

STORAGE OF HANGING GARMENTS

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1.0 SCOPE

This data sheet provides fire protection recommendations for storage of hanging garments composed of natural, synthetic, or blends of natural and synthetic materials, with or without polyethylene (plastic) covers, on horizontal stationary pipe racks as well as revolving vertical storage modules (carousels).

Refer to Data Sheet 8-1, *Commodity Classification*, for the classification of boxed garments and Data Sheet 8-9, *Storage of Class 1, 2, 3, 4 and Plastic Commodities*, for the protection of boxed garments.

Refer to Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*, for installation guidelines for the sprinklers listed in this data sheet, as well as their compatibility with the facility's construction features.

The recommendations in this data sheet are intended for the design of new automatic sprinkler systems, or existing systems that are to be modified. To evaluate existing automatic sprinkler systems, or to determine whether new protection options based on recently FM Approved products and/or fire testing are a viable option to help lower their risk of loss, clients of FM can contact their local servicing office.

The fire protection recommendations in this data sheet are based on the results of full-scale fire testing, loss experience, and/or engineering judgment. Not every storage arrangement or protection option has been tested, nor has every potential solution been identified.

Before selecting one of the protection options in this data sheet for either a new building or a building being retrofitted with a protection system, consider the susceptibility of this type of occupancy to nonthermal damage. Ceiling-only protection options are available for some hanging garment storage arrangements; however, they generally require a large volume of sprinkler discharge and typically result in high nonthermal damage during a fire. Consider lowering the potential for nonthermal damage by providing protection for hanging garments whenever possible in the form of horizontal barriers in combination with quick-response sprinklers under these barriers, in accordance with this data sheet.

Note that the metric (SI) equivalent values in this data sheet are not based on strict mathematical conversion, but on design-desired values.

1.1 How to Use This Data Sheet

As with any data sheet, a complete understanding of the information in this document can only be achieved by a thorough review of its contents. However, to assist with the proper use of this data sheet, a flowchart has been created (see Figure 1). This flowchart represents the process for determining the proper design of an automatic sprinkler system that is intended to protect hanging garment storage, whether in a horizontal or vertical storage arrangement. Use this flowchart in combination with the text of this data sheet to determine all possible protection options.

1.2 Changes

October 2019. Interim revision. Minor editorial changes were made.

1.3 Superseded Information

This data sheet incorporates and supersedes the following engineering bulletins:

- 01-11, *Victaulic Company Model V4603, K25.2 (K360), Upright Sprinkler*
- 02-09, *Storage Type Sprinklers*
- 02-01, *Tyco Fire Products (Central, GEM and Star) Model EC-25 Control-Mode Extended-Coverage Sprinklers (SIN TY9128)*

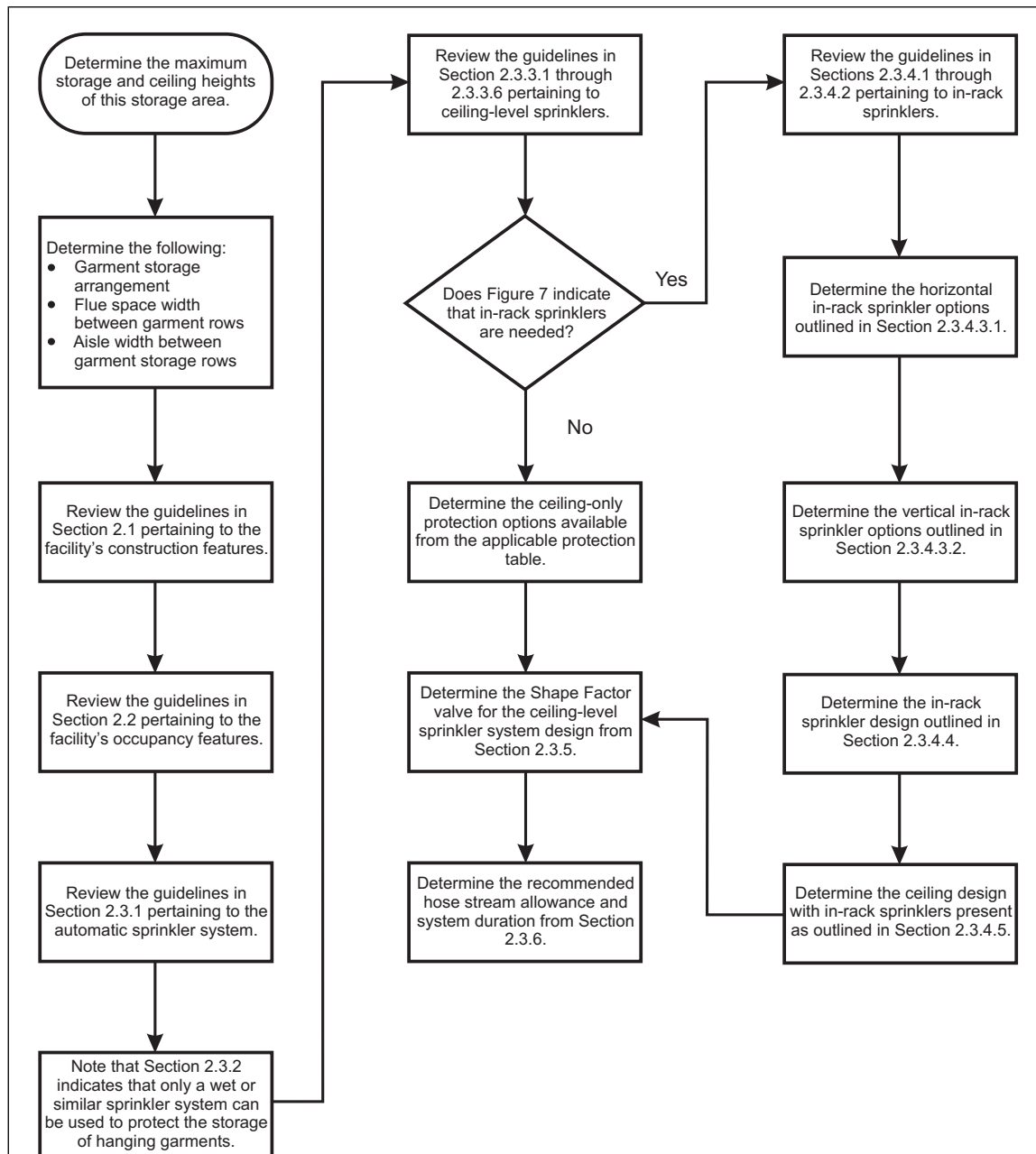


Fig. 1. Flowchart for determining the protection options for hanging garment storage

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Construction and Location

2.1.1 General

2.1.1.1 Construct storage facilities containing hanging garments in accordance with the relevant data sheets. See the 1-series data sheets for recommendations relevant to the construction features of most storage facilities. Pay particular attention to any walls and/or ceilings that will consist of plastic materials. See the recommendations in Data Sheet 1-57, *Plastics in Construction*, when such materials are present within the hanging garment storage area.

2.1.1.2 Adhere to the recommendations in the relevant data sheet to ensure the construction features of the facility are compatible with the storage sprinkler being used.

2.1.1.3 Properly anchor all hanging garment support structures to prevent them from toppling. Take into consideration the effects of support structure loads, the additional load created by the collection or absorption of fire protection water by the hanging garments, the weight of water-filled, in-rack sprinkler piping (if provided), and any seismic conditions (see Data Sheet 1-2, *Earthquakes*).

2.1.1.4 Design rack-supported structures taking into consideration the effects of weather (wind, snow, rain, hail, etc.), rack loads, seismic conditions (see Data Sheet 1-2, *Earthquakes*), and the additional load created by the collection or absorption of fire protection water by the hanging garments, the weight of water-filled sprinkler piping (from ceiling or in-rack sprinklers), and any other loads to which the rack or structure may be exposed.

2.1.1.5 See Section 2.2.1 of Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*, for recommendations related to the presence of items such as heat and/or smoke vents, draft curtains, etc.

2.1.2 Exposed Structural Steel Protection

Adhering to the design guidelines in this data sheet eliminates the need for additional protection of any exposed building structural steel due to fire exposure.

2.1.3 Ceiling Slope

2.1.3.1 Ceiling Slope up to 10°

The ceiling-level protection recommendations in Section 2.3.3 are applicable for a maximum ceiling slope of 10°.

2.1.3.2 Ceiling Slope Over 10° and up to 20°

When the ceiling over a hanging garment storage area will have a slope of more than 10° and but not more than 20°, implement one of the following protection options:

- A. Install a horizontal noncombustible false ceiling directly over and at least 15 ft (4.5 m) beyond the storage area. Design the false ceiling in accordance with Data Sheet 1-12, *Ceilings and Concealed Spaces*. Provide sprinklers under the false ceiling and design them in accordance with this data sheet based on the height above the floor over which the false ceiling has been installed.
- B. Limit the storage height to a maximum of 5 ft (1.5 m).
- C. Install in-rack sprinkler protection in accordance with Section 2.3.4, but limit the storage above the top level of in-rack sprinklers to a single tier of garments.

2.1.3.3 Ceiling Slope Over 20° (or Excessive Clearance per Section 2.3.4.5)

When the ceiling over a hanging garment storage area will have a slope of more than 20°, implement one of the following protection options:

- A. Install a horizontal noncombustible false ceiling directly over and at least 15 ft (4.5 m) beyond the storage area. Design the false ceiling in accordance with Data Sheet 1-12, *Ceilings and Concealed Spaces*. Provide sprinklers under the false ceiling and design them in accordance with this data sheet based on the height above the floor over which the false ceiling has been installed.
- B. Install in-rack sprinkler protection in accordance with Section 2.3.4, but maintain all hanging garment storage below the top level of in-rack sprinklers. Design the ceiling sprinklers for this affected area using Table 3 based on a storage height of 5 ft (1.5 m) and a ceiling height of 25 ft (7.5 m).

2.1.4 Openings in Solid Floors or Mezzanines Between Hanging Garment storage Areas

Avoid openings in solid floors or mezzanines between hanging garment storage areas whenever possible. When openings in solid floors cannot be avoided, protect against vertical fire spread from one hanging garment storage level to another by implementing both of the following recommendations:

- A. Install a minimum 2 ft (0.6 m) deep draft curtain around the perimeter of the opening, and

- B. Prevent storage below the vertical opening.

2.1.5 Open-Grated Mezzanines and/or Walkways

2.1.5.1 General

Avoid the installation of open-grated mezzanines and walkways in hanging garment storage areas. As an alternative, make mezzanines or walkways solid and provide sprinkler protection underneath them in accordance with Data Sheet 2-0. Base the design for the sprinklers installed under solid mezzanines in accordance with Section 2.1.6.1, or solid walkways in accordance with Section 2.1.6.2.

If open-grated mezzanines or walkways cannot be avoided, follow the recommendations in Section 2.1.5.2 for open-grated mezzanines and Section 2.1.5.3 for open-grated walkways.

2.1.5.2 Open-Grated Mezzanines

2.1.5.2.1 Install sprinklers directly under open-grated mezzanines when hanging garment storage is maintained under the mezzanine. Design and install the sprinklers under the mezzanine per the recommendations in Section 2.3.4 for in-rack sprinklers.

2.1.5.2.2 Sprinklers can be omitted from under open-grated mezzanines when all of the following conditions are met:

- A. There is no storage above the open-grated mezzanine, and
- B. The open-grated mezzanine is at least 70% open, and
- C. The ceiling sprinkler system can protect the hanging garment storage located below the open-grated mezzanine in the absence of the open grating

2.1.5.3 Open-Grated Walkways

A. Install 160°F (70°C) nominally rated quick-response sprinklers under an open-grated walkway on a maximum linear spacing of 8 ft (2.4 m) and on a maximum area spacing of 64 ft² (6 m²) if the walkway is wider than 10 ft (3.0 m). Base the design flow of the sprinklers under the open-grated walkway as follows:

1. If the vertical distance between walkways, or walkways and floor, is equal to or less than 10 ft (3.0 m): 30 gpm (115 L/min).
2. If the vertical distance between walkways, or walkways and floor, is greater than 10 ft (3.0 m): 60 gpm (230 L/min).

