NFPA No.

231C

RACK STORAGE OF MATERIALS 1973

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Official NFPA Definitions

Adopted Jan. 23, 1964: Revised Dec. 9, 1969 and June 26, 1973. Where variances to these definitions are found, efforts to eliminate such conflicts are in process.

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Standard for

Rack Storage of Materials

NFPA No. 231C— 1973

1973 Edition of No. 231C

This edition of NFPA No. 231C was adopted in May 1973 and supersedes the 1972 edition. The principal change is the provision of coverage for storage heights above 25 feet, which previously was the height limitation. Also, advisory material has been relocated to the Appendix.

Origin and Development of No. 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 No. 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.

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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.

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Standard for

Rack Storage of Materials

NFPA No. 231C — 1973

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

Introduction

*1. Application and Scope

This standard applies to storage of materials representing the broad range of combustibles stored over 12 feet in height on racks. For storage heights of 12 feet or less, see NFPA No. 13.

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

Storage of high hazard materials such as tires, plastics, and flammable liquids, is outside the scope of this standard. See NFPA Nos. 30, Flammable and Combustible Liquids Code; 40, Cellulose Nitrate Motion Picture Film; 43, Pyroxylin Plastic; 490, Ammonium Nitrate Storage; 58, Liquefied Petroleum Gases; 81, Fur Storage, Fumigation and Cleaning; 231, Indoor General Storage; and 232, 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.

2. Definitions

Bulkhead. A vertical barrier across the rack.

Commodity. Designates combinations of product, packing material, and container.

Conventional Pallets. A material handling aid designed to support a unit load with stringers to provide support for material handling devices (see Fig. 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 pallets enclosed only by a plastic sheet as described are not considered to fall under this definition.

Face Sprinklers. Standard sprinklers located in transverse flue spaces along the aisle or in the rack within 18 inches of the aisle face of storage to oppose vertical development of fire on the external face of storage.

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

Longitudinal Flue Space. The space between rows of storage perpendicular to the direction of loading (see Fig. 1).

Racks. Any combination of vertical, horizontal, and diagonal members that support stored materials. Some rack structures use solid shelves. Racks may be fixed or portable (see Figs. A3111 through A3115).

Shelf Storage. Storage in structures usually less than 30 inches deep, seldom more than 2 feet between shelves and seldom higher than 12 feet.

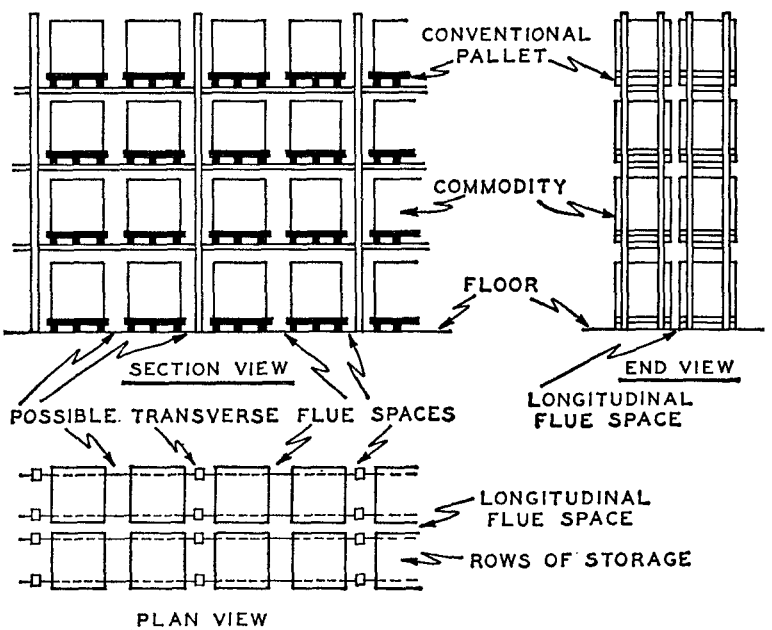
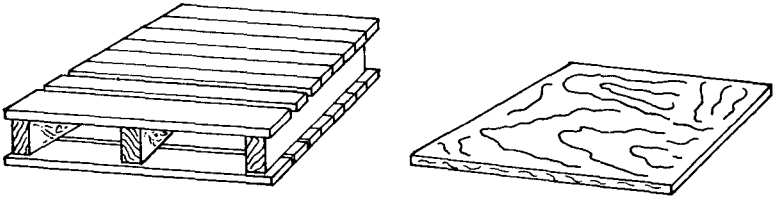


Fig. 1. Typical Double Row (Back-to-Back) Rack Arrangement.

Slave Pallet. A special pallet captive to a material handling system (see Fig. 2).

Transverse Flue Space. The space between rows of storage parallel to the direction of loading (see Fig. 1).



Typical Conventional Pallet **Typical Slave Pallet**

Fig. 2.

Chapter 1. Classification of Storage

*11. Commodity Classifications

111. The following guide for commodity classification applies specifically to rack storage and is not related to any other method of classification of materials.

1111. Class I commodity is defined as essentially noncombustible products on wood pallets, or in ordinary corrugated cartons with or without single thickness dividers, or in ordinary paper wrappings; on wood pallets, such as: metal parts; empty cans; noncombustible food stuffs or beverages; stoves; washers; dryers; and metal cabinets. Such commodities may have a negligible amount of plastic trim, such as knobs or handles.

Other examples of Class I commodities 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.

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

FOODS. Foods in noncombustible containers; frozen foods; meats; fresh fruits and vegetables in nonplastic trays or containers; dairy products in nonwax coated paper containers.

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

1112. Class II commodity is defined as Class I products in slatted wooden crates, solid wooden boxes, or equivalent combustible packaging material on wood pallets.

Examples of Class II commodities are: thinly coated fine wire such as radio coil wire on reels or in cartons; incandescent or fluorescent light bulbs; and Class I products, if in small cartons or small packages placed in ordinary corrugated cartons.

1113. Class III commodity is defined as wood, paper, natural fiber cloth, or products thereof, on wood pallets, such as: natural fiber clothing or textile products; wood cabinets; furniture or other wood products; bicycles; luggage (except plastic); combustible foods or cereal products; paper products; and leather goods. Prod-

ucts may contain a limited amount of plastics. Metal bicycles with plastic handles, pedals, seats, and tires are an example of a commodity with a limited amount of plastic.

Other examples of Class III commodities are:

PAPER PRODUCTS. Books, magazines, stationary; plastic coated paper food containers; newspapers; paper or cardboard games; tissue products; rolled paper on side or steel banded on end; and non-negative producing film packs in sealed metal foil wrappers in paperboard packages.

LEATHER PRODUCTS. Shoes; jackets; gloves; and luggage.

WOOD PRODUCTS. Doors; windows; door and window frames; and combustible fiberboard.

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; and natural fiber and viscose yarns, thread, and products.

OTHERS. Tobacco products in paperboard cartons; nonflammable liquids such as soaps, detergents and bleaches, and nonflammable pharmaceuticals in plastic containers.

1114. Class IV commodity is defined as Class I, II, and/or III products containing an appreciable amount of plastics in a paperboard carton or Class I, II and/or III products with plastic packing in paperboard cartons on wood pallets.

Examples of Class IV commodities 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 commodity also includes:

TEXTILES. Synthetic thread and yarn except viscose.

OTHERS. Telephones; vinyl floor tile; wood or metal frame upholstered furniture or mattresses with plastic covering and/or padding; and plastic padded metal dashboards.

Chapter 2. Building Construction

21. Construction

211. 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 Standard Types of Building Construction, NFPA No. 220.

22. Fire Protection of Steel

***221.** With sprinkler systems installed in accordance with design curves in Chapter 4, fire protection of roof steel is not necessary.

***222.** When ceiling sprinklers and sprinklers in racks are installed in accordance with design curves in Chapter 4, fire protection of steel building columns is not necessary.

***232.** When storage height exceeds 15 feet, 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 foot elevation, pointed towards one side of the steel column.

(c) For storage heights above 15 feet, up to and including 20 feet, provision of ceiling sprinkler density for a minimum of 2000 square feet with 165°F or 286°F temperature-rated sprinklers as follows:

Commodity Class	4 ft. Aisle	8 ft. Aisle
I	0.37	0.33
II	0.44	0.37
III	0.49	0.42
IV	0.68	0.57

23. Ventilation

231. Design curves are based upon roof vents and draft curtains not being used.

Chapter 3. Storage Arrangements

31. Rack Structure

*311. Typical rack configurations are described in Appendix A311.

32. Rack Design

*321. Racks shall not be loaded beyond their design capacity.

33. Flue Space

*331. In double row racks with height of storage up to and including 25 feet, and without solid shelves, no minimum or maximum longitudinal flue space (back-to-back clearance) is necessary when an approximate 6-inch transverse flue space between loads or at uprights is maintained. (See Figs. Nos. 331 and A3111b.)

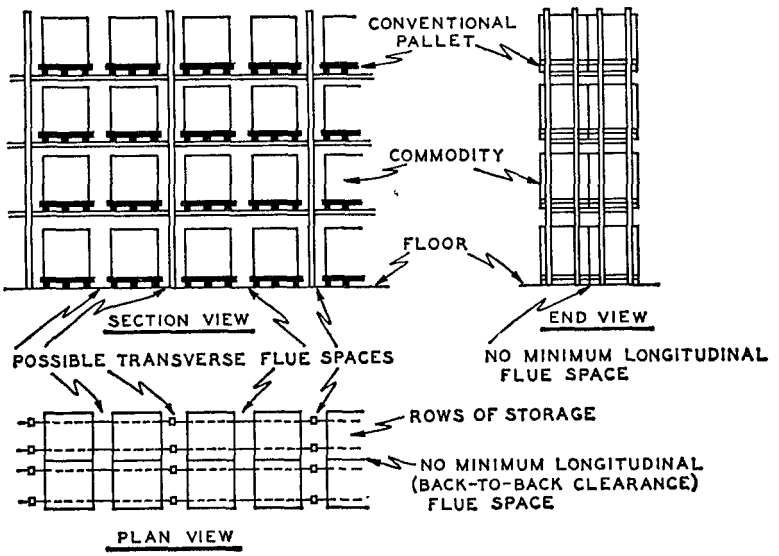


Fig. 331. Typical Double Row Rack

*332. In double row racks with solid shelves, minimum 6-inch flue spaces shall be maintained between the shelf sections thereby defining the shelf size (see A332, A3114a and b.).

34. Aisle Widths

341. 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 Chapter 4).

342. 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.

35. Storage Heights

351. The fire protection system design shall contemplate the maximum height of storage.

*352. The distance from the top of the pile to the ceiling sprinkler deflectors shall be not less than three feet.

