

PROTECTION FOR AUTOMATIC STORAGE AND RETRIEVAL SYSTEMS

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1.0 SCOPE

This data sheet provides loss prevention guidelines specific to Class 1, 2, 3, 4, and plastic commodities being maintained within the following types of automatic storage and retrieval systems (ASRS):

- A. Horizontal-loading (i.e., mini-load and shuttle type) (HL-ASRS) that use small containers or small trays
- B. Top-loading automatic storage and retrieval systems (TL-ASRS) that use small containers
- C. Vertically enclosed automatic storage and retrieval systems

See Appendix A for definitions of these storage arrangements.

Note that the following ASRS conditions are outside the scope of this data sheet and currently do not have any known protection options:

- ASRS arrangements that use expanded plastic trays and/or expanded plastic containers
- ASRS arrangements that use non-solid (gridded) bottom, open-top containers in either a horizontal-loading or top-loading ASRS storage arrangement
- Commodity hazards higher than plastics, such as flammable gasses and other special hazards

See FM Global Property Loss Prevention Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers*, to determine if protection options are available when ignitable liquids are to be stored within an ASRS storage arrangement.

See FM Global Property Loss Prevention Data Sheet 7-31, *Storage of Aerosol Products*, to determine if protection options are available when aerosols are to be stored within an ASRS storage arrangement.

See FM Global Property Loss Prevention Data Sheet 7-112, *Lithium-Ion Battery Manufacturing and Storage*, to determine if protection options are available when lithium-ion type batteries are to be stored within an ASRS storage arrangement.

1.1 Changes

July 2024. Interim revision. The scope of this data sheet was enhanced to instruct the end user to see FM Global Property Loss Prevention Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers*, when ignitable liquids are being stored within an ASRS, to see FM Global Property Loss Prevention Data Sheet 7-31, *Storage of Aerosol Products*, when aerosols are being stored within an ASRS, or FM Global Data Sheet 7-112, *Lithium-Ion Battery Manufacturing and Storage*, when lithium-ion batteries are being stored within an ASRS.

1.2 How to Use this Data Sheet

As with any FM Global property 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. However, the following flowchart in Figure 1 is intended to assist the user with an understanding of how best to navigate this data sheet for the specific automatic storage and retrieval system (ASRS) being installed.



Fig. 1. Summarized guidance on how to navigate Data Sheet 8-34

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 General Recommendations for All Automatic Storage and Retrieval Systems

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

2.1.1 FM Approved Equipment, Materials, and Services

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

2.1.2 Construction and Location

2.1.2.1 Construct storage facilities in accordance with the relevant FM Global property loss prevention data sheets (i.e., data sheets). See the 1-series data sheets for guidelines relevant to the construction features of most storage facilities.

2.1.2.2 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.

2.1.2.3 Building Structural Steel Protection

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

2.1.2.4 See Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*, for guidelines specific to:

- Heat and smoke vents
- Airflow from ventilation systems
- Draft curtains

2.1.2.5 Additional Weight Due to Collection of Sprinkler Discharge

When open-top, combustible containers are maintained in a horizontal-loading ASRS storage arrangement, account for the potential increased weight load on the storage structure and supporting floor from the collection of sprinkler discharge within the containers. Assume that:

1. One-half of the containers stored vertically below the in-rack sprinklers will be filled with water, and
2. One-half of the containers stored vertically below the in-rack sprinklers will be consumed during a fire event

2.1.3 Occupancy

2.1.3.1 Commodity Hazard

2.1.3.1.1 Use FM Global Property Loss Prevention Data Sheet (i.e., Data Sheet) 8-1, *Commodity Classification*, to determine the commodity classification of the products being maintained within the ASRS storage arrangement.

2.1.3.1.2 Protection guidelines offered in this data sheet are limited to commodities that are indicated by Data Sheet 8-1 as being Class 1, 2, 3, 4, or plastic.

2.1.3.1.3 Design the sprinkler protection for the ASRS storage arrangement using the most severe commodity hazard present, taking into consideration both the products being stored and the composition of the product material handling (i.e., trays and/or containers).

2.1.3.2 Clearances Between Storage and Sprinkler Deflectors

2.1.3.2.1 Maintain a minimum 3 ft (0.9 m) clearance between the top of the storage and the deflectors of standard-coverage ceiling-level sprinklers.

2.1.3.2.2 Maintain a minimum 5 ft (1.5 m) clearance between the top of the storage and the deflectors of extended-coverage, ceiling-level sprinklers.

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

2.1.4 Protection

2.1.4.1 In addition to the recommendations in this data sheet, follow the sprinkler, ceiling and in-rack, installation guidelines indicated for Storage sprinklers in FM Global Property Loss Prevention Data Sheet (i.e., Data Sheet) 2-0, *Installation Guidelines for Automatic Sprinklers*, including recommendations specific to:

1. Temperature rating of the ceiling sprinklers based on the ambient temperature of the protected area
2. Linear and area spacing of the ceiling sprinklers based on unobstructed or obstructed ceiling construction
3. Mixing of ceiling sprinklers on the same sprinkler system
4. Obstruction of ceiling sprinkler discharge

2.1.4.2 For facilities located in earthquake-prone regions, refer to FM Global Property Loss Prevention Data Sheet (i.e., Data Sheet) 2-8, *Earthquake Protection for Water-Based Fire Protection Systems*.

2.1.4.3 In addition, see Data Sheet 3-0, *Hydraulics of Fire Protection Systems*, for guidelines on calculating the sprinkler designs obtained from this data sheet.

2.1.4.4 The units for sprinkler K-factor used throughout this data sheet are $\text{gpm}/\text{psi}^{0.5}$ ($[\text{L}/\text{min}]/\text{bar}^{0.5}$).

2.1.4.5 Ceiling Sprinkler Designs

2.1.4.5.1 Ceiling-Level Sprinkler Protection Design Format

The ceiling-level sprinkler system design options provided in the protection tables of this data sheet use a design format based on an indicated number of operating sprinklers at a given minimum operating pressure from the hydraulically most remote sprinkler. Do not interpolate or adjust the protection values obtained from these tables.

2.1.4.5.2 Minimum Ceiling Design Area

2.1.4.5.2.1 Unobstructed Ceiling Construction

The minimum design area (i.e., the number of sprinklers in the design multiplied by the spacing of the sprinklers) is as follows:

1. 576 ft² (53.5 m²) when the number of sprinklers in the indicated design is 9
2. 640 ft² (59.5 m²) when the number of sprinklers in the indicated design is 10
3. 768 ft² (71.3 m²) when the number of sprinklers in the indicated design is 12 or more

Increase the number of sprinklers in the ceiling design, when applicable, to meet or exceed the required minimum design area.

