PROTECTION FOR AUTOMATIC STORAGE AND RETRIEVAL SYSTEMS

Table of Contents

Page

List of Figures

List of Tables

1.0 SCOPE

This data sheet provides loss prevention guidelines for automatic storage and retrieval systems (ASRS), including systems such as vertically enclosed, rack-structure, mini-load, and other storage arrangements in which the horizontal support for product material handling uses rails, angle irons, or other similar supporting structures.

1.1 Changes

July 2017. This data sheet has been completely rewritten. The following major changes were made:

A. This data sheet now addresses protection options for ASRS vertically enclosed, rack-structure, mini-load, and other storage arrangements in which the horizontal support for product material handling uses rails, angle irons, or other similar supporting structures. When in-rack automatic sprinkler (IRAS) protection is needed, the protection now offered in this data sheet is designed to prevent the fire from growing vertically past the in-rack sprinkler protection that has been installed. With this arrangement, the ceiling and in-rack sprinkler systems operate independent of each other and thus do not need to be hydraulically balanced nor designed with both systems operating concurrently.

B. The term “storage sprinkler” has been incorporated into this data sheet to replace “Control Mode Density Area (CMDA) sprinkler.”

C. Ceiling-level sprinkler designs now use the “number of sprinklers @ minimum pressure” design format in place of the previously used “density/demand area” design format.

D. Added terms to Appendix A, Glossary of Terms.

1.2 Hazards

See the FM Global Understanding the Hazard (UTH) brochure *Fire in Carousel Storage and Retrieval Systems* (P0380)

1.3 How to Use this Data Sheet

1.3.1 General

1.3.1.1 As with any FM Global loss prevention data sheet, a complete and comprehensive understanding of the information in this document can only be achieved by a thorough review of its contents. To assist with the proper use of this data sheet, however, a flowchart (Figure 1) has been created. Use this flowchart in combination with the written text of this data sheet to determine the potential automatic sprinkler protection options for the given ASRS storage arrangement.

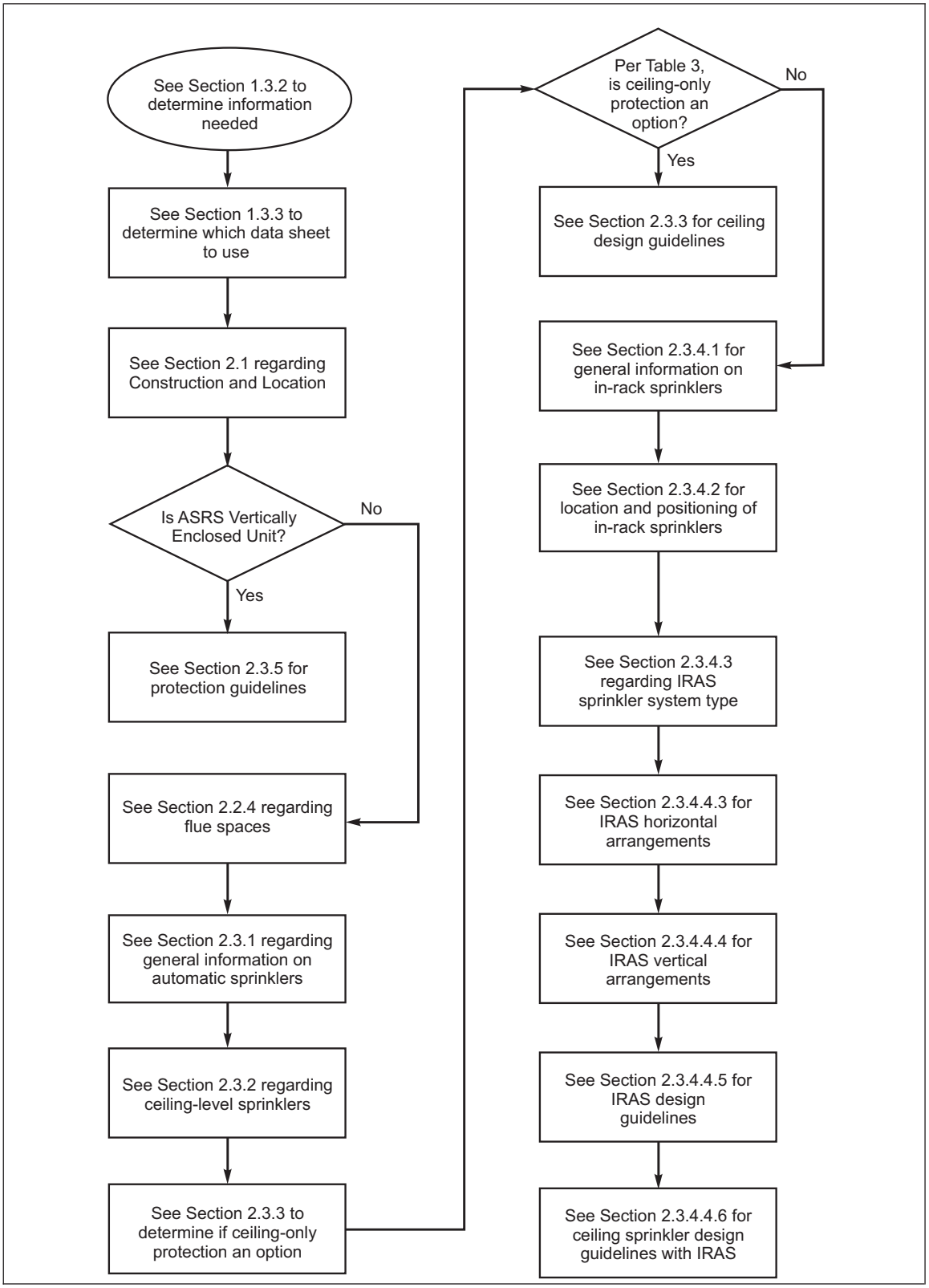

Fig. 1. Flowchart for determining the protection options for ASRS storage arrangements

1.3.2 Information Needed

1.3.2.1 In order to use this data sheet to determine the available protection options for a given ASRS storage arrangement, the following information is needed (see Appendix A, Glossary of Terms, for any term that is unclear):

A. Maximum commodity hazard to be protected (see Data Sheet 8-1, *Commodity Classification*)

B. Type of ASRS unit (mini-load, rack-structure, or vertically enclosed)

C. Depth of the ASRS unit (row depth)

D. Material composition (i.e., chemical construction) of the trays and/or containers used for material handling

E. Type of containers (open-top, closed-top, vented, solid-walled, or mesh)

F. Transverse flue space width

G. Horizontal distance between transverse flue spaces

H. Longitudinal flue space width (if provided)

I. Tier height

J. Maximum storage height

K. Maximum ceiling height over the storage area

1.3.3 Which Data Sheet to Use?

1.3.3.1 Once the information listed in Section 1.3.2 is known, use Figure 2 to determine if the sprinkler protection options for the ASRS storage arrangement can be obtained from Data Sheet 8-9, *Class 1, 2, 3, 4, and Plastic Commodities,* and, if so, based on what design criteria.

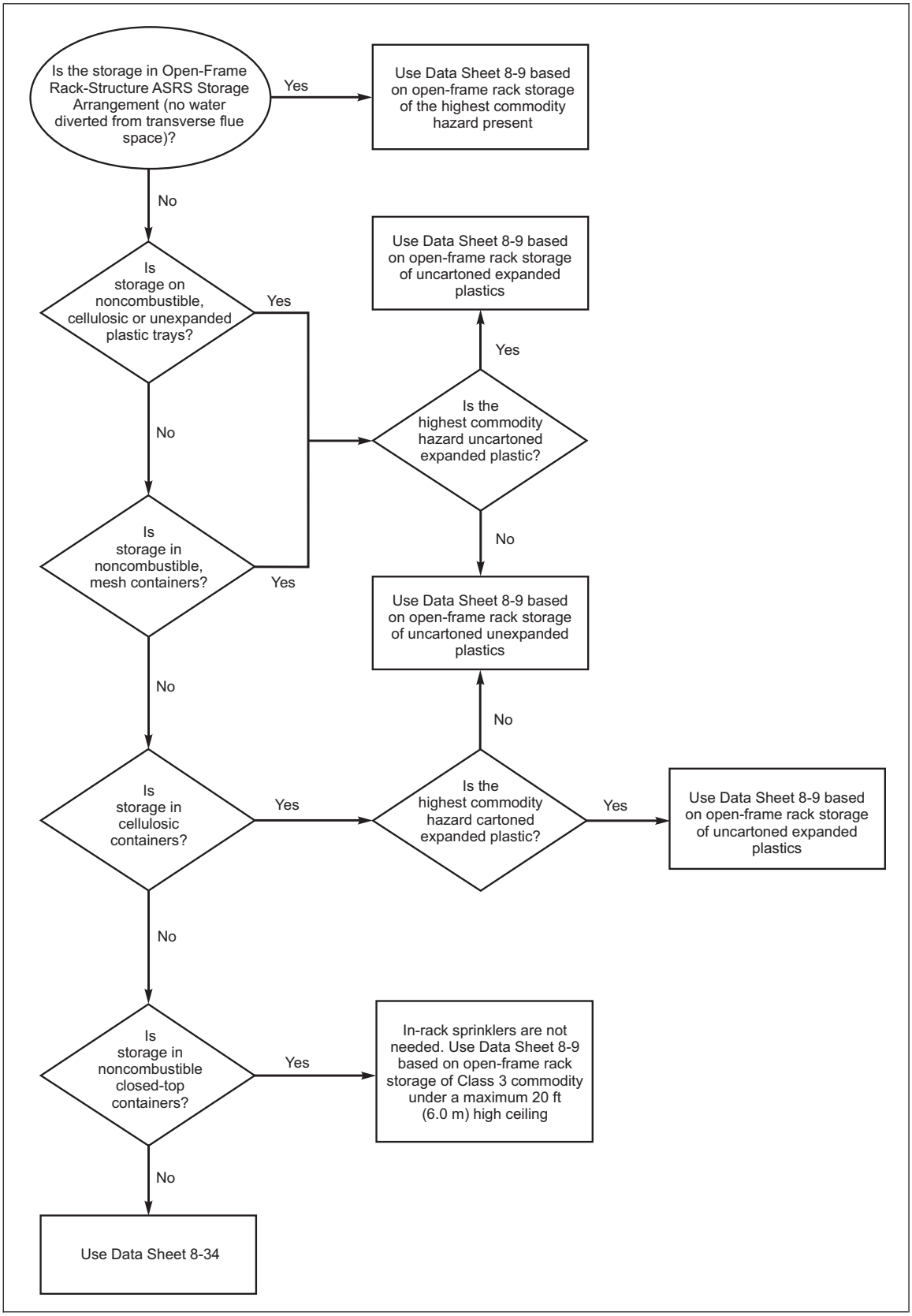

Fig. 2. When Data Sheet 8-9 can be used

2.0 LOSS PREVENTION RECOMMENDATIONS

Coordinate the facility's construction, occupancy, and protection details in the planning stages so they are all compatible.

Use FM Approved equipment, materials, and services whenever they are applicable and available. For a list of products and services that are FM Approved, see the *Approval Guide,* an online resource of FM Approvals.

2.1 Construction and Location

2.1.1 General

2.1.1.1 Construct storage facilities in accordance with the relevant FM Global property loss prevention data sheets. See the 1-series data sheets for guidelines relevant to the construction features of most storage facilities.

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 ceiling-level storage sprinkler being used.

2.1.1.3 Properly anchor all automatic storage and retrieval system (ASRS) structures to prevent them from falling over and causing nearby racks to fall over (i.e., a "domino" effect). Take into consideration the effects of rack loads, the additional load created by the collection of fire protection water by the stored commodity and its container (see 2.1.1.5), 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 ASRS rack-supported structures taking into consideration the effects of weather (wind, snow, rain, hail, etc.), rack loads, seismic conditions (see Data Sheet 1-2), and the additional load created by the stored commodity and/or its container collecting or absorbing fire protection water (see 2.1.1.5), 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 Additional Weight Due to Collection and/or Absorption of Sprinkler Discharge

2.1.1.5.1 If corrugated containers are present, assume a value of 0.012 lb (5.44 g) per 1 ft^3 (0.028 m^3) will be added to the overall weight of the load due to the absorption of sprinkler water.

2.1.1.5.2 If open-top noncombustible containers are present, assume all of the containers stored vertically within the footprint of the in-rack sprinkler design will be filled with water up to the point where they will vent. The weight of water is 8.33 lb (3.78 kg) for every 1.0 US gallon (3.8 L).

2.1.1.5.3 If open-top combustible containers are present, assume roughly one-third of the containers stored vertically within the footprint of the in-rack sprinkler design will be filled with water up to the point where they will vent, but the other two-thirds of containers will be completely consumed during a fire. The weight of water is 8.33 lb (3.78 kg) for every 1.0 US gallon (3.8 L).

2.1.2 Building Structural Steel Protection

Adhering to the design guidelines in this data sheet eliminates the need for both building column and overhead steel protection.