36. Commodity Clearances

361. Commodity clearances shall be maintained in accordance with NFPA Standards as follows:

Heat Producing Appliances, NFPA No. 89M

Blower and Exhaust Systems, NFPA No. 91

362. Clearance shall be maintained between commodity and lights or light fixtures to prevent possible ignition.

37. Storage of Empty Combustible Pallets

371. For bulk storage of empty combustible pallets, see NFPA No. 231, Indoor General Storage.

Chapter 4. Fire Protection

40. General

401. Protection systems which are provided for rack storage facilities shall be in accordance with the provisions of this chapter.

41. Sprinkler System Design Criteria

***411.** Where automatic sprinkler systems are installed, they shall be in accordance with the Standard for Installation of Sprinkler Systems, NFPA No. 13, except as modified by this Rack Storage of Materials Standard.

412. System Size or Area Limitation

4121. The maximum area protected by a single sprinkler system at the ceiling shall not exceed 40,000 square feet (see Standard for Installation of Sprinkler Systems, NFPA No. 13).

4122. The area protected by a single system of sprinklers in racks (in-rack sprinklers) shall not exceed 40,000 square feet of floor area occupied by the racks including aisles regardless of the number of intermediate sprinkler levels.

*4123. Office areas, equipment rooms, and similar areas may be protected by an extension of the ceiling sprinkler system, and such areas may be excluded from the total area limitation of 40,000 square feet if a one-hour fire resistant separation is provided. The combined areas of such systems shall not exceed 52,000 square feet.

413. System Division

4131. When sprinklers are installed in racks, separate gate valves and drains shall be provided for ceiling sprinklers and sprinklers in racks except for small in-rack installations of less than 20 sprinklers. (See 451.)

414. Ceiling Sprinklers

4141. Sprinkler spacing for high piled storage occupancies as defined in NFPA No. 13 shall apply to Class I, II, III, or IV commodities except as modified in 4142 of this standard.

4142. Sprinkler spacing may exceed 100 square feet, but shall not exceed 130 square feet, in systems hydraulically designed in accordance with the design curves shown in Figs. 4811a through 4811k for densities below 0.25 gpm per square foot. Densities shall

not be less than those shown on the design curves and the minimum discharge from any ceiling sprinkler in the design area shall be 15 gpm in designs of new system.

*4143. 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.

4144. In buildings that are occupied in part for rack storage of commodities, where only a portion of the sprinkler system is hydraulically designed, the design area shall extend 15 feet beyond the area occupied by the racks.

***415. Sprinklers in Racks.** When sprinklers are installed in racks, the number of levels shall be as follows:

4151. Double row racks—height of storage up to and including 25 feet.

4151a. In double row racks without solid shelves, one level of in-rack sprinklers shall be installed for Class IV nonencapsulated storage exceeding 22 feet in height.

*4152. Double row racks — height of storage over 25 feet, maximum of 10 feet between maximum height of storage and ceiling.

4152a. In double row racks without solid shelves in racks sprinklers shall be installed as indicated in Table 4152 and Figs. 4152a through j. The highest level of in-rack sprinklers shall not be more than 10 feet below maximum height of storage.

4152b. 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 two inches of rack members. (See Table 4152 and Figs. 4152a, g, and j.)

Table 4152

In-Rack Sprinkler Arrays — Double Row Racks Without Solid Shelves — Storage Higher Than 25 Feet.

Commodity Class	In-Rack Sprinklers — Approximate Vertical Spacing and Maximum Horizontal Spacing		Fig. No.	Maximum Storage Height
	Longitudinal Flue	Face		
I	Vertical 20 ft. Horizontal 10 ft. Under Horizontal Barriers	None	4152a	30 ft.
	Vertical 20 ft. Horizontal 10 ft.	Vertical 20 ft. Horizontal 10 ft.	4152b	Higher than 25 ft.
I — II — III	Vertical 10 ft. or at 15 ft. & 25 ft. Horizontal 10 ft.	None	4152c	30 ft.
	Vertical 10 ft. Horizontal 10 ft.	Vertical 30 ft. Horizontal 10 ft.	4152d	Higher than 25 ft.
	Vertical 20 ft. Horizontal 10 ft.	Vertical 20 ft. Horizontal 5 ft.	4152e	Higher than 25 ft.
	Vertical 25 ft. Horizontal 5 ft.	Vertical 25 ft. Horizontal 5 ft.	4152f	Higher than 25 ft.
	Horizontal Barriers at 20 ft. Vertical Intervals — 2 Lines of Sprinklers Under Barriers — Maximum Horizontal Spacing 10 ft. Staggered.		4152g	Higher than 25 ft.
I — II — III — IV	Vertical 15 ft. Horizontal 10 ft.	Vertical 20 ft. Horizontal 10 ft.	4152h	Higher than 25 ft.
	Vertical 20 ft. Horizontal 5 ft.	Vertical 20 ft. Horizontal 5 ft.	4152i	Higher than 25 ft.
	Horizontal Barriers at 15 ft. Vertical Intervals — 2 Lines of Sprinklers Under Barriers — Maximum Horizontal Spacing 10 ft. Staggered.		4152j	Higher than 25 ft.

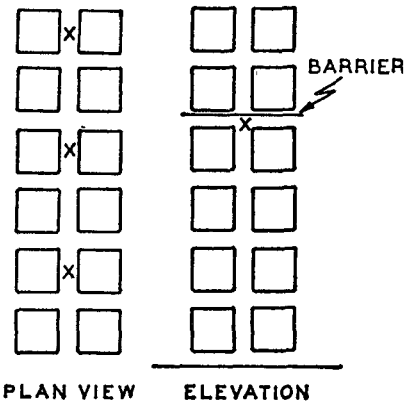


Fig. 4152a. In-Rack Sprinkler Arrangement, Class I Commodity, Maximum Height of Storage 25 Ft. to 30 Ft.

NOTE:

1. Symbol X indicates in-rack sprinklers.

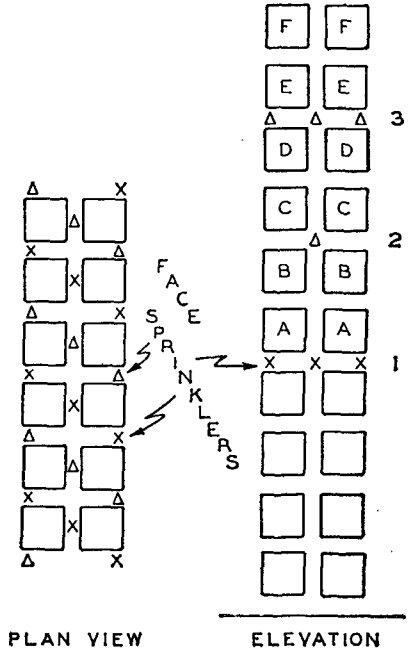


Fig. 4152b. In-Rack Sprinkler Arrangement, Class I Commodity, Height of Storage over 25 Feet

NOTES:

1. Sprinklers labeled 1 (the selected array from Table 4152) 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 △ or X indicate sprinklers on vertical or horizontal stagger.

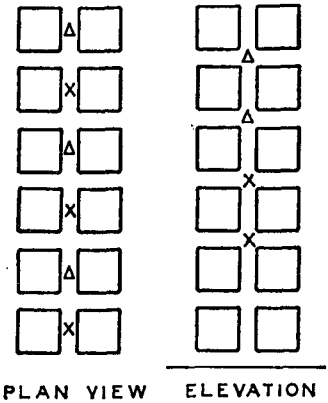


Fig. 4152c. In-Rack Sprinkler Arrangement, Class I, II or III Commodity, Maximum Height of Storage 25 Ft. to 30 Ft.

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 △ or X indicate sprinklers on vertical or horizontal stagger.

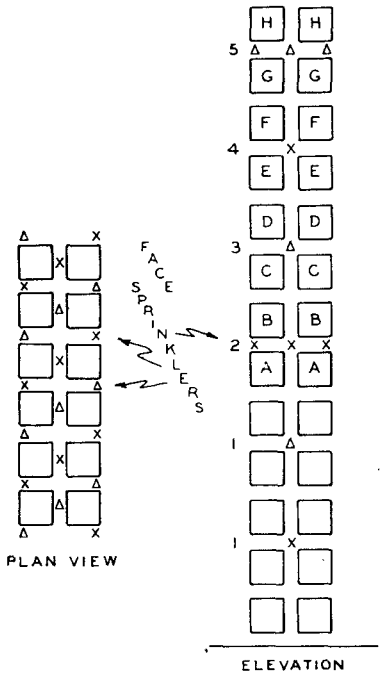


Fig. 4152d. In-Rack Sprinkler Arrangement, Class I, II or III Commodity, Height of Storage over 25 Feet

NOTES:

1. For any storage height above 25 feet, all sprinklers shown below that top of storage are required, with stagger as indicated.

For storage higher than shown, the cycle defined by sprinklers shown in elevation repeats with the bottom sprinkler two loads above the top sprinklers shown.

2. The indicated face sprinklers may be omitted when commodity consists of unwrapped or unpackaged metal parts on wood pallets.

3. Symbols M or X indicate sprinklers on vertical or horizontal stagger.

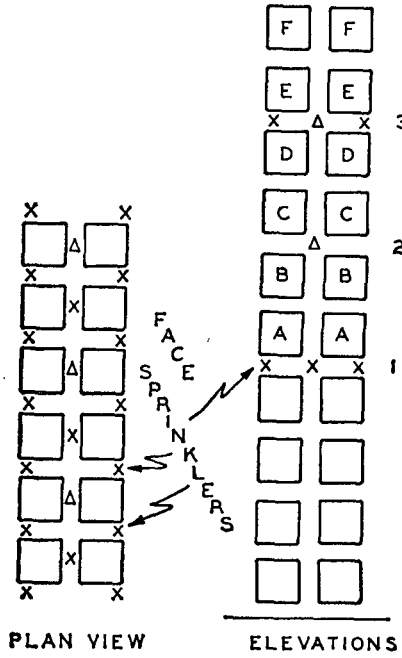


Fig. 4152e. In-Rack Sprinkler Arrangement, Class I, II or III Commodity, Height of Storage over 25 feet

NOTES:

1. Sprinklers labeled 1 (the selected array from Table 4152) 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 △ or X indicate sprinklers on vertical or horizontal stagger.