2.1.4.5.2.2 Obstructed Ceiling Construction

When ceiling sprinklers can be installed under the ceiling structural members in the presence of obstructed ceiling construction, follow the guidelines for minimum ceiling design area indicated in Section 2.1.4.5.2.1. When ceiling sprinklers are required in every channel created by obstructed ceiling construction, and the linear and area sprinkler spacing is in accordance with Data Sheet 2-0, a minimum ceiling design area is not applicable.

2.1.4.5.3 Non-ASRS Areas Adjacent to an ASRS Storage Area

2.1.4.5.3.1 Provide separation between the ASRS storage area and any adjacent non-ASRS areas by either full-height walls or minimum 2 ft (0.6 m) deep draft curtains.

2.1.4.5.3.2 Separation between the ASRS storage area and any adjacent non-ASRS areas, as recommended in Section 2.1.4.5.3.1, is not needed when:

1. Both the ASRS storage area and the adjacent non-ASRS area require the same ceiling-level sprinkler design and use the same RTI rated sprinklers, or

2. The ceiling-level sprinkler system designs are different, but the ceiling-level sprinkler system with the higher demand has been extended one sprinkler or one branch line, depending on how the sprinkler piping is arranged, into the area requiring the lower ceiling-level sprinkler demand. Note that if the ceiling-level sprinklers protecting the two adjacent areas have different RTI ratings (i.e., quick-response and standard-response), then a minimum 2 ft (0.6 m) deep draft curtain is needed as separation between these two sprinkler types.

2.1.4.5.4 Number of Sprinklers per Branch Line for Ceiling-Level Sprinkler System Calculations

Instead of using the calculation methods in Data Sheet 3-0, use Table 1 to determine the number of ceiling-level sprinklers needed per branch line for hydraulic calculation purposes. Use Data Sheet 3-0 for all other means of determining the flow and pressure required for a sprinkler system.

When using Equation 1 or Equation 2, if the result is not a whole number, round to the nearest whole number using normal rounding methods (i.e., round down for 0.49 or less; round up for 0.50 and greater).

Equation 1: Number of Sprinklers per Branch Line in Design Area, Ceiling Slope ≤ 1 in 12 = $(1.2 / \text{SAVG}) \times \text{SQRT} ([\text{Number of Sprinklers in Ceiling Design} \times \text{SAVG} \times \text{LAVG}])$

Where:

SAVG = Average on-line spacing used within the calculated sprinkler system.

LAVG = Average between line spacing used within the calculated sprinkler system.

Equation 2: Number of Sprinklers per Branch Line in Demand Area, 1 in $12 < \text{Ceiling Slope} \leq 2$ in $12 = (1.4 / \text{SAVG}) \times \text{SQRT} ([\text{Number of Sprinklers in Ceiling Design} \times \text{SAVG} \times \text{LAVG}])$

Where:

SAVG = Average on-line spacing used within the calculated sprinkler system.

LAVG = Average between line spacing used within the calculated sprinkler system.

Note that the average distance is indicated for Equations 1 and 2 to account for fluctuations in spacing due to the presence of ceiling structural members or similar potential obstructions. The most common sprinkler spacing can be used when sprinkler spacing values are generally consistent.

Table 1. Determining Number of Sprinklers per Branch Line for Ceiling Sprinkler System Hydraulic Design

Number. of Sprinklers in Ceiling Design	Ceiling Sprinkler Type	Maximum Ceiling Slope	Ceiling Construction Type	Ceiling Sprinkler On-Line Spacing, ft (m)	Number of Sprinklers per Branch Line in Design Area
6	Extended Coverage	2 in 12	Any	Any	3
		4 in 12	Unobstructed	Any	See Equation 1
			Obstructed	Any	See Equation 2
8	Extended Coverage	1 in 12	Any	≤ 12 (3.7)	4
				> 12 (3.7)	3
		2 in 12	Any	Any	4
		4 in 12	Unobstructed	Any	See Equation 1
			Obstructed	Any	See Equation 2
		9	Standard Coverage	2 in 12	Any
4 in 12	Unobstructed			Any	See Equation 1
	Obstructed			Any	See Equation 2
Extended Coverage	2 in 12		Any	Any	4
	4 in 12		Unobstructed	Any	See Equation 1
			Obstructed	Any	See Equation 2
10	Standard Coverage	1 in 12	Any	< 10 (3.0)	4
				≥ 10 (3.0)	3
		2 in 12	Any	Any	4
		4 in 12	Unobstructed	Any	See Equation 1
			Obstructed	Any	See Equation 2
	Extended Coverage	1 in 12	Any	Any	See Equation 1
		2 in 12	Any	Any	See Equation 2
		4 in 12	Unobstructed	Any	See Equation 1
			Obstructed	Any	See Equation 2
		12	Standard Coverage	2 in 12	Any
4 in 12	Unobstructed			Any	See Equation 1
	Obstructed			Any	See Equation 2
Extended Coverage	1 in 12		Any	Any	See Equation 1
	2 in 12		Any	Any	See Equation 2
	4 in 12		Unobstructed	Any	See Equation 1
			Obstructed	Any	See Equation 2
> 12	Any	1 in 12	Any	Any	See Equation 1
		2 in 12	Any	Any	See Equation 2
		4 in 12	Unobstructed	Any	See Equation 1
			Obstructed	Any	See Equation 2

2.1.5 Final Extinguishment

Establish a pre-incident plan in cooperation with the local fire service and your local FM Global Engineering Operations Center to address a means of achieving final extinguishment of a fire originating within the ASRS storage array. See FM Global Property Loss Prevention Data Sheet (i.e., Data Sheet) 10-1, *Pre-Incident Planning*, for general guidelines related to a pre-incident plan.

At a minimum, consider the following:

1. How access will be achieved to a fire anywhere within the storage array
2. How will the storage array be disassembled, if required, and what equipment will be needed to get to the seat of the fire
3. How many storage containers may be removed from the storage array to get to the seat of the fire and where they will be placed during this process
4. What resources will be needed and how they can be implemented for restoration of the storage array to minimize business interruption

5. Identifying and providing operational guidance on the specialized firefighting equipment, such as hose station connections, fixed-in-place monitors, visible or infrared cameras, remote monitor nozzle steering mechanisms, etc., installed at the facility for protection of the ASRS storage array

In addition, free training is available on the FM Global Fire Service Learning Network in multiple languages at www.fmglobalfireserviceresources.com. The network provides several different training modules and has a module specific to pre-incident planning at a facility with a TL-ASRS. The training is free and available to the fire service, facility owners/managers or anyone that would like to learn more about fire protection systems and firefighting operations in sprinklered properties.