2.1.3 Heat and Smoke Venting and Draft Curtains

2.1.3.1 Heat and Smoke Venting

See Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers,* for recommendations related to the use of heat and smoke venting in the presence of Storage sprinklers.

2.1.3.2 Draft Curtains

See Data Sheet 2-0 for recommendations related to the use of draft curtains in the presence of Storage sprinklers.

2.2 Occupancy

2.2.1 Commodity Hazard

2.2.1.1 Use Data Sheet 8-1, *Commodity Classification,* to determine the commodity classification of the products being maintained within an ASRS storage arrangement.

2.2.1.2 Base the protection for the ASRS storage arrangement on the most severe commodity hazard present, taking into consideration both the commodity hazard and the composition of the product material handling (i.e., trays and/or containers).

2.2.2 ASRS Storage Types

2.2.2.1 General

Storage arrangements vary among locations but, in general, most automatic storage and retrieval system (ASRS) storage arrangements can be classified as either (1) vertically enclosed storage units, (2) rack-structure storage racks, or (3) mini-load storage racks. See Figures 3 through 6 for images of these storage arrangements (see Appendix A for detailed descriptions). These ASRS units typically use trays or storage containers that consist of noncombustible, cellulosic, or plastic materials.

Fig. 3. Example of vertically enclosed ASRS storage unit

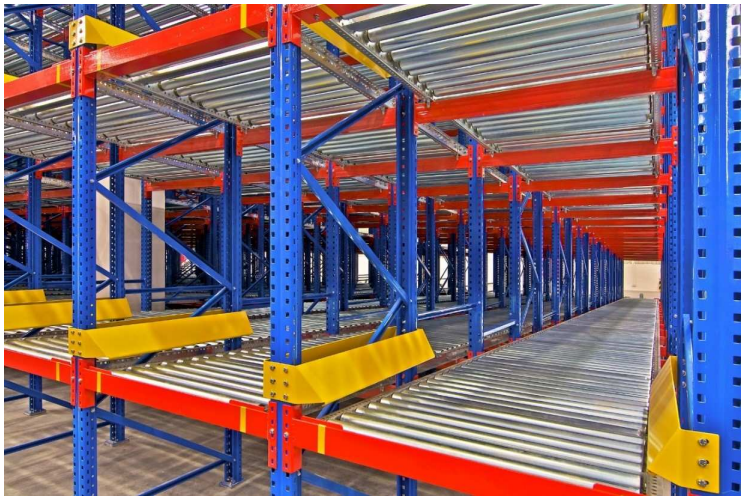

Fig. 4. Example of rack-structure ASRS storage arrangement with roller-type conveyor supports

Fig. 5. Example of mini-load ASRS storage arrangement with cartoned commodity on unexpanded plastic trays

2.2.2.2 Vertically Enclosed ASRS Storage Arrangements

See Section 2.3.5 for protection options when product is being maintained within a vertically enclosed ASRS storage unit.

2.2.2.3 Rack-Structure ASRS Storage Arrangements

2.2.2.3.1 Rack-Structure ASRS Storage Arrangements: No Diversion of Water from Transverse Flue Spaces

When product material handling is accomplished within a rack-structure ASRS storage arrangement by horizontal supports, roller-type conveyors, or some other means that does not divert water from the transverse flue space, determine the protection options using Data Sheet 8-9, *Storage of Class 1, 2, 3, 4 and Plastic Commodities.*

2.2.2.3.2 Rack-Structure ASRS Storage Arrangements: Diversion of Water from Transverse Flue Spaces

When product material handling is accomplished within a rack-structure ASRS storage arrangement by rails, angle irons, or similar horizontal supporting structures arranged parallel to the transverse flue space and diverts water from the transverse flue space, determine the protection options using Data Sheet 8-9, with the following exceptions:

A. Install in-rack sprinklers every 10 ft (3.0 m) vertically using the horizontal arrangement indicated in Figure 13 of Data Sheet 8-9, and

B. Use a minimum flow of 60 gpm (230 L/min) for the in-rack sprinkler design flow.

Fig. 6. Example of mini-load ASRS storage arrangement with open-top cellulosic and unexpanded plastic containers

2.2.2.4 Mini-Load ASRS Storage Arrangements

Use the protection options described in this data sheet when mini-load ASRS rack structures are present.

2.2.3 Product Material Handling

The protection guidelines in this data sheet are dependent on the material composition (noncombustible, cellulosic, or plastic) of the product material handling devices, such as trays and containers (including totes) when they are used within a mini-load ASRS storage arrangement. Noncombustible trays and containers offer the lowest fire hazard within an ASRS storage arrangement and should be used whenever possible.

2.2.4 Flue Spaces

2.2.4.1 Transverse Flue Spaces

2.2.4.1.1 Provide minimum net 1 in. (25 mm) wide transverse flue spaces a maximum of every 10 ft (3.0 m) horizontally within mini-load storage arrangements containing noncombustible open-top containers. Note that a “net” flue space width is the actual width of the flue space minus any horizontal support members, such as angle irons, that are located within the flue space.

2.2.4.1.2 For product handling materials and commodity hazards not addressed in Section 2.2.4.1.1, see Table 1 to determine the minimum transverse flue space width to provide throughout the vertical height of the storage array within mini-load ASRS storage arrangements.

Table 1. Minimum Requirements for Transverse Flue Spaces

Horizontal Distance Between Transverse Flue Spaces	*Min. Transverse Flue Space Width*
Up to 2 ft (0.6 m)	Gross 1.5 in. (38 mm)
Over 2 ft (0.6 m) and up to 5 ft (1.5 m)	Gross 3 in. (75 mm)

2.2.4.1.3 When the guidelines from Sections 2.2.4.1.1 and 2.2.4.1.2 cannot be met, install vertical barriers (minimum 24 gauge [0.7 mm] sheet metal or nominal ¾ in. [20 mm] plywood) within the ASRS storage arrangement. Install the vertical barrier perpendicular to the aisle so it spans the entire horizontal distance from rack face to rack face within the rack structure, including across the longitudinal flue space (if provided). Space the barriers horizontally so the number of in-rack sprinklers between the barriers does not exceed the total per level indicated in the in-rack sprinkler design per Table 8.

2.2.4.2 Longitudinal Flue Spaces

Treat any longitudinal flue space over 24 in. (0.6 m) wide as an aisle for in-rack sprinkler location purposes.

2.2.5 Clearances Between Storage and Sprinkler Deflectors

2.2.5.1 Maintain a minimum 3 ft (0.9 m) clearance between the top of the storage and the ceiling-level sprinkler deflectors.

2.2.5.2 Maintain a minimum 4 in. (100 mm) clearance between the top of the storage and the in-rack sprinkler deflectors.

2.3 Protection

2.3.1 General

2.3.1.1 FM Approval

Use only FM Approved sprinklers listed in the Approval Guide, an online resource of FM Approvals, for any of the sprinkler protection options offered in this data sheet.

2.3.1.2 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 for guidelines related to obstructions of storage sprinklers.

2.3.1.3 In addition to the recommendations in this data sheet, follow the sprinkler installation guidelines indicated for storage sprinklers in Data Sheet 2-0.

2.3.1.4 For facilities located in earthquake-prone regions, refer to Data Sheet 2-8, *Earthquake Protection for Water-Based Fire Protection Systems.*

2.3.1.5 To aid in potential initial-stage firefighting and after-extinguishment mop-up operations, provide small hose station connections not exceeding 100 ft (30 m) apart horizontally. Consult with the local fire service or authority having jurisdiction to determine their recommendation regarding (1) the size of the connection, and (2) the provision of hose lines. Water supplies for these connections can be **any of** the following:

A. A piping system dedicated solely for the small hose station connections

B. Valved hose connections on sprinkler risers when such connections are made upstream from all sprinkler control valves

C. Sprinkler systems that are adjacent to the ASRS storage area

D. Ceiling sprinklers in the protected area when separately controlled in-rack sprinklers are provided and located over the top of storage

It may be preferable from an operations standpoint to locate hose stations on the ends of racks.

2.3.1.6 Install smoke or heat detection to allow for early notification of a potential fire event. Arrange for automatic shutdown of material handling systems upon detection activation.

2.3.2 Ceiling-Level Sprinkler Protection

2.3.2.1 Ceiling-Level Sprinkler System Types

Depending on the ambient temperature of the area being protected, ceiling-level sprinkler systems protecting mini-load ASRS storage arrangements can be wet-pipe, antifreeze solution, or preaction, but the sprinkler system type must meet the guidelines for being the equivalent of "wet" for design purposes in order to be used for the protection of mini-load ASRS arrangements. Ceiling-level sprinkler systems protecting vertically enclosed ASRS arrangements can be wet-pipe, dry-pipe, antifreeze solution, preaction, deluge, or refrigerated area. Note, however, that grid-type piping configurations are only recommended for wet-pipe and antifreeze solution sprinkler systems.

2.3.2.1.1 See Data Sheet 2-0 for additional recommendations related to the installation of all sprinkler system types. See Data Sheet 8-29, *Refrigerated Storage,* for additional recommendations related to the installation of refrigerated area sprinkler systems when protecting vertically enclosed ASRS arrangements.

2.3.2.1.2 See Data Sheet 5-48, *Automatic Fire Detection,* for recommendations related to the installation of detection devices for preaction-type sprinkler systems.

2.3.2.1.3 Use the design guidelines indicated for wet-pipe sprinkler systems when the ceiling-level sprinkler system is an antifreeze solution sprinkler system consisting of a maximum 30% propylene glycol concentration in water and the ambient temperature is at or above 32°F (0°C). Otherwise, use the design guidelines indicated for dry-pipe sprinkler systems.

2.3.2.1.4 The design guidelines for single-interlocked preaction sprinkler systems are dependent on the detector spacing used to activate the ceiling-level system. See Data Sheet 5-48 to determine the ceiling-level sprinkler system design (i.e., wet-pipe or dry-pipe) for the detector spacing to be used.

2.3.2.1.5 When using a dry-pipe sprinkler system to protect a vertically enclosed ASRS arrangement, the maximum water delivery time is 60 seconds based on the operation of the most remote sprinkler.

2.3.2.2 Ceiling-Level Sprinklers

2.3.2.2.1 FM Approval

Use only FM Approved sprinklers listed in the *Approval Guide* under the heading of "Storage Sprinklers (Ceiling-Level)" for any ceiling-level sprinkler options in this data sheet.

2.3.2.2.2 Spacing of Ceiling-Level Storage Sprinklers

Install ceiling-level Storage sprinklers under unobstructed ceiling construction in accordance with the linear and area spacing guidelines in Table 2. See Data Sheet 2-0 for ceiling-level sprinkler spacing guidelines under obstructed ceiling construction.

Table 2. Spacing of Ceiling-Level Storage Sprinklers Under Unobstructed Ceiling Construction

Sprinkler K-Factor	*Sprinkler Orientation*	*Sprinkler Response*	*Sprinkler Linear Spacing, ft (m)*		*Sprinkler Area Spacing, ft² (m²)*	
			Min.	Max.	Min.	Max.
11.2 (160)	Pendent or Upright	Quick or Standard	8 (2.4)	12 (3.6)	80 (7.5)	100 (9.0)
14.0 (200), 16.8 (240), 19.6 (280), 22.4 (320), 25.2 (360)	Pendent	Quick or Standard	8 (2.4)	12 (3.6)	64 (6.0)	100 (9.0)
	Upright	Quick	8 (2.4)	12 (3.6)	64 (6.0)	100 (9.0)
		Standard	8 (2.4)	12 (3.6)	80 (7.5)	100 (9.0)
25.2EC (360EC)	Pendent or Upright	Quick	10 (3.0)	14 (4.2)	100 (9.0)	196 (18.0)

2.3.2.2.3 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 a result, the minimum required ceiling-level sprinkler pressure is the value indicated in the applicable protection table.

2.3.2.2.4 Extension of Hydraulic Design

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

2.3.2.2.5 Mixing Different Ceiling-Level Storage Sprinklers Within the Same Protected Area

For a sprinkler system protecting an ASRS storage occupancy, install ceiling-level storage sprinklers having the same K-factor, coverage listing (i.e., standard or extended), orientation, response time index (RTI) rating, and temperature rating throughout the sprinkler system, whenever possible.

2.3.2.2.5.1 K-Factor

Mixing sprinklers having different K-factors on the same ceiling-level sprinkler system within the same protected area is acceptable when either (1) there are two different storage occupancies in the same area that require different ceiling-level sprinkler designs, or (2) there is a change in the ceiling height in the same area that requires a different ceiling-level sprinkler design.

2.3.2.2.5.2 Coverage Listing

Mixing of sprinklers having different coverage listings (i.e., standard-coverage or extended-coverage) on the same ceiling-level sprinkler system within the same protected area is acceptable when either (1) there are two different storage occupancies in the same area that require different ceiling-level sprinkler designs, or (2) there is a change in the ceiling height in the same area that requires a different ceiling-level sprinkler design.

2.3.2.2.5.3 Orientation

Mixing of sprinklers having different orientations (i.e., pendent or upright) on the same ceiling-level sprinkler system within the same protected area is acceptable when it is for the purpose of eliminating obstructions to sprinkler discharge in accordance with Data Sheet 2-0.