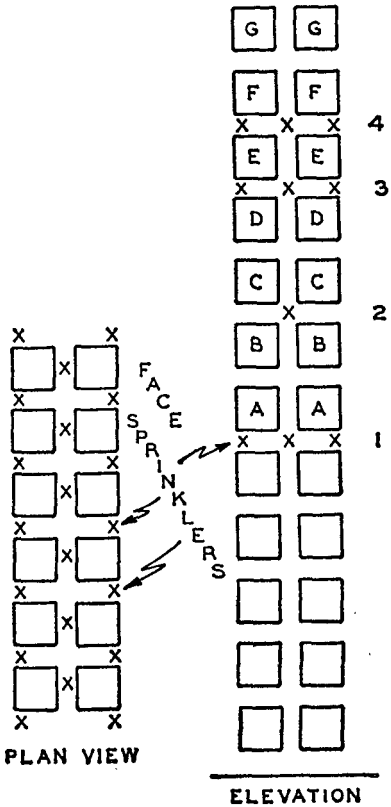


Fig. 4152f. In-Rack Sprinkler Arrangement, Class I, II or III Commodity, Height of Storage over 25 Feet.

NOTES:

1. Sprinklers labeled 1 (the selected array from Table 4152) 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.

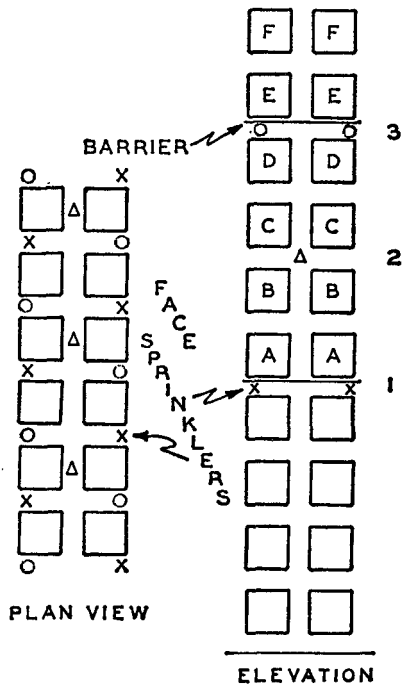


Fig. 4152g. In-Rack Sprinkler Arrangement, Class I, II or III Commodity, Height of Storage over 25 Feet.

NOTES:

1. Sprinklers labeled 1 (the selected array from Table 4152) 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 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, △ or X indicate sprinklers on vertical or horizontal stagger.

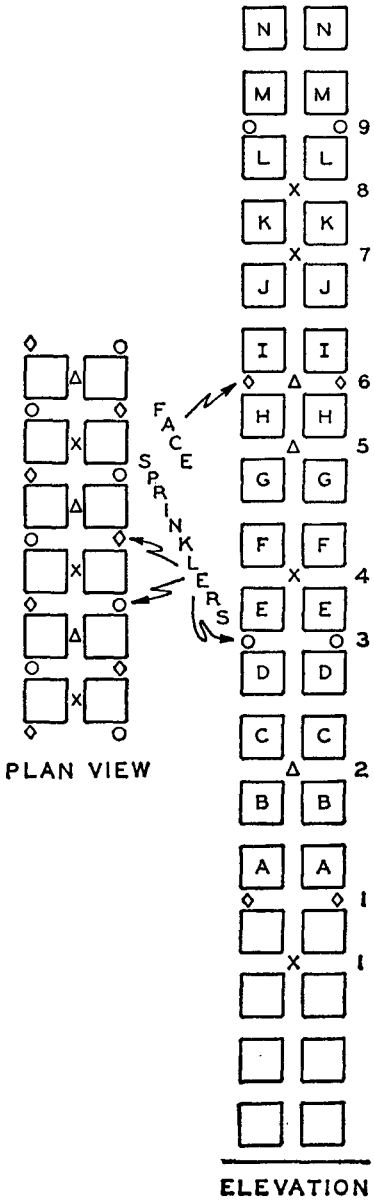


Fig. 4152h. In-Rack Sprinkler Arrangement, Class I, II, III or IV Commodity, Height of Storage over 25 Feet.

NOTES:

1. Sprinklers labeled 1 (the selected array from Table 4152) 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, △, indicate sprinklers on vertical or horizontal stagger.

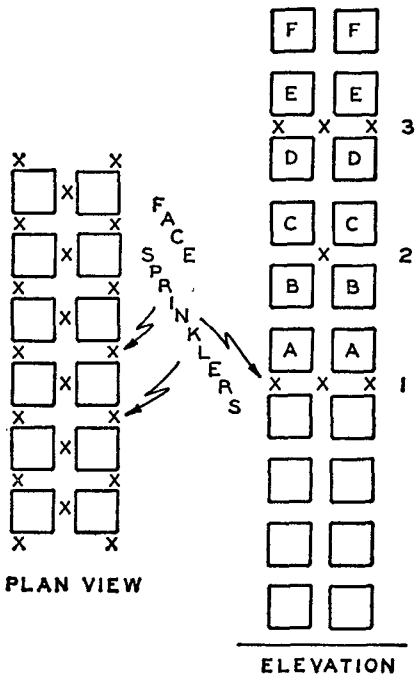


Fig. 4152i. In-Rack Sprinkler Arrangement, Class I, II, III or IV Commodity, Height of Storage over 25 Feet.

NOTES:

1. Sprinklers labeled 1 (the selected array from Table 4152) 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.

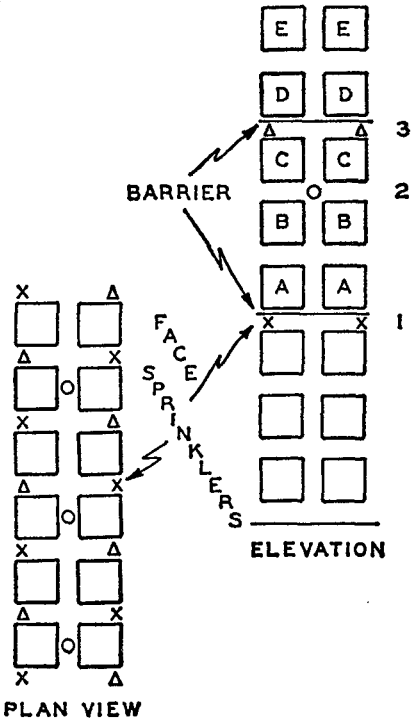


Fig. 4152j. In-Rack Sprinkler Arrangement, Class I, II, III or IV Commodity, Height of Storage over 25 Feet

NOTES:

1. Sprinklers and barrier labeled 1 (the selected array from Table 4152) 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.

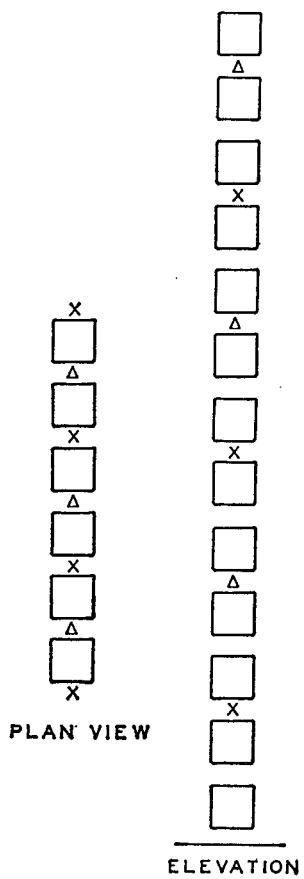
4. For storage higher than represented by loads labeled E, the cycle defined by notes 2 and 3 is repeated.

5. Symbols △ or X indicate sprinklers on vertical or horizontal stagger.

6. Symbol O indicates longitudinal flue space sprinklers.

4153. Single row racks without solid shelves — height o storage over 25 feet — maximum 10 feet between maximum height of storage and ceiling.

4153a. In single row racks without solid shelves sprinklers shall be installed as indicated in Fig. 4153.



NOTES:

1. For all storage heights, install sprinklers in every other tier and stagger as indicated.

2. Symbols △ or X indicate sprinklers on vertical or horizontal stagger.

Fig. 4153. In-Rack Sprinkler Arrangement, Single Row Racks. Height of Storage over 25 Feet.

4154. Multiple row racks — height of storage up to and including 25 feet.

4154a. For encapsulated or nonencapsulated storage in multiple row racks no deeper than 16 feet with aisles no narrower than 8 feet, one level of in-rack sprinklers shall be installed for Class II and III storage over 20 feet in height. One level of in-rack sprinklers shall be installed for Class IV storage over 15 feet up to and including 20 feet in height and two levels of in-rack sprinklers shall be installed for Class IV storage over 20 feet in height.

4154b. For encapsulated or nonencapsulated storage in multiple row racks deeper than 16 feet or with aisles less than 8 feet wide, one level of in-rack sprinklers shall be installed for Class I, II and III storage over 15 feet in height. One level of in-rack sprinklers shall be installed for Class IV storage over 15 feet up to and including 20 feet in height and two levels of in-rack sprinklers shall be installed for Class IV storage exceeding 20 feet in height.

*4155. Multiple row racks — height of storage over 25 feet.

4155a. In multiple row racks with a maximum of 10 feet between maximum height of storage and ceiling, in-rack sprinklers shall be installed as indicated in Figs. 4155a, b and c. The highest level of in-rack sprinklers shall be not more than 10 feet below maximum height of storage for Class I, II or III commodities or 5 feet below maximum height of storage for Class IV commodity.

*4156. In-rack sprinklers at one level only for storage up to and including 20 feet high in double row racks shall be located at ½ to ⅔ of the storage height. The elevation of in-rack sprinkler deflectors with respect to storage is not a consideration.

4156a. In-rack sprinklers at one level only for storage over 20 feet high and up to and including 25 feet high in double row racks shall be located at the tier level nearest ½ to ⅔ of the storage height.

4157. In-rack sprinklers at two levels only for storage up to and including 25 feet high in double row racks shall be located at ¼ to ⅓ and ⅔ to ¾ of the storage height.

4157a. In-rack sprinklers at two levels only for storage up to and including 25 feet high in multiple row racks shall be located at tier levels nearest ¼ to ⅓ and ⅔ to ¾ of the storage height.

4158. In-rack sprinklers for storage higher than 25 feet in double row racks shall be spaced horizontally and located in horizontal space nearest the vertical intervals indicated in Table 4152, Figs. 4152a through j.