2.1.6 Electrical Systems for ASRS Storage Arrangements

2.1.6.1 Design the robot's overall electrical system in accordance with the applicable international electrical safety standard, such as IEC 60950-1.

2.1.6.2 If lithium ion batteries are used in the robot's system, use batteries that have passed a thermal runaway propagation test in accordance with IEC 62619 or equivalent industrial standard.

2.1.6.3 Follow the manufacturer's periodic maintenance and testing program of the battery charging contacts, looking for any potential signs of arcing. If such a program is not offered by the manufacturer, perform weekly visual inspections. Increase the frequency if operating history indicates arcing is a possibility. Take corrective action when signs of arcing start to appear.

2.1.6.4 Replace the battery-charging contacts when they approach the end of cycle life to remove the potential for overheating.

2.1.6.5 At a minimum, on an annual basis conduct infrared scanning for all ASRS electrical components while the system is in normal operation including, when applicable, the charging operation.

2.1.6.6 Establish an alarm management program in accordance with FM Global Property Loss Prevention Data Sheet 10-8, *Operators*. Prioritize critical alarms including a robot power board hardware failure alarm as well as robot battery management system temperature and state of health indicators, when the robots are battery powered.

2.1.6.7 For robots powered by batteries, establish a robot battery system replacement program for aged batteries. Review the battery replacement program regularly and include, at a minimum, the following components:

1. Regular monitoring of the state of health of batteries which is generally available through the BMS, particularly for li-ion batteries.
2. The OEM design life expectancy of the batteries. This will be based on the number of years and the number of cycles that the battery is expected to perform adequately. After this point, the batteries will have performance deterioration (i.e., capacity decrease) due to aging condition, the likelihood of thermal runaway will also increase, and the batteries should be replaced.
3. When replacing a Li-ion battery with a different chemistry, consult with the battery and equipment OEM to ensure matching of performance such as voltage between the charger and the level required by the Li-ion battery packs and their battery management systems. Do not replace lead-acid batteries with Li-ion batteries.

2.1.6.8 Implement a Management of Change (MOC) procedure in accordance with FM Global Property Loss Prevention Data Sheet 7-43, *Process Safety*, for any major changes planned for the ASRS electrical system.

2.1.7 Control Systems for ASRS Storage Arrangements

To minimize potential property damage and business interruption due to loss of the control systems responsible for the operation of the ASRS storage system, review and implement the recommendations outlined in FM Global Property Loss Prevention Data Sheet 7-110, *Industrial Control Systems*, that are applicable to the facility's ASRS.

2.2 Horizontal-Loading Automatic Storage and Retrieval Systems (ASRS) Using Small Containers or Small Trays

2.2.1 General Guidelines for Horizontal-Loading ASRS Storage Arrangements

2.2.1.1 How to Use Section 2.2

2.2.1.1.1 Section 2.2 provides protection guidelines for horizontal-loading automatic storage and retrieval systems (ASRS). This type of storage arrangement is further subdivided into two specific types of ASRS storage: (1) a shuttle ASRS, and (2) a mini-load type ASRS. A shuttle ASRS has horizontal supports that do not interfere with the flow of sprinkler discharge into the transverse flue space. See Figure 2 for an example of this storage arrangement. The shuttle system shown in Figure 2 uses metal slats for the support of the trays or containers; other shuttle systems use mesh type or similar shelving to support the trays or containers. A mini-load type ASRS uses angle irons, or similar guides, for the support of trays or containers within the rack structure. See Figure 3 for an example of this storage arrangement.



Fig. 2. Example of a shuttle horizontal-loading ASRS



Fig. 3. Example of a mini-load ASRS having angle irons that support the trays and/or containers

2.2.1.1.2 What differentiates horizontal-loading ASRS storage arrangements from traditional pallet load storage rack arrangements include:

1. Rack uprights in a mini-load type ASRS that are typically only about 2 ft (0.6 m) apart horizontally as opposed to about 8 ft (2.4 m),
2. Tiers that are only about 12 to 18 in. (300 to 450 mm) high as opposed to about 5 ft (1.5 m),
3. Product handling that consists of 18 in. x 24 in. (450 mm x 600 mm) trays or open-top containers as opposed to 4 ft x 4 ft (1.2 m x 1.2 m) pallets,
4. Material handling support in mini-load type ASRS storage arrangements which is accomplished by angle irons as opposed to horizontal supports.

While bullet points 1 through 4 create a unique storage arrangement for horizontal-loading ASRS, it is the presence of the angle irons within the mini-load ASRS rack structure that has a major impact on the protection requirements for them. This is because the angle irons divert most of the sprinkler discharge out to the face of the rack, thus limiting the amount of sprinkler discharge that can be distributed into the transverse flue spaces of the storage rack.

2.2.1.1.3 To determine recommendations for the protection of products stored within a horizontal-loading ASRS storage array, use the following generic procedure:

1. See Section 2.1 for general recommendations that apply to all ASRS storage arrangements, including construction, occupancy, protection and final extinguishment.
2. See Section 2.2.1 for additional general recommendations that apply specifically to horizontal-loading ASRS storage arrangements.
3. Obtain the specific protection guidelines from the applicable section for the type of storage being maintained within the horizontal-loading ASRS.

The applicable sections are as follows:

- A. Section 2.2.2 for shuttle ASRS arrangements that use closed-top, noncombustible, solid-walled containers or FM Approved, non-propagating, open-top containers.

B. Section 2.2.3 for shuttle ASRS arrangements that use either (1) products that do not collect water that are stored on trays, or (2) closed-top combustible containers.

C. Section 2.2.4 for shuttle ASRS arrangements that use either (1) open-top cardboard or unexpanded plastic containers, or (2) products or containers that collect water and are stored on trays.

D. Section 2.2.5 for mini-load ASRS arrangements that use closed-top, noncombustible, solid-walled containers or FM Approved, non-propagating, open-top containers

E. Section 2.2.6 for mini-load ASRS arrangements that use either (1) products that do not collect water that are stored on trays, or (2) closed-top combustible containers.

F. Section 2.2.7 for mini-load ASRS arrangements that use either (1) open-top cardboard or unexpanded plastic containers, or (2) products or containers that collect water and are stored on trays.

2.2.1.1.4 The protection of expanded plastic trays or expanded plastic containers in a mini-load type of horizontal-loading ASRS storage array is outside the scope of this data sheet.

