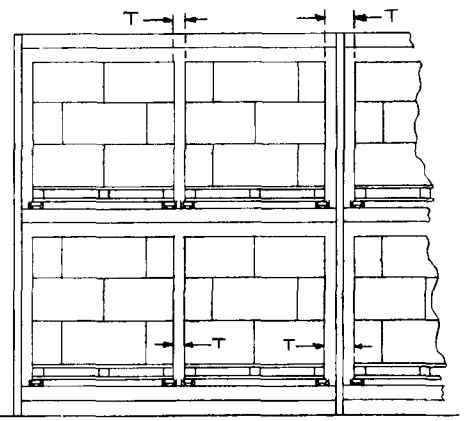
Figure A-4-1(e) Automatic Storage Type Rack.



L — Longitudinal Flue Space

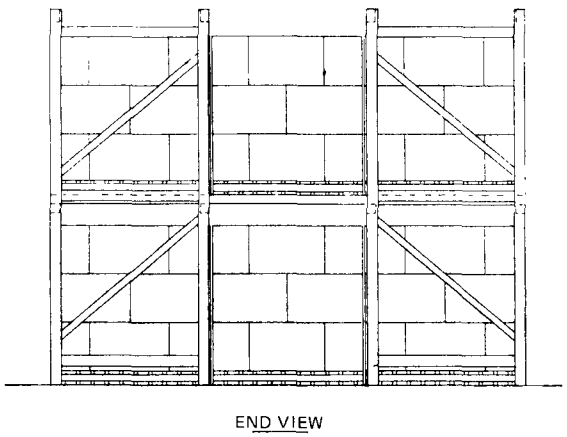
Figure A-4-1(f) Multi-Row Rack to be Served by a Reach Truck.

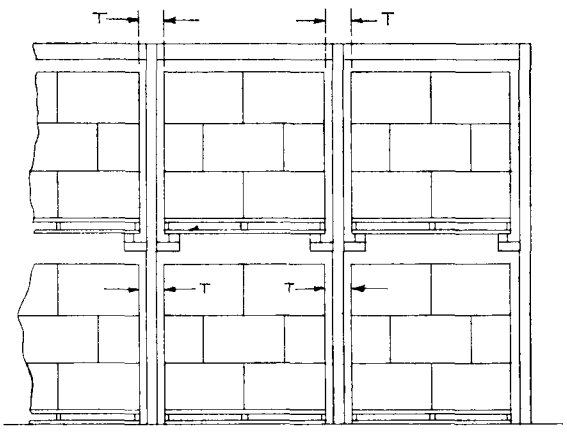




T — Transverse Flue Space

Figure A-4-1(g) Flow-Through Pallet Rack.

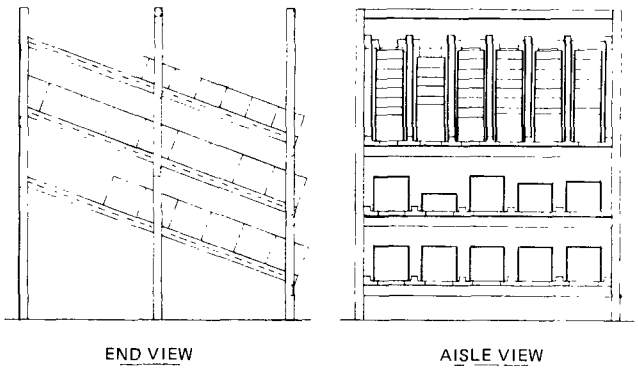




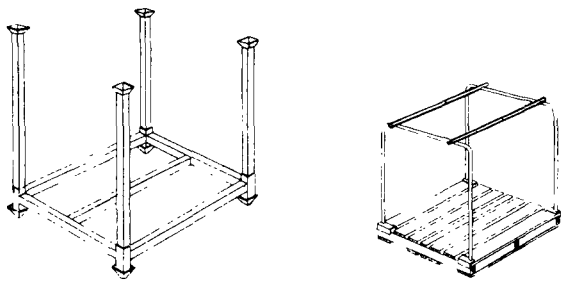
T — Transverse Flue Space

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.



Flow-Through Rack



Portable Racks

Figure A-4-1(i).