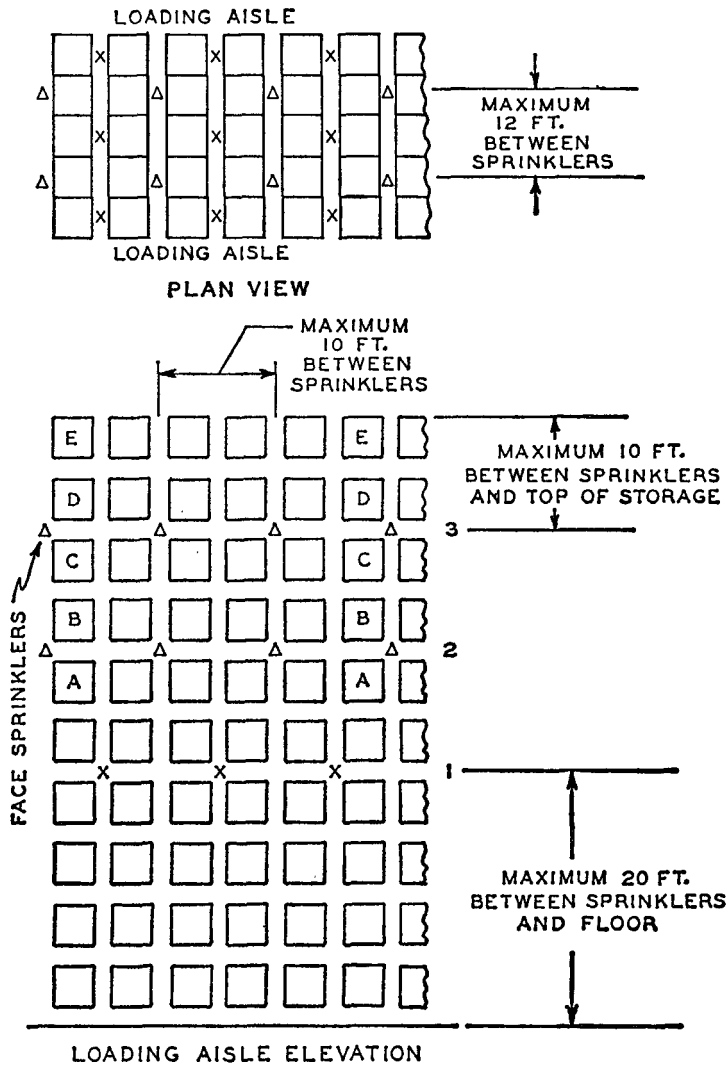
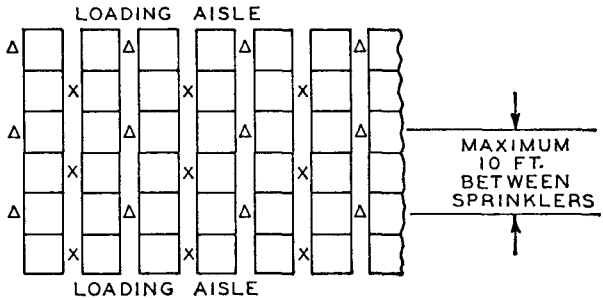


Fig. 4155a. In-Rack Sprinkler Arrangement — Multiple Row Racks, Class I Commodity. Height of Storage over 25 Feet.

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 △ or X indicate sprinklers on vertical or horizontal stagger.



PLAN VIEW

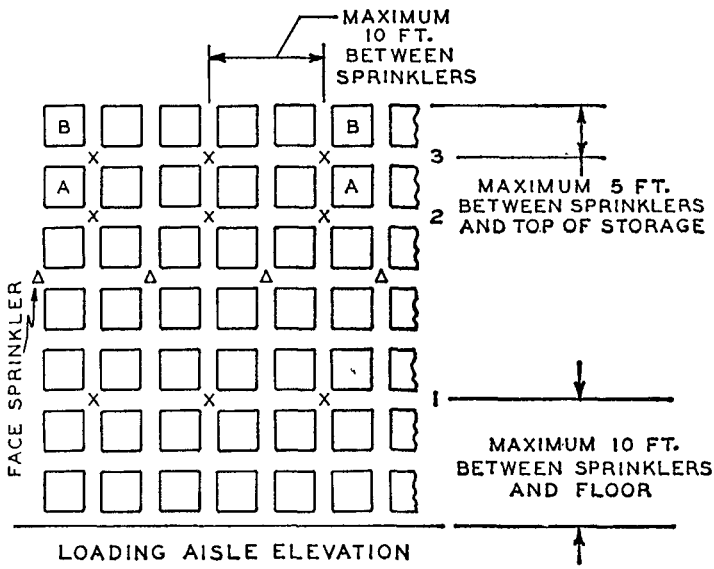


Fig. 4155b. In-Rack Sprinkler Arrangement — Multiple Row Racks. Class II or III Commodity. Height of Storage over 25 Feet.

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 △ or X indicate sprinklers on vertical or horizontal stagger.

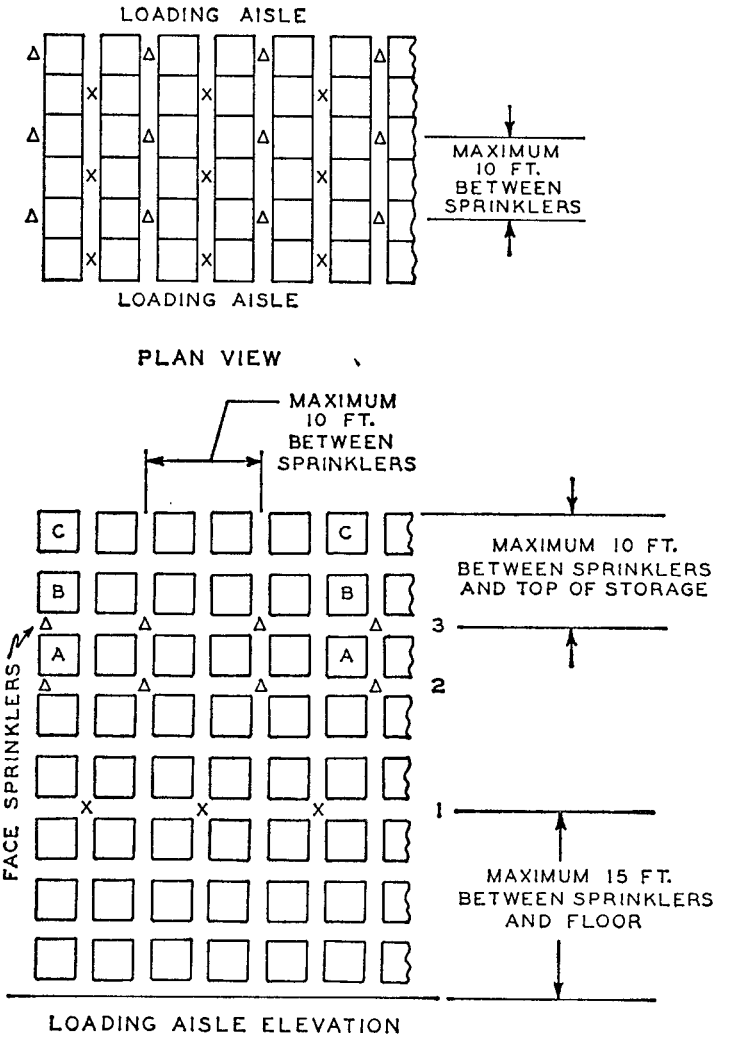


Fig. 4155c. In-Rack Sprinkler Arrangement, Class IV Commodity, Multiple Row Racks. Height of Storage over 25 Feet.

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 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 △ or X indicate sprinklers on vertical or horizontal stagger.

4159. In-rack sprinklers shall be staggered horizontally and vertically when installed as indicated in Table 4152, Figs. 4152a through j and 4154a, b and c.

4160. Sprinklers in racks shall be ordinary temperature classification with nominal ½-inch orifice size pendent or upright.

*4161. Maximum horizontal spacing of sprinklers in double row racks with nonencapsulating storage up to and including 25 feet 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 feet.

4162. Maximum horizontal spacing of sprinklers in double row racks with nonencapsulating storage higher than 25 feet shall be as indicated in Table 4152 and Figs. 4152a through j.

4163. Maximum horizontal spacing of sprinklers on branch lines in multiple row racks with nonencapsulating storage up to and including 25 feet in height shall not exceed 12 feet for Class I, II or III commodities and 8 feet for Class IV commodities with area limitations of 100 square feet per sprinkler for Class I, II or III commodities, and 80 square feet 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.)

4164. Maximum horizontal spacing of sprinklers in multiple row racks with storage higher than 25 feet shall conform to Figs. 4154a, b and c.

4165. 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. Minimum pipe diameter shall be one inch.

*4166. Water shields shall be provided directly above in-rack sprinklers when there is more than one level if not shielded by horizontal barriers.

*4167. The sprinklers installed in racks with height of storage up to and including 20 feet may be spaced without regard to rack uprights except as noted in 4168.

4168. In double row racks without solid shelves with height of storage over 20 feet and in multiple row racks or double row racks with solid shelves, a minimum 6-inch 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 inches from rack uprights and no more than 18 inches from the aisle face of storage, and other sprinklers in racks shall be located a minimum of 2 feet from rack uprights.

42. Solid and Slatted Shelves

***421.** Slatted shelves shall be considered the same as solid shelves.

***422.** 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 (see Fig. 332).

45. Alarms

***451.** Central station, auxiliary, remote station, or proprietary sprinkler water-flow alarm shall be provided except that local water-flow alarm is acceptable where approved guard service is provided (see NFPA Nos. 71, 72A, 72B, 72C and 72D).

46. High Expansion Foam

461. When high expansion foam systems are installed they shall be in accordance with the Standard for High Expansion Foam Systems, NFPA No. 11A, except as modified by this Rack Storage of Materials Standard and they shall be automatic in operation.

462. Height of Storage Up to and Including 25 Feet

*4621. When high expansion foam systems are used without sprinklers the maximum submergence time shall be five minutes for Class I, II or III commodities and four minutes for Class IV commodities.

4622. When high expansion foam systems are used in combination with ceiling sprinklers for Class I, II or III commodities the maximum submergence time shall be seven minutes and the mini-

mum ceiling sprinkler design shall be a density of 0.2 gpm per square foot for the most hydraulically remote 2000 square foot area. For Class IV commodities the maximum submergence time shall be five minutes and the minimum ceiling sprinkler design shall be 0.25 gpm per square foot for the most hydraulically remote 2000 square foot area.

463. Height of Storage Over 25 Feet Up to and Including 35 Feet.

4631. High expansion foam systems shall be used in combination with ceiling sprinklers. The maximum submergence time for the high expansion foam shall be five minutes for Class I, II or III commodities and four minutes for Class IV commodities. Ceiling sprinkler design shall be 0.2 gpm per square foot for Class I, II or III commodities and 0.25 gpm per square foot for Class IV commodities over the most hydraulically remote 2000 square foot area.

464. Detectors shall be listed by a recognized testing lab and shall be installed:

4641. At ceiling only at ½ listed spacing, or

4642. At ceiling at listed spacing and in racks at alternate levels, or

4643. 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.