2.2.1.2 Information Needed

To determine the protection options available within Section 2.2, the following information is needed:

1. Maximum commodity hazard to be protected (see Data Sheet 8-1, Commodity Classification)
2. Depth of the ASRS unit (rack row depth; see Appendix A for a definition of this term)
3. Material composition (i.e., chemical construction) of the trays and/or containers used for material handling
4. Type of containers (closed-top, solid-walled open-top, and non-solid walled open-top)
5. Transverse flue space width
6. Horizontal distance between transverse flue spaces
7. Longitudinal flue space width (if provided)
8. Tier height
9. Maximum storage height
10. Maximum ceiling height over the storage area

2.2.1.3 General Construction Features for Horizontal-Loading ASRS Storage Arrangements

2.2.1.3.1 Properly anchor all horizontal-loading ASRS rack 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 Section 2.1.2.5), the weight of water-filled, in-rack sprinkler piping (if provided), any seismic conditions (see FM Global Property Loss Prevention Data Sheet [i.e., Data Sheet] 1-2, *Earthquakes*) and the type of flooring to which the rack structure will be anchored to. Retain a qualified structural engineer to perform the analysis and design of any anchoring of the storage racks.

2.2.1.3.2 Design horizontal-loading 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 Section 2.1.2.5), 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.

2.2.1.4 General Occupancy Features for Horizontal-Loading ASRS Storage Arrangements – Transverse Flue Spaces

2.2.1.4.1 When measuring for the net width of a transverse flue space, account for the width of any angle irons or alignment guides, located between containers or trays, that are pitched at an angle less than 30°.

2.2.1.4.2 Transverse Flue Spaces a Nominal 2 ft (0.6 m) Apart: Where the horizontal distance between transverse flue spaces is a nominal 2 ft (0.6 m) or less, transverse flue spaces are considered adequate when:

1. Minimum 2 in. (50 mm) gross wide transverse flue spaces are provided between containers or trays for transverse flue spaces at rack uprights, and
2. Minimum 2 in. (50 mm) net wide vertically aligned transverse flue spaces are provided between containers or trays for transverse flue spaces that are not at rack uprights.

2.2.1.4.3 Transverse Flue Spaces a Nominal 4 ft (1.2 m) Apart: Where the horizontal distance between transverse flue spaces is a nominal 4 ft (1.2 m) or less, transverse flue spaces are considered adequate when:

1. Minimum 3 in. (75 mm) gross wide transverse flue spaces are provided between containers or trays for transverse flue spaces at rack uprights, and
2. Minimum 3 in. (75 mm) net wide vertically aligned transverse flue spaces are provided between containers or trays for transverse flue spaces that are not at rack uprights.

2.2.1.4.4 Transverse Flue Spaces a Nominal 10 ft (3.0 m) Apart: Where the horizontal distance between transverse flue spaces is a nominal 10 ft (3.0 m) or less, transverse flue spaces are considered adequate when:

1. Minimum 6 in. (150 mm) gross wide transverse flue spaces are provided between containers or trays for transverse flue spaces at rack uprights, and
2. Minimum 6 in. (150 mm) net wide vertically aligned transverse flue spaces are provided between containers or trays for transverse flue spaces that are not at rack uprights.

2.2.1.4.5 In-rack sprinklers and vertical barriers are needed when the guidelines indicated in Sections 2.2.1.4.2, 2.2.1.4.3, or 2.2.1.4.4 are not met. However, vertical barriers can be avoided when:

1. The transverse flue spaces are not vertically aligned, but the width of the transverse flue spaces is in accordance with Section 2.2.1.4.2, 2.2.1.4.3, and 2.2.1.4.4, or
2. The width of the transverse flue spaces is not in accordance with Sections 2.2.1.4.2, 2.2.1.4.3, and 2.2.1.4.4, but the net width of the transverse flue spaces is at least 2 in. (50 mm).

2.2.1.4.6 When Section 2.2.1.4.5 indicates that vertical barriers are needed, install the vertical barriers at rack uprights on maximum 10 ft (3.0 m) horizontal spacing. Arrange the vertical barriers to cover the entire depth of the rack row as well as the entire storage height located between each vertical level of in-rack sprinklers. Note that the vertical barriers do not need to extend into the roughly 1 ft (0.3 m) high horizontal space where in-rack sprinklers are being installed.

2.2.1.5 General Protection Guidelines for Horizontal-Loading ASRS Storage Arrangements

2.2.1.5.1 Sprinkler System Types

2.2.1.5.1.1 Ceiling-Level Sprinkler System Types

1. Depending on the ambient temperature of the ASRS area being protected, ceiling-level sprinkler systems can be:
 - a. Wet-pipe sprinkler systems
 - b. Antifreeze solution sprinkler system consisting of a 20% to 30% propylene glycol or up to 35% glycerin
 - c. Dry-pipe sprinkler systems
 - d. Non-interlocked, single-interlocked, or double-interlocked preaction sprinkler systems
 - e. Refrigerated area sprinkler systems, or
 - f. Vacuum-type sprinkler systems
2. A ceiling-level sprinkler system consisting of 20% to 30% concentration of propylene glycol in water or a glycerin solution with a concentration up to 35% in water is acceptable for ambient temperatures between 32°F (0°C) and 40°F (4°C). Wet-pipe sprinkler system designs can be utilized for ceiling sprinkler systems having these anti-freeze solution concentrations.
3. The maximum water delivery time for all ceiling-level dry-pipe and similar sprinkler systems is 40 seconds upon the operation of the hydraulically most remote 4 sprinklers (2 sprinklers on 2 lines).
4. When installing a preaction, refrigerated area, or vacuum-type sprinkler system, see Data Sheet 2-0 for recommendations pertaining to the sprinkler system's activating detection system.
5. Ceiling sprinkler designs for single-interlocked preaction sprinkler systems can be either classified as "wet-pipe" or "dry-pipe," depending on the installation of the activating detection system. See Data Sheet 2-0 to determine the installation requirements needed for the detection system to achieve a sprinkler system design classification of wet pipe. Design the single-interlocked preaction system using the dry-pipe sprinkler system designs when the detection installation is not in compliance with the

recommendations provided in Data Sheet 2-0 for a wet-pipe sprinkler system design.

6. See Data Sheet 2-0 for additional recommendations related to the specific sprinkler system type that is to be installed.