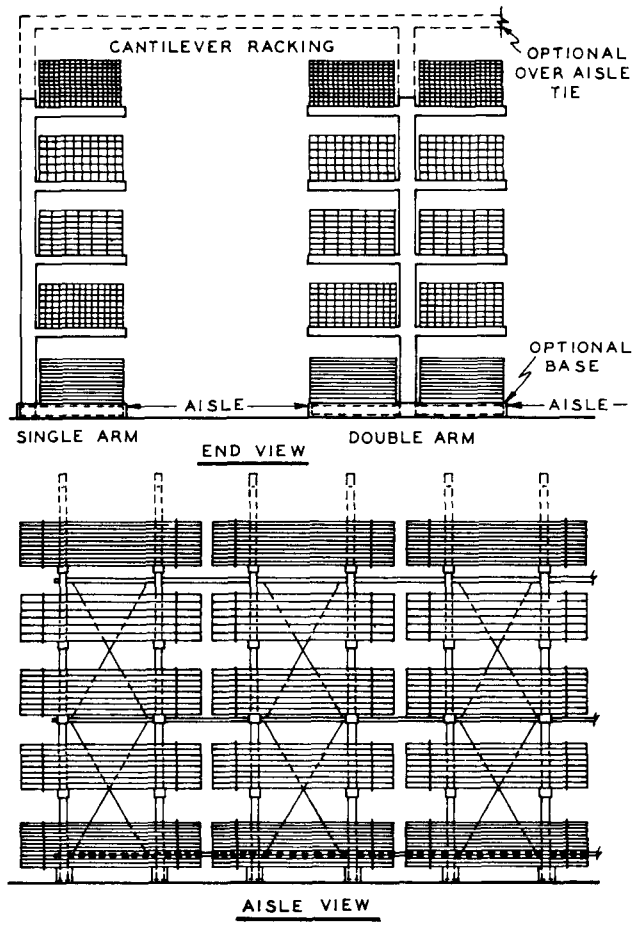
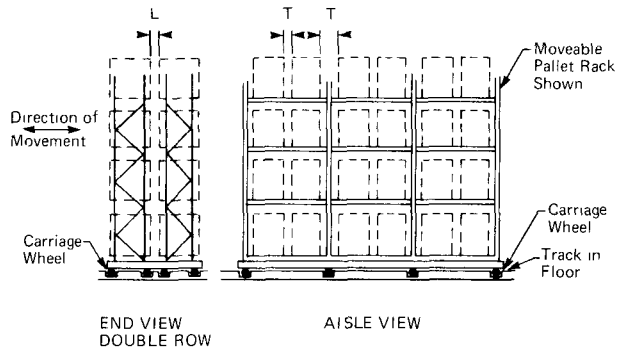


Figure A-4-1(j) Cantilever Rack.



T — Transverse Flue Space
L — Longitudinal Flue Space

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

A-4-2 Fixed rack structures should be designed to facilitate removal or repair of damaged sections without resorting to flame cutting or welding in the storage area. Where sprinklers are to be installed in racks, rack design should anticipate the additional clearances required 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 may render protection ineffective and should be discouraged.

A-4-5 The fire protection system design should contemplate the maximum height of storage. For new sprinkler installations, maximum height of storage 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 height of storage is the maximum existing if space between sprinklers and storage is equal or greater than 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 when 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 commodity from hot bulbs where possibility of contact with storage exists.

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

Chapter 5 Fire Protection — General

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

Dry systems are acceptable 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 which are highly susceptible to water damage.

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

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

A-5-4 Systems of in-rack sprinklers should be within the area protected by the corresponding system of ceiling sprinklers.

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.

Central station, auxiliary, remote station, or proprietary sprinkler water-flow alarm should be provided except that local water-flow alarm is acceptable where approved guard service is provided (*see NFPA 71, Standard for the Installation, Maintenance and Use of Central Station Signaling Systems; NFPA 72A, Standard for the Installation, Maintenance and Use of Local Protective Signaling Systems for Guards Tour, Fire Alarm and Supervisory Service; NFPA 72C, Standard for the Installation, Maintenance and Use of Remote Station Protective Signaling Systems; and NFPA 72D, Standard for the Installation, Maintenance and Use of Proprietary Protective Signaling Systems*).

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.

Chapter 6 Fire Protection — Storage up to and Including 25 Feet (7.62 m) in Height

A-6-4.1 Where possible, it is preferable to locate in-rack sprinkler deflectors at least 6 in. (152.4 mm) above pallet loads.

A-6-4.2 Where possible, it is preferable to locate in-rack sprinklers away from rack uprights.

A-6-5.1 Spacing of sprinklers on branch lines in racks in the various tests indicates maximum spacing as indicated is proper.

A-6-8.1 Bulkheads are not a substitute for sprinklers in racks. Their installation does not justify reduction in sprinkler densities or design operating areas as called for in the design curves.

A-6-9.1 When high expansion foam is being contemplated as the protection media, consideration should be given to possible damage to the commodity from soaking and corrosion. Consideration should be given to the problems associated with removal of foam after discharge.

A-6-11.1 Where dry pipe systems are used the areas of operation indicated 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 6,000 sq ft (557.4 m^2).