Base the number of sprinklers in the design on 3 sprinklers if only one level is provided, or 6 sprinklers (3 on the top two levels) if more than one level is provided.

The design for the sprinklers located under the open-grated walkway does not have to be hydraulically balanced with the ceiling-level system nor an adjacent in-rack sprinkler system, if provided.

B. Exception: Sprinklers are not necessary under an open-grated walkway when all of the following conditions are met (see Figure 2):

1. The open-grated walkway is a maximum 8 ft (2.4 m) wide, and
2. In-rack sprinkler protection is provided within the hanging garment storage array at the same level as the open-grated walkway, and
3. In-rack sprinklers closest to the open-grated walkway are no more than 18 in. (450 mm) horizontally from the face of the storage array.

2.1.6 Solid Mezzanines and/or Walkways

2.1.6.1 Solid Mezzanines

2.1.6.1.1 Provide sprinkler protection under a solid mezzanine having hanging garment storage below it in accordance with Section 2.3. Base the design of the sprinklers on the following:

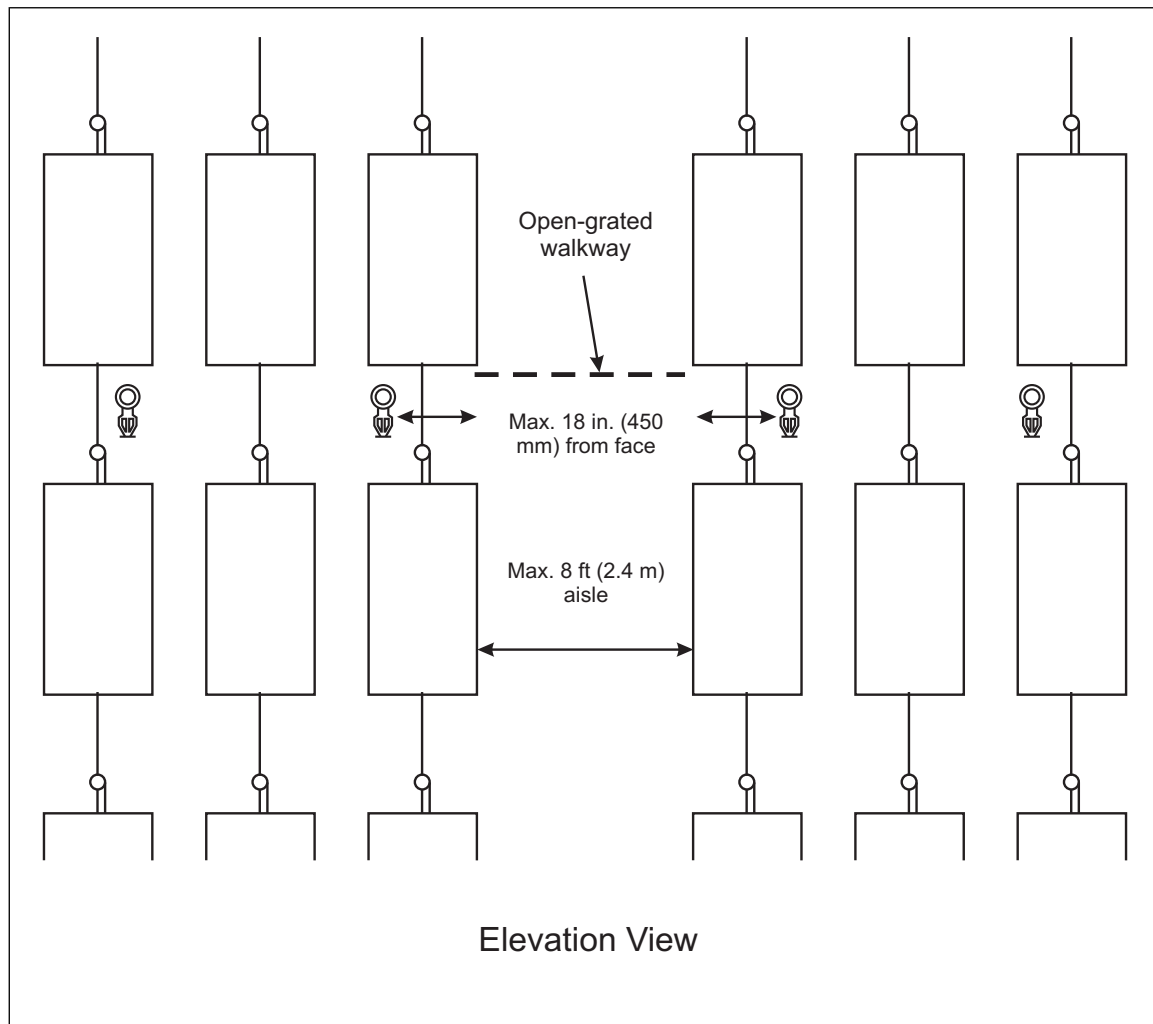


Fig. 2. Exception when sprinklers not necessary under open-rated walkway

A. When a minimum 3 ft (0.9 m) clearance is provided between the top of storage and the sprinkler deflector, follow the recommendations for a ceiling sprinkler system in Section 2.3.3.

B. When a minimum 3 ft (0.9 m) clearance is not provided between the top of storage and the sprinkler deflector, follow the recommendations for an in-rack sprinkler system in Section 2.3.4.

2.1.6.1.2 Sprinklers installed in accordance with Section 2.1.6.1.1 do not need to be hydraulically balanced with any sprinkler system located above the solid mezzanine if the edges of the solid mezzanine are equipped with a minimum 2 ft (0.6 m) deep draft curtain.

2.1.6.1.3 If the edges of the solid mezzanine are not equipped with a minimum 2 ft (0.6 m) deep draft curtain, ensure sprinklers are hydraulically balanced with any sprinkler system located above the solid mezzanine.

2.1.6.2 Solid Walkways

2.1.6.2.1 Provide sprinkler protection under a solid walkway located adjacent to hanging garment storage using the recommendations in Section 2.3.4 for in-rack sprinklers located under a horizontal barrier.

2.1.6.2.2 Base the design flow of the sprinklers under the solid walkway as follows:

A. If the vertical distance between walkways, or walkways and floor, is equal to or less than 10 ft (3.0 m), use 30 gpm (115 L/min).

B. If the vertical distance between walkways, or walkways and floor, is more than 10 ft (3.0 m), use 60 gpm (230 L/min).

Base the number of sprinklers in the design on the most remote three sprinklers on the most remote level.

2.1.6.2.3 Sprinklers installed in accordance with Sections 2.1.6.2.1 and 2.1.6.2.2 do not need to be hydraulically balanced with any sprinkler system located above the solid walkway nor an adjacent in-rack sprinkler system, if provided.

2.2 Occupancy

2.2.1 General

Storage arrangements vary among locations and usually consist of either "horizontal" or "vertical" hanging garment arrangements. Except for in Sections 2.2.4 and 2.3.4.1.7, the protection options in this data sheet do not distinguish between the two hanging garment storage arrangements and are applicable to both.

2.2.2 Commodity Hazard

2.2.2.1 The design recommendations in this data sheet address garments composed of natural, synthetic, or blends of natural and synthetic materials, with or without polyethylene (plastic) covers. For garments that are not stored in a hanging arrangement, see Data Sheet 8-1, Commodity Classification, and then Data Sheet 8-9, *Storage of Class 1, 2, 3, 4 and Plastic Commodities*.

2.2.2.2 When hanging garments are mixed in with other commodities within a rack arrangement (e.g., bottom two tiers of a storage rack are filled with hanging garments but the rest of the upper tiers are filled with cartoned commodities), provide in-rack sprinkler protection over the hanging garment storage in accordance with Section 2.3.4.

2.2.3 Clearance Between Top of storage and Sprinkler Deflector

2.2.3.1 Maintain a minimum 3 ft (0.9 m) clearance between the top of the hanging garment storage and the ceiling-level sprinkler deflectors. If a this is not possible, design and install the ceiling-level sprinklers as in-rack sprinklers in accordance with Section 2.3.4.

2.2.3.2 Except as noted in Section 2.3.4.3.1 for Figure 11, maintain a minimum 6 in. (150 mm) clearance between the top of the hanging garment storage and the in-rack sprinkler deflectors, when provided. For in-rack sprinkler installations in accordance with Section 2.3.4.3.1, maintain a minimum 18 in. (450 mm) clearance between the top of the hanging garment storage and the in-rack sprinkler deflectors.

2.2.4 Power Interlock for Rotating Carousel Type storage Systems

2.2.4.1 Interlock the power for vertical rotating carousel-type module motors to stop at the point of normal retrieval upon the operation of a sprinkler waterflow alarm.

2.2.4.2 Interlock the power for horizontal rotating carousel-type module motors to automatically stop upon the operation of a very early warning fire detection system.

2.2.5 Clearance Between the Floor and Hanging Garments

To help avoid potential water damage to hanging garments remote from a fire area, maintain a minimum clearance of 4 in. (100 mm) between the bottom of the hanging garments and the floor.

2.3 Protection

2.3.1 General

2.3.1.1 When choosing fire protection for a hanging garment storage facility, consider all the protection options the water supply can support. This approach will help maximize operational flexibility when considering potential future changes.

2.3.1.2 Regardless of the sprinkler system protection option chosen, it is imperative to coordinate a facility's construction, occupancy, and protection details in the planning stages so they are all compatible. It is critical

that no objects between the top of storage and the ceiling-level sprinklers interfere with the sprinkler's proper discharge pattern. See Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*, for recommendations related to obstruction of storage sprinklers.

2.3.1.3 In addition to the recommendations in this data sheet, follow the sprinkler installation recommendations for storage sprinklers in Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*, except as modified by this data sheet.

2.3.2 Sprinkler System Types

2.3.2.1 Install a wet-pipe sprinkler system (ceiling and/or in-rack) for the protection of hanging garment storage. If the ambient temperature of the area being protected will not support a wet-pipe system, install either an antifreeze solution sprinkler system (as permitted in Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*) or a single-interlocked, single-path-flow (i.e., not looped or gridded) pre-action sprinkler system that can be treated as a wet-pipe system for design purposes (see Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*).

2.3.2.2 See Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*, for additional recommendations related to the installation of all sprinkler system types.

2.3.2.3 See Data Sheet 5-48, *Automatic Fire Detection*, for recommendations related to the installation of detection devices when single-interlocked pre-action sprinkler systems are installed.

2.3.3 Ceiling-Level storage Sprinklers

2.3.3.1 General

2.3.3.1.1 FM Approved sprinklers for storage occupancy hazards and other similar high heat-release fires are listed in the *Approval Guide*, an online resource of FM Approvals, under the heading "Storage Sprinklers (Ceiling-Level)" or "Storage Sprinklers (In-Racks)." Use only FM Approved ceiling-level storage sprinklers for the protection of hanging garments as described in this section.

2.3.3.1.2 Follow the recommendations in Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*, for the installation of ceiling-level storage sprinklers.

2.3.3.2 K-Factors, Nominal Temperature Rating, RTI Rating, and the Orientation of Ceiling-Level storage Sprinklers

2.3.3.2.1 See Tables 1 and 2 for the recommended K-factors, nominal temperature ratings, response time index (RTI) ratings, and orientations of ceiling-level storage sprinklers protecting hanging garment storage.

2.3.3.2.2 Tables 1 and 2 recommend the use of 160°F (70°C) nominal temperature-rated, ceiling-level sprinklers in wet-pipe, antifreeze solution, or equivalent systems. Use 212°F (100°C) nominal temperature rated ceiling-level sprinklers when the ambient temperature will exceed 100°F (38°C). When 212°F (100°C) rated sprinklers are recommended due to ambient temperature conditions, treat their presence the same as 160°F (70°C) rated sprinklers for design purposes.