2.2.1.5.1.2 In-Rack Sprinkler System Types

1. Depending on the ambient temperature of the ASRS area being protected, in-rack sprinkler systems can be:
 - a. Wet-pipe sprinkler systems
 - b. Antifreeze solution sprinkler system consisting of 20% to 25% propylene, or 30% to 35% glycerin
 - c. Dry-pipe sprinkler systems
 - d. Non-interlocked, single-interlocked, or double-interlocked preaction sprinkler systems
 - e. Refrigerated area sprinkler systems, or
 - f. Vacuum-type sprinkler systems
2. An in-rack sprinkler system consisting of 20% to 25% concentration of propylene glycol in water or a glycerin solution with a concentration of 30% to 35% in water is acceptable for ambient temperatures between 32°F (0°C) and 40°F (4°C). Wet-pipe sprinkler system designs can be used for in-rack sprinkler systems having these anti-freeze solution concentrations.
3. Except for wet-pipe sprinkler systems and the anti-freeze solution sprinkler systems outlined above, use dry-pipe sprinkler system designs for all other in-rack sprinkler system types.
4. The maximum water delivery time for all in-rack sprinkler dry-pipe and similar sprinkler systems is 40 seconds upon the operation of the hydraulically most remote in-rack sprinkler.
5. When installing a preaction or refrigerated area sprinkler system, see Data Sheet 2-0 for recommendations pertaining to the sprinkler system's activating detection system.
6. See Data Sheet 2-0 for additional recommendations related to the specific sprinkler system type that is to be installed.

2.2.1.5.2 Sprinklers

2.2.1.5.2.1 Ceiling-Level Sprinklers

Install FM Approved, Storage ceiling-level sprinklers having the attributes indicated in the applicable horizontal-loading ASRS protection tables.

2.2.1.5.2.2 In-Rack Sprinklers

When in-rack sprinklers are required, install FM Approved, quick-response, 160°F (70°C) nominally rated, Storage sprinklers having the appropriate K-factor value indicated in the applicable horizontal-loading ASRS in-rack sprinkler protection table. Note that if not specifically indicated, in-rack sprinklers can be either pendent or upright.

2.2.1.6 Hose Demand Design and Water Supply Duration for Horizontal-Loading ASRS Storage Arrangements

See Table 2 to determine the hose demand design and the water supply duration for either (1) a ceiling-only sprinkler system arrangement, or (2) a ceiling and in-rack sprinkler system arrangement where the two sprinkler systems must be hydraulically balanced.

Table 2. Hose Demand Design and Water Supply Duration

<i>Ceiling Sprinkler Type</i>	<i>Number of Sprinklers in the Ceiling Sprinkler System Design</i>	<i>Hose Demand, gpm (L/min)</i>	<i>Water Supply Duration, min</i>
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

2.2.1.7 Fire Detection for Horizontal-Loading ASRS Storage Arrangements

2.2.1.7.1 Install a FM Approved ceiling-level fire detection system over the horizontal-loading ASRS storage area in accordance with FM Global Property Loss Prevention Data Sheet (i.e., Data Sheet) 5-48, *Automatic Fire Detection*.

2.2.1.7.2 When the ceiling construction over the storage area is considered obstructed per Data Sheet 2-0, install the detectors on the same maximum spacing indicated for the ceiling-level sprinklers using an obscuration rate that is in accordance with the detection system manufacturer's guidelines.

2.2.1.7.3 Arrange the fire detection system upon activation to:

1. send an alarm to a constantly attended location, and
2. automatically shut-down the operations of the ASRS robots

2.2.1.7.4 A ceiling-level fire detection system over the horizontal-loading ASRS storage area is not needed when Closed-Top, Noncombustible, Solid-Walled Containers are used throughout the ASRS storage array.

2.2.1.8 Final Extinguishment: Small Hose Connection Stations

2.2.1.8.1 To aid in manual firefighting efforts and after-extinguishment mop-up operations, install small hose connection stations near the access points to the horizontal-loading ASRS storage aisles for the fire service. Consult with the local fire service or authority having jurisdiction to determine their recommendations regarding the following:

1. The use of wet-barrel or dry-barrel stations
2. The size of the hose connections
3. The horizontal distance between stations

2.2.1.8.2 Design the small hose connection station system to provide a minimum flow of 50 gpm (190 L/min) from each of the two most hydraulically remote stations (100 gpm [380 L/min] total).

2.2.1.8.3 Arrange the water supplies feeding these stations in one of the following ways:

1. A piping system dedicated solely for the small hose connection stations, or
2. Piping that connects the stations to a sprinkler system different than the one protecting the ASRS storage area

2.2.1.8.4 The installation of small hose connection stations can be avoided:

1. When noncombustible solid-walled containers are used throughout the ASRS storage array, or
2. At the documented discretion of the local authority having jurisdiction.

2.2.2 Protection of Horizontal-Loading Shuttle ASRS Storage Arrangements Where Closed-Top, Noncombustible, Solid-Walled Containers, or FM Approved, Non-Propagating, Open-Top Containers are Being Used**2.2.2.1 Protection of Horizontal-Loading Shuttle ASRS Storage Arrangements Where Closed-Top, Noncombustible, Solid-Walled Containers are Being Used**

2.2.2.1.1 Automatic sprinkler protection can be designed for the surrounding occupancy hazard when Closed-Top, Noncombustible, Solid-Walled Containers are used throughout the entire horizontal-loading ASRS storage array.

2.2.2.1.2 Where closed-top, noncombustible, solid-walled containers are being used, but not throughout the entire storage array, provide protection in accordance with the worst-case container or tray being used.

2.2.2.2 Protection of Horizontal-Loading, Shuttle ASRS Storage Arrangements Where FM Approved, Non-Propagating Open-Top Containers are Being Used (Reserved)

Protection guidelines for FM Approved, non-propagating, open-top containers will be provided upon the release of a FM Approval Standard specific to these types of containers.

2.2.3 Protection of Horizontal-Loading Shuttle ASRS Storage Arrangements Using (1) Closed-Top Combustible Containers, or (2) Products that Do Not Collect Water that are Stored on Trays

The protection guidelines in Section 2.2.3 apply only to storage that is not considered open-top, whether stored directly on the support rails of the ASRS or on trays. Such products will be subsequently referred to in Section 2.2.3 as “storage on trays”. If the product or containers allow for water collection, use the protection guidelines provided in Section 2.2.4.

Section 2.2.3 is organized as follows:

- Section 2.2.3.1 determines if a ceiling-only protection option is available and, if it is, the recommended ceiling-only protection designs.
- Section 2.2.3.2 determines the recommended designs when both ceiling and in-rack sprinklers are installed. This section is further broken down into the following subsections:
 - Section 2.2.3.2.1 provides acceptable horizontal in-rack sprinkler arrangements.
 - Section 2.2.3.2.2 provides both the acceptable vertical in-rack sprinkler arrangements as well as the corresponding in-rack sprinkler system design.
 - Section 2.2.3.2.3 provides the acceptable ceiling sprinkler system design with the chosen in-rack sprinkler system arrangement.