2.3.2.2.5.4 RTI Rating

Mixing of sprinklers having different RTI ratings (i.e., quick-response and standard-response) on the same ceiling-level sprinkler system within the same protected area is acceptable when there are two different occupancies in the same area that require different ceiling-level sprinkler RTI ratings. Install a draft curtain between the areas having sprinklers with dissimilar RTI ratings when **either of** the following is true:

A. The roofs over the two areas are at the same elevation.

B. The quick-response ceiling-level sprinklers are at a higher elevation than the standard-response ceiling-level sprinklers.

See the recommendations in Data Sheet 1-10, *Smoke and Heat Venting in One-Story Sprinklered Buildings,* regarding the installation of a draft curtain and the minimum clear space needed below it.

2.3.2.2.5.5 Temperature Rating

Mixing of sprinklers having different nominal temperature ratings (i.e., 160°F [70°C], 212°F [100°C], or 280°F [140°C]) on the same ceiling-level sprinkler system within the same protected area is acceptable when ambient conditions, such as the immediate area around unit heaters, require a higher temperature-rated sprinkler to avoid the potential for premature operation.

2.3.3 Ceiling-Only Sprinkler System Designs for Mini-Load ASRS Storage Arrangements

2.3.3.1 The potential for a ceiling-only sprinkler system protection option is dependent on the following factors:

- Storage height
- Ceiling height
- Material handling type (trays, containers)
- Material handling composition (noncombustible, cellulosic, or plastic)
- Container arrangement (closed-top, open-top or mesh)
- Open-top container type (vented or solid-walled)

- Commodity hazard

The available water supply must also be capable of meeting the flow and pressure requirements of a ceiling-only sprinkler system design to avoid the need for in-rack sprinklers.

See Table 3 to determine the conditions that would allow for ceiling-only sprinkler system protection options.

Table 3. Acceptable Conditions for Ceiling-Only Protection of Mini-Load ASRS Storage Arrangements

Maximum Storage Height, ft (m)	*Maximum Ceiling Height, ft (m)*	*Material Handling*	*Material Handling Composition*	*Container Arrangement*	*If Open-Top, Vented or Solid-Walled*	*Commodity*	*Ceiling-Only Protection Available?*
10 (3.0)	15 (4.5)	Containers	Unexpanded Plastic	Open-Top	Solid-Walled	Class 1, 2, 3, 4, Cartoned Plastics or Uncartoned Unexpanded Plastics	Yes
						Expanded Plastics	No
10 (3.0)	20 (6.0)	Trays	Noncombustible, Cellulosic, or Unexpanded Plastic	DNA	DNA	Class 1, 2, 3, 4, Cartoned Plastics or Uncartoned Unexpanded Plastics	Yes
						Uncartoned Expanded Plastics	No
			Corrugated or Expanded Plastic	DNA	DNA	Any	No
		Containers	Noncombustible	Closed-Top	DNA	Any	Yes
				Open-Top	Any	Any	Yes
				Mesh	DNA	Class 1, 2, 3, 4 or Cartoned Plastics	Yes
						Uncartoned Unexpanded Plastics	Yes
						Uncartoned Expanded Plastics	No
			Cellulosic	Closed-Top	DNA	Any	Yes
				Open-Top	Any	Class 1, 2, 3, 4, Cartoned Plastics or Uncartoned Unexpanded Plastics	Yes
						Expanded Plastics	No
			Unexpanded Plastic	Closed-Top	DNA	Class 1, 2, 3, 4, Cartoned Plastics or Uncartoned Unexpanded Plastics	Yes
						Expanded Plastics	No
				Open-Top	Vented	Class 1, 2, 3, 4, Cartoned Plastics or Uncartoned Unexpanded Plastics	Yes
						Expanded Plastics	No
					Solid-Walled	Any	No
				Open-Top / Gridded Bottom	Any	Any	No
			Corrugated or Expanded Plastic	Any	Any	Any	No
15 (4.5)	30 (9.0)	Containers	Noncombustible	Closed-Top	DNA	Any	Yes
				Open-Top	Any	Any	Yes

2.3.3.2 Provide in-rack sprinklers when Table 3 indicates a ceiling-only protection option is not available. See Section 2.3.4 to determine the design and installation options for in-rack sprinklers.

2.3.3.3 When Table 3 indicates that a ceiling-only protection option is available, see Table 4 for the ceiling-level sprinkler design options protecting noncombustible containers, or Table 5 for ceiling-level sprinkler design options protecting trays and combustible containers.

Note that the design options offered in Tables 4 and 5 highlighted in green are ceiling-level sprinkler designs where the hose demand is 250 gpm (950 L/min) and the water supply duration is 60 minutes.

Table 4. Ceiling Sprinkler Designs for Noncmbustible Containers

Max. Storage Height ft (m)	*Max. Ceiling Height ft (m)*	*Wet System, Pendent Sprinklers*										*Wet System, Upright Sprinklers*						
		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)
10 (3.0)	30 (9.0)	20 @ 7 (0.5)	12 @ 25 (1.7)	12 @ 18 (1.2)	10 @ 15 (1.0)	10 @ 15 (1.0)	6 @ 20 (1.4)	20 @ 7 (0.5)	20 @ 7 (0.5)	12 @ 16 (1.1)	12 @ 7 (0.5)	20 @ 7 (0.5)	12 @ 25 (1.7)	12 @ 18 (1.2)	6 @ 20 (1.4)	20 @ 7 (0.5)	20 @ 7 (0.5)	20 @ 7 (0.5)
15 (4.5)	20 (6.0)	20 @ 7 (0.5)	12 @ 25 (1.7)	12 @ 18 (1.2)	12 @ 15 (1.0)	12 @ 15 (1.0)	6 @ 20 (1.4)	20 @ 7 (0.5)	20 @ 7 (0.5)	12 @ 16 (1.1)	12 @ 7 (0.5)	20 @ 7 (0.5)	12 @ 25 (1.7)	12 @ 18 (1.2)	6 @ 20 (1.4)	20 @ 7 (0.5)	20 @ 7 (0.5)	20 @ 7 (0.5)
	30 (9.0)	20 @ 30 (2.1)	12 @ 25 (1.7)	12 @ 18 (1.2)	12 @ 15 (1.0)	12 @ 15 (1.0)	6 @ 30 (2.1)	20 @ 30 (2.1)	20 @ 18 (1.2)	12 @ 16 (1.1)	12 @ 7 (0.5)	20 @ 30 (2.1)	12 @ 25 (1.7)	12 @ 18 (1.2)	6 @ 30 (2.1)	20 @ 30 (2.1)	20 @ 13 (0.9)	12 @ 20 (1.4)

Table 5. Ceiling Sprinkler Designs for Trays and Combustible Containers

Max. Storage Height ft (m)	*Max. Ceiling Height ft (m)*	*Wet System, Pendent Sprinklers*										*Wet System, Upright Sprinklers*						
		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)	25.2 (K360)	K11.2 (K160)	K14.0 (K200)	K16.8 (K240)	K25.2EC (K360EC)	11.2 (K160)	K16.8 (K240)	K25.2 (K360)
5 (1.5)	10 (3.0)	20 @ 30 (2.1)	12 @ 25 (1.7)	12 @ 18 (1.2)	10 @ 15 (1.0)	10 @ 15 (1.0)	10 @ 22 (1.5)	20 @ 30 (2.1)	20 @ 18 (1.2)	20 @ 16 (1.1)	20 @ 7 (0.5)	20 @ 30 (2.1)	20 @ 18 (1.2)	20 @ 13 (0.9)	10 @ 22 (1.5)	20 @ 30 (2.1)	20 @ 13 (0.9)	20 @ 7 (0.5)
	15 (4.5)	25 @ 50 (3.5)	10 @ 35 (2.4)	10 @ 25 (1.7)	10 @ 15 (1.0)	10 @ 15 (1.0)	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)
10 (3.0)*	15 (4.5)	25 @ 50 (3.5)	10 @ 35 (2.4)	10 @ 25 (1.7)	10 @ 15 (1.0)	10 @ 15 (1.0)	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)
	20 (6.0)		12 @ 50 (3.5)	12 @ 35 (2.4)	12 @ 20 (1.4)	12 @ 20 (1.4)												

2.3.3.4 See Table 6 to determine the recommended ceiling-level sprinkler system hose demand that accounts for potential manual intervention. When small hose station connections are provided per Section 2.3.1.5, account for 100 gpm (380 L/min) of inside hose stream usage, 50 gpm (190 L/min) at two small hose station connections, and add the remaining balance of the hose demand to the overall ceiling-level sprinkler demand at their point of connection.

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, minutes*
Standard-Coverage	Up to 12	250 (950)	60
	13 to 19	500 (1900)	90
	20 or More	500 (1900)	120
Extended-Coverage	Up to 6	250 (950)	60
	7 to 9	500 (1900)	90
	10 or More	500 (1900)	120

2.3.3.5 Size the water supplies so they are capable of providing the flow requirements of the ceiling-level sprinkler system and the hose demand at adequate pressure per the duration guidelines in Table 6.

2.3.4 In-Rack Automatic Sprinkler (IRAS) Protection for Mini-Load ASRS Storage Arrangements

2.3.4.1 General

2.3.4.1.1 Use only quick-response, 160°F (70°C) nominally rated, minimum K11.2 (K160) FM Approved sprinklers listed in the Approval Guide, an online resource of FM Approvals, under the heading of Storage Sprinklers (Ceiling-Level) for any in-rack sprinkler options offered in this data sheet.

2.3.4.1.2 The minimum design pressure of any in-rack sprinkler is 7 psi (0.5 bar). See Table 8 for the minimum design flow for the in-rack sprinkler, depending on the type of in-rack sprinkler protection arrangement to be installed.

2.3.4.2 Location and Positioning of In-Rack Sprinklers

2.3.4.2.1 When installing in-rack sprinklers in accordance with the recommendations for horizontal arrangements of in-rack sprinklers and their allowable vertical increments, also incorporate the guidelines below in Sections 2.3.4.2.2 through 2.3.4.2.7.

2.3.4.2.2 Locate all in-rack sprinklers (longitudinal and face) horizontally within the footprint of the ASRS rack storage structure. Note that in-rack sprinklers installed within a longitudinal flue space that does not exceed 2 ft (0.6 m) in width are considered installed within the footprint of the storage structure.

2.3.4.2.3 Locate all in-rack sprinklers (longitudinal and face) within the flue spaces they are intended to protect and a minimum of 3 in. (75 mm) horizontally from rack uprights.

2.3.4.2.4 Locate longitudinal flue sprinklers (where needed) no more than 12 in. (300 mm) horizontally from the edge of storage.

2.3.4.2.5 Locate all in-rack sprinklers (longitudinal and face) in accordance with the minimum and maximum horizontal distances indicated in the applicable figure.

2.3.4.2.6 Locate the in-rack sprinkler's deflector at or below the bottom of the rack's horizontal support member at each tier level where in-rack sprinklers are needed.

2.3.4.2.7 Arrange in-rack sprinklers and their associated sprinkler piping to avoid mechanical damage while at the same time allowing for proper in-rack sprinkler distribution. Prior to installing in-rack sprinklers, check the proposed in-rack sprinkler locations to ensure both adequate protection against mechanical damage and proper sprinkler discharge are provided.

2.3.4.3 In-Rack Sprinkler System Type

2.3.4.3.1 Use only wet-pipe sprinkler systems for in-rack sprinkler systems installed for the protection of mini-load ASRS storage arrangements.

2.3.4.3.2 When the ambient temperature can be maintained at or above 32°F (0°C), the use of an antifreeze solution type sprinkler system for the protection of mini-load ASRS storage arrangements is acceptable.

2.3.4.3.3 Use the design guidelines indicated for wet-pipe sprinkler systems when the in-rack sprinkler system is an antifreeze solution sprinkler system as outlined in Section 2.3.4.3.2.

2.3.4.3.4 See Data Sheet 2-0 for additional guidelines related to the installation of wet-pipe and antifreeze solution sprinkler system types.

2.3.4.4 Determining Acceptable Ceiling-Level and IRAS Sprinkler Arrangements

2.3.4.4.1 Use the following procedure to determine the recommended protection options for both the ceiling and in-rack sprinkler systems:

A. Determine the available horizontal in-rack sprinkler arrangement options per Section 2.3.4.4.3.

B. Determine the maximum allowable vertical distances between in-rack sprinkler levels per Section 2.3.4.4.4.

C. Determine the in-rack sprinkler system design guidelines, including the hose demand and system duration, per Section 2.3.4.4.5.

D. Determine the ceiling-level sprinkler system design guidelines, including the hose demand and system duration, per Section 2.3.4.4.6.

2.3.4.4.2 See Sections 2.3.4.1 and 2.3.4.2 for in-rack sprinkler protection recommendations that supplement the recommendations in this section.

2.3.4.4.3 IRAS Horizontal Arrangements

2.3.4.4.3.1 This data sheet provides figures showing plan views for in-rack sprinkler arrangements for mini-load ASRS storage arrangements to assist in the proper location and spacing of the in-rack sprinklers. These figures use blue rectangles and squares to represent trays or containers and the flue spaces between them.