2.3.3.3 Spacing of Ceiling-Level storage Sprinklers

Install ceiling-level storage sprinklers on linear and area spacings in accordance with Table 17 and Section 2.2.3.2 of Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*.

2.3.3.4 Minimum Recommended Pressures for Ceiling-Level storage Sprinklers

The sprinkler system designs in this data sheet for ceiling-level sprinklers are based on an indicated minimum operating pressure for a given sprinkler K-factor as shown in Tables 1 and 2. As a result, base the minimum recommended ceiling-level sprinkler pressure on the value indicated in the applicable protection table for the storage height (see Appendix A for the definition of storage height) and ceiling height involved.

2.3.3.5 Extension of Hydraulic Design

Extend the hydraulic design for hanging garment storage occupancies at least 15 ft (4.5 m) beyond all edges of the storage, or to a wall, whenever there is mixed-use occupancy. Whenever two adjacent storage occupancies are protected differently, extend the design for the higher hazard a minimum of 15 ft (4.5 m) into the lower hazard area.

2.3.3.6 Ceiling-Only Protection Options

Ceiling-only sprinkler options are available when any open-grated flooring within the storage array is in accordance with Section 2.1.5.2.2, and any of the conditions in Table 1 are met.

Table 1. Determining Applicable Ceiling-Only Protection Table

Max. Storage Height, ft (m)	Max. Ceiling Height, ft (m)	Any Specific Conditions	Applicable Figure	Applicable Protection Table
5 (1.5)	45 (13.5)	None	3	2 or 3
15 (4.5)	30 (9.0)	Garment storage is max. 2 garment rows wide and separated by min. 3 ft (0.9 m) wide aisle	4	2
15 (4.5)	30 (9.0)	Flue spaces between hanging garment rows are min. 6 in. (150 mm) wide	5 or 6	3

If none of the conditions in Table 1 are met, or if open-grated flooring is not in accordance with Section 2.1.5.2.2, then in-rack sprinkler protection will be needed.

These guidelines are summarized in the flowchart found in Figure 7.

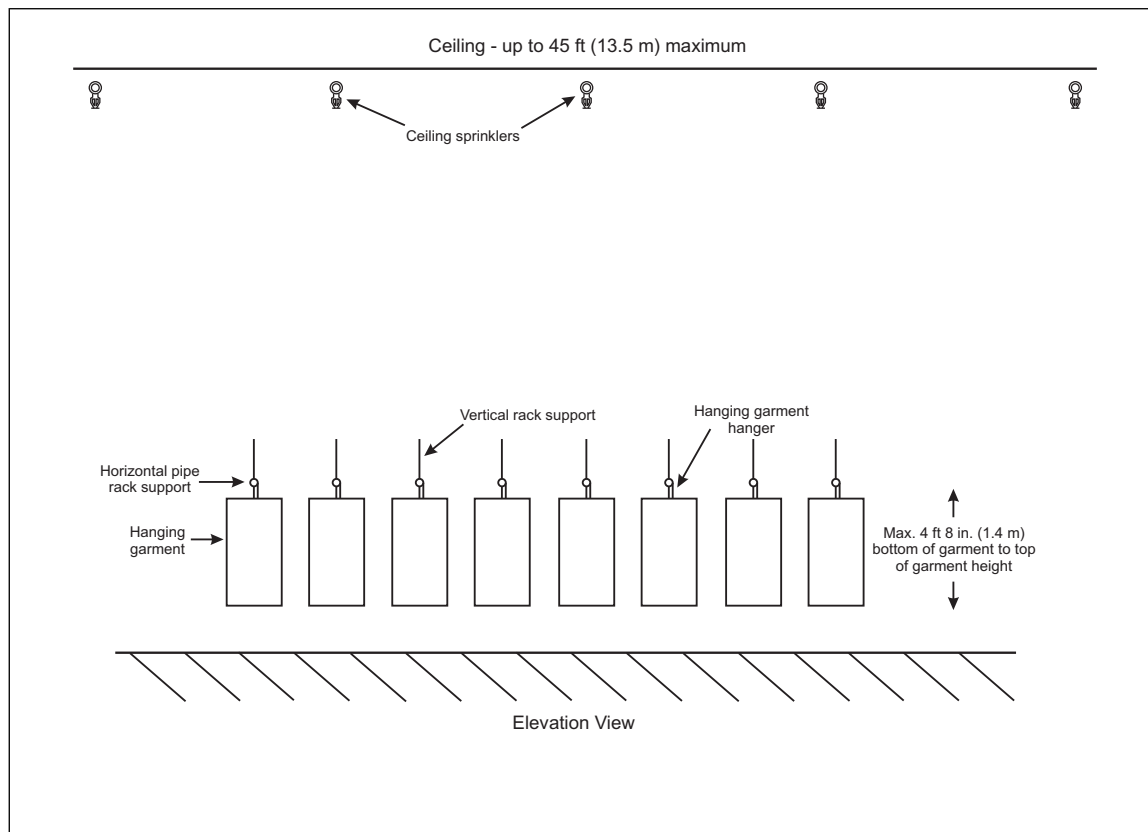


Fig. 3. Ceiling-only protection, maximum 45 ft (13.5 m) ceiling and maximum 5 ft (1.5 m) storage height

2.3.3.6.1 When Ceiling-Only Sprinkler Protection Options are Available

When the flowchart in Figure 7 indicates a ceiling-only protection option is available, see Section 2.3.3.7 to determine the acceptable ceiling-level designs based on the storage height, ceiling height, and storage arrangement of the hanging garment storage area.

2.3.3.6.2 When In-Rack Sprinkler Protection is Needed

When the flowchart in Figure 7 indicates in-rack sprinkler protection is needed, see Section 2.3.4.3 to determine the acceptable in-rack sprinkler arrangements, in-rack sprinkler designs, and the ceiling-level sprinkler designs that are recommended.

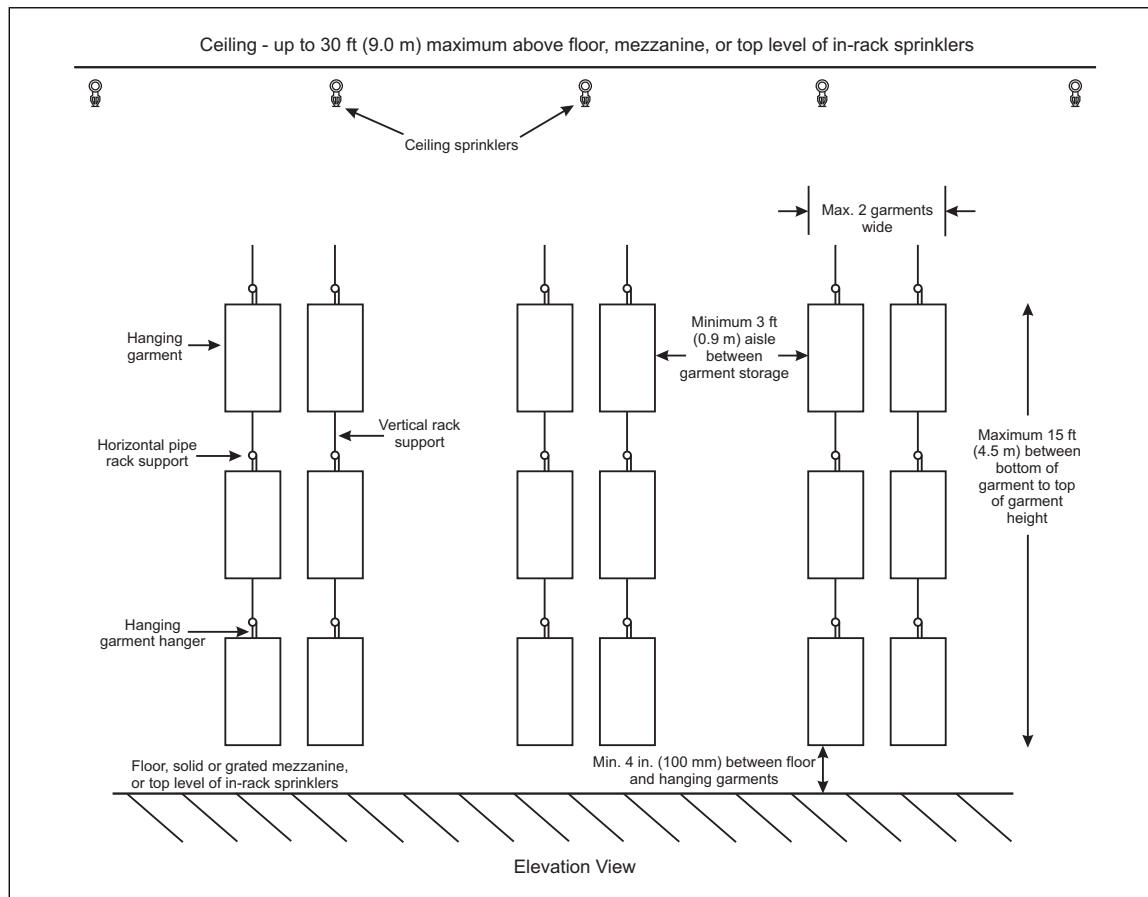


Fig. 4. Ceiling-only protection, maximum 30 ft (9.0 m) ceiling, maximum 15 ft (4.5 m) storage, maximum 2 garment wide rows, and minimum 3 ft (0.9 m) aisle (applies to Table 2)

2.3.3.7 Ceiling-Level Sprinkler System Design Criteria

2.3.3.7.1 The ceiling-level protection options in this data sheet are provided in Tables 1 and 2. See the flowchart in Figure 7 to determine if a ceiling-only protection option is a possibility.

The design recommendations for ceiling-level storage sprinklers are based on five main attributes assigned to a sprinkler. They are:

- K-factor (orifice size); the units for K-factor values given in Tables 1 and 2 are $\text{gpm}/\text{psi}^{0.5}$ ($[\text{L}/\text{min}]/\text{bar}^{0.5}$)
- Orientation (pendent or upright)
- Response time index rating (quick-response or standard-response)
- Nominal temperature rating
- Sprinkler spacing (standard or extended-coverage)

If Figure 7 indicates the ceiling protection must be supplemented with in-rack sprinklers, the storage and ceiling heights (see Appendix A for the definition of storage height) to be used for the ceiling design are indicated in Section 2.3.4.3, depending on the type of in-rack sprinkler arrangement chosen.

If Figure 7 indicates a ceiling-only protection option is available, the protection design options for the sprinkler system can be determined using the applicable protection table in combination with the five sprinkler attributes, once the storage height, ceiling height, and storage arrangement for the hanging garment storage area are known.