2.2.3.1 Ceiling-Only Sprinkler System Design Criteria for Closed-Top Combustible Containers, or Storage on Trays

2.2.3.1.1 A ceiling-only sprinkler system protection scheme is possible when:

1. Adequately aligned transverse flue spaces as outlined in Section 2.2.1.4 are provided, and
2. For Class 1 through 4, cartoned plastics, and uncartoned unexpanded plastics, minimum 3-1/2 ft (1.1 m) wide aisles are provided for ceiling heights not exceeding 30 ft (9.1 m), and
3. Minimum 4 ft (1.2 m) wide aisles are provided when:
 - a. Uncartoned, expanded plastics are stored in the racks, or
 - b. The ceiling height exceeds 30 ft (9.1 m) (unless indicated otherwise by a footnote at the bottom of the applicable protection table), and
4. For the given material handling scenario outlined in this section, ceiling-only protection is provided per the applicable protection table (Tables 4 through 13) for the specific sprinkler being installed at ceiling level, and
5. The water supply can provide the flow and pressure requirements for the protection option chosen from the applicable protection table.

If the conditions outlined in (1) through (5) cannot be met, see Section 2.2.3.2 regarding the guidelines for installing in-rack sprinklers in combination with ceiling-level sprinklers.

2.2.3.1.2 When a ceiling-only protection scheme is acceptable per items (1) through (5) in Section 2.2.3.1.1, use Table 3 to determine which protection table provides the recommended ceiling sprinkler design, depending on the commodity hazard, the type of material handling being used (i.e., directly on the rack's horizontal supporting rails or on trays) and the type of ceiling sprinkler system (i.e., wet or dry) being installed.

2.2.3.1.3 See Section 2.2.1.6 to determine the ceiling sprinkler's hose demand design and water supply duration.

2.2.3.1.4 See Section 2.1.4.5.4 to determine the number of sprinklers per branch line for ceiling-level sprinkler calculations.

Table 3. Determining Which Ceiling Sprinkler Protection Table to Use for the Protection of Closed-Top Combustible Containers or Storage Trays

<i>Material Handling Method</i>	<i>Commodity Classification (No Open-Top Containers Permitted)</i>	<i>Ceiling Sprinkler System Type</i>	<i>Protection Table to Use</i>
Directly on Supporting Rails	Class 1 through Class 3	Wet	4
		Dry	5
	Class 4 and Cartoned Unexpanded Plastics	Wet	6
		Dry	7
	Cartoned Expanded Plastics	Wet	8
		Dry	9
	Uncartoned Unexpanded Plastics	Wet	10
		Dry	11
	Uncartoned Expanded Plastics	Wet	12
		Dry	13
On Trays	Class 1 through 4, Cartoned Plastics, and Uncartoned Unexpanded Plastics	Wet	10
		Dry	11
	Uncartoned Expanded Plastics	Wet	12
		Dry	13

Note: In Tables 4 through 12, the ceiling-level protection options highlighted in green represent those for which the hose stream demand is 250 gpm (950 L/min) and the sprinkler system duration is 1 hour.

Table 4. Ceiling-Level Protection Guidelines on a Wet System for Class 1, 2, and 3 Commodities Stored Directly on the Supporting Rails of a Shuttle ASRS; No. of AS @ psi (bar)

Max. Ceiling Height, ft (m)	Wet System, 160°F (70°C) Nominally Rated, Pendent Sprinklers												Wet System, 160°F (70°C) Nominally Rated, 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)	K28.0 (K400)	K33.6 (K480)	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)	12 @ 7 (0.5)	9 @ 7 (0.5)	9 @ 7 (0.5)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 20 (1.4)	9 @ 40 (2.8)	9 @ 55 (3.8)	12 @ 7 (0.5)	9 @ 7 (0.5)	9 @ 16 (1.1)	9 @ 7 (0.5)	12 @ 7 (0.5)	9 @ 7 (0.5)	9 @ 7 (0.5)	6 @ 20 (1.4)	12 @ 7 (0.5)	9 @ 7 (0.5)	9 @ 7 (0.5)		
20 (6.1)	12 @ 10 (0.7)	12 @ 7 (0.5)	12 @ 13 (0.9)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 20 (1.4)	9 @ 40 (2.8)	9 @ 55 (3.8)	12 @ 10 (0.7)	12 @ 7 (0.5)	9 @ 16 (1.1)	9 @ 10 (0.7)	12 @ 10 (0.7)	12 @ 7 (0.5)	12 @ 7 (0.5)	6 @ 20 (1.4)	12 @ 10 (0.7)	12 @ 7 (0.5)	12 @ 7 (0.5)		
25 (7.6)	15 @ 16 (1.1)	12 @ 16 (1.1)	12 @ 11 (0.8)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 22 (1.5)	9 @ 40 (2.8)	9 @ 55 (3.8)	15 @ 16 (1.1)	15 @ 10 (0.7)	9 @ 16 (1.1)	9 @ 10 (0.7)	15 @ 16 (1.1)	12 @ 16 (1.1)	12 @ 11 (0.8)	6 @ 22 (1.5)	15 @ 16 (1.1)	15 @ 7 (0.5)	10 @ 20 (1.4)		
30 (9.1)	18 @ 50 (3.5)	12 @ 50 (3.5)	12 @ 35 (2.4)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 30 (2.1)	9 @ 40 (2.8)	9 @ 55 (3.8)	18 @ 50 (3.5)	18 @ 32 (2.2)	9 @ 16 (1.1)	9 @ 10 (0.7)	18 @ 50 (3.5)	12 @ 50 (3.5)	12 @ 35 (2.4)	6 @ 30 (2.1)	18 @ 50 (3.5)	18 @ 22 (1.5)	12 @ 20 (1.4)		
35 (10.7)		12 @ 75 (5.2)	12 @ 52 (3.6)	12 @ 29 (2.0)	12 @ 23 (1.6)	6 @ 60 (4.1)	9 @ 40 (2.8)	9 @ 55 (3.8)			15 @ 25 (1.7)	9 @ 30 (2.1)				8 @ 40 (2.8)					
40 (12.2)		12 @ 75 (5.2)	12 @ 52 (3.6)	9 @ 50 (3.5)	9 @ 40 (2.8)		9 @ 40 (2.8)	9 @ 55 (3.8)				9 @ 30 (2.1)									
50 (15.2)				10 @ 63 (4.3) ^{a,c}	10 @ 50 (3.5) ^{a,c}		10 @ 40 (2.8) ^{a,c}	9 @ 55 (3.8) ^a													
55 (16.8)							9 @ 80 (5.5) ^{b,c}	9 @ 55 (3.8) ^a													