2.3.4.4.3.2 Determine the horizontal in-rack sprinkler arrangement for mini-load ASRS storage arrangements taking into consideration **all** of the following parameters:

- Depth of the ASRS row
- Container composition (noncombustible, cellulosic, or unexpanded plastic)
- Container type (solid-walled open-top or vented open-top)
- Commodity hazard
- Horizontal distance between transverse flue spaces
- Whether a longitudinal flue space will be provided

2.3.4.4.3.3 Mini-Load Rack Row Depths up to 3 ft (0.9 m)

2.3.4.4.3.3.1 For mini-load rack row depths up to 3 ft (0.9 m), install in-rack sprinklers down the center of the rack at every flue space intersection as shown in Figure 7. If the horizontal distance between transverse flue spaces is 12 in. (300 mm) or less, then in-rack sprinklers can be installed at every other transverse flue space as demonstrated in Figure 8. The maximum horizontal distance between in-rack sprinklers is 4 ft (1.2 m).

2.3.4.4.3.3.2 In-rack sprinklers can be installed within mini-load racks with row depths up to 3 ft (0.9 m) down the center of the rack at every other transverse flue space intersection, as shown in Figure 8, for the conditions indicated in Table 7.

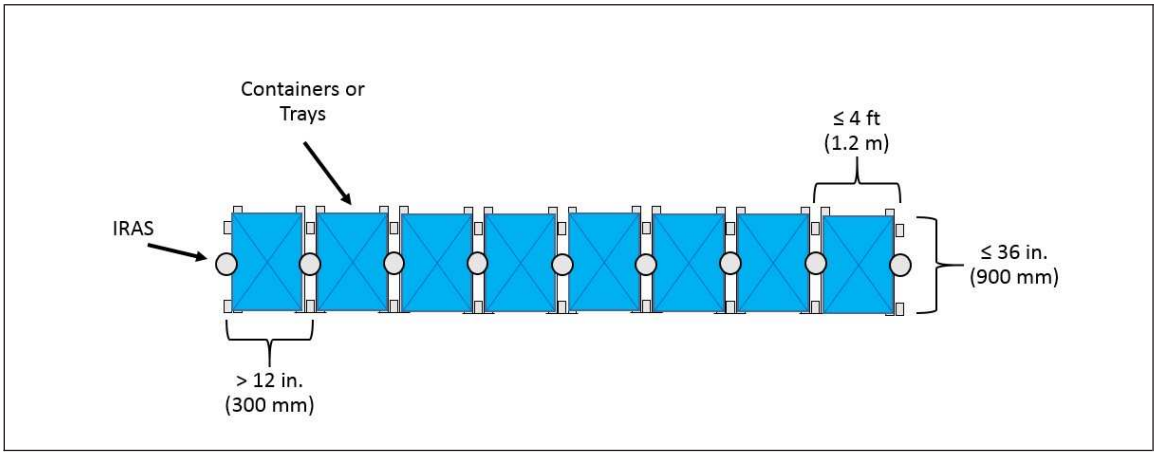

Fig. 7. Horizontal IRAS(E) arrangement for mini-load rack row depths up to 3 ft (0.9 m)

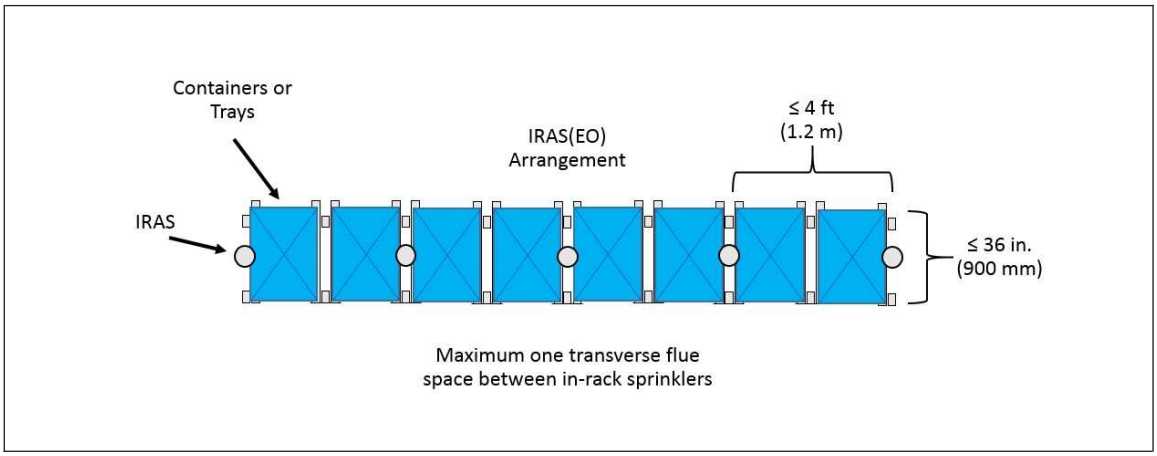

Fig. 8. Horizontal IRAS(EO) arrangement for mini-losd rack row depth up to 3ft (0.9 m) permitted by Table 7

Table 7. Acceptable Conditions for IRAS Arrangements per Figure 8

Tray Composition	*Container Composition*	*Container Type*	*Commodity Hazard*
Noncombustible	DNA	DNA	Class 1, 2, 3, 4, cartoned plastics and uncartoned unexpanded plastics
Unexpanded Plastic	DNA	DNA	Class 1, 2, 3, 4, cartoned plastics and uncartoned unexpanded plastics
DNA	Noncombustible	Closed-Top	Any
DNA	Noncombustible	Open-Top	Any
DNA	Noncombustible	Mesh	Class 1, 2, 3, 4, cartoned plastics and uncartoned unexpanded plastics
DNA	Cellulosic	Closed-Top	Any
DNA	Unexpanded Plastic	Closed-Top	Any
DNA	Unexpanded Plastic	Open-Top	Class 1, 2, 3, 4, cartoned plastics and uncartoned unexpanded plastics

2.3.4.4.3.4 Mini-Load Rack Row Depths Over 3 ft (0.9 m) and up to 6 ft (1.8 m)

2.3.4.4.3.4.1 For mini-load rack row depths over 3 ft (0.9 m) and up to 6 ft (1.8 m), install in-rack sprinklers at every flue space intersection as shown in Figure 9 for rack rows horizontally separated by more than 2 ft (0.6 m), or per Figure 10 when rack rows are separated by a maximum 2 ft (0.6 m) distance. If the horizontal distance between transverse flue spaces is 12 in. (300 mm) or less, in-rack sprinklers can be installed at every other transverse flue space as shown in Figure 11. The maximum horizontal distance between in-rack sprinklers is 4 ft (1.2 m).

2.3.4.4.3.4.2 In-rack sprinklers can be installed within mini-load racks with row depths over 3 ft (0.9 m) and up to 6 ft (1.8 m) at every other transverse flue space intersection as shown in Figure 11, or per Figure 12 when rack rows are separated by a maximum 2 ft (0.6 m) horizontal distance, for the conditions indicated in Table 8.

2.3.4.4.3.4.3 Locate face sprinklers horizontally so that they are a minimum of 10 in. (250 mm) up to a maximum of 18 in. (450 mm) from the face of the storage array.

2.3.4.4.3.4.4 In-rack sprinkler spacing in the longitudinal flue can be increased to every other transverse flue space intersection if (a) the maximum horizontal distance between every other transverse flue space is 4 ft (1.2 m), and (b) a horizontal barrier that spans the entire length and width of the longitudinal flue space is provided directly over each longitudinal in-rack sprinkler tier level.

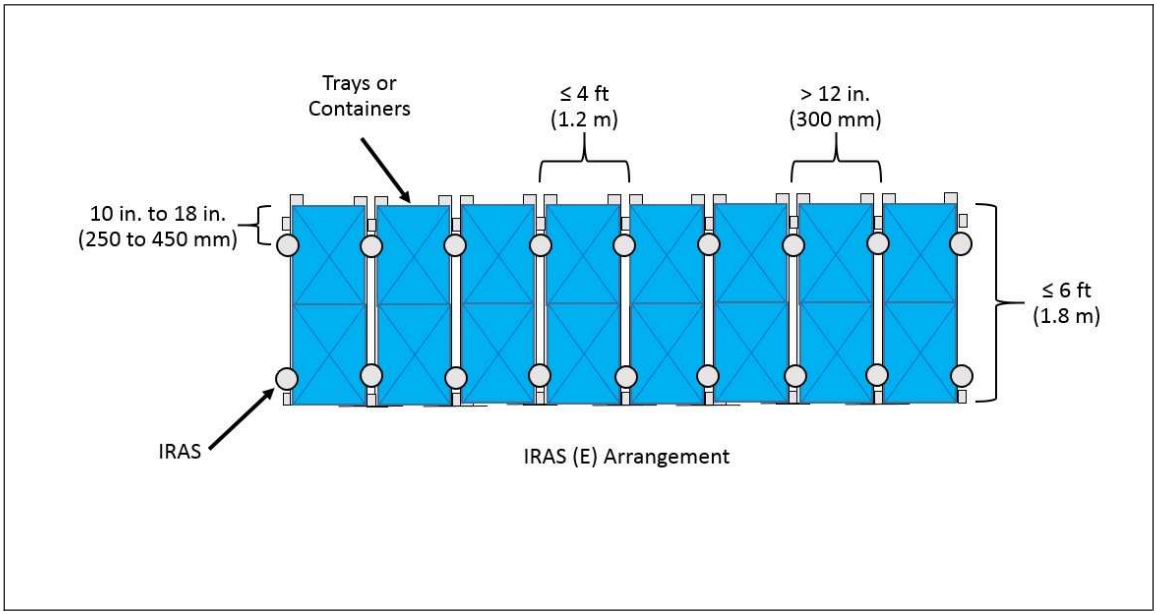

Fig. 9. Horizontal IRAS(E) arrangement for mini-load rack row depths over 3 ft (0.9 m) and up to 6 ft (1.8 m) separated by a minimum 2 ft (0.6 m) distance

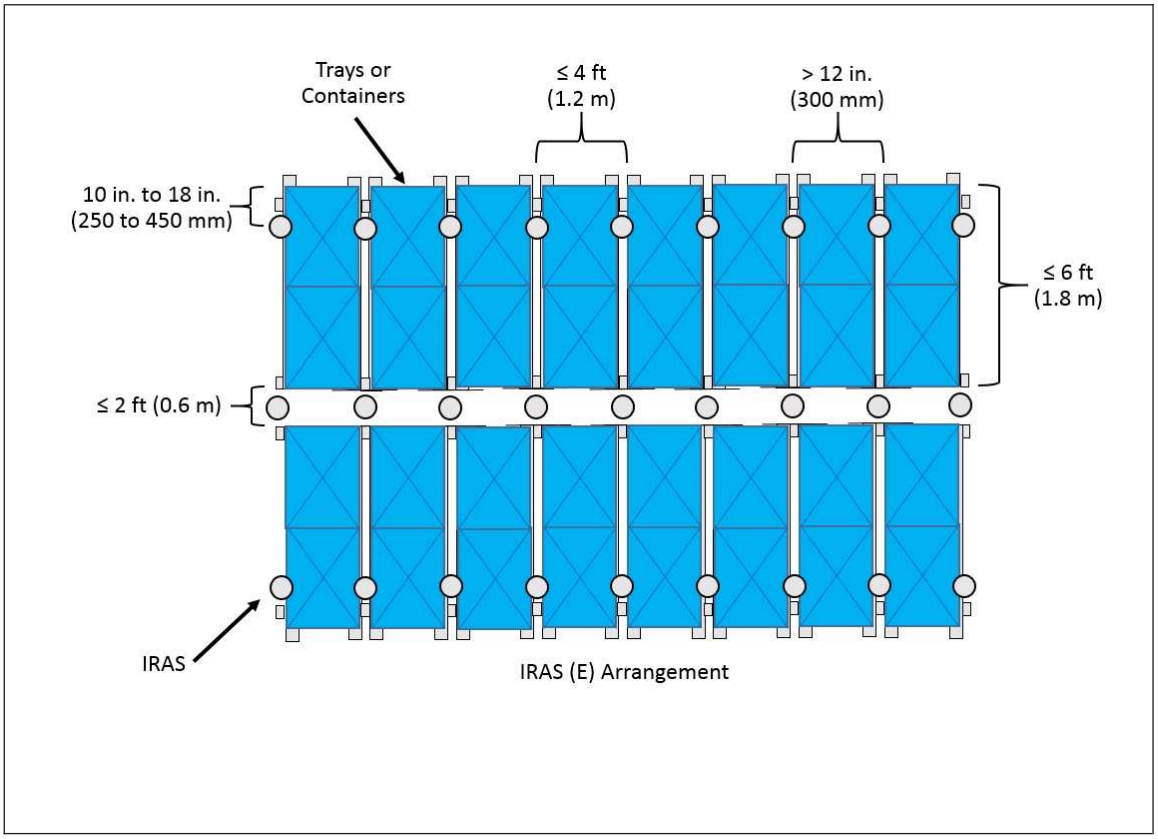

Fig. 10. Horizontal IRAS(E) arrangement for mini-load rack row depths over 3 ft (0.9 m) and up to 6 ft (1.8 m) separated by 2 ft (0.6 m) or less