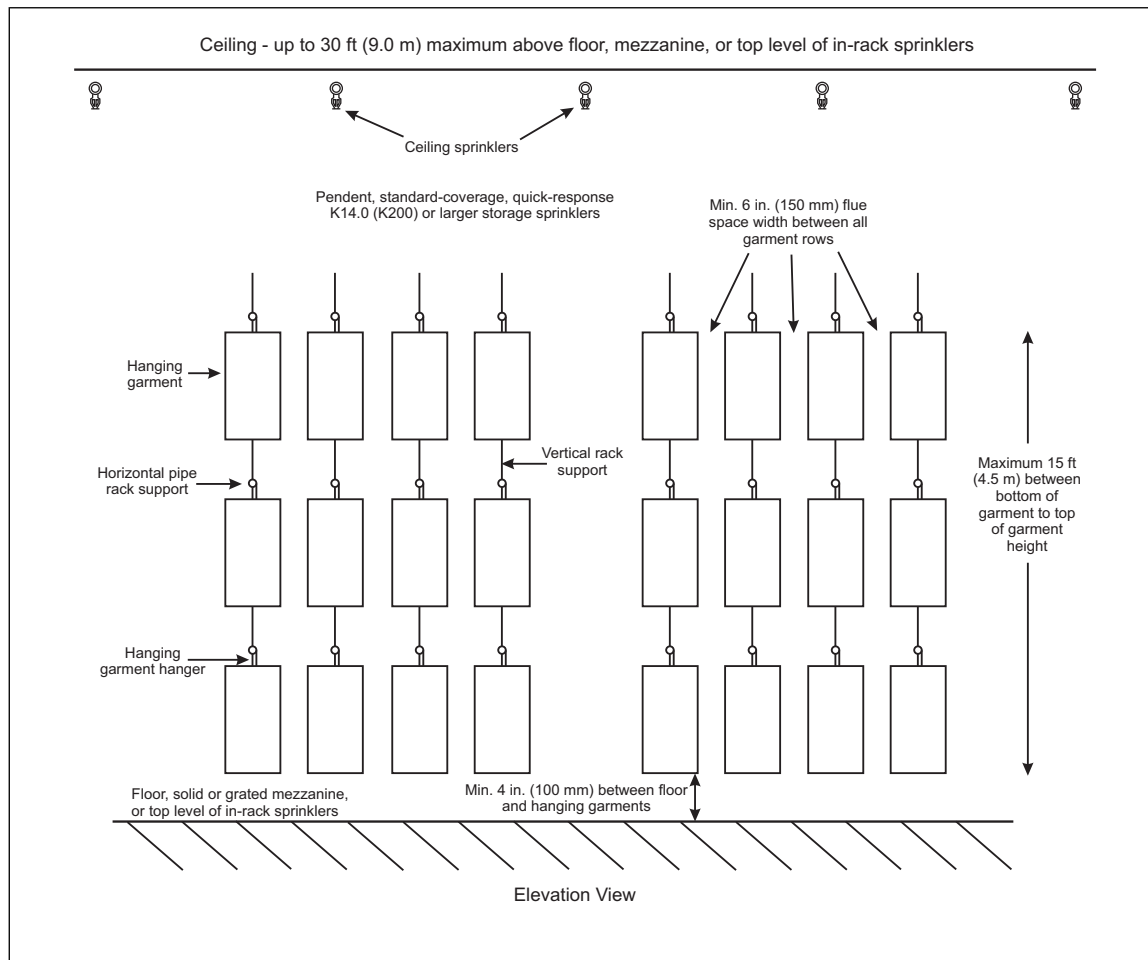


Fig. 5. Ceiling-only protection, maximum 30 ft (9.0 m) ceiling, maximum 15 ft (4.5 m) storage, and minimum 6 in. (150 mm) flue space between garment rows (applies to Table 3)

Once the protection options are obtained from the applicable protection table, see Section 2.3.5 to determine the shape factor value for the ceiling-level sprinkler system design, and Section 2.3.6 to determine the recommended hose stream allowance and system duration.

2.3.3.7.2 Do not interpolate or adjust the values listed in Tables 1 or 2.

2.3.3.7.3 The ceiling height and storage height values listed in Tables 1 and 2 represent a range of values up to and including the indicated number. For a given storage height and ceiling height, use the number in the applicable table that is either equal to or higher in value (e.g., if the storage height is 13 ft [3.9 m], then use the row indicated for 15 ft [4.5 m]).

2.3.3.7.4 Although Tables 1 and 2 use the number of sprinklers as a design format, ensure the size of the design area (i.e., number of sprinklers times sprinkler area spacing) is not less than 768 ft² (71 m²). If the size of the design area would be less than 768 ft² (71 m²) based on the number of sprinklers indicated in the protection table, increase the number of sprinklers in the design to make the design area a minimum of 768 ft² (71 m²).

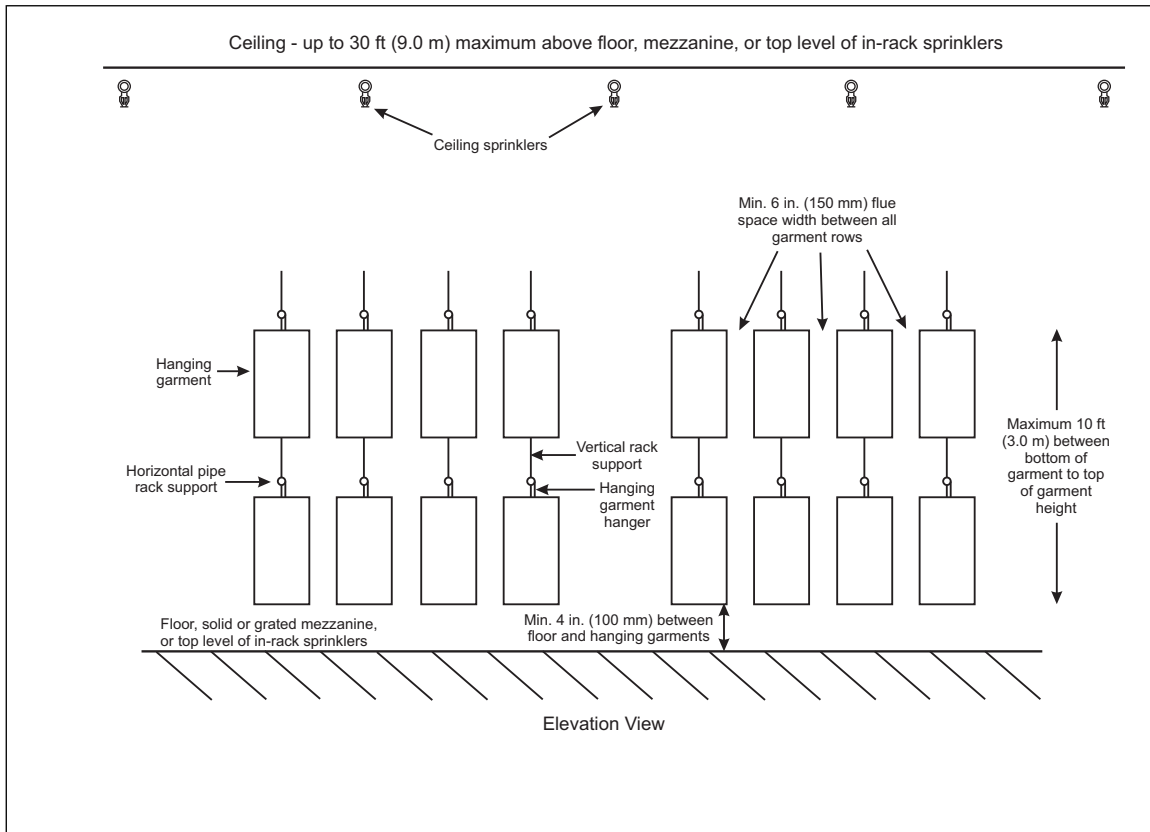


Fig. 6. Ceiling-only protection, maximum 30 ft (9.0 m) ceiling, maximum 10 ft (3.0 m) storage, and minimum 6 in. (150 mm) flue space between garment rows (applies to Table 3)

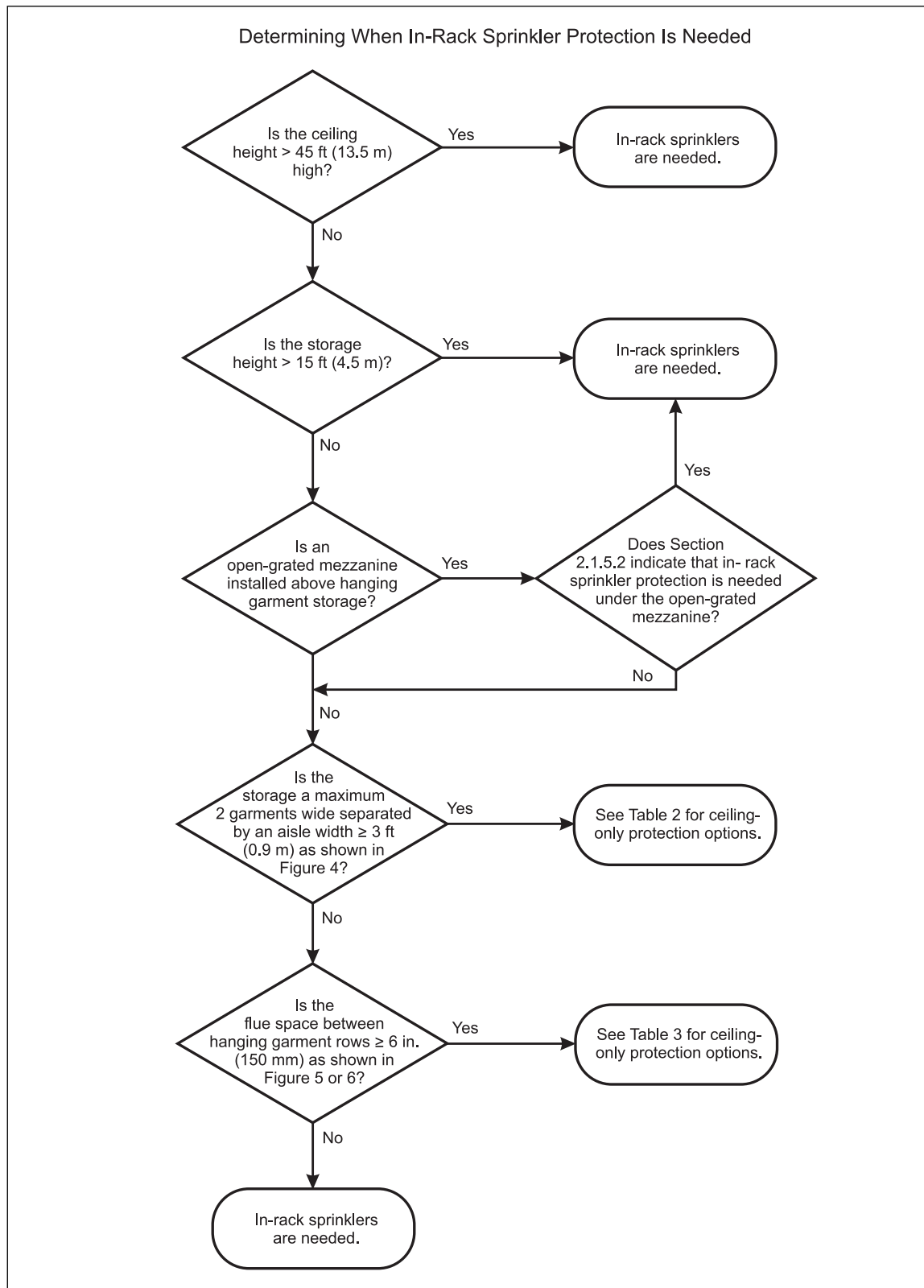


Fig. 7. Determining when in-rack sprinkler protection is needed

Table 2. Ceiling-Level Protection Guidelines for Hanging Garment Storage: Maximum Two Garment Rows Wide Separated by Minimum 3 ft (0.9 m) Wide Aisle