465. Detection systems, concentrate pumps, generators and other system components essential to the operation of the system shall have an approved standby power source.

47. Hose Connections

***471.** For first aid fire fighting and for mop-up operations small (1½ inch) 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.

48. Water Demand

481. Sprinklers at Ceiling

*4811. For Class I, II, III or IV commodities encapsulated or nonencapsulated in double row racks and nonencapsulated in multiple row racks with height of storage up to and including 25 feet ceiling sprinkler water demand in terms of density (gpm per square foot) and area of sprinkler operation (square feet of ceiling or roof) shall be selected from curves given in Fig. 4811a through k. The curves in Fig. 4811a through k 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. Fig. 4813 shall be used to adjust density for storage height unless otherwise specified.

For Class I, II, III or IV commodities encapsulated with height of storage up to and including 25 feet on multiple row racks, ceiling sprinkler density shall be 25 percent greater than for encapsulated commodities on double row racks.

*4811a. Design curves for single and double row racks shall be selected corresponding to aisle width. For aisle widths between 4 feet and 8 feet a direct linear interpolation between curves may be made. Density given for 8 foot wide aisles shall be applied to aisles wider than 8 feet. Density given for 4 foot wide aisles shall be applied to aisles narrower than 4 feet down to 3½ feet. Aisles narrower than 3½ feet shall be considered as multiple row racks.

*4811b. Where storage is nonencapsulated, water demand for height of storage over 25 feet on racks without solid shelves separated by aisles at least 4 feet wide and with not more than 10 feet between top of storage and sprinklers, shall be based on sprinklers in a 2000 square foot operating area for double row racks and 3000 square foot operating area for multiple row racks, discharging a minimum of 0.25 gpm per square foot for Class I commodity, 0.3 gpm per square foot for Class II and III commodity, and 0.35 gpm per square foot for Class IV commodity, for 165°F sprinklers; or a minimum of 0.35 gpm per square foot for Class I commodity, 0.40 gpm per square foot for Class II and III commodity, and 0.45 gpm per square foot for Class IV commodity, for 286°F sprinklers.

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

4812. Where solid wood flat bottom slave pallets are used, or solid shelves (see Fig. A332) are used in single or double row racks 4 feet to 8 feet deep, with height of storage up to and including 25 feet, the densities indicated in the design curves, based on conventional pallets, shall be increased 20 percent for the given area.

*4813. Design curves 4811a through k apply to nominal 20 foot height of storage.

4813a. For height of storage up to and including 25 feet protected with ceiling sprinklers only and for height of storage up to and including 20 feet protected with ceiling sprinklers and minimum acceptable in-rack sprinklers, densities given in design curves shall be adjusted according to Fig. 4813, but to not less than 15 gpm per sprinkler.

4813b. For height of storage over 20 feet up to and including 25 feet protected with ceiling sprinklers and minimum acceptable in-rack sprinklers, densities given in design curves shall be used. Densities shall not be adjusted per Fig. 4813.

4813c. For height of storage up to and including 25 feet protected with ceiling sprinklers and with more than one level of in-rack sprinklers, but not in every tier, densities given in design curves can be reduced 20 percent, but to not less than 15 gpm per sprinkler.

4813d. For height of storage up to and including 25 feet protected with ceiling sprinklers and in-rack sprinklers at each tier, densities given in design curves can be reduced 40 percent, but to not less than 15 gpm per sprinkler.

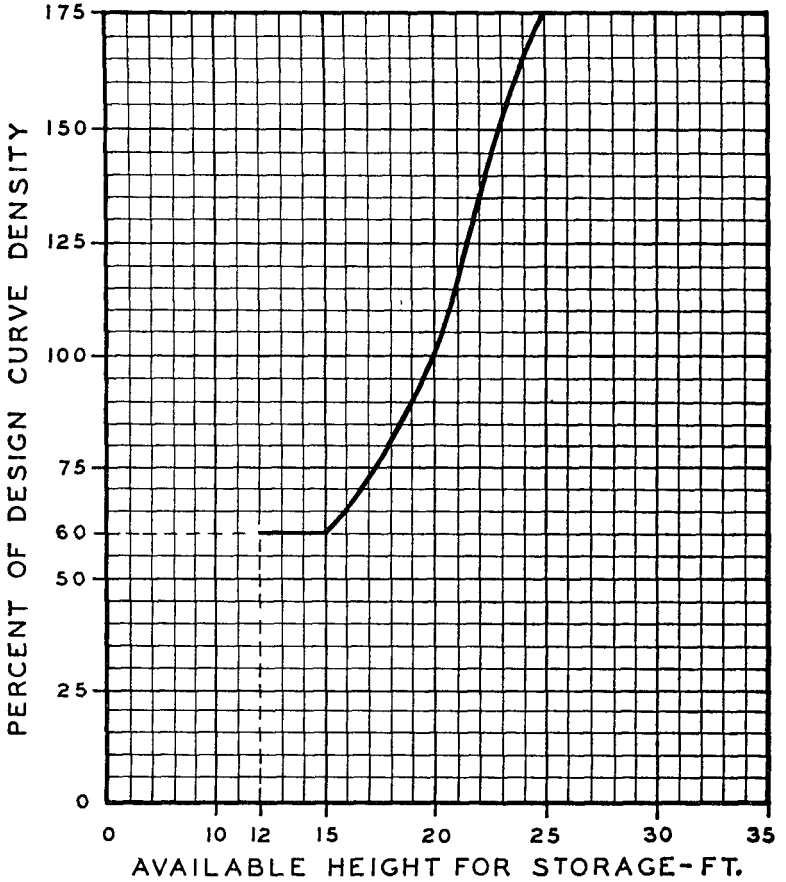


Fig. 4813

4814. The design curves indicate water demands for nominal 165°F and nominal 286°F sprinklers at the ceiling. The 165°F design curves shall be used for sprinklers with ordinary and intermediate temperature classification but not less than 160°F. The 286°F design curve shall be used for sprinklers with high temperature classification.

*4814a. When clearance from maximum height of storage to ceiling is less than 4½ feet (see 352), the sprinkler operating area indicated in curves E, F, G, and H in Figures 4811 a, b, c, d, e, f, and g can be reduced as indicated in Figure 4814A but not less than 2,000 square feet.

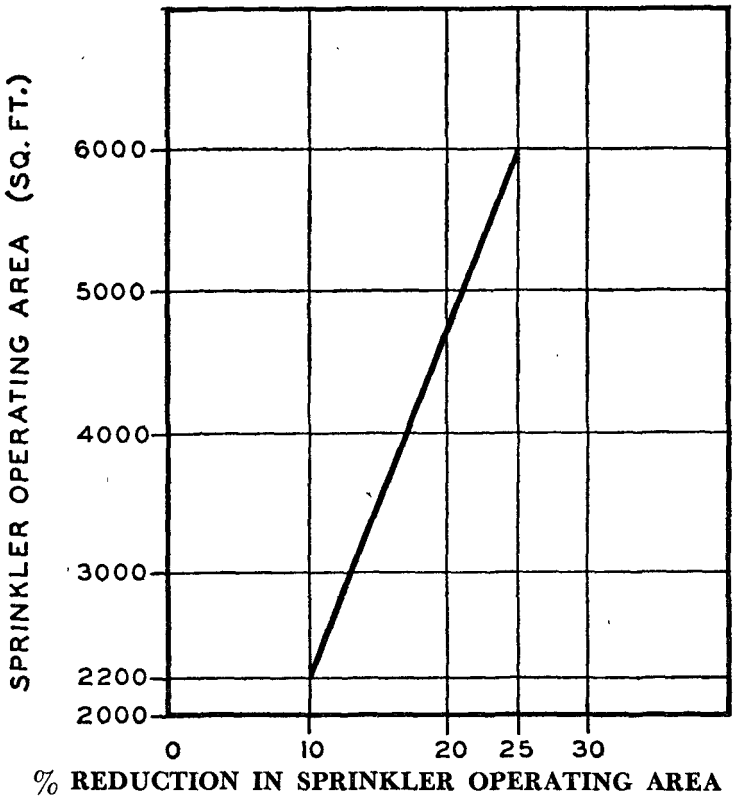


Fig. 4814a

482. Sprinklers in Racks

*4821. Sprinklers in racks shall discharge at not less than 15 psi for all classes of commodity with height of storage up to and including 25 feet and 30 psi with height of storage over 25 feet.

*4822. Water demand for sprinklers installed in racks shall be based on simultaneous operation of the most hydraulically remote:

a. 6 sprinklers when only one level is installed in racks with Class I, II or III commodity.

b. 8 sprinklers when only one level is installed in racks with Class IV commodity.

c. 10 sprinklers (5 on each two top levels) when more than one level is installed in racks with Class I, II or III commodity.

d. 14 sprinklers (7 on each two top levels) when more than one level is installed in racks with Class IV commodity.

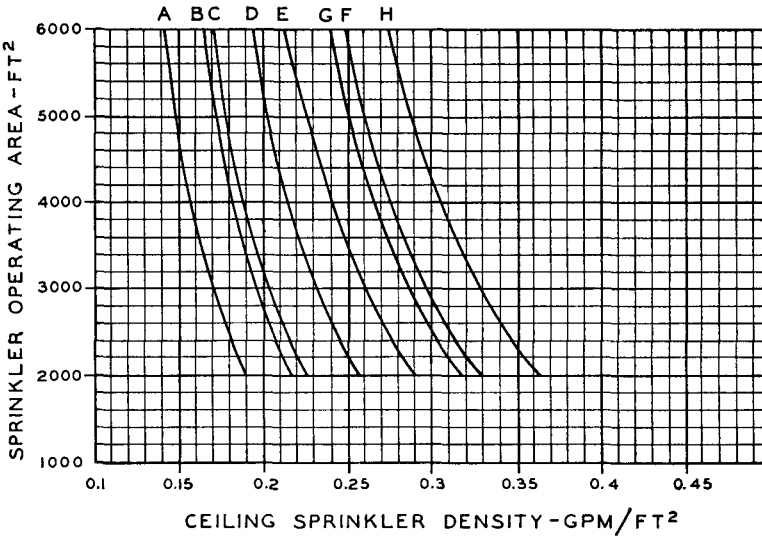
4823. Water demand of sprinklers installed in racks shall be added to ceiling sprinkler water demand at the point of connection.

483. Hose Streams

4831. For hose stream demand at least 500 gallons per minute shall be added to the sprinkler demand for Class I, II and III commodities and at least 750 gallons per minute shall be added for Class IV commodities.