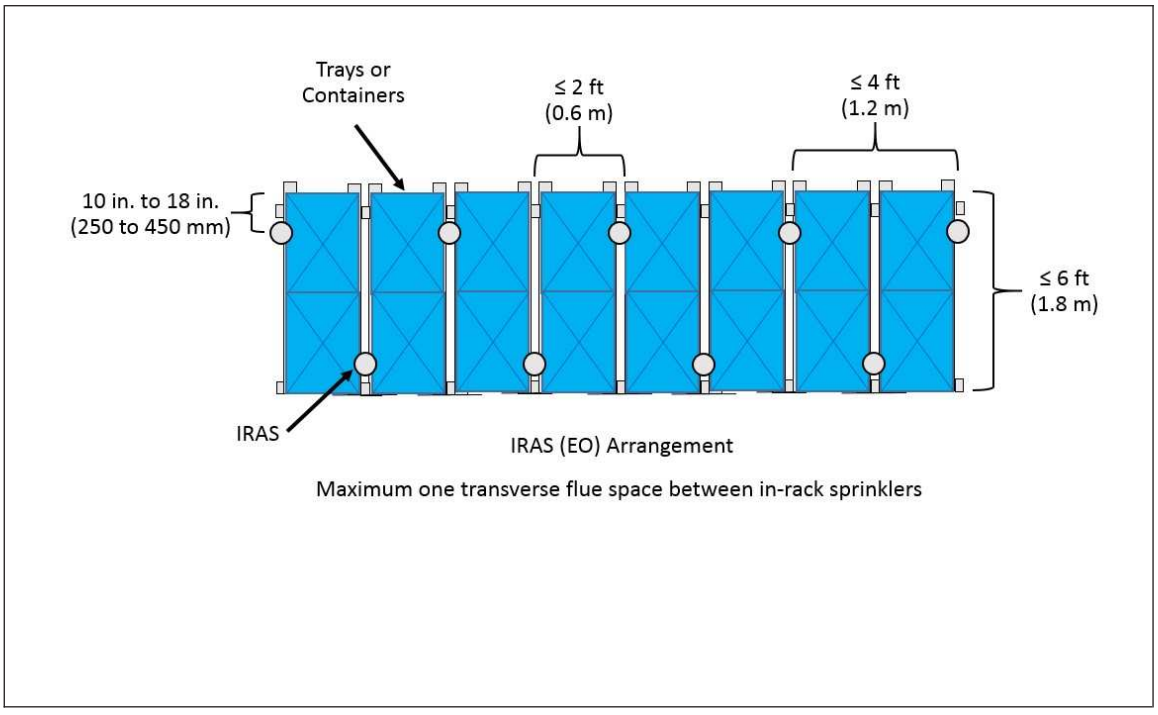

Fig. 11. Horizontal IRAS(EO) arrangement per Table 8 when racks separated by minimum 2 ft (0.6 m) distance

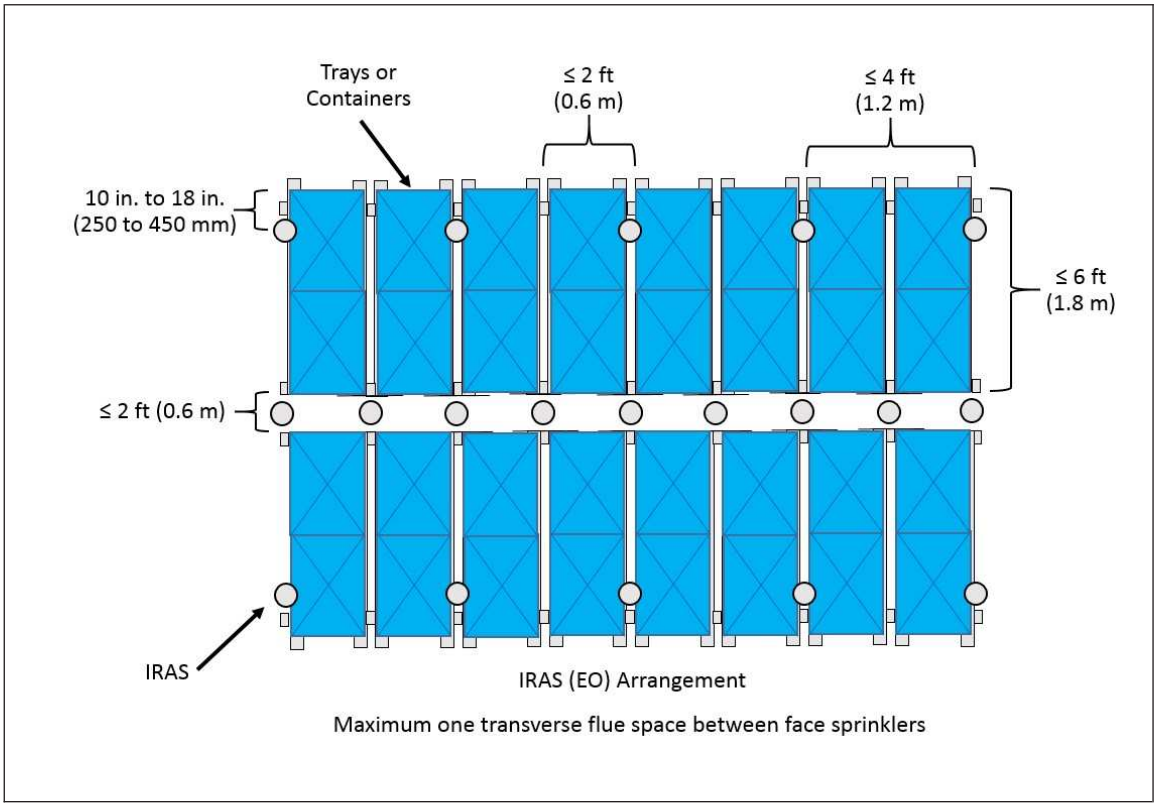

Fig. 12. Horizontal IRAS arrangement per Table 8 when racks separated by 2 ft (0.6 m) or less

Table 8. Acceptable Conditions for IRAS Arrangements per Figures 11 and 12

Tray Composition	*Container Composition*	*Container Type*	*Commodity Hazard*
Noncombustible	DNA	DNA	Class 1, 2, 3, 4, cartoned plastics and uncartoned unexpanded plastics
Unexpanded Plastic	DNA	DNA	Class 1, 2, 3, 4, cartoned plastics and uncartoned unexpanded plastics
DNA	Noncombustible	Closed-Top	Any
DNA	Noncombustible	Open-Top	Any
DNA	Noncombustible	Mesh	Class 1, 2, 3, 4, cartoned plastics and uncartoned unexpanded plastics
DNA	Cellulosic	Closed-Top	Any
DNA	Unexpanded Plastic	Closed-Top	Any
DNA	Unexpanded Plastic	Open-Top	Class 1, 2, 3, 4, cartoned plastics and uncartoned unexpanded plastics

2.3.4.4.3.5 Mini-Load Rack Row Depths over 6 ft (1.8 m)

2.3.4.4.3.5.1 For mini-load rack row depths over 6 ft (1.8 m), install in-rack sprinklers at every flue space intersection as shown in Figure 13 for rack rows horizontally separated by more than 2 ft (0.6 m), or per Figure 14 when rack rows are separated by a maximum 2 ft (0.6 m) distance. If the horizontal distance between transverse flue spaces is 12 in. (300 mm) or less, then in-rack sprinklers can be installed at every other transverse flue space as shown in Figure 15. The maximum horizontal distance between in-rack sprinklers is 4 ft (1.2 m).

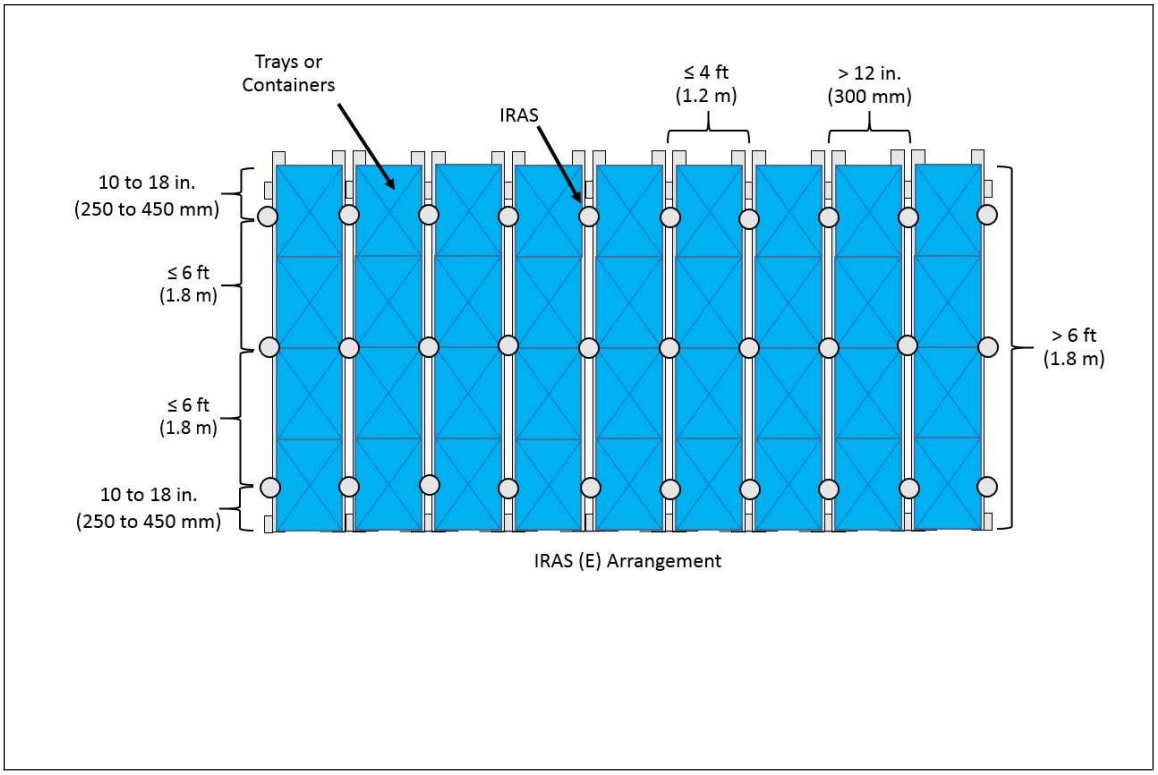

Fig. 13. Horizontal IRAS(E) arrangement for mini-load rack row depths over 6 ft (1.8 m) separated by a minimum 2 ft (0.6 m) distance

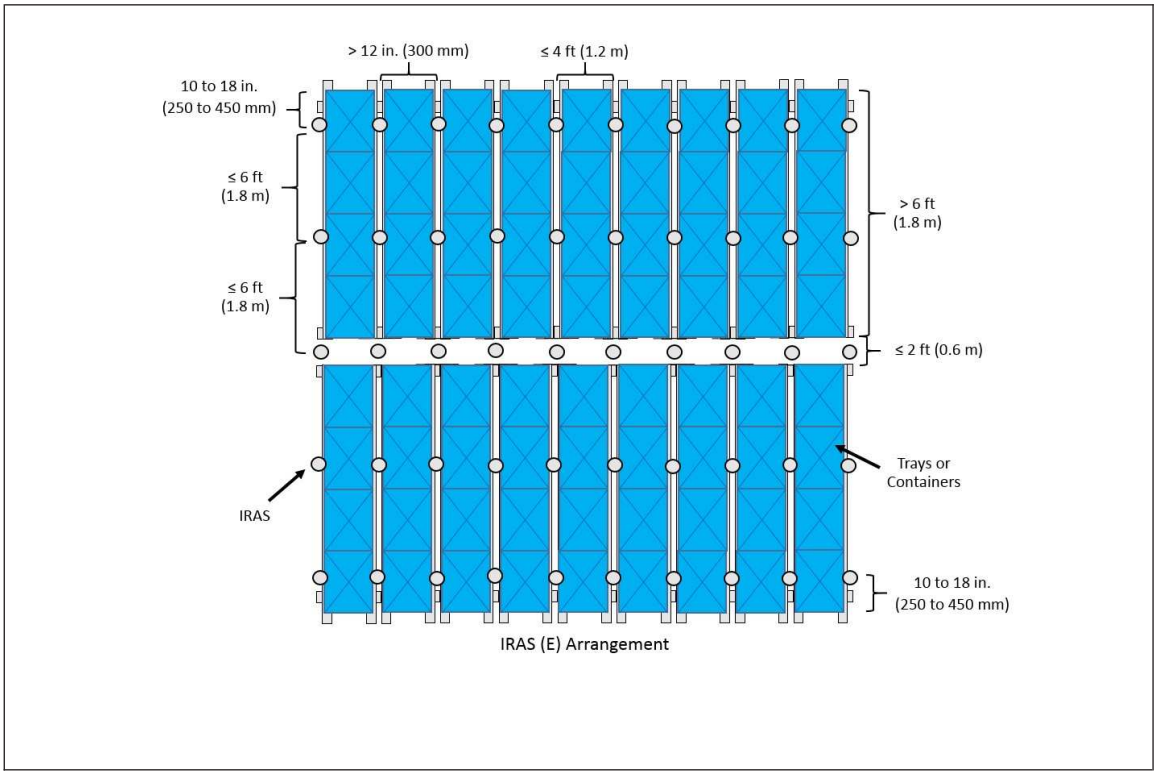

Fig. 14. Horizontal IRAS(E) arrangement for mini-load rack row depths over 6 ft (1.8 m) separated by 2 ft (0.6 m) or less

2.3.4.4.3.5.2 In-rack sprinklers can be installed within mini-load racks with row depths over 6 ft (1.8 m) at every other transverse flue space intersection as shown in Figure 15, or per Figure 16 when rack rows are separated by a maximum 2 ft (0.6 m) horizontal distance, for the conditions indicated in Table 9.