Protection Options for Hanging Garment Storage on a Wet or Equivalent Sprinkler System; No. of AS @ psi (bar)*																		
Max. Storage Height, ft (m)	Max. Ceiling Height, ft (m)	Pendent, Nominal 160°F (70°C) Rated										Upright, Nominal 160°F (70°C) Rated						
		Quick Response						Standard Response				Quick Response				Standard Response		
		K11.2 (K160)	K14.0 (K200)	K16.8 (K240)	K22.4 (K320)	K25.2 (K360)	K25.2EC (K360EC)	K11.2 (K160)	K14.0 (K200)	K19.6 (K280)**	K25.2 (K360)	K11.2 (K160)	K14.0 (K200)	K16.8 (K240)	K25.2EC (K360EC)	K11.2 (K160)	K16.8 (K240)	K25.2 (K360)
5 (1.5)	15 (4.5)	15 @ 7 (0.5)	12 @ 50 (3.5)	12 @ 35 (2.4)	12 @ 25 (1.7)	12 @ 20 (1.4)	7 @ 15 (1.0)	15 @ 7 (0.5)	15 @ 7 (0.5)	15 @ 16 (1.1)	15 @ 7 (0.5)	15 @ 7 (0.5)	12 @ 50 (3.5)	12 @ 35 (2.4)	7 @ 15 (1.0)	15 @ 7 (0.5)	15 @ 7 (0.5)	15 @ 7 (0.5)
	20 (6.0)	15 @ 25 (1.7)	12 @ 50 (3.5)	12 @ 35 (2.4)	12 @ 25 (1.7)	12 @ 20 (1.4)	7 @ 19 (1.3)	15 @ 25 (1.7)	15 @ 16 (1.1)	15 @ 16 (1.1)	15 @ 7 (0.5)	15 @ 25 (1.7)	12 @ 50 (3.5)	12 @ 35 (2.4)	7 @ 19 (1.3)	15 @ 25 (1.7)	15 @ 11 (0.8)	15 @ 7 (0.5)
	30 (9.0)	20 @ 25 (1.7)	12 @ 50 (3.5)	12 @ 35 (2.4)	12 @ 25 (1.7)	12 @ 20 (1.4)	10 @ 19 (1.3)	20 @ 25 (1.7)	20 @ 16 (1.1)	20 @ 16 (1.1)	20 @ 7 (0.5)	20 @ 25 (1.7)	12 @ 50 (3.5)	12 @ 35 (2.4)	10 @ 19 (1.3)	20 @ 25 (1.7)	20 @ 11 (0.8)	20 @ 7 (0.5)
	40 (12.0)		12 @ 75 (5.2)	12 @ 52 (3.6)	12 @ 29 (2.0)	12 @ 23 (1.6)												
	45 (13.5)				12 @ 50 (3.5)	12 @ 50 (3.5)												
10 (3.0)	15 (4.5)	15 @ 25 (1.7)	12 @ 50 (3.5)	12 @ 35 (2.4)	12 @ 25 (1.7)	12 @ 20 (1.4)	7 @ 19 (1.3)	15 @ 25 (1.7)	15 @ 16 (1.1)	15 @ 16 (1.1)	15 @ 7 (0.5)	15 @ 25 (1.7)	15 @ 16 (1.1)	15 @ 11 (0.8)	7 @ 19 (1.3)	15 @ 25 (1.7)	15 @ 11 (0.8)	15 @ 7 (0.5)
	20 (6.0)	20 @ 25 (1.7)	12 @ 50 (3.5)	12 @ 35 (2.4)	12 @ 25 (1.7)	12 @ 20 (1.4)	10 @ 19 (1.3)	20 @ 25 (1.7)	20 @ 16 (1.1)	20 @ 16 (1.1)	20 @ 7 (0.5)	20 @ 25 (1.7)	20 @ 16 (1.1)	20 @ 11 (0.8)	10 @ 19 (1.3)	20 @ 25 (1.7)	20 @ 11 (0.8)	20 @ 7 (0.5)
	25 (7.5)	20 @ 50 (3.5)	12 @ 75 (5.2)	12 @ 52 (3.6)	12 @ 29 (2.0)	12 @ 23 (1.6)	10 @ 38 (2.6)	20 @ 50 (3.5)	20 @ 32 (2.2)	20 @ 16 (1.1)	20 @ 10 (0.7)	20 @ 50 (3.5)	20 @ 32 (2.2)	20 @ 22 (1.5)	10 @ 38 (2.6)	20 @ 50 (3.5)	20 @ 22 (1.5)	20 @ 10 (0.7)
	30 (9.0)	25 @ 50 (3.5)	12 @ 75 (5.2)	12 @ 52 (3.6)	12 @ 29 (2.0)	12 @ 23 (1.6)	12 @ 38 (2.6)	25 @ 50 (3.5)	25 @ 32 (2.2)	25 @ 16 (1.1)	25 @ 10 (0.7)	25 @ 50 (3.5)	25 @ 32 (2.2)	25 @ 22 (1.5)	12 @ 38 (2.6)	25 @ 50 (3.5)	25 @ 22 (1.5)	25 @ 10 (0.7)
15 (4.5)	20 (6.0)	15 @ 50 (3.5)	12 @ 50 (3.5)	12 @ 35 (2.4)	12 @ 25 (1.7)	12 @ 20 (1.4)	7 @ 38 (2.6)	15 @ 50 (3.5)	15 @ 32 (2.2)	15 @ 16 (1.1)	15 @ 10 (0.7)	15 @ 50 (3.5)	15 @ 32 (2.2)	15 @ 22 (1.5)	7 @ 38 (2.6)	15 @ 50 (3.5)	15 @ 22 (1.5)	15 @ 10 (0.7)
	25 (7.5)	20 @ 50 (3.5)	12 @ 75 (5.2)	12 @ 52 (3.6)	12 @ 29 (2.0)	12 @ 23 (1.6)	10 @ 38 (2.6)	20 @ 50 (3.5)	20 @ 32 (2.2)	20 @ 16 (1.1)	20 @ 10 (0.7)	20 @ 50 (3.5)	20 @ 32 (2.2)	20 @ 22 (1.5)	10 @ 38 (2.6)	20 @ 50 (3.5)	20 @ 22 (1.5)	20 @ 10 (0.7)
	30 (9.0)	30 @ 50 (3.5)	12 @ 75 (5.2)	12 @ 52 (3.6)	12 @ 29 (2.0)	12 @ 23 (1.6)	15 @ 38 (2.6)	30 @ 50 (3.5)	30 @ 32 (2.2)	30 @ 16 (1.1)	30 @ 10 (0.7)	30 @ 50 (3.5)	30 @ 32 (2.2)	30 @ 22 (1.5)	15 @ 38 (2.6)	30 @ 50 (3.5)	30 @ 22 (1.5)	30 @ 10 (0.7)

* See the flowchart in Figure 7 to determine if in-rack sprinklers are needed

** The current minimum allowable design pressure is 16 psi (1.1 bar)

Table 3. Ceiling-Level Protection Guidelines for Hanging Garment Storage: Minimum 6 in. (150 mm) Wide Flue Space Between Garment Rows

Protection Options for Hanging Garment Storage on a Wet or Equivalent Sprinkler System; No. of AS @ psi (bar)*																		
Max. Storage Height, ft (m)	Max. Ceiling Height, ft (m)	Pendent, Nominal 160°F (70°C) Rated										Upright, Nominal 160°F (70°C) Rated						
		Quick Response						Standard Response				Quick Response				Standard Response		
		K11.2 (K160)	K14.0 (K200)	K16.8 (K240)	K22.4 (K320)	K25.2 (K360)	K25.2EC (K360EC)	K11.2 (K160)	K14.0 (K200)	K19.6 (K280)**	K25.2 (K360)	K11.2 (K160)	K14.0 (K200)	K16.8 (K240)	K25.2EC (K360EC)	K11.2 (K160)	K16.8 (K240)	K25.2 (K360)
5 (1.5)	15 (4.5)	15 @ 7 (0.5)	12 @ 50 (3.5)	12 @ 35 (2.4)	12 @ 25 (1.7)	12 @ 20 (1.4)	7 @ 15 (1.0)	15 @ 7 (0.5)	15 @ 7 (0.5)	15 @ 16 (1.1)	15 @ 7 (0.5)	15 @ 7 (0.5)	12 @ 50 (3.5)	12 @ 35 (2.4)	7 @ 15 (1.0)	15 @ 7 (0.5)	15 @ 7 (0.5)	15 @ 7 (0.5)
	20 (6.0)	15 @ 25 (1.7)	12 @ 50 (3.5)	12 @ 35 (2.4)	12 @ 25 (1.7)	12 @ 20 (1.4)	7 @ 19 (1.3)	15 @ 25 (1.7)	15 @ 16 (1.1)	15 @ 16 (1.1)	15 @ 7 (0.5)	15 @ 25 (1.7)	12 @ 50 (3.5)	12 @ 35 (2.4)	7 @ 19 (1.3)	15 @ 25 (1.7)	15 @ 11 (0.8)	15 @ 7 (0.5)
	30 (9.0)	20 @ 25 (1.7)	12 @ 50 (3.5)	12 @ 35 (2.4)	12 @ 25 (1.7)	12 @ 20 (1.4)	10 @ 19 (1.3)	20 @ 25 (1.7)	20 @ 16 (1.1)	20 @ 16 (1.1)	20 @ 7 (0.5)	20 @ 25 (1.7)	12 @ 50 (3.5)	12 @ 35 (2.4)	10 @ 19 (1.3)	20 @ 25 (1.7)	20 @ 11 (0.8)	20 @ 7 (0.5)
	40 (12.0)		12 @ 75 (5.2)	12 @ 52 (3.6)	12 @ 29 (2.0)	12 @ 23 (1.6)												
	45 (13.5)				12 @ 50 (3.5)	12 @ 50 (3.5)												
10 (3.0)	15 (4.5)	15 @ 25 (1.7)	12 @ 50 (3.5)	12 @ 35 (2.4)	12 @ 25 (1.7)	12 @ 20 (1.4)	7 @ 19 (1.3)	15 @ 25 (1.7)	15 @ 16 (1.1)	15 @ 16 (1.1)	15 @ 7 (0.5)	15 @ 25 (1.7)	15 @ 16 (1.1)	15 @ 11 (0.8)	7 @ 19 (1.3)	15 @ 25 (1.7)	15 @ 11 (0.8)	15 @ 7 (0.5)
	20 (6.0)	20 @ 25 (1.7)	12 @ 50 (3.5)	12 @ 35 (2.4)	12 @ 25 (1.7)	12 @ 20 (1.4)	10 @ 19 (1.3)	20 @ 25 (1.7)	20 @ 16 (1.1)	20 @ 16 (1.1)	20 @ 7 (0.5)	20 @ 25 (1.7)	20 @ 16 (1.1)	20 @ 11 (0.8)	10 @ 19 (1.3)	20 @ 25 (1.7)	20 @ 11 (0.8)	20 @ 7 (0.5)
	25 (7.5)	20 @ 50 (3.5)	12 @ 75 (5.2)	12 @ 52 (3.6)	12 @ 29 (2.0)	12 @ 23 (1.6)	10 @ 38 (2.6)	20 @ 50 (3.5)	20 @ 32 (2.2)	20 @ 16 (1.1)	20 @ 10 (0.7)	20 @ 50 (3.5)	20 @ 32 (2.2)	20 @ 22 (1.5)	10 @ 38 (2.6)	20 @ 50 (3.5)	20 @ 22 (1.5)	20 @ 10 (0.7)
	30 (9.0)	25 @ 50 (3.5)	12 @ 75 (5.2)	12 @ 52 (3.6)	12 @ 29 (2.0)	12 @ 23 (1.6)	12 @ 38 (2.6)	25 @ 50 (3.5)	25 @ 32 (2.2)	25 @ 16 (1.1)	25 @ 10 (0.7)	25 @ 50 (3.5)	25 @ 32 (2.2)	25 @ 22 (1.5)	12 @ 38 (2.6)	25 @ 50 (3.5)	25 @ 22 (1.5)	25 @ 10 (0.7)
15 (4.5)	20 (6.0)		12 @ 50 (3.5)	12 @ 35 (2.4)	12 @ 25 (1.7)	12 @ 20 (1.4)												
	25 (7.5)		12 @ 75 (5.2)	12 @ 52 (3.6)	12 @ 29 (2.0)	12 @ 23 (1.6)												
	30 (9.0)		12 @ 75 (5.2)	12 @ 52 (3.6)	12 @ 29 (2.0)	12 @ 23 (1.6)												

* See the flowchart in Figure 7 to determine if in-rack sprinklers are needed

** The current minimum allowable design pressure is 16 psi (1.1 bar)

2.3.4 In-Rack Sprinklers (IRAS)

2.3.4.1 General

Protection options for hanging garment storage arrangements are based on ceiling-only sprinkler systems, or a combination of ceiling-level and in-rack sprinkler systems. The need for in-rack sprinkler protection is dependent on several parameters including storage height (see Appendix A for the definition of storage height), ceiling height, aisle width, the width of the flue spaces between garments, the number of hanging garment rows between aisles and the available water supply.

When in-rack sprinklers are needed per Figure 7, they can be used in combination with any of the ceiling sprinklers listed in the applicable protection tables in Section 2.3.4.3.