^a Minimum 6 ft (1.8 m) wide aisles needed^b Minimum 8 ft (2.4 m) wide aisles needed^c Maximum vertical distance of sprinkler's thermal element below ceiling is 13 in. (325 mm)

Table 5. Ceiling-Level Protection Guidelines on a Dry System for Class 1, 2, and 3 Commodities Stored Directly on the Supporting Rails of a Shuttle ASRS; No. of AS @ psi (bar)

Max. Ceiling Height, ft (m)	Dry System, 280°F (140°C) Nominally Rated, Upright Sprinklers			
	Standard-Response			
	K11.2 (K160)	K16.8 (K240)	K25.2 (K360)	K33.6 (K480)
10 (3.0)	16 @ 7 (0.5)	16 @ 7 (0.5)	16 @ 7 (0.5)	16 @ 50 (3.5)
20 (6.1)	16 @ 10 (0.7)	16 @ 7 (0.5)	16 @ 7 (0.5)	16 @ 50 (3.5)
25 (7.6)	20 @ 16 (1.1)	20 @ 7 (0.5)	20 @ 7 (0.5)	20 @ 50 (3.5)
30 (9.1)	25 @ 50 (3.5)	25 @ 22 (1.5)	25 @ 10 (0.7)	25 @ 50 (3.5)
40 (12.2)			24 @ 15 (1.0) ^a	12 @ 50 (3.5) ^b
45 (13.7)			12 @ 50 (3.5) ^b	12 @ 50 (3.5) ^b
50 (15.2)				15 @ 50 (3.5) ^c
55 (16.8)				16 @ 50 (3.5) ^c

^a Minimum 4 ft (1.2 m) wide aisle and maximum 25 second water delivery time is needed. An acceptable alternative design is 12 AS @ 50 psi (3.5 bar), but a minimum 6 ft (1.8 m) wide aisle and a maximum 20 second water delivery time is needed.

^b Minimum 6 ft (1.8 m) wide aisle and maximum 20 second water delivery time is needed.

^c Minimum 8 ft (2.4 m) wide aisle and maximum 20 second water delivery time is needed.

Table 6. Ceiling-Level Protection Guidelines on a Wet System for Class 4 and Cartoned Unexpanded Plastic Commodities Stored Directly on the Supporting Rails of a Shuttle ASRS;
No. of AS @ psi (bar)

Max. Ceiling Height, ft (m)	Wet System, 160°F (70°C) Nominally Rated, Pendent Sprinklers												Wet System, 160°F (70°C) Nominally Rated, 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)	K28.0 (K400)	K33.6 (K480)	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)	12 @ 7 (0.5)	9 @ 7 (0.5)	9 @ 7 (0.5)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 20 (1.4)	9 @ 40 (2.8)	9 @ 55 (3.8)	12 @ 7 (0.5)	9 @ 7 (0.5)	9 @ 16 (1.1)	9 @ 7 (0.5)	12 @ 7 (0.5)	9 @ 7 (0.5)	9 @ 7 (0.5)	6 @ 20 (1.4)	12 @ 7 (0.5)	9 @ 7 (0.5)	9 @ 7 (0.5)		
15 (4.6)	15 @ 16 (1.1)	12 @ 16 (1.1)	12 @ 11 (0.8)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 20 (1.4)	9 @ 40 (2.8)	9 @ 55 (3.8)	15 @ 16 (1.1)	12 @ 16 (1.1)	9 @ 16 (1.1)	10 @ 7 (0.5)	15 @ 16 (1.1)	12 @ 16 (1.1)	12 @ 11 (0.8)	6 @ 20 (1.4)	15 @ 16 (1.1)	12 @ 11 (0.8)	10 @ 7 (0.5)		
20 (6.1)	12 @ 30 (2.1)	12 @ 18 (1.2)	12 @ 13 (0.9)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 22 (1.5)	9 @ 40 (2.8)	9 @ 55 (3.8)	12 @ 30 (2.1)	12 @ 16 (1.1)	9 @ 16 (1.1)	12 @ 7 (0.5)	12 @ 30 (2.1)	12 @ 16 (1.1)	12 @ 13 (0.9)	6 @ 22 (1.5)	12 @ 30 (2.1)	12 @ 13 (0.9)	12 @ 7 (0.5)		
25 (7.6)	15 @ 65 (4.5)	9 @ 35 (2.4)	9 @ 24 (1.7)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 22 (1.5)	9 @ 40 (2.8)	9 @ 55 (3.8)	15 @ 65 (4.5)	12 @ 50 (3.5)	9 @ 16 (1.1)	12 @ 10 (0.7)	15 @ 65 (4.5)	12 @ 50 (3.5)	12 @ 35 (2.4)	6 @ 22 (1.5)	15 @ 65 (4.5)	15 @ 29 (2.0)	12 @ 20 (1.4)		
30 (9.1)		12 @ 50 (3.5)	12 @ 35 (2.4)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 30 (2.1)	9 @ 40 (2.8)	9 @ 55 (3.8)			9 @ 16 (1.1)	12 @ 15 (1.0)				6 @ 30 (2.1)			12 @ 20 (1.4)		
35 (10.7)		12 @ 75 (5.2)	12 @ 52 (3.6)	12 @ 29 (2.0)	12 @ 23 (1.6)	6 @ 60 (4.1)	9 @ 40 (2.8)	9 @ 55 (3.8)			15 @ 25 (1.7)	9 @ 30 (2.1)				8 @ 40 (2.8)					
40 (12.2)		12 @ 75 (5.2)	12 @ 52 (3.6)	9 @ 50 (3.5)	9 @ 40 (2.8)		9 @ 40 (2.8)	9 @ 55 (3.8)				9 @ 30 (2.1)									
50 (15.2)				10 @ 63 (4.3)a,c	10 @ 50 (3.5)a,c		10 @ 40 (2.8)a,c	9 @ 55 (3.8)a													
55 (16.8)							9 @ 80 (5.5)b,c	9 @ 55 (3.8)a													

^a Minimum 6 ft (1.8 m) wide aisles needed

^b Minimum 8 ft (2.4 m) wide aisles needed

^c Maximum vertical distance of sprinkler's thermal element below ceiling is 13 in. (325 mm)

Table 7. Ceiling-Level Protection Guidelines on a Dry System for Class 4 and Cartoned Unexpanded Plastic Commodities Stored Directly on the Supporting Rails of a Shuttle ASRS; No. of AS @ psi (bar)