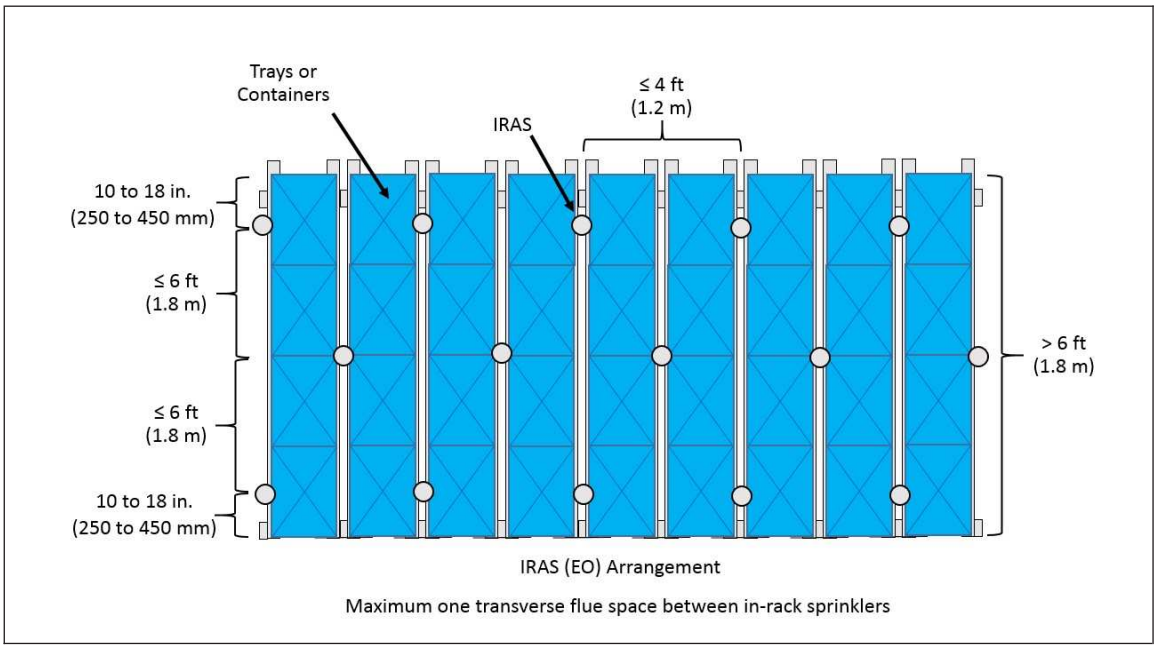

Fig. 15. Horizontal IRAS arrangement per Table 9 when racks separated by minimum 2 ft (0.6 m) distance

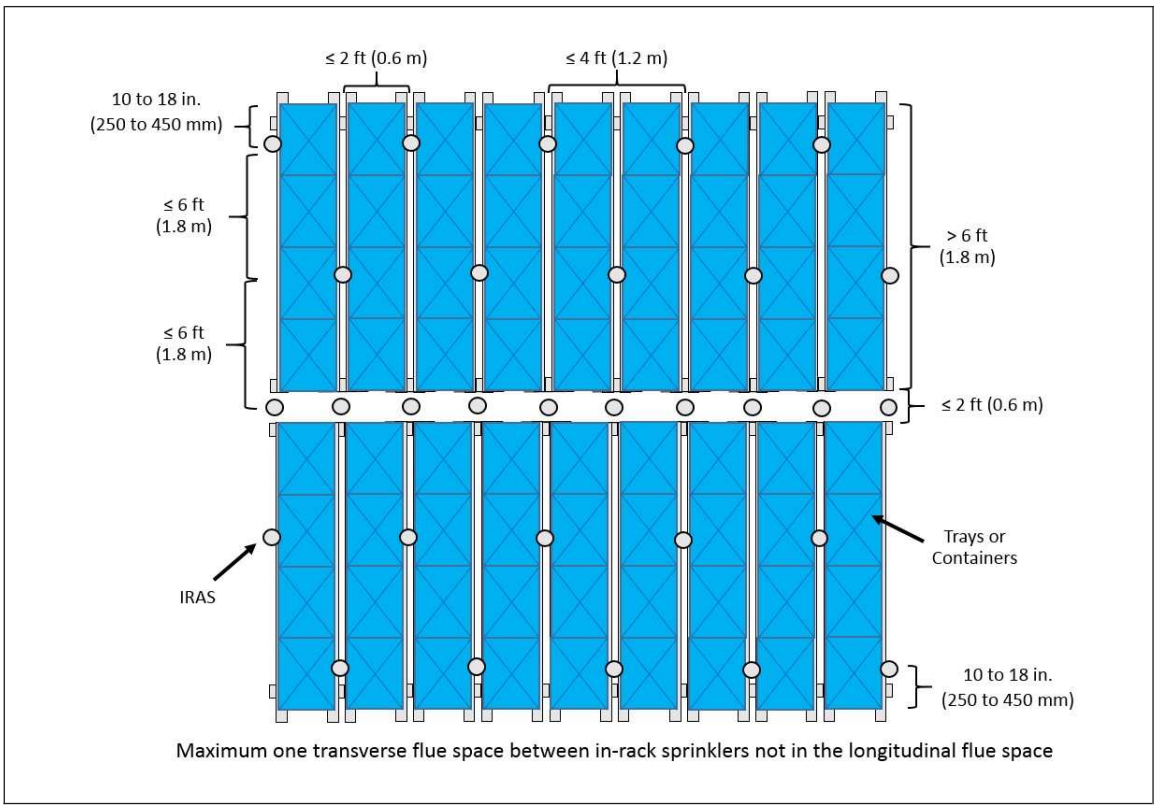

Fig. 16. Horizontal IRAS arrangement per Table 9 when racks separated by 2 ft (0.6 m) or less

Table 9. Acceptable Conditions for IRAS Arrangements per Figures 15 and 16

Tray Composition	*Container Composition*	*Container Type*	*Commodity Hazard*
Noncombustible	DNA	DNA	Class 1, 2, 3, 4, cartoned plastics and uncartoned unexpanded plastics
Unexpanded Plastic	DNA	DNA	Class 1, 2, 3, 4, cartoned plastics and uncartoned unexpanded plastics
DNA	Noncombustible	Closed-Top	Any
DNA	Noncombustible	Open-Top	Any
DNA	Noncombustible	Mesh	Class 1, 2, 3, 4, cartoned plastics and uncartoned unexpanded plastics
DNA	Cellulosic	Closed-Top	Any
DNA	Unexpanded Plastic	Closed-Top	Any
DNA	Unexpanded Plastic	Open-Top	Class 1, 2, 3, 4, cartoned plastics and uncartoned unexpanded plastics

2.3.4.4.3.5.3 Locate face sprinklers horizontally so that they are a minimum of 10 in. (250 mm) up to a maximum of 18 in. (450 mm) from the face of the storage array.

2.3.4.4.3.5.4 In-rack sprinkler spacing in the longitudinal flue can be increased to every other transverse flue space intersection if (a) the maximum horizontal distance between every other transverse flue space is 4 ft (1.2 m), and (b) a horizontal barrier that spans the entire length and width of the longitudinal flue space is provided directly over each longitudinal in-rack sprinkler tier level.

2.3.4.4.4 IRAS Vertical Arrangements

2.3.4.4.4.1 Except for the conditions indicated in Table 10, the maximum vertical distance between in-rack sprinklers is 10 ft (3.0 m).

2.3.4.4.4.2 The maximum storage height above the top tier of in-rack sprinkler protection is 10 ft (3.0 m). See Section 2.3.4.4.6 to determine the ceiling-level sprinkler system design for the amount of storage maintained above the top in-rack sprinkler level.

Table 10. Acceptable Conditions Where Vertical IRAS Increments can be 15 ft (4.5 m) Maximum

Material Handling	*Material Handling Composition*	*Container Arrangement*	*Commodity*
Trays	Noncombustible, Cellulosic, or Unexpanded Plastic	DNA	Class 1, 2, 3, 4, Cartoned Plastics or Uncartoned Unexpanded Plastics
Containers	Noncombustible	Closed-Top or Open-Top	Any
		Mesh	Class 1, 2, 3, 4, Cartoned Plastics or Uncartoned Unexpanded Plastics
	Cellulosic	Closed-Top	Class 1, 2, 3, 4 or Plastics
		Vented Open-Top	Class 1, 2, 3, 4, Cartoned Plastics or Uncartoned Unexpanded Plastics
	Unexpanded Plastic	Closed-Top	Class 1, 2, 3, 4, Cartoned Plastics or Uncartoned Unexpanded Plastics
		Vented Open-Top	Class 1, 2, 3, 4, Cartoned Plastics or Uncartoned Unexpanded Plastics

2.3.4.4.5 IRAS Design Guidelines

2.3.4.4.5.1 The IRAS design guidelines are dependent on **all** of the following:

- The depth of the ASRS row
- The material composition of the tray or container
- The container type
- The vertical distance between in-rack sprinkler levels
- The vertical height of the tier levels

2.3.4.4.5.2 See Table 11 to obtain the in-rack sprinkler design (i.e., number of in-rack sprinklers and the minimum flow from the most remote in-rack sprinkler) depending on the parameters indicated in the table.

2.3.4.4.5.3 The design indicated in Table 11 applies to the single most hydraulically remote in-rack sprinkler level.

Table 11. IRAS Design Guidelines

Depth of ASRS Row	*Tray or Container Material Composition*	*Maximum Vertical Distance Between In-Rack Sprinklers*	*No. of IRAS in Design*	*Design Flow from Most Remote IRAS, gpm (L/min)*	
				Vertical Distances Between Tier Levels ≥ 9 in. (225 mm)	Vertical Distances Between Tier Levels < 9 in. (225 mm)
Up to 3 ft (0.9 m)	Noncombustible Closed-Top Container	10 ft (3.0 m)	4	30 (115)	50 (190)
		15 ft (4.5 m)	6	60 (230)	80 (300)
	Corrugated or Expanded Plastic Trays or Containers	10 ft (3.0 m)	6	60 (230)	80 (300)
	Everything Else	10 ft (3.0 m)	4	60 (230)	80 (300)
		15 ft (4.5 m)	6	100 (380)	120 (455)
Over 3 ft (0.9 m) and up to 6 ft (1.8 m)	Noncombustible Closed-Top Container	10 ft (3.0 m)	6	30 (115)	50 (190)
		15 ft (4.5 m)	9	60 (230)	80 (300)
	Corrugated or Expanded Plastic Trays or Containers	10 ft (3.0 m)	8	60 (230)	80 (300)
	Everything Else	10 ft (3.0 m)	4	60 (230)	80 (300)
		15 ft (4.5 m)	6	100 (380)	120 (455)
Over 6 ft (1.8 m)	Noncombustible Closed-Top Container	10 ft (3.0 m)	8	30 (115)	50 (190)
		15 ft (4.5 m)	12	60 (230)	80 (300)
	Corrugated or Expanded Plastic Trays or Containers	10 ft (3.0 m)	10	60 (230)	80 (300)
	Everything Else	10 ft (3.0 m)	8	60 (230)	80 (300)
		15 ft (4.5 m)	12	100 (380)	120 (455)

2.3.4.4.5.4 For in-rack sprinkler system design calculation purposes, when more than one line of in-rack sprinklers is provided at a tier level (occurs once rack rows are more than 3 ft [0.9 m] deep), split the number of sprinklers in the design evenly between the face sprinklers and the next closest line of sprinklers. If the number of sprinklers in the in-rack sprinkler design is an odd number, use an odd number of sprinklers at the face and an even number of sprinklers one line adjacent to the face sprinklers. In addition, where in-rack sprinklers are spaced 2 ft (0.6 m) or closer, the design can be based on every other in-rack sprinkler operating. See Figure 17 for an example of this guidance.

2.3.4.4.5.5 When the in-rack sprinkler system is installed in accordance with Section 2.3.4.4, the in-rack sprinkler demand does not need to be hydraulically balanced with the ceiling-level sprinkler system, nor does it have to be accounted for operating simultaneously with the ceiling-level sprinkler system.