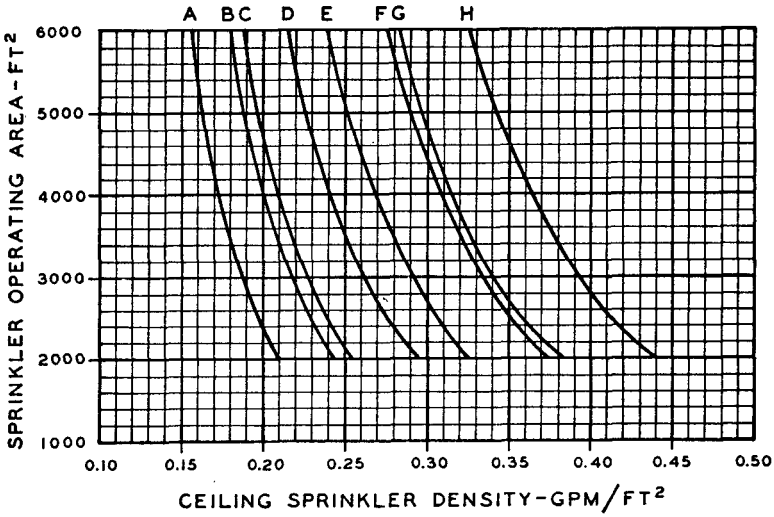
484. Duration of Water Supplies

*4841. For double row racks the water supply duration shall be at least 1½ hours for Class I, II and III Commodities and at least two hours for Class IV Commodities. For multiple row racks the water supply duration shall be at least two hours for all classifications of commodities.



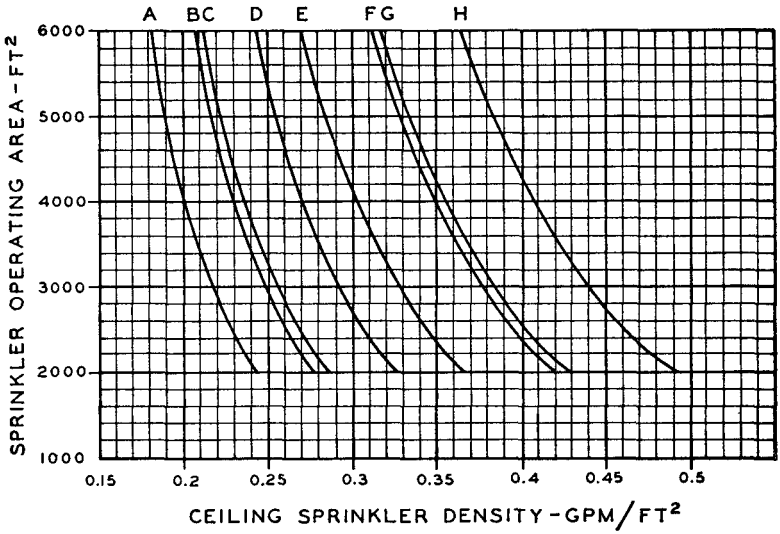
Curve	Legend
A	*8 ft. aisles with 286°F ceiling sprinklers and 165°F in-rack sprinklers*
B	*8 ft. aisles with 165°F ceiling sprinklers and 165°F in-rack sprinklers*
C	*4 ft. aisles with 286°F ceiling sprinklers and 165°F in-rack sprinklers*
D	*4 ft. aisles with 165°F ceiling sprinklers and 165°F in-rack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

Fig. 4811a. Double Row Racks — 20 Foot High Rack Storage — Sprinkler System Design Curves — Class I Nonencapsulated Commodities — Conventional Pallets.



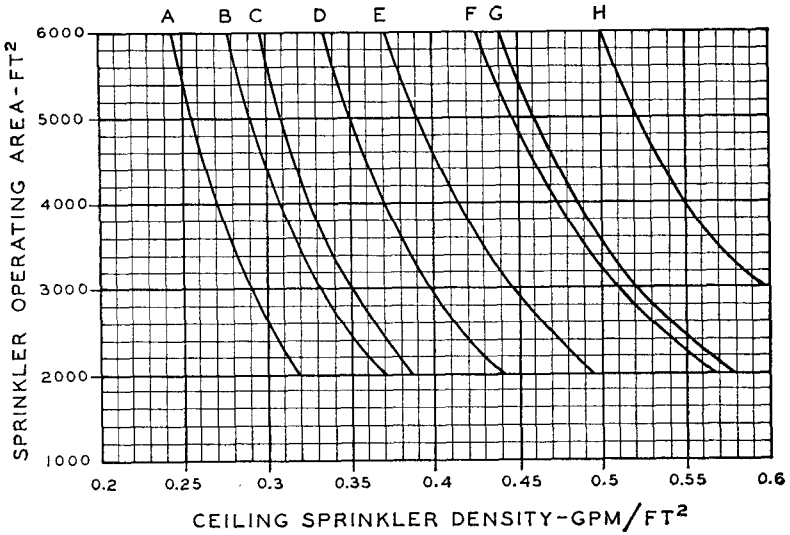
Curve	Legend
A	*8 ft. aisles with 286°F ceiling sprinklers and 165°F in-rack sprinklers*
B	*8 ft. aisles with 165°F ceiling sprinklers and 165°F in-rack sprinklers*
C	*4 ft. aisles with 286°F ceiling sprinklers and 165°F in-rack sprinklers*
D	*4 ft. aisles with 165°F ceiling sprinklers and 165°F in-rack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

Fig. 4811b. Double Row Racks — 20 Foot High Rack Storage — Sprinkler System Design Curves — Class II Nonencapsulated Commodities — Conventional Pallets.



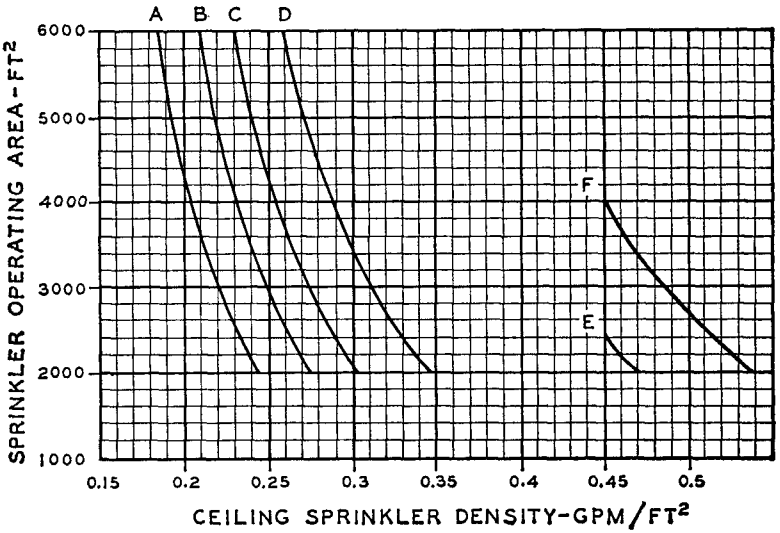
Curve	Legend
A	*8 ft. aisles with 286°F ceiling sprinklers and 165°F in-rack sprinklers*
B	*8 ft. aisles with 165°F ceiling and 165°F in rack sprinklers*
C	*4 ft. aisles with 286°F ceiling sprinklers and 165°F in-rack sprinklers*
D	*4 ft. aisles with 165°F ceiling sprinklers and 165°F in-rack sprinklers*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

Fig. 4811c. Double Row Racks — 20 Foot High Rack Storage — Sprinkler System Design Curves — Class III Nonencapsulated Commodities — Conventional Pallets.



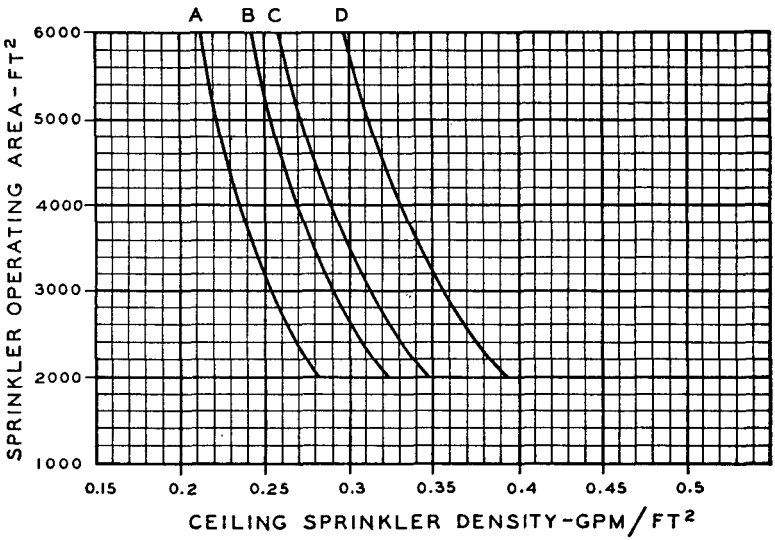
Curve	Legend
A	*8 ft. aisles with 286°F ceiling sprinklers and 165°F in-rack sprinklers*
B	*8 ft. aisles with 165°F ceiling sprinklers and 165°F in-rack sprinklers*
C	*4 ft. aisles with 286°F ceiling sprinklers and 165°F in-rack sprinklers*
D	*4 ft. aisles with 165°F ceiling sprinklers and 165°F in-rack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

Fig. 4811d. Double Row Racks — 20 Foot High Rack Storage — Sprinkler System Design Curves — Class IV Nonencapsulated Commodities — Conventional Pallets.



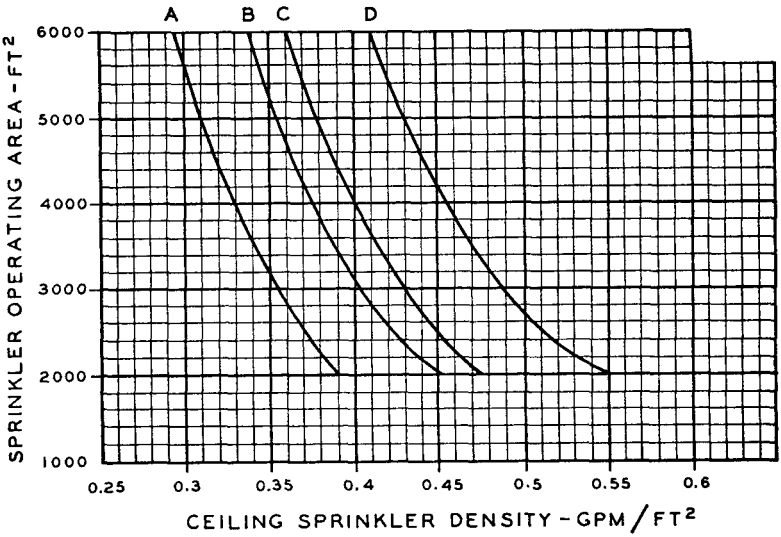
Curve	Legend
A	*8 ft. aisles with 286°F ceiling sprinklers and 165°F in-rack sprinklers*
B	*8 ft. aisles with 165°F ceiling sprinklers and 165°F in-rack sprinklers*
C	*4 ft. aisles with 286°F ceiling sprinklers and 165°F in-rack sprinklers*
D	*4 ft. aisles with 165°F ceiling sprinklers and 165°F in-rack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

Fig. 4811e. Double Row Racks — 20 Foot High Rack Storage — Sprinkler System Design Curves — Class I N II Encapsulated Commodities — Conventional Pallets.