A-6-13.3 In-rack sprinklers at one level only for storage up to and including 25 ft (7.62 m) high in multiple row racks should be located at the tier level nearest one-half to two-thirds of the storage height.

Chapter 7 Fire Protection — Storage over 25 Feet (7.62 m) in Height

A-7-10.3 In single-row racks with more than 10 ft (3.05 m) between top of storage and ceiling, a horizontal barrier should be installed above storage with one line of sprinklers under the barrier.

A-7-11 Double row racks — height of storage over 25 ft (7.62 m) — more than 10 ft (3.05 m) between maximum height of storage and ceiling.

When the ceiling is more than 10 ft (3.05 m) above 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 need not be provided above a Class

I or Class II commodity with in-rack sprinkler arrays according to Figure 7-10.1(a) and Figure 7-10.1(b), provided one line of in-rack sprinklers is installed above the top tier of storage.

A-7-12.1 Water demand for height of storage over 25 ft (7.62 m) on racks without solid shelves separated by aisles at least 4 ft (1.22 m) wide and with more than 10 ft (3.05 m) between top of storage and sprinklers should be based on sprinklers in 2,000 sq ft (185.8 m^2) operating area for double row racks and 3,000 sq ft (278.7 m^2) operating area for multiple row racks discharging a minimum of 0.18 gpm per sq ft [(7.33 L/min)/m^2] for Class I commodities, 0.21 gpm per sq ft [(8.56 L/min)/m^2] for Class II and III commodities, and 0.25 gpm per sq ft [(10.19 L/min)/m^2] for Class IV commodities, for 165°F (74°C) sprinklers; or a minimum of 0.25 gpm per sq ft [(10.19 L/min)/m^2] for Class I commodities, 0.28 gpm per sq ft [(11.41 L/min)/m^2] for Class II and III commodities, and 0.32 gpm per sq ft [(13.04 L/min)/m^2] for Class IV commodities, for 286°F (141°C) 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.

A-7-13 In multiple row racks with more than 10 ft (3.05 m) between 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), (b), and (c).

Chapter 11 Building Maintenance and Operation

A-11-1 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. When welding or cutting operations are absolutely necessary, the precautions contained in NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, should be followed.

Locomotives should not be allowed to enter the storage area.

A-11-2 Containers should be emptied and contents removed from the premises at frequent intervals (*see NFPA 82, Standard on Incinerators, Waste and Linen Handling Systems and Equipment*).

A-11-4 Periodic inspections of all fire protection equipment should be made in conjunction with regular inspection of the premises. Unsatisfactory conditions should be immediately reported and necessary corrective measures taken promptly.

The sprinkler system and the water supplies should be checked and maintained in accordance with NFPA 13A, *Recommended Practice for the Inspection, Testing and Maintenance of Sprinkler Systems.*

A-11-5 Plant Emergency Organization. Arrangements should be made to permit rapid entry into the premises in case of fire or other emergency of the municipal fire department, police department, or other personnel as may be summoned to deal with any emergency without delay. A well-trained plant emergency organization should be provided to control emergency conditions that may arise.

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

(a) Maintaining 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 sprinkler system and water supply equipment

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

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

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

A-11-6 General Fire Protection.

All fire fighting and safety personnel should realize the great danger of 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 ways.

Sprinkler water may be safely shut off only after the fire is extinguished or completely under 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.

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 of any fire is in the incipient stage and the action taken by fire protection personnel upon notification of fire may permit containing the fire in early stages.

Pre-emergency planning should contemplate the following:

(a) Availability of hand fire fighting equipment for the height and type of commodity involved.

(b) Availability of fire fighting equipment and personnel properly trained for type of storage arrangement involved.

(c) Assurance that all automatic fire protection equipment, such as sprinkler systems, water supplies, fire pumps, hand hose, etc., is in service at all times.

Fire Department Operations. Sprinkler protection installed as recommended in this standard is expected to

protect the building occupancy without supplemental fire department activity. Fires which occur in rack storage occupancies, protected in accordance with the standard, should be controlled within the limits outlined in Appendix B, Section B-1-1. 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 immediately connect to the sprinkler siamese fire department connection and start pumping operations.

In the test series up to 25 ft (7.62 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 three minutes. Considering response time for the waterflow device to transmit a waterflow signal, approximately nine minutes remains between time of receipt of a waterflow alarm signal at fire department headquarters and time of smoke obscuration within the building as an overall average.

In the over-25-ft (7.62 m) high test series, 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 desirable.) 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 are not a substitute for sprinkler protection.

The sprinkler system must 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 time period had been reached. 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 them to coordinate the smoke removal (ventilation) with their mop-up operations.

Appendix B

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

Appendix B explains test data and procedures which led to the promulgation of this standard. The paragraphs bear the same number as the text of this standard to which they apply.