2.3.4.1.1 When in-rack sprinklers are needed as a supplement to ceiling-level sprinklers, use FM Approved in-rack sprinklers listed in the *Approval Guide*, an online resource of FM Approvals, under the heading of "Storage Sprinklers (In-Racks)."

2.3.4.1.2 If in-rack sprinklers are recommended per Figure 7 for the hanging garment storage arrangement, see Section 2.3.4.3 for the acceptable in-rack sprinkler arrangements, Section 2.3.4.4 for their recommended designs, and Section 2.3.4.5 for the corresponding ceiling design with the in-rack sprinkler arrangement present.

2.3.4.1.3 Provide a minimum clear space of 6 in. (150 mm) between the top of the hanging garment storage and the in-rack sprinkler deflector.

2.3.4.1.4 Arrange sprinkler piping and in-rack sprinklers to avoid interruption to hanging garment handling and mechanical damage, but ensure proper distribution from the in-rack sprinkler can be achieved. Prior to installing in-rack sprinklers, check the proposed in-rack sprinkler locations to ensure these conditions will be met.

2.3.4.1.5 Unless indicated otherwise, ensure the minimum design pressure of the in-rack sprinklers is 7 psi (0.5 bar).

2.3.4.1.6 Unless indicated otherwise in other sections of this data sheet, balance the in-rack sprinkler system water demand with the ceiling-level sprinkler water demand at the point where the two systems are connected.

2.3.4.1.7 When in-rack sprinklers are provided to protect vertical carousel-type storage systems, locate the in-rack sprinklers vertically so that when the conveyor is stopped at the point of normal retrieval, the in-rack sprinkler deflectors are in line with the clear space between tiers.

2.3.4.2 K-Factors, Nominal Temperature Rating, and RTI Rating of In-Rack storage Sprinklers

2.3.4.2.1 Use nominally rated 160°F (70°C) FM Approved storage in-rack sprinklers for all in-rack sprinkler installations.

2.3.4.2.2 Use in-rack sprinklers listed as quick-response when installing K14.0 (K200) or smaller sprinklers. Unless indicated otherwise, in-rack sprinklers larger than K14.0 (K200) can be either quick-response or standard-response.

2.3.4.2.3 Use a minimum K8.0 (K115) sprinkler for in-rack sprinkler design flows greater than 30 gpm (115 L/min).

2.3.4.2.4 Use a minimum quick-response K14.0 (K200) pendent sprinkler for in-rack sprinkler design flows of more than 60 gpm (230 L/min).

2.3.4.3 In-Rack Sprinkler Arrangements

If in-rack sprinklers are recommended per Figure 7, use the following procedure to determine the recommended protection for both the ceiling and in-rack sprinkler systems:

1. Determine the available horizontal in-rack sprinkler arrangements per Section 2.3.4.3.1.
2. Determine the available vertical increments between in-rack sprinkler levels per Section 2.3.4.3.2.
3. Determine the in-rack sprinkler system design guidelines per Section 2.3.4.4.

4. Determine the ceiling-level sprinkler system design guidelines when supplemented with in-rack sprinklers per Section 2.3.4.5.
5. Determine the shape factor value for the ceiling-level sprinkler system design per Section 2.3.5.
6. Determine the hose demand and duration for the combined ceiling-level and in-rack sprinkler system per Section 2.3.6.

2.3.4.3.1 Horizontal In-Rack Sprinkler Arrangements

When in-rack sprinkler protection is recommended per Figure 7, install in-rack sprinklers as follows:

- A. Maximum 4 ft (1.2 m) horizontal linear spacing for storage that is up to two hanging garment rows wide as shown in Figure 8.
- B. Maximum 4 ft (1.2 m) horizontal linear spacing and maximum 16 ft² (1.5 m²) area spacing for storage that is more than two hanging garment rows wide as shown in Figure 9.
- C. Maximum 8 ft (2.4 m) horizontal linear and maximum 64 ft² (6.0 m²) area spacing when both of the following are true:
 1. A horizontal barrier is provided over the hanging garment storage array as shown in Figure 10 for storage up to two hanging garment rows wide or Figure 11 for storage wider than two hanging garment rows, and
 2. A minimum clearance of 18 in. (450 mm) is provided between the top of storage and the in-rack sprinkler deflector.

Construct the horizontal barrier of either minimum 22 ga (0.75 mm) sheet metal (preferred) or minimum 3/8 in. (10 mm) plywood, and vertically position it a maximum 12 in. (300 mm) above the sprinkler.

Install in-rack sprinklers so they are no more than 18 in. (450 mm) horizontally from the edge of the storage array when the storage array is more than two hanging garment rows wide as shown in Figures 9 and 11.

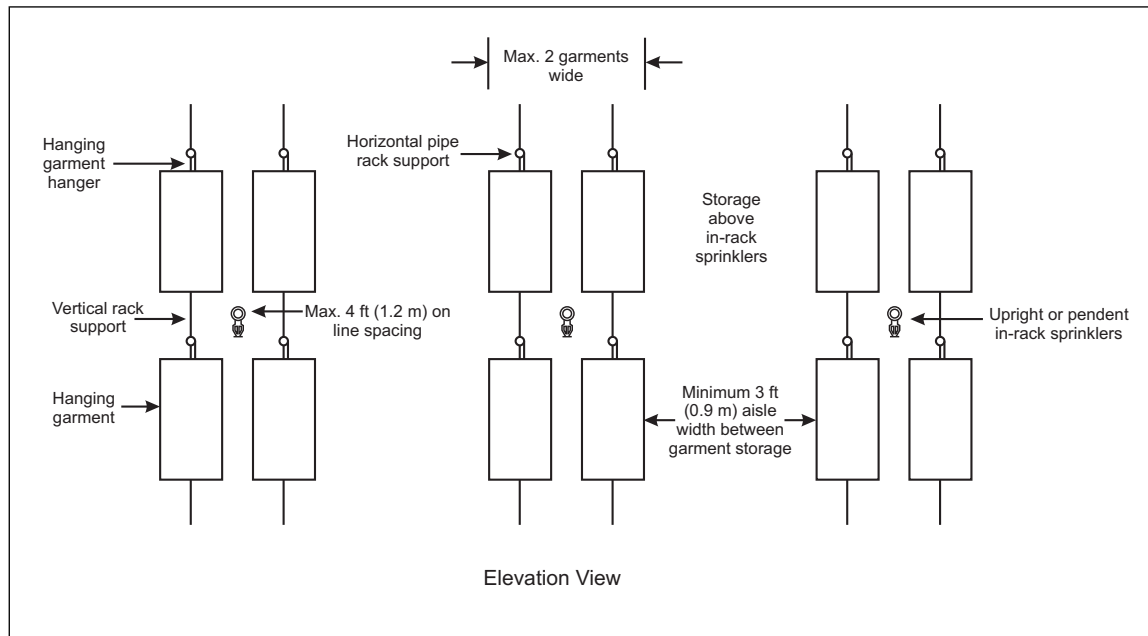


Fig. 8. Horizontal location of in-rack sprinklers for storage up to hanging garment rows wide

2.3.4.3.2 Vertical In-Rack Sprinkler Arrangements

See Table 4 to determine the allowable vertical increment between in-rack sprinklers. If the storage array does not meet the conditions in Table 4, install in-rack sprinklers at every hanging garment storage tier level.

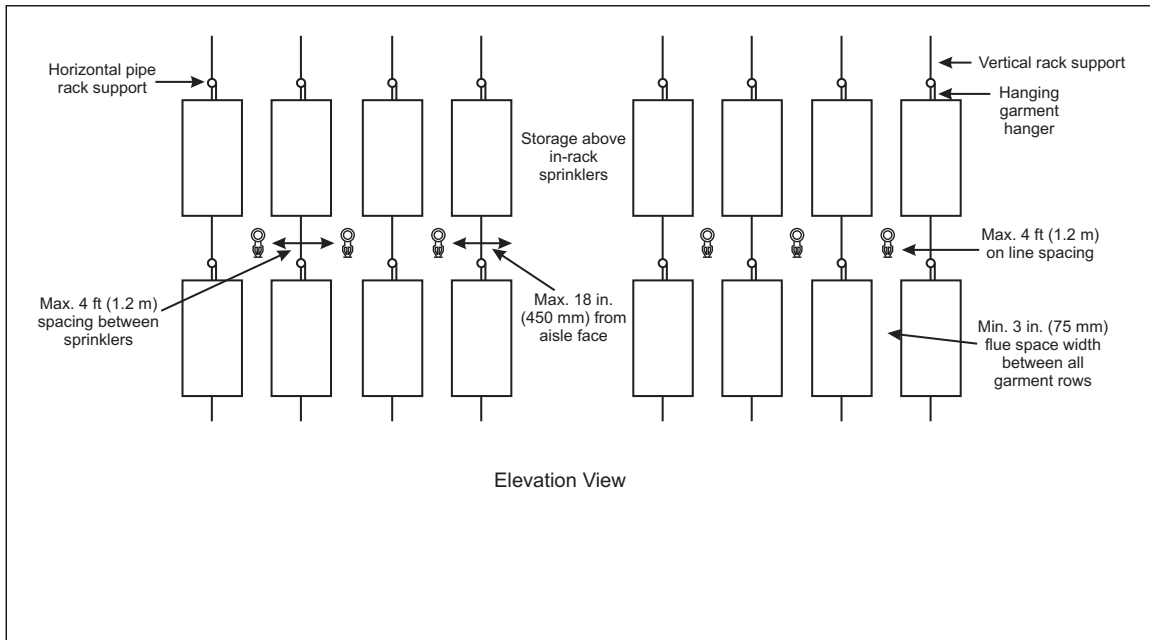


Fig. 9. Horizontal location of in-rack sprinklers for storage over 2 hanging garment rows wide

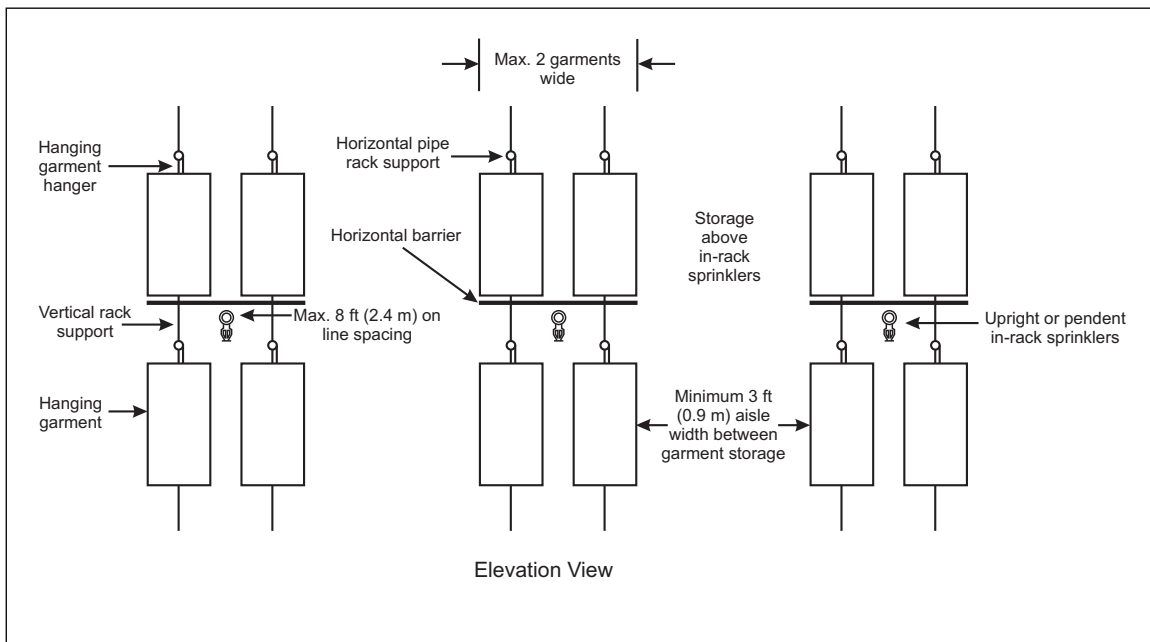


Fig. 10. Horizontal location of in-rack sprinklers for storage up to 2 hanging garment rows wide with horizontal barriers