2.3.4.4.5.6 Include a hose demand flow of 250 gpm (950 L/min) to account for potential manual intervention. When small hose station connections are provided per Section 2.3.1.5, account for 100 gpm (380 L/min) of inside hose stream usage, 50 gpm (190 L/min) at two small hose station connections, and add the remaining balance of 150 gpm (570 L/min) to the overall in-rack sprinkler demand at their point of connection.

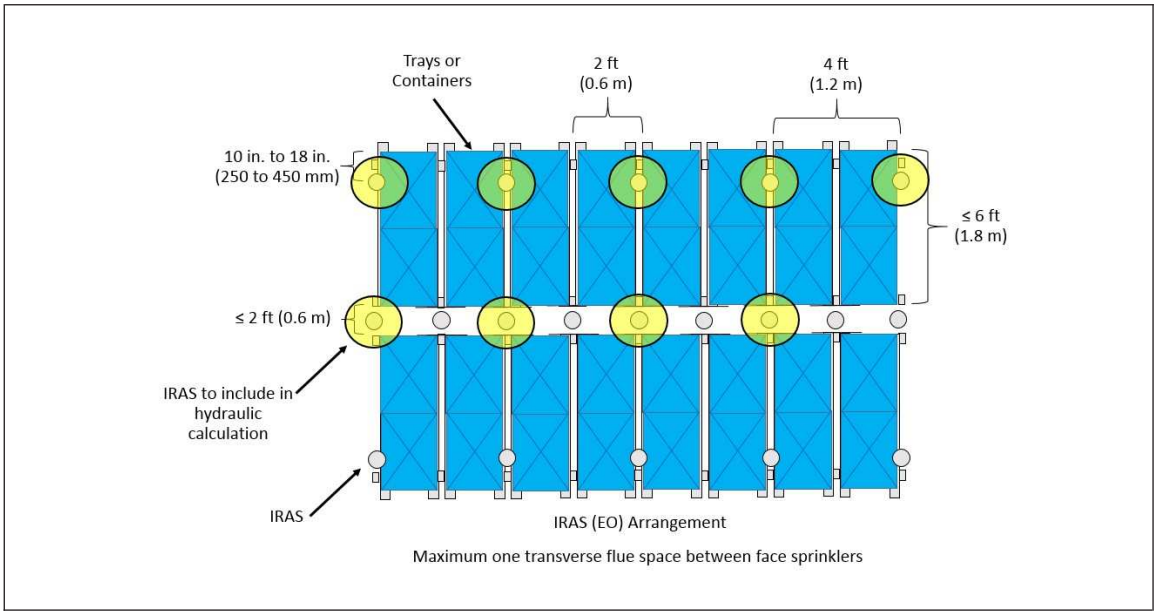

Fig. 17. Example of which in-rack sprinklers to choose when the IRAS design is based on 9 sprinklers and longitudinal IRAS are 2 ft (0.6 m) apart

2.3.4.4.5.7 Size the water supplies so they are capable of providing the flow requirements of the in-rack sprinkler system and the hose demand at adequate pressure for a minimum duration of 60 minutes.

2.3.4.4.6 Ceiling-Level Design Guidelines with IRAS Protection

2.3.4.4.6.1 See Section 2.3.2.2 regarding general guidelines for ceiling-level sprinklers.

2.3.4.4.6.2 For noncombustible closed-top and open-top containers, design the ceiling sprinkler system in accordance with Table 12 taking into account (a) the maximum storage height above the top in-rack sprinkler level, and (b) the vertical distance between the top level of in-rack sprinklers and the ceiling above. Note that the design options offered in Table 12 highlighted in green are ceiling-level sprinkler designs where the hose demand is 250 gpm (950 L/min) and the water supply duration is 60 minutes.

2.3.4.4.6.3 For all trays and combustible containers, design the ceiling sprinkler system in accordance with Table 13 taking into account (a) the maximum storage height above the top in-rack sprinkler level, and (b) the vertical distance between the top level of in-rack sprinklers and the ceiling above. Note that the design options offered in Table 13 highlighted in green are ceiling-level sprinkler designs where the hose demand is 250 gpm (950 L/min) and the water supply duration is 60 minutes.

Table 12. Ceiling Sprinkler Designs for Noncombustible Containers Protected by In-Rack Sprinklers

Max. Storage Height Above Top Level of IRAS, ft (m)	Max. Vertical Distance Between Top IRAS Level and the Ceiling, ft (m)	Wet System, Pendent Sprinklers										Wet System, Upright Sprinklers						
		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)
0 (0)	Any	20 @ 7 (0.5)	12 @ 25 (1.7)	12 @ 18 (1.2)	10 @ 15 (1.0)	10 @ 15 (1.0)	6 @ 20 (1.4)	20 @ 7 (0.5)	20 @ 7 (0.5)	12 @ 16 (1.1)	12 @ 7 (0.5)	20 @ 7 (0.5)	12 @ 25 (1.7)	12 @ 18 (1.2)	6 @ 20 (1.4)	20 @ 7 (0.5)	20 @ 7 (0.5)	20 @ 7 (0.5)
10 (3.0)	30 (9.0)	20 @ 7 (0.5)	12 @ 25 (1.7)	12 @ 18 (1.2)	10 @ 15 (1.0)	10 @ 15 (1.0)	6 @ 20 (1.4)	20 @ 7 (0.5)	20 @ 7 (0.5)	12 @ 16 (1.1)	12 @ 7 (0.5)	20 @ 7 (0.5)	12 @ 25 (1.7)	12 @ 18 (1.2)	6 @ 20 (1.4)	20 @ 7 (0.5)	20 @ 7 (0.5)	20 @ 7 (0.5)
15 (4.5)	20 (6.0)	20 @ 7 (0.5)	12 @ 25 (1.7)	12 @ 18 (1.2)	12 @ 15 (1.0)	12 @ 15 (1.0)	6 @ 20 (1.4)	20 @ 7 (0.5)	20 @ 7 (0.5)	12 @ 16 (1.1)	12 @ 7 (0.5)	20 @ 7 (0.5)	12 @ 25 (1.7)	12 @ 18 (1.2)	6 @ 20 (1.4)	20 @ 7 (0.5)	20 @ 7 (0.5)	20 @ 7 (0.5)
	30 (9.0)	20 @ 30 (2.1)	12 @ 25 (1.7)	12 @ 18 (1.2)	12 @ 15 (1.0)	12 @ 15 (1.0)	6 @ 30 (2.1)	20 @ 30 (2.1)	20 @ 18 (1.2)	12 @ 16 (1.1)	12 @ 7 (0.5)	20 @ 30 (2.1)	12 @ 25 (1.7)	12 @ 18 (1.2)	6 @ 30 (2.1)	20 @ 30 (2.1)	20 @ 13 (0.9)	12 @ 20 (1.4)

Table 13. Ceiling Sprinkler Designs for Trays and Combustible Containers Protected by In-Rack Sprinklers

Max. Storage Height Above Top Level of IRAS, ft (m)	Max. Vertical Distance Between Top IRAS Level and the Ceiling, ft (m)	Wet System, Pendent Sprinklers										Wet System, Upright Sprinklers						
		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)	25.2 (K360)	K11.2 (K160)	K14.0 (K200)	K16.8 (K240)	K25.2EC (K360EC)	11.2 (K160)	K16.8 (K240)	K25.2 (K360)
0 (0)	Any	20 @ 7 (0.5)	12 @ 25 (1.7)	12 @ 18 (1.2)	10 @ 15 (1.0)	10 @ 15 (1.0)	6 @ 20 (1.4)	20 @ 7 (0.5)	20 @ 7 (0.5)	12 @ 16 (1.1)	12 @ 7 (0.5)	20 @ 7 (0.5)	12 @ 25 (1.7)	12 @ 18 (1.2)	6 @ 20 (1.4)	20 @ 7 (0.5)	20 @ 7 (0.5)	20 @ 7 (0.5)
5 (1.5)	10 (3.0)	20 @ 30 (2.1)	12 @ 25 (1.7)	12 @ 18 (1.2)	10 @ 15 (1.0)	10 @ 15 (1.0)	10 @ 22 (1.5)	20 @ 30 (2.1)	20 @ 18 (1.2)	20 @ 16 (1.1)	20 @ 7 (0.5)	20 @ 30 (2.1)	20 @ 18 (1.2)	20 @ 13 (0.9)	10 @ 22 (1.5)	20 @ 30 (2.1)	20 @ 13 (0.9)	20 @ 7 (0.5)
	15 (4.5)	25 @ 50 (3.5)	10 @ 35 (2.4)	10 @ 25 (1.7)	10 @ 15 (1.0)	10 @ 15 (1.0)	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)
10 (3.0)*	15 (4.5)	25 @ 50 (3.5)	10 @ 35 (2.4)	10 @ 25 (1.7)	10 @ 15 (1.0)	10 @ 15 (1.0)	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)
	20 (6.0)		12 @ 50 (3.5)	12 @ 35 (2.4)	12 @ 20 (1.4)	12@20 (1.4)												

2.3.4.4.6.4 See Table 14 to determine the recommended ceiling-level sprinkler system hose demand that accounts for potential manual intervention. When small hose station connections are provided per Section 2.3.1.5, account for 100 gpm (380 L/min) of inside hose stream usage, 50 gpm (190 L/min) at two small hose station connections, and add the remaining balance of the hose demand to the overall ceiling-level sprinkler demand at their point of connection.

2.3.4.4.6.5 Size the water supplies so they are capable of providing the flow requirements of the ceiling-level sprinkler system and the hose demand at adequate pressure per the duration guidelines in Table 14.

Table 14. Hose Demand and Water Supply Duration Design Guidelines

Ceiling-Level Sprinkler Type	*No. of Sprinklers in Ceiling Design*	*Hose Demand, gpm (L/min)*	*Duration, minutes*
Standard-Coverage	Up to 12	250 (950)	60
	13 to 19	500 (1900)	90
	20 or More	500 (1900)	120
Extended-Coverage	Up to 6	250 (950)	60
	7 to 9	500 (1900)	90
	10 or More	500 (1900)	120

2.3.5 Protection options for Vertically Enclosed Storage Units

2.3.5.1 For vertically enclosed ASRS units up to a maximum height of 25 ft (7.5 m), provide sprinkler protection at the top of the ASRS unit using quick-response, standard-coverage, 160°F (70°C) nominally rated, minimum K11.2 (K160) pendent sprinklers on maximum 8 ft (2.4 m) linear spacing and maximum 64 ft^2 (6.0 m^2) area spacing. Design the sprinkler system accounting for all sprinklers within the unit operating with a minimum flow of 30 gpm (115 L/min) from the most remote sprinkler. Include a hose demand allowance of 250 gpm (950 L/min) for manual intervention and size the water supply so both the sprinkler system and hose demand flows are available at adequate pressure for a minimum duration of 60 minutes.

2.3.5.2 For vertically enclosed ASRS units over 25 ft (7.5 m) tall, provide sprinkler protection per **one** of the following options:

A. Supplement the sprinkler protection outlined in Section 2.3.5.1 with intermediate levels of quick response, 160°F (70°C) nominally rated, minimum K8.0 (K115) sidewall or extended-coverage sidewall sprinklers installed at both ends of the ASRS unit and designed to flow a minimum 30 gpm (115 L/min) at the most remote intermediate level sprinkler with all of the sprinklers within the ASRS operating. Locate the intermediate levels of sprinklers a maximum of 10 ft (3.0 m) vertically while leaving no more than 15 ft (4.5 m) of storage above the top level of intermediate sprinklers.

B. Provide sprinkler protection at the top of the ASRS unit using a quick-response sprinkler option offered in Table 8 of Data Sheet 8-9 based on the height of the ASRS unit. Regardless of the sprinkler chosen, install the sprinklers on maximum 8 ft (2.4 m) linear spacing and maximum 64 ft^2 (6.0 m^2) area spacing and account for all sprinklers within the unit operating. Include a hose demand allowance of 250 gpm (950 L/min) for manual intervention and size the water supply so both the sprinkler system and hose demand flows are available at adequate pressure for a minimum duration of 60 minutes.

2.3.5.3 To aid in water penetration throughout the vertical height of the ASRS unit, provide a minimum 10% venting area uniformly around the sides of the metal trays a maximum one in. (25 mm) above the bottom of the tray.

2.3.5.4 If the materials being maintained within the ASRS unit are (a) of high value, and/or (b) could result in a major interruption to business if damaged, consider the installation of an FM Approved total flooding gaseous suppression system in accordance with the applicable FM Global 4-Series Data Sheet to supplement the sprinkler protection recommended in Sections 2.3.5.1 and 2.3.5.2.