Chapter 1 Introduction

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 [50,000 sq ft (4.65 km²) in area], of fire-resistive construction, and contains a volume of approximately 2.25 million cu ft (63 761.86 m³), the equivalent of a 100,000 sq ft (9.29 km²) 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 (9.15 m) high and the west section is 60 ft (18.29 m) high.

The 20 ft (6.10 m) test series was conducted in the 30 ft (9.15 m) section with clearances from top of storage to ceiling nominally 10 ft (3.05 m).

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

The entire test series was fully instrumented with thermocouples in rack members, simulated building column, bar joist, and at 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. (12.7 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 test. 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 sq ft (9.29 m²) sprinkler spacing.

The test configuration in the 15 ft (4.57 m), 20 ft (6.10 m), and 25 ft (7.62 m) high tests covered an 1800 sq ft (167.2 m²) floor area, including aisles between racks. Tests, which were used in producing this standard, limited fire damage to this area. Maximum water damage area anticipated in the standard is 6000 sq ft (557.4 m²), 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, or water damage.

The following table illustrates these points. Information shown is taken from the 20 ft (6.10 m) high test series using the standard commodity.

These basic facts, the reduction in both fire damage and area of water application as sprinkler densities are increased or when sprinklers are installed in racks, should be considered carefully by those responsible for applying this standard to the rack storage situation.

In the 25 ft (7.62 m) high test, a density of 0.55 gpm per sq ft [(22.4 L/min)/m²] produced 42 percent, or 756 sq ft (70.26 m), fire damage in the test array and a sprinkler wetted area of 1400 sq ft (130.1 m²). Lesser densities would not be expected to achieve the same limited degree

Density GPM/Sq. Ft.		Fire Damage in Test Array %	Fire Damage in Test Array Sq. Ft.	Sprinkler Operation (165°F) Area — Sq. Ft.
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 = ⅝ (F-32); 1 gpm/ft² = 40.746 (L/min)/m²

of control. Therefore, if smaller areas of fire damage are to be achieved, sprinklers in racks should be considered.

The over-25-ft (7.62 m) test series was conducted in the 60 ft (18.29 m) section of the test building with nominal clearances from top of storage to ceiling of either 30 ft (9.15 m) or 10 ft (3.05 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 (7.62 m) series was to:

1. Determine the arrangement of in-rack sprinklers that can be repeated as pile height increases and that produce control of the fire.

2. Determine other protective arrangements, such as high expansion foam, that produce control of the fire.

Control was felt to be 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 (7.62 m) test rack. To aid in this judgment, control was considered achieved if the fire did not:

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

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

Control is defined as holding the fire in check through the extinguishing system until commodities initially involved are consumed or 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 (7.62 m) tests. Hallmark products and 3-M products described in the 20 ft (6.1 m) report were also used as representative of Class III and/or IV commodities in several tests. The result of privately sponsored tests on Hallmark products and plastic encapsulated standard commodity were also made available to the committee.

A 25 ft (7.62 m) long test array was used for the majority of over-25-ft (7.62 m) high test series. This decision was reached as it was felt that a fire in racks over 25 ft (7.62 m) high which extended to 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 produce control of the fire. The 30 ft (9.15 m) tests 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 burn out of the top tiers of both the main rack and the target rack occurred.) In the case of the 30 ft (9.15 m) Hallmark Test 134 on the 60 ft (18.29 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 itself downward into the south end of the fourth tier. In the test on the floor, a nominal 30 ft (9.15 m) clearance occurred between top of storage and ceiling sprinklers, whereas on the platform this clearance was reduced to nominal 10 ft (3.05 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 the actual case with clearance of 10 ft (3.05 m) or less above storage, ceiling sprinklers would be expected to control damage above the top level of protection within the racks. Tests are 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 (9.15 m) clearance from ceiling sprinklers to 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 when the ignition point is changed was noted in Tests 126 and 127. Here again, 30 ft (9.15 m) clearance occurred between top of storage and ceiling sprinklers, and, as such, ceiling sprinklers had little effect on the face fire. Comparisons of Tests 129, 130, and 131 in the 50 ft (15.24 m) series indicate little effect of point of ignition in the particular configuration tested.

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

Chapter 2 Classification of Storage

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 (abrasives, pressure sensitive tapes of plastic fiber, and paper, etc.); and of the considerable number of commodity tests conducted indicates 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 must be made when selecting a commodity classification.

Chapter 3 Building Construction

B-3-2.1 None of the tests which were conducted with densities in accordance with the design curves produced critical temperatures in bar joists 12 ft 6 in. (3.81 m) from the ignition source. Therefore, with sprinkler systems de-