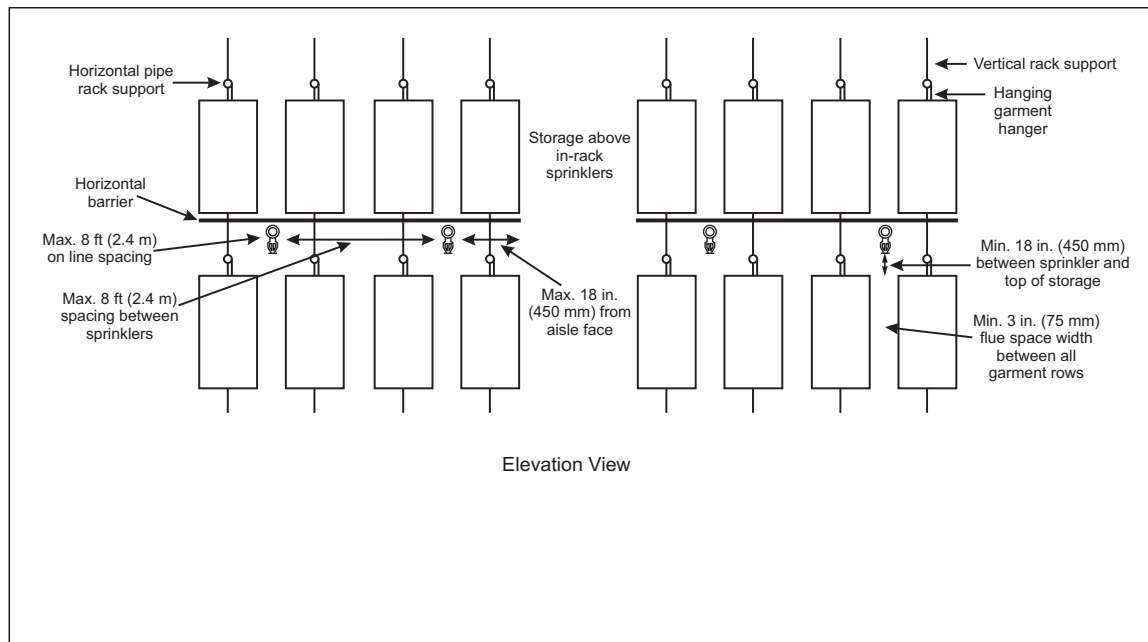


Fig. 11. Horizontal location of in-rack sprinklers for storage over 2 hanging garment rows wide with horizontal barriers

Table 4. Allowable Vertical Increments Between In-Rack Sprinklers

<i>Hanging Garment storage Arrangement</i>	<i>In-Rack Sprinklers</i>	<i>In-Rack Sprinkler Vertical Increment, ft (m)</i>	<i>Applicable Figure</i>
Hanging garment rows separated by min. 3 in. (75 mm) wide flue spaces	Any	10, (3.0)	9 or 11
Up to two hanging garment rows separated on each side by a min. 3 ft (0.9 m) wide aisle	Any	15, (4.5)	8 or 10
Hanging garment rows separated by min. 3 in. (75 mm) wide flue spaces	Quick-response, min. K14.0 (K200) pendent sprinklers	20, (6.0)	9 or 11

2.3.4.4 In-Rack Sprinkler Design

Design the in-rack system based on the values indicated in Table 5.

Table 5. In-Rack Sprinkler Design

Max. Storage Height Protected by IRAS, ft (m)	Hanging Garment Row Width, No. of Garments	Horizontal Barriers Provided?	IRAS Design, No. of IRAS		IRAS Design Flow, gpm (L/min)
			No. of IRAS Levels Needed		
			1 Level	More than 1 Level	
5 (1.5)	Up to 2	N	4	8 (4 on top 2 levels)	30 (115)
		Y	3	6 (3 on top 2 levels)	30 (115)
	More than 2	N	6	10 (5 on top 2 levels)	30 (115)
		Y	4	8 (4 on top 2 levels)	30 (115)
10 (3.0)	Up to 2	N	8	14 (7 on top 2 levels)	30 (115)
		Y	5	8 (4 on top 2 levels)	30 (115)
	More than 2	N	8	14 (7 on top 2 levels)	30 (115)
		Y	6	12 (6 on top 2 levels)	30 (115)
15 (4.5)	Up to 2	N	8	14 (7 on top 2 levels)	60 (230)
		Y	6	12 (6 on top 2 levels)	60 (230)
	More than 2	N	8	14 (7 on top 2 levels)	60 (230)
		Y	7	14 (7 on top 2 levels)	60 (230)
20 (6.0)	Up to 2	N	8	14 (7 on top 2 levels)	120 (455)
		Y	6	12 (6 on top 2 levels)	120 (455)
	More than 2	N	8	14 (7 on top 2 levels)	120 (455)
		Y	7	14 (7 on top 2 levels)	120 (455)

2.3.4.5 Ceiling Design in Combination with In-Rack Sprinklers

2.3.4.5.1 When in-rack sprinklers are installed in accordance with Sections 2.3.4.3.1 and 2.3.4.3.2, determine the ceiling design from Tables 2 or 3 as follows:

- A. Use Table 2 when the storage array consists of up to two hanging garment rows separated on each side by a minimum 3 ft (0.9 m) wide aisle.
- B. Use Table 3 for all other storage arrays.

2.3.4.5.2 Base the storage height and ceiling height for these tables in the presence of in-rack sprinklers as follows:

- A. Storage height: Use a storage height equal to the vertical distance between the top in-rack sprinkler level and the top of storage located above the in-rack sprinklers.
- B. Ceiling height: Use a ceiling height equal to the vertical distance between the top in-rack sprinkler level and the ceiling. If this ceiling height value exceeds 30 ft (9.0 m), use one of the options in Section 2.1.3.3 to address the excessive clearance between the top of storage and the ceiling.

2.3.5 Shape Factor for Ceiling-Level Sprinkler Hydraulic Analysis

Base the shape factor for the hydraulic analysis of the ceiling-level sprinkler system as follows.

2.3.5.1 Use a Shape Factor of 1.2 for any of the following conditions:

- A. The storage is protected by a ceiling-only sprinkler system and the ceiling slope does not exceed 5°.

B. The maximum storage height is 5 ft (1.5 m) and the ceiling slope does not exceed 10°.

C. The storage is protected by a combined ceiling and in-rack sprinkler system, there is no more than 5 ft (1.5 m) of storage above the top level of in-rack sprinklers, and the ceiling slope does not exceed 10°.

2.3.5.2 Use a Shape Factor of 1.4 for conditions not addressed in Section 2.3.5.1.

2.3.6 Hose Demands, Hose Connections, and System Duration

2.3.6.1 See Table 6 to determine the recommended hose demand for system design purposes that account for potential manual intervention. Allow at least 100 gpm (380 L/min) for inside hose stream usage when provided per 2.3.6.3, and add the hose demand to the overall sprinkler demand at the point of connection.

2.3.6.2 Ensure the water supplies are capable of providing the combined sprinkler system (ceiling and, if provided, in-rack) and hose demands at adequate pressure for the duration indicated in Table 6.

2.3.6.3 Provide permanent small hose lines (1½ in. [40 mm]) not exceeding 100 ft (30 m) in length and capable of reaching all storage areas to aid in potential initial-stage firefighting as well as for after-extinguishment mop-up operations. Supply small hose lines from any of the following:

- A. A separate piping system for small hose stations
- B. Valved hose connections on sprinkler risers where such connections are made upstream from all sprinkler control valves
- C. Adjacent sprinkler systems
- D. Ceiling sprinklers in the protected area when separately controlled in-rack sprinklers are provided

Locate hose stations on the ends of storage arrays rather than in aisles.

Table 6. Hose Demand and Water Supply Duration Design Guidelines

Ceiling-Level Sprinkler Type	No. of Sprinklers in Ceiling Design	Hose Demand, gpm (L/min)	Duration, min
Standard-Coverage	12 or less	250 (950)	60
	13 to 19	500 (1,900)	90
	20 or more	500 (1,900)	120
Extended-Coverage	6 or less	250 (950)	60
	7 to 9	500 (1,900)	90
	10 or more	500 (1,900)	120

3.0 SUPPORT FOR RECOMMENDATIONS

The fire protection recommendations in this data sheet are based on the results of full-scale fire testing, loss experience, and/or engineering judgment. Not every storage arrangement or protection option has been tested, nor has every potential solution been identified.

3.1 Illustrative Losses

3.1.1 Clothing Distribution Warehouse

A fire occurred in a fully sprinklered 203,000 ft² (18,800 m²) one-story warehouse with a 88,000 ft² (8,200 m²) mezzanine approximately 11 ft (3.4 m) above the floor. Storage of the more than 600,000 garments in the building was on double-row pipe racks to 10 ft (3.0 m) with 45 in. (1.1 m) aisles, above and below the mezzanine. Clearance between storage and the roof, above the mezzanine, was approximately 5 ft (1.5 m). Clearance between storage and the underside of the mezzanine was approximately 7 in. (175 mm). The roof of the warehouse was supported by steel columns passing through the mezzanine to the foundation.

A penetration opening in the mezzanine at the fire area measured 14 x 10 in. (355 x 254 mm) where an 8 in. (200 mm) I-beam passed through it. Sprinkler protection above the mezzanine provided 0.32 gpm ft² (13 mm/min) over 4,000 ft² (370 m²) after a deduction of 250 gpm (950 L/min). A closed-sprinkler water curtain was provided in the middle of, and above, the mezzanine approximately 30 in. (760 mm) below the ceiling.

The sprinklers were provided with 8 in. (200 mm) diameter “heat collectors.” Sprinkler protection below the mezzanine provided 0.32 gpm/ft² (13 mm/min) over 3,000 ft² (280 m²) after deducting 250 gpm (950 L/min) for hose demand.

The fire started in the floor-level storage directly below the closed-sprinkler water curtain and the 14 x 10 in. (355 x 254 mm) opening. Even with the relatively small opening, the fire was able to spread above the mezzanine through the opening.

Due to a relatively strong water supply and low clearance between the top of storage and the sprinklers, only four sprinklers below the mezzanine and two sprinklers at the roof level operated and controlled the fire. However, due to the opening in the mezzanine, the fire was able to spread above the mezzanine and increase the amount of damage.

The sprinklers located near the fire and equipped with “heat collectors” did not operate. A fire service pumper supplemented the water supply via the pumper connection. A 1½ in. (40 mm) hose from a warehouse hose station was used to cool smoldering piles of garments. Fire destroyed 3,584 garments. Smoke and water damaged another 83,522 garments (51,627 smoke, 31,985 smoke and water).

3.1.2 Retail Sales storage Area

An overhead incandescent light bulb came in contact with improperly stored garments and started a fire in the stockroom of a department store.

Six sprinklers controlled the fire in approximately 800 ft² (72 m²) of garments hanging from pipe racks, electrical conduit, and sprinkler piping and low-piled garments in boxes. Smoke damaged many garments not scorched or consumed by fire. Water damaged items in the layaway room, including a television and a stereo.

3.1.3 Work Uniform Laundry storage

An apparent incendiary fire in the 3,500 ft² (325 m²) stock room containing approximately 42,700 clean work uniform pants and shirts was controlled by six operating sprinklers.

The garments were stored on double-row pipe racks with 3 ft (0.9 m) aisles, four tiers to 16 ft (4.9 m) high in the 18 ft (5.5 m) high metal deck roof building. A grated steel walkway was located between the second and third tiers of storage.

Sprinkler protection was designed to provide a density of 0.30 gpm/ft² (12 mm/min) over a 3,000 ft² (280 m²) demand area.