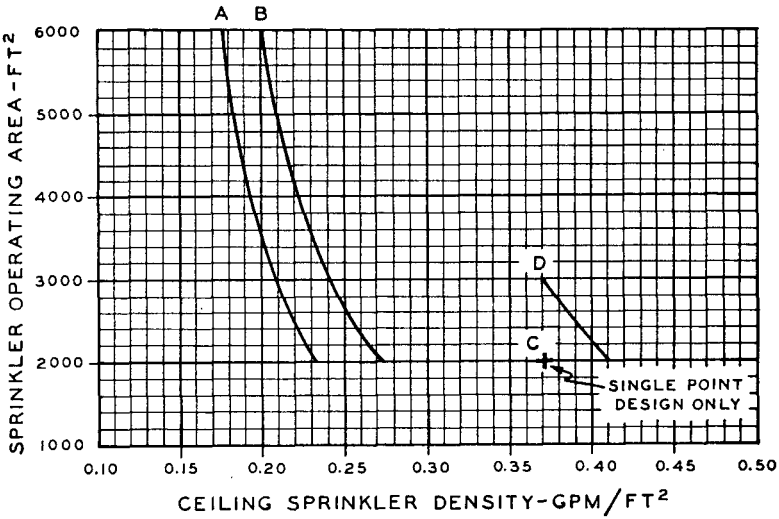
Curve	Legend
A	*8 ft. aisles with 286°F ceiling sprinklers and 165°F in-rack sprinklers*
B	*8 ft. aisles with 165°F ceiling sprinklers and 165°F in-rack sprinklers*
C	*4 ft. aisles with 286°F ceiling sprinklers and 165°F in-rack sprinklers*
D	*4 ft. aisles with 165°F ceiling sprinklers and 165°F in-rack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

Fig. 4811f. Double Row Racks — 20 Foot High Rack Storage — Sprinkler System Design Curves — Class III Encapsulated Commodities — Conventional Pallets.



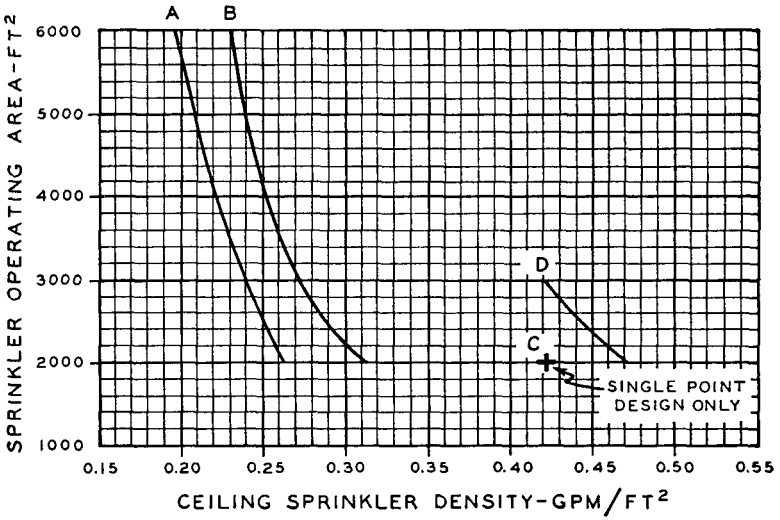
Curve	Legend
A	*— 8 ft. aisles with 286°F ceiling sprinklers and 165°F in-rack sprinklers*
B	*— 8 ft. aisles with 165°F ceiling sprinklers and 165°F in-rack sprinklers*
C	*— 4 ft. aisles with 286°F ceiling sprinklers and 165°F in-rack sprinklers*
D	*— 4 ft. aisles with 165°F ceiling sprinklers and 165°F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

Fig. 4811g. Double Row Racks — 20 Foot High Rack Storage — Sprinkler System Design Curves — Class IV Encapsulated Commodities — Conventional Pallets.



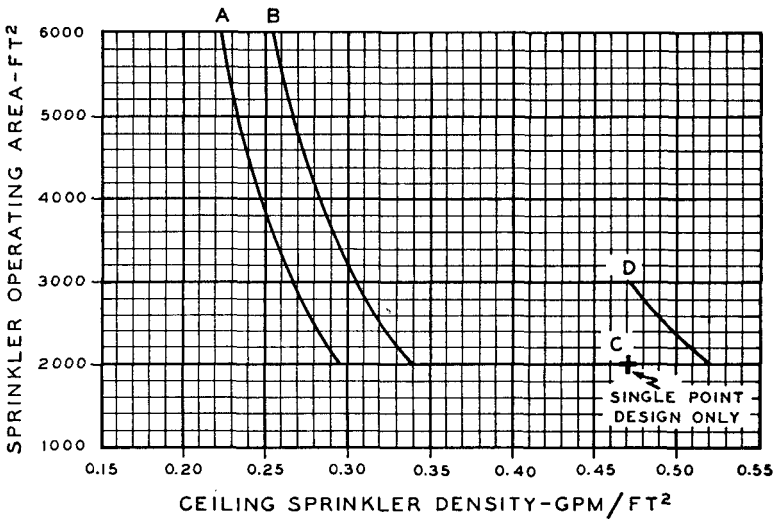
Curve	Legend
A	*8 ft. aisles with 286°F ceiling sprinklers and 165°F in-rack sprinklers*
B	*8 ft. aisles with 165°F ceiling sprinklers and 165°F in-rack sprinklers*
C	*8 ft. aisles with 286°F ceiling sprinklers*
D	*8 ft. aisles with 165°F ceiling sprinklers*

Fig. 4811h. Multiple Row Racks — 20 Foot High Rack Storage — Sprinkler System Curves Storage — Class I Nonencapsulated Commodities — Conventional Pallets.



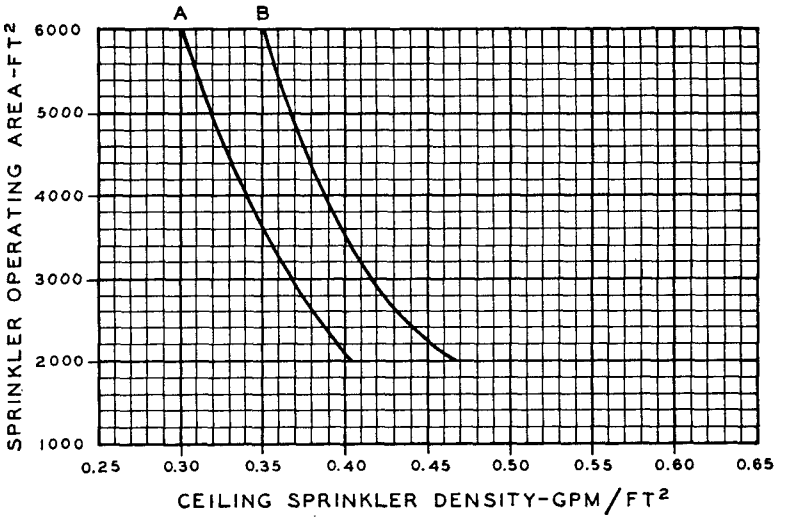
Curve	Legend
A	*8 ft. aisles with 286°F ceiling sprinklers and 165°F in-rack sprinklers*
B	*8 ft. aisles with 165°F ceiling sprinklers and 165°F in-rack sprinklers*
C	*8 ft. aisles with 286°F ceiling sprinklers*
D	*8 ft. aisles with 165°F ceiling sprinklers*

Fig. 4811i. Multiple Row Racks — 20 Foot High Rack Storage — Sprinkler System Design Curves — Class II 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	*8 ft. aisles with 286°F ceiling sprinklers*
D	*8 ft. aisles with 165°F ceiling sprinklers*

Fig. 4811j. Multiple Row Racks — 20 Foot High Rack Storage — Sprinkler System Design Curves — Class III Nonencapsulated Commodities — Conventional Pallets.



Curve	Legend	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*

Fig. 4811k. Multiple Row Racks — 20 Foot High Rack Storage — Sprinkler System Design Curves — Class IV Nonencapsulated Commodities — Conventional Pallets.

NOTE: Curves A and B also apply to ceiling sprinklers only for height of storage up to and including 15 feet and Fig. 4813 shall not be applied.

Chapter 5. Equipment

51. Mechanical Handling Equipment

511. Industrial Trucks

5111. Power-operated industrial trucks shall be of the type designated in Standard for Type Designations, Areas of Use, Maintenance and Operation of Powered Industrial Trucks, NFPA No. 505 — 1968, Part A, and their maintenance and operation shall be in accordance with NFPA No. 505, Parts B and C.

*5112. Industrial trucks using LP-gas or liquid fuel shall be refueled outside of the storage building at a location designated for that purpose.

Chapter 6. Building Maintenance and Operation

61. Building Operations Other Than Storage

611. 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 feet of the working area, and flame-proof tarpaulins enclose this section. During any of these operations the sprinkler system shall be in service. Two and one-half (2½) gallon 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 minutes additional.

62. Waste Disposal

***621.** Approved type containers for rubbish and other trash materials shall be provided.

63. Smoking

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

*64. Maintenance

641. Fire walls, fire doors, and floors shall be maintained in good repair at all times.

*65. Plant Emergency Organization

651. A fire watch shall be maintained when the sprinkler system is not in service.

*66. General Fire Protection

Appendix A. Introduction

A1. 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 feet x 250 feet (50,000 square feet in area), of fire-resistive construction, and contains a volume of approximately 2.25 million cubic feet, the equivalent of a 100,000 square foot building 22.5 feet high. The test building has two primary heights beneath a single large ceiling. The east section is 30 feet high and the west section is 60 feet high.

The 20 foot test series was conducted in the 30 foot section with clearances from top of storage to ceiling nominally 10 feet.

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 4,000 pound loads. Vertical members were 8 foot O.C. for conventional racks and 4 foot O.C., for simulated automated racks. Racks were 3½ feet wide with 6-inch longitudinal flue space for an overall width of 7½ feet. Simulated automated racks and slave pallets were used in the main central rack in the 4 foot aisle tests. Conventional racks and conventional pallets were used in the main central rack in the 8 foot aisle tests. The majority of the tests were conducted with 100 square foot sprinkler spacing.