2.3.5.5 Arrange for automatic shutdown of the ASRS unit upon heat/smoke detection or sprinkler operation.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Description of Automatic Storage and Retrieval Systems (ASRS)

3.1.1 Mini-Load ASRS Storage Arrangements

Mini-load ASRS typically consist of multiple levels of trays or containers that slide into a rack structure (see Figure 18). The rack structure generally consists of rack uprights that are somewhat smaller, such as 2 in. (50 mm) wide by 3 in. (75 mm) deep (see Figure 19), compared to traditional pallet-load type rack uprights. The rack uprights tend to be on the order of 18 in. (450 mm) to 24 in. (600 mm) horizontally apart parallel to the loading aisle. Tier heights will vary, but are usually from 9 in. (225 mm) to 16 in. (400 mm) in height and use angle irons for material handling support (see Figure 19). While some systems can be small, others are used as rack-supported structures where they act as the structural support for the building they are in (see Figure 20) and thus can be very tall.

Trays or containers used for product handling are removed from the rack by a motorized picker. Trays and containers are typically constructed of unexpanded plastic; however, some containers are constructed of noncombustible, cellulosic, or expanded plastic materials. Containers are usually open-top (see Figure 21). The picker, located in the aisle on a set of rails (see Figure 22), is typically operated via a computer terminal. The picker can move in three directions: back and forth in the aisle, up and down the height of the rack, and in and out of the rack when removing or returning a container to its location. Depending on the size of the system, more than one picker may be used. Aisles are usually a minimum of about 3 ft (0.9 m) wide.

There are various types of containers in which parts may be stored within the retrieval system. For purposes of providing protection guidelines they have been divided into the following three groups.

3.1.1.1 Noncombustible Containers

These containers are typically painted or galvanized sheet metal. When product is maintained in closed-top, solid-walled containers, the fire hazard is greatly reduced due to the shielding of the product from direct flame impingement and therefore in-rack sprinkler protection is not required. When the containers are open-top and have solid walls, the fire growth is typically very slow and the solid walls help reduce the likelihood of horizontal fire spread. However, if the container walls or bottoms are mesh and/or gridded, then heat transfer is more readily achieved and the protection needed is driven more by the product inside the container.

3.1.1.2 Cellulosic Containers

These containers are typically single-walled or double-walled thick cardboard. They can be closed-top or open-top, but are usually open-top unless maintained on a tray. While the heat release rate of cellulosic containers is less than those made of plastic, they tend to ignite easier and burn faster than containers constructed from unexpanded plastics. As a result, care is needed to make sure the horizontal in-rack sprinkler arrangement as outlined in Section 2.3.4.4 is appropriate to avoid the fire from growing vertically past the in-rack sprinklers. While some cellulosic containers may have venting along the bottom sides of the container perpendicular to the loading aisle, most containers either have no vents or vents in the bottom of the container, which would reduce the amount of sprinkler discharge realized in the transverse flue spaces.

3.1.1.3 Plastic Containers

These containers are typically constructed using injection molded unexpanded plastic; however, containers are sometimes made of expanded or corrugated plastic. They are very often open-top, but can be closed-top. Care must be taken in classifying closed-top containers because most of these containers use folding tops that do not seal completely, which allows water that collects on top of them to drain into the container, thus creating an open-top container hazard. Unexpanded plastic containers are typically either solid throughout or collapsible where the hinge is located near the bottom of container. This hinge does allow for water to vent from the container in a timely fashion as long as the hinge is located close enough to the bottom of the container and the product inside the container doesn’t block the water from escaping.

Fig. 18. Mini-load ASRS storage arrangement IRAS are 2 ft (0.6 m) apart

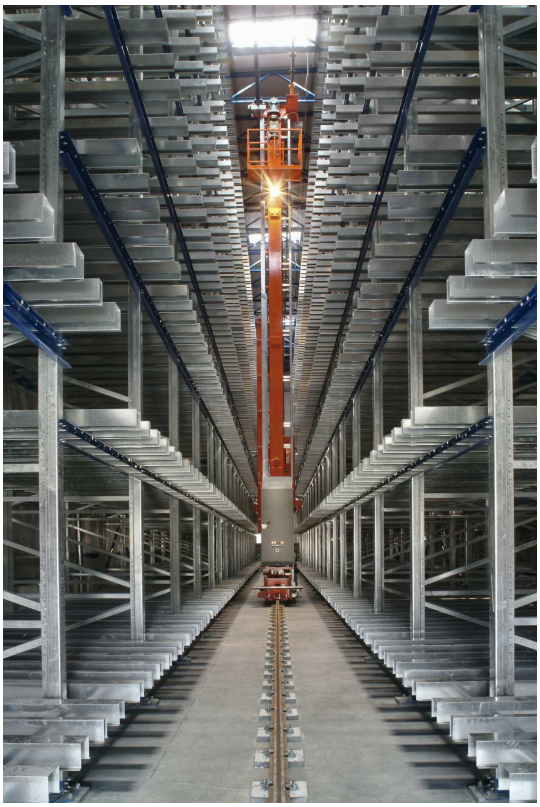

Fig. 19. Empty mini-load ASRS storage arrangement IRAS are 2 ft (0.6 m) apart

Fig. 20. Rack-supported ASRS storage arrangement

Fig. 21. Open-top plastic containers in mini-load ASRS storage arrangement

Fig. 22. Mini-load ASRS storage arrangement with open-top unexpanded plastic containers

3.1.2 Rack-Structure ASRS Storage Arrangements

Rack-structure ASRS storage arrangements are very similar to traditional open-frame racks, except the rack uprights tend to be horizontally separated by only the width of each pallet load. In addition, the horizontal supports for the pallet loads are usually orientated perpendicular to the loading aisle. The horizontal supports can be either horizontal beams (see Figure 23), which are similar to traditional open-frame racks, roller-type conveyors (see Figure 24), or angle-irons, similar to mini-load ASRS storage arrangements.

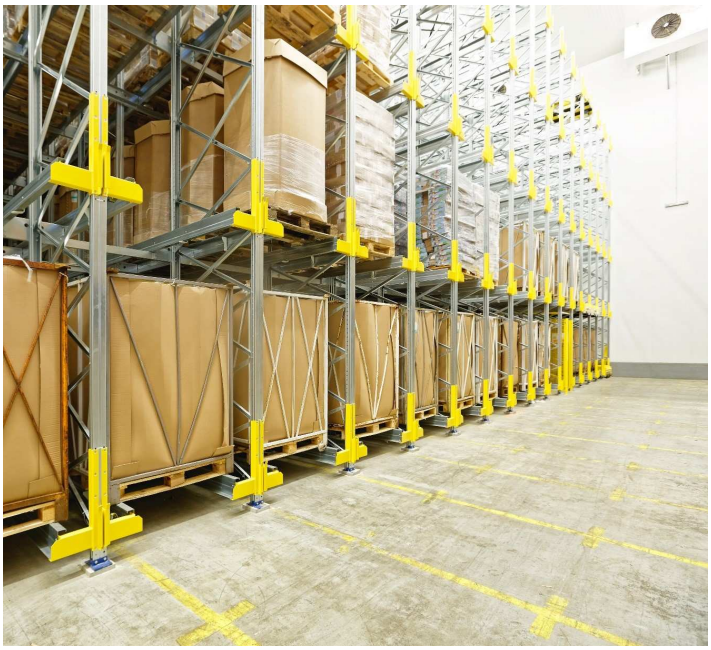

Fig. 23. Rack-structure ASRS storage arrangement with traditional horizontal supports

Fig. 24. Rack-structure ASRS storage arrangement with roller-type conveyor supports

3.1.3 Vertically Enclosed ASRS Storage Arrangements

Vertically enclosed systems can vary in size, but are usually of the “lift” or the “carousel” type. The lift type uses a robotic picker to store and remove trays that rest on fixed storage supports within the unit and deliver it to the user, whereas the conveyor type uses a rotating storage arrangement that brings the storage tray to the user (see Figure 25). Typical systems are package units in which metal trays supported on a rack structure are contained within a metal enclosure.

Systems are often used for storage of parts that are high in value and very prone to heat, smoke, or water damage, or parts that are low in value but critical for production. Such situations warrant the installation of supplemental protection to help further reduce loss potentials.

Fig. 25. Vertically enclosed ASRS storage unit

3.2 Loss History

Loss experience shows that when there are no major automatic sprinkler system deficiencies, fires in storage occupancies are controlled by the existing sprinkler system protection arrangement. Major protection deficiencies include inadequate water supplies, closed or partially closed valves, obstructed sprinkler piping, missing sprinklers, and ignitable liquid or aerosol protection deficiencies. Protection deficiencies were identified in all storage losses in which the fire was uncontrolled.

As of 2017, FM Global clients have experienced very few losses involving automatic storage and retrieval systems (ASRS), but a significant loss involving a rack-supported ASRS took place at a non-client location on July 13, 2002. Reportedly due to deficient welding and design aspects of the rack framing, a portion of a rack-structure ASRS storage unit collapsed starting a domino effect with the remaining rack framing in the warehouse area. Storage in the racking consisted of paper goods, which were then ignited by the building's lighting system. The building, which was reportedly 10 stories high and 115,000 ft^2 (10,685 m^2) in size, was completely lost.

4.0 REFERENCES

4.1 FM Global

Data Sheet 1-2, *Earthquakes*
Data Sheet 1-10, *Smoke and Heat Venting in One-story Sprinklered Buildings*
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*
Data Sheet 8-29, *Refrigerated Storage*

APPENDIX A GLOSSARY OF TERMS

ASRS row depth: The maximum horizontal length of storage within either an individual mini-load or rack-structure ASRS storage arrangement measured perpendicular to the loading aisle. See Figure A-1 for a visual representation of this term.

Fig. A-1. ASRS rack row depth

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 used to calculate the flow from a sprinkler by taking the square root of the pressure available at the sprinkler multiplied by the sprinkler's K-factor. The units for the K-factor are gpm/psi$^{0.5}$ (Lpm/bar$^{0.5}$).

Mesh noncombustible container: A noncombustible container where either the bottom of the container and/or at least one side of the container is at least 30% open.

Mini-load ASRS storage arrangement: An automatic storage and retrieval system that uses trays or small totes/containers for material handling as opposed to traditional pallet loads. Mini-load ASRS rack structures typically use rack uprights that are about 18 to 24 in. (450 to 600 mm) horizontally apart and are about 2 to 3 in. (50 to 75 mm) in size (both width and depth). Tier heights are roughly 1 ft (0.3 m) and product handling is typically supported on angle irons (see Figure 22).

Modular in-rack sprinkler protection arrangement: An in-rack sprinkler protection arrangement that is designed to prevent the vertical spread of fire beyond the first level of in-rack sprinklers that the fire encounters. This in-rack sprinkler arrangement therefore allows the in-rack design to be based on the operation of a given number of sprinklers at only one level and does not need to account for ceiling sprinkler operation as part of its design.

Rack structure ASRS storage arrangement: An automatic storage and retrieval system that is similar to traditional open-frame storage racks except that (1) the horizontal distance between rack uprights is sized for only one pallet load, and (2) the support within the rack for the pallet loads tends to be either roller-type conveyors or horizontal supports that are oriented perpendicular to the loading aisle as opposed to parallel to it (see Figures 23 and 24).

Solid-walled container: Containers that do not allow the external release of water from them in a timely fashion into the transverse flue space. Containers that do not meet the guidelines outlined for vented containers are treated as solid-walled containers for sprinkler protection design purposes.

Tray: A product material handling unit that has an extension around its perimeter that does not rise more than 1 in. (25 mm) vertically.

Vented container: Containers that release water into the transverse flue space from within them in a timely fashion. Containers that meet this definition include (1) collapsible containers that are hinged along the bottom perimeter of the container, or (2) containers whose sides, when loaded parallel to the transverse flue space, have a minimum 30% venting area within 0.5 in. (13 mm) vertically from the internal bottom of the container.

Vertical barrier: A barrier that is installed within the transverse flue space of a storage rack for the purpose of preventing fire from spreading beyond it. It spans the entire height of the rack as well as its depth, including across any longitudinal flue spaces, from one face of the rack to the other. It is not intended to span across a material-handling aisle located between storage racks.

Vertically enclosed ASRS: An ASRS unit that typically works with a vertical lift system or a vertical carousel. The lift system uses a robotic picker that will store and remove trays that rest on fixed storage supports within the unit and deliver it to the user. The carousel conveyor system uses a rotating storage arrangement that brings the storage tray to the user. Typical systems are package units where metal trays supported on a rack

APPENDIX B DOCUMENT REVISION HISTORY

July 2017. This data sheet has been completely rewritten. The following major changes were made:

A. This data sheet now addresses protection options for ASRS vertically enclosed, rack-structure, mini-load, and other storage arrangements in which the horizontal support for product material handling uses rails, angle irons, or other similar supporting structures. When in-rack automatic sprinkler (IRAS) protection is needed, the protection now offered in this data sheet is designed to prevent the fire from growing vertically past the in-rack sprinkler protection that has been installed. With this arrangement, the ceiling and in-rack sprinkler systems operate independent of each other and thus do not need to be hydraulically balanced nor designed with both systems operating concurrently.

B. The term “storage sprinkler” has been incorporated into this data sheet to replace “Control Mode Density Area (CMDA) sprinkler.”

C. Ceiling-level sprinkler designs now use the “number of sprinklers @ minimum pressure” design format in place of the previously used “density/demand area” design format.

D. Added terms to Appendix A, Glossary of Terms.

January 2003. Clarification regarding the storage clearance was added.

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