Approximately 2,200 shirts and 1,000 pants were burned. The balance of 22,000 shirts and 17,500 pants were wetted by sprinkler water. The wet garments had black, oily water stains and were discarded without salvage.

3.1.4 Hanging Garments Stored 11 ft (3.4 m) High

Various garments made of wool and nylon bonded to polyurethane foam were hung two-tiers high in double-row racks throughout a 39 ft (11.9 m) high noncombustible warehouse. All garments had polyethylene dust covers. Water supplies consisted of the public water supply with booster pump and fire pump and suction tank. Thirteen 286°F (140°C) nominally rated sprinklers on 100 ft² (9.0 m²) spacing operated, and employees used three small hoses to control the fire until the fire service arrived. Garments outside the immediate fire area received extensive smoke damage.

3.1.5 Automated Garment storage

A fire caused by apparent incendiarism in 34 ft (10.4 m) high automated vertical storage modules in a 39 ft (11.9 m) high building was controlled by two in-rack sprinklers and the timely use of two, 1½ in. (40 mm) hoses by facility personnel.

Two types of vertical storage modules were located next to each other with a 5 ft (1.5 m) wide, 7 ft (2.1 m) high aisle-way for loading and picking.

Automatic sprinklers at the ceiling were designed to provide a 0.35 gpm/ft² (14 mm/min) density over the most remote 2,000 ft² (186 m²) demand area. Three levels of in-rack sprinklers at the 7 ft (2.1 m), at the 13

ft (3.9 m), and at the 27 ft (8.2 m) level were designed to provide a minimum operating pressure of 30 psi (2.1 bar) per sprinkler with the most remote 14 sprinklers operating (seven sprinklers on each of two levels).

Ceiling sprinklers were 286°F (140°C) nominally rated K8.0 (K115), whereas sprinklers within the storage racks were K5.6 (K80) nominally rated for 165°F (70°C).

Approximately 16,000 garments were damaged by fire, water, and smoke (number of fire damaged garments or total number of garments in the building is unknown).

4.0 REFERENCES

4.1 FM

Data Sheet 1-2, *Earthquakes*

Data Sheet 1-10, *Interaction of Sprinklers, Smoke and Heat Vents, and Draft Curtains*

Data Sheet 1-12, *Ceilings and Concealed Spaces*

Data Sheet 1-57, *Plastics in Construction*

Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*

Data Sheet 2-8, *Earthquake Protection for Water-Based Fire Protection Systems*

Data Sheet 5-48, *Automatic Fire Detection*

Data Sheet 8-1, *Commodity Classification*

Data Sheet 8-9, *Storage of Class 1, 2, 3, 4 and Plastic Commodities*

Engineering Bulletin 01-11, *Victaulic Company Model V4603, K25.2 (K360), Upright Sprinkler*

Engineering Bulletin 02-01, *Tyco Fire Products (Central, GEM and Star) Model EC-25 Control-Mode Extended-Coverage Sprinklers (SIN TY9128)*

Engineering Bulletin 02-09, *Storage Type Sprinklers*

4.2 Other

Man-Made Fiber Producers Association, Inc. *Man-Made Fiber Fact Book*, 1974

APPENDIX A GLOSSARY OF TERMS

Aisle: A clear space maintained between hanging garment storage greater than 2 ft (0.6 m) wide. See Section 2.3 for aisle width requirements for various ceiling or combined ceiling and in-rack sprinkler designs.

Approval Guide: An online resource of FM Approvals that provides a guide to equipment, materials, and services that have been FM Approved for property conservation.

Clearance: The clear space maintained between the top of storage and the deflector of the sprinkler (ceiling or in-rack) located above it.

Duration or system duration: Water supply system duration is a defined time period between when a fire initially activates a sprinkler system and when the fire is extinguished. Fire extinguishment usually is accomplished by the manual firefighting efforts of public fire service personnel, facility fire service personnel, or facility emergency response team personnel applying hose streams directly onto the surfaces of the burning commodity. Duration takes into consideration the commodity hazard's expected fire size in the presence of the system's specific sprinklers, as well as manual fire extinguishment by either one or two applied hose streams.

Excessive clearance: A condition that exists when the vertical distance between the top level of in-rack sprinklers and the ceiling above exceeds the maximum ceiling height indicated in the applicable protection table.

Fabric (cloth, textile): A product formed by weaving, knitting or pressing together natural and/or synthetic fibers

Fiber (filament): A threadlike, natural or synthetic substance suitable for weaving. Fibers may be subdivided into two groups: natural and synthetic.

FM Approved: Products and services that have satisfied the criteria for FM Approval. Refer to the *Approval Guide* for a complete listing of products and services that are FM Approved.

Flue spaces: The spaces between rows of storage. Flue spaces that are less than 3 in. (75 mm) wide are not considered flue spaces for fire protection purposes. In addition, any space between rows of storage that exceeds 24 in. (600 mm) horizontally is considered an aisle for fire protection design purposes.

Garments (apparel): Items of clothing.

Horizontal barrier: A solid barrier installed on a horizontal plane beneath which in-rack sprinklers are installed. A horizontal barrier is typically constructed of minimum 22 ga (0.75 mm) sheet metal; however, minimum 3/8 in. (10 mm) plywood can also be used. As a minimum a horizontal barrier extends over the entire hanging garment storage array covering up any flue spaces that may exist below the horizontal barrier. The purpose of the horizontal barrier is to impede vertical fire spread by blocking off flue spaces, while also helping to achieve prompt in-rack sprinkler operation by banking heat over to the nearest in-rack sprinkler that has been installed under the barrier.

Horizontal hanging garment storage: A storage arrangement involving hanging garments in which the garment is typically maintained on either stationary pipe racks or on horizontal moving conveyor systems.

In-rack sprinklers: These sprinklers are typically K5.6 (K80), K8.0 (K115) or K11.2 (K160) sprinklers equipped with an attached water shield over the top of the thermal sensing element. The water shield prevents wetting of the thermal sensing element by water from sprinklers at a higher elevation in the rack or at ceiling level. Note that the water shield is not a heat collector and has virtually no effect on how fast the in-rack sprinkler will operate.

K-factor: Also known as the discharge coefficient, it is a numerical value representing the orifice size of the sprinkler in combination with the expected flow through the sprinkler orifice at a given pressure value. It is calculated using the following equation:

$$K = Q / \sqrt{P}$$

Where:

Q is the flow through the sprinkler orifice in gpm (L/min).

P is the pressure at the sprinkler orifice in psi (bar).

The units for K are gpm/psi^{0.5} ([L/min]/bar^{0.5}).

Monofilament: A continuous strand of synthetic material

Natural fiber: Fibers that occur in nature (i.e. derived from plants and animals). Common examples of natural fibers include Cotton, cashmere, flax, hemp, mohair, silk and wool.

Nominal temperature rating: An indicated temperature rating that represents a given range applicable for the conditions the sprinkler is to be used for. This data sheet recommends sprinklers having a nominal temperature rating of 160°F (70°C), or 212°F (100°C) when the ambient temperatures are too high for a 160°F (70°C) rated sprinkler. The following indicates the ranges these nominal temperature ratings represent:

Nominal Temperature Rating, °F (°C)	Actual Temperature Range, °F (°C)
160 (70)	155 (68) - 165 (74)
212 (100)	200 (93) - 220 (104)

Occupancy-specific data sheet: An FM property loss prevention data sheet that addresses a specific occupancy hazard. Individual data sheets belong to a numbered "series" representing the following subjects:

<i>Series Number</i>	<i>Data Sheet Subject</i>
1	Construction
2	Sprinklers
3	Water supply
4	Extinguishing equipment
5	Electrical
6	Boilers and industrial heating equipment
7	Hazards
8	storage
9	Miscellaneous
10	Human factor
11	Systems instrumentation and control
12	Pressure vessels
13	Mechanical
15	Welding
17	Boiler and machinery miscellaneous

Polyester: A manufactured synthetic fiber in which the fiber-forming substance is any long chain synthetic polymer composed of at least 85% by weight of an ester of a substituted aromatic carboxylic acid including, but not restricted to, substituted terephthalate units, p(-R-O-C₆H₄-C-O-) and parasubstituted hydroxybenzoate units, p(-R-O-C₆H₄-C-O-) (from Man-Made Fiber Fact Book, 1974).

Staple: A fiber of finite length.

Synthetic ("man-made") fiber: Fibers that do not occur in nature. Synthetic fibers may be subdivided into categories: cellulosic and non-cellulosic. Common cellulosic synthetic fibers include acetate and rayon. Common non-cellulosic fibers include acrylic, nylon and polyester.

Storage height: A vertical segment of storage that is defined by a lower and upper boundary. The lower boundary is established by the bottom of a hanging garment located either above a floor or a level of in-rack sprinklers. The upper boundary of this vertical segment is established by the top of a hanging garment located either below a ceiling or a level of in-rack sprinklers.

Tier: A vertical segment of storage defined by an open space between one row of hanging garment storage and the underside of the storage above.

Tow: A group of continuous, parallel strands of synthetic material.

Vertical hanging garment storage: A storage arrangement involving hanging garments in which the garment is typically handled via rotating carousels in a vertical plane.

Yarn: An orderly arrangement of fibers held in position by lateral twisting.

APPENDIX B DOCUMENT REVISION HISTORY

October 2019. Interim revision. Minor editorial changes were made.

October 2015. This data sheet has been completely rewritten. The following major changes were made:

A. The terms "control mode density area (CMDA)" sprinkler, "control mode specific application (CMSA)" sprinkler, "large-drop" sprinkler, and "suppression mode" sprinkler have been replaced by the term "storage" sprinkler.

B. The ceiling-level designs in this data sheet are now all based on a minimum pressure at the most remote sprinkler for an indicated number of operating sprinklers. As a result, Table 1 from the previous version of this data sheet has been replaced.

C. Ceiling-level designs now incorporate quick-response sprinklers having K-factor values of 11.2 (160), 14.0 (200), 16.8 (240), 22.4 (320), and 25.2 (360). The units for these K-factors are gpm/psi^{0.5} ([L/min]/bar^{0.5}).

D. The installation of K5.6 (K80) and K8.0 (K115) sprinklers at ceiling-level is no longer recommended for hanging garment storage areas.

E. The recommended nominal temperature rating of automatic sprinklers recommended for installation at ceiling-level is 160°F (70°C).

F. The protection options in this data sheet no longer distinguish between hanging garments on horizontal supports or on vertically moving carousel units, except as noted.

G. New protection options have been added to allow for storage heights in excess of 15 ft (4.5 m) and above the top of horizontal barriers without the need for a solid mezzanine.

H. New recommendations have been added to enable storage heights up to 20 ft (6.0 m) to be protected by in-rack sprinklers.

I. For some protection options, garment widths can now be more than 48 in. (1.2 m), and aisles can now be less than 3 ft (0.9 m) wide.

J. New protection options have been added that address excessive clearance between the top of hanging garment storage and the ceiling above it.

K. New guidelines have been added that address ceiling slope.

L. The installation recommendations for automatic sprinklers are now provided in Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*.

M. Protection recommendations for the presence of open-grated mezzanines and walkways have been added.

N. A new flowchart (Figure 1) has been added to assist readers in using this data sheet.

O. New figures have been added to visually demonstrate recommended in-rack sprinkler layouts.

P. Appendix A, Glossary of Terms, has been added to this data sheet.

January 2000. This revision of the document has been reorganized to provide a consistent format.

May 1992. Notable changes included in this revision are:

- a) The addition of recommendations for the protection of revolving vertical storage.
- b) The use of nominally rated 160°, 212° or 280°F (70°, 100° or 140°C) sprinklers at ceiling level without adjustment of design area.
- c) The addition of guidelines related to heat-and-smoke venting.
- d) The addition of the protection option indicated for hanging garment storage up to 5 ft (1.5 m) as outlined in Table 1.
- e) The addition of protection options using large-drop sprinklers.
- f) The reduced design area in Table 1 for clearances of 3 ft (1 m) to 10 ft (3 m) between sprinklers and storage.