The test configuration in the 15 foot, 20 foot, and 25 foot high tests covered an 1800 square foot 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 square feet, 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 foot high test series using the standard commodity.

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 & in racks)	8	144	4100
0.30	(Sprinklers at ceiling & in racks)	7	126	700

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 foot high test, a density of 0.55 gpm/square foot produced 42 percent or 756 square foot fire damage in the test array and a sprinkler wetted area of 1400 square feet. Lesser densities would not be expected to achieve the same limited degree of control. Therefore, if smaller areas of fire damage are to be achieved, sprinklers in racks should be considered.

The over-25 foot test series was conducted in the 60 foot section of the test building with nominal clearances from top of storage to ceiling of either 30 feet or 10 feet.

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 foot series was to:

1. Determine the arrangements 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 foot test rack. To aid in this judgment, control was considered achieved if the fire did not:

1. Jump the 4 foot 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 foot test series was used in the majority of over-25-foot tests. Hallmark products and 3M products described in the 20 foot report were also used as representative of Class III and/or IV commodities in several tests. The results of privately sponsored tests on Hallmark products and plastic encapsulated standard commodity were also made available to the committee.

A 25 foot long test array was used for the majority over-25-foot high test series. This decision was reached as it was felt that a fire in racks over 25 feet high which extended to the full length of a 50 foot 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 foot 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.) In the case of the 30 foot Hallmark Test 134 on the 60 foot 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 tests on the floor, a nominal 30 foot clearance occurred between top of storage and ceiling sprinklers, whereas on the platform this clearance was reduced to nominal 10 feet. 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 feet 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 foot 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 were noted in Tests 126 and 127. Here again, 30 foot 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 foot series indicates little effect of point of ignition in the particular configuration tested.

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

Chapter A1. Classification of Storage

A11. A review of full scale fire tests run on the standard commodity (double tri-wall carton with metal liner), Hallmark products and 3-M products (abrasives, pressure sensitive tapes of plastic fiber, and paper, etc.) as well as a review 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 A2. Building Construction

A221. None of the tests which were conducted with densities in accordance with the design curves produced critical temperatures in bar joists 12 feet 6 inches from the ignition source. Therefore, with sprinkler systems designed in accordance with the curves, fireproofing of roof steel is not necessary.

A222. Temperatures in the test column were maintained below 1,000°F in all tests where sprinklers in racks were used.

A223. Temperatures in the test column were maintained below 1,000°F with densities of roof ceiling sprinklers only of 0.375 gal. per minutes per square foot with 8 foot aisles and 0.45 gal. per square foot with 4 foot aisles using the standard commodity.

A231. Venting tests which were conducted as a part of the test program are not considered conclusive as to either the advantageous or detrimental effect of roof vents and draft curtains. Venting tests which have been conducted in other programs were without the benefit of sprinkler protection, and, as such, are not considered in this report which is dealing only with buildings protected by sprinklers. The design curves are based upon roof vents or draft curtains not being installed in the building. During mop-up operations, ventilating systems, where installed, should be capable of manual exhaust operations.

Chapter A3. Storage Arrangements

A311. 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 solid shelves. The standard commodity used in most of the tests was 42 inches on a side. Type of racks covered in this standard:

Conventional pallet racks — pallets rest on two beams parallel to the aisle. Any number of pallets can be supported by one pair of beams.

Automatic storage type rack — the pallet is supported by two rails running perpendicular to the aisle.

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 inches.

Solid shelving — conventional pallet rack with plywood shelves on the shelf beams. This is a special case (see Chapter 4).

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.

Pallet widths in conventional or automatic racks are considered a nominal 48 inches.

A321. 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.

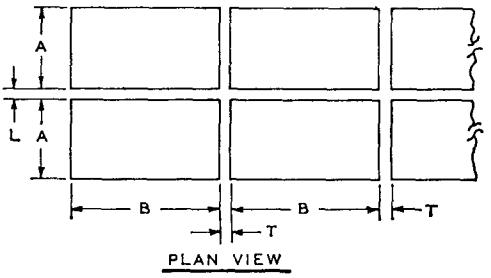
Where sprinklers are to be installed in racks, rack design should anticipate the additional clearances required to facilitate installation of sprinklers. The rack structure should be anchored to prevent damage to sprinkler lines and supply piping in racks.

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

A331. Test 80 was conducted to determine the effect of closing back-to-back longitudinal 6 inch flue space in conventional pallet

racks. Test results indicated fewer sprinklers operating than with the flue space open, and, as such, no minimum back-to-back clearance is necessary if the transverse flue space is maintained open.

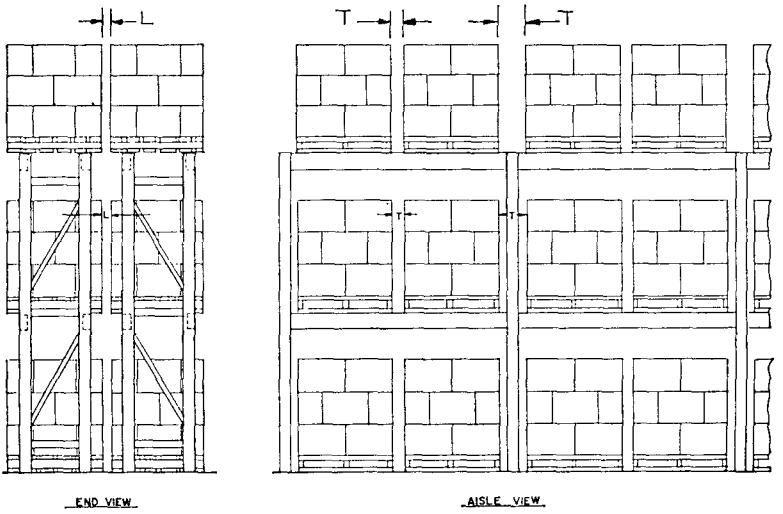
A352. Tests were conducted with deflector clearance of 10 feet to top of storage with no adverse effects.



Legend

A — Shelf Width
B — Shelf Length
L — Longitudinal Flue Space
T — Transverse Flue Space

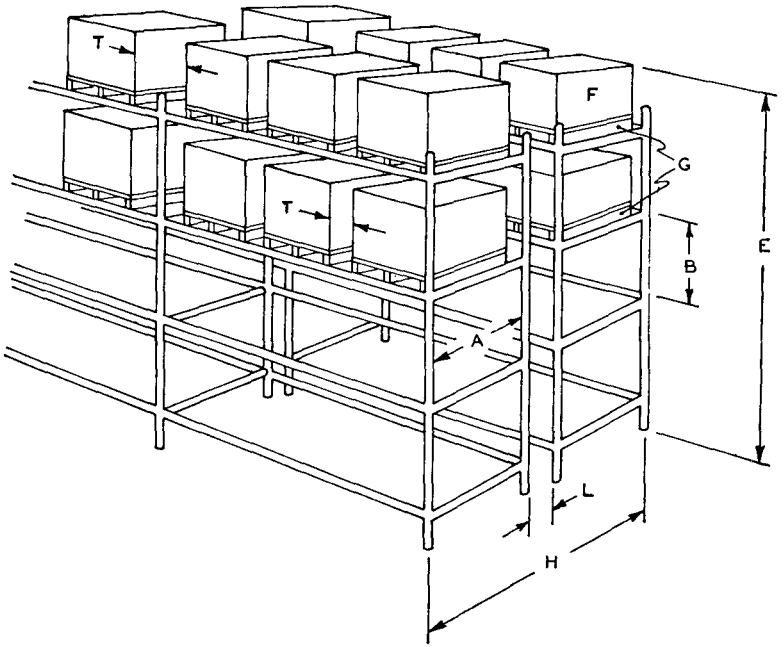
Fig. A332. Double Row Rack Solid Shelf Layout.



Legend

L — Longitudinal Flue Space
T — Transverse Flue Space

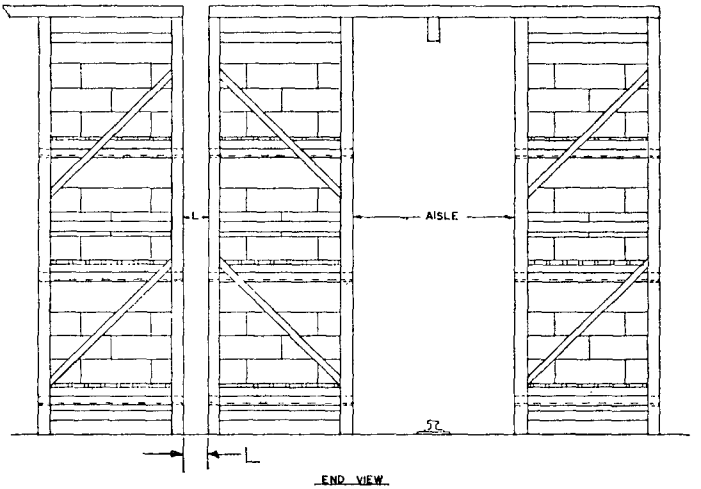
Fig. A3111a. Conventional Pallet Rack.

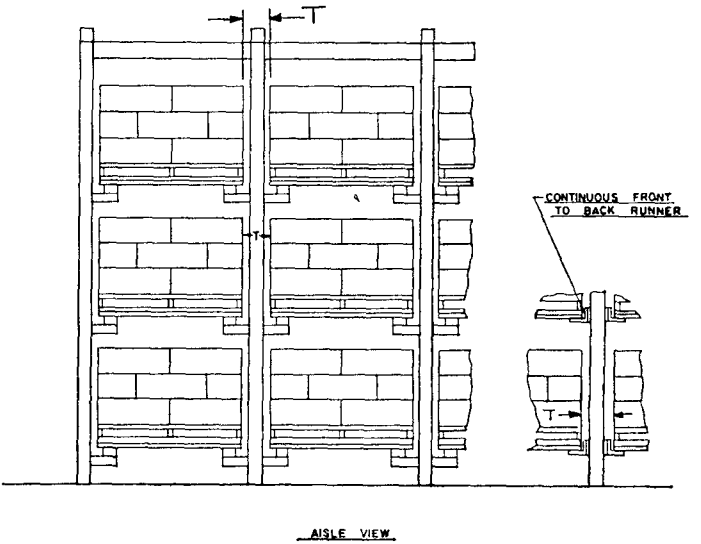


LEGEND

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

Fig. A3111b. Double Row Racks with Open Shelves.





Legend

L — Longitudinal Flue Space T — Transverse Flue Space

Fig. A3112. Automatic Storage Type Rack.