Max. Ceiling Height, ft (m)	Dry System, 280°F (140°C) Nominally Rated, Upright Sprinklers			
	Standard-Response			
	K11.2 (K160)	K16.8 (K240)	K25.2 (K360)	K33.6 (K480)
10 (3.0)	16 @ 7 (0.5)	16 @ 7 (0.5)	16 @ 7 (0.5)	16 @ 50 (3.5)
15 (4.6)	20 @ 16 (1.1)	20 @ 7 (0.5)	20 @ 7 (0.5)	20 @ 50 (3.5)
20 (6.1)	20 @ 30 (2.1)	20 @ 13 (0.9)	20 @ 7 (0.5)	20 @ 50 (3.5)
25 (7.6)	20 @ 65 (4.5)	20 @ 29 (2.0)	20 @ 13 (0.9)	20 @ 50 (3.5)
30 (9.1)			30 @ 20 (1.4)	30 @ 50 (3.5)

Table 8. Ceiling-Level Protection Guidelines on a Wet System for Cartoned Expanded Plastic Commodities Stored Directly on the Supporting Rails of a Shuttle ASRS; No. of AS @ psi (bar)

Max. Ceiling Height, ft (m)	Wet System, 160°F (70°C) Nominally Rated, Pendent Sprinklers										Wet System, 160°F (70°C) Nominally Rated, 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)	K28.0 (K400)	K33.6 (K480)	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)	15 @ 10 (0.7)	15 @ 7 (0.5)	15 @ 7 (0.5)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 20 (1.4)	9 @ 40 (2.8)	9 @ 55 (3.8)	15 @ 10 (0.7)	15 @ 7 (0.5)	12 @ 19 (1.1)	15 @ 7 (0.5)	15 @ 10 (0.7)	15 @ 7 (0.5)	15 @ 7 (0.5)	6 @ 20 (1.4)	15 @ 10 (0.7)	15 @ 7 (0.5)	15 @ 7 (0.5)
20 (6.1)	18 @ 28 (1.9)	12 @ 18 (1.2)	12 @ 13 (0.9)	9 @ 20 (1.4)	9 @ 20 (1.4)	9 @ 21 (1.4)	9 @ 40 (2.8)	9 @ 55 (3.8)	18 @ 28 (1.9)	15 @ 18 (1.2)	15 @ 16 (1.1)	15 @ 7 (0.5)	18 @ 28 (1.9)	12 @ 50 (3.5)	12 @ 35 (2.4)	8 @ 35 (2.4)	18 @ 28 (1.9)	15 @ 22 (1.5)	15 @ 10 (0.7)
25 (7.6)		12 @ 35 (2.4)	12 @ 24 (1.7)	10 @ 20 (1.4)	9 @ 20 (1.4)	8 @ 60 (4.1)	9 @ 40 (2.8)	9 @ 55 (3.8)		15 @ 50 (3.5)	15 @ 25 (1.7)	15 @ 15 (1.0)		12 @ 50 (3.5)	12 @ 35 (2.4)				
30 (9.1)		12 @ 50 (3.5)	12 @ 35 (2.4)	12 @ 25 (1.7)	12 @ 20 (1.4)		12 @ 40 (2.8)	12 @ 55 (3.8)											
40 (12.2)				12 @ 75 (5.2)	12 @ 60 (4.1)		12 @ 49 (3.4)	12 @ 55 (3.8)											

Table 9. Ceiling-Level Protection Guidelines on a Dry System for Cartoned Expanded Plastic Commodities Stored Directly on the Supporting Rails of a Shuttle ASRS; No. of AS @ psi (bar)

Max. Ceiling Height, ft (m)	Dry System, 280°F (140°C) Nominally Rated, Upright Sprinklers			
	Standard-Response			
	K11.2 (K160)	K16.8 (K240)	K25.2 (K360)	K33.6 (K480)
10 (3.0)	20 @ 10 (0.7)	20 @ 7 (0.5)	20 @ 7 (0.5)	20 @ 50 (3.5)
20 (6.1)	20 @ 50 (3.5)	20 @ 22 (1.5)	20 @ 10 (0.7)	20 @ 50 (3.5)

Table 10. Ceiling-Level Protection Guidelines on a Wet System for Uncartoned Unexpanded Plastic Commodities Stored in a Shuttle ASRS; No. of AS @ psi (bar)

Max. Ceiling Height, ft (m)	Wet System, 160°F (70°C) Nominally Rated, Pendent Sprinklers										Wet System, 160°F (70°C) Nominally Rated, 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)	K28.0 (K400)	K33.6 (K480)	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)	15 @ 10 (0.7)	15 @ 7 (0.5)	15 @ 7 (0.5)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 20 (1.4)	9 @ 40 (2.8)	9 @ 55 (3.8)	15 @ 10 (0.7)	15 @ 7 (0.5)	12 @ 16 (1.1)	15 @ 7 (0.5)	15 @ 10 (0.7)	15 @ 7 (0.5)	15 @ 7 (0.5)	6 @ 20 (1.4)	15 @ 10 (0.7)	15 @ 7 (0.5)	15 @ 7 (0.5)
15 (4.6)	15 @ 50 (3.5)	12 @ 32 (2.2)	12 @ 22 (1.5)	9 @ 25 (1.7)	9 @ 20 (1.4)	6 @ 60 (4.1)	9 @ 40 (2.8)	9 @ 55 (3.8)	15 @ 50 (3.5)	12 @ 50 (3.5)	12 @ 25 (1.7)	12 @ 15 (1.0)	15 @ 50 (3.5)	15 @ 32 (2.2)	15 @ 22 (1.5)	8 @ 35 (2.4)	15 @ 50 (3.5)	15 @ 22 (1.5)	15 @ 10 (0.7)
20 (6.1)		9 @ 50 (3.5)	9 @ 35 (2.4)	9 @ 25 (1.7)	9 @ 20 (1.4)	6 @ 60 (4.1)	9 @ 40 (2.8)	9 @ 55 (3.8)		12 @ 50 (3.5)	12 @ 25 (1.7)	12 @ 15 (1.0)							
25 (7.6)		10 @ 50 (3.5)	10 @ 35 (2.4)	10 @ 25 (1.7)	10 @ 20 (1.4)		10 @ 40 (2.8)	10 @ 55 (3.8)											
30 (9.1)		15 @ 50 (3.5)	15 @ 35 (2.4)	10 @ 50 (3.5)	10 @ 40 (2.8)		10 @ 40 (2.8)	10 @ 55 (3.8)											
40 (12.2)				12 @ 75 (5.2)	12 @ 60 (4.1)		12 @ 49 (3.4)	12 @ 55 (3.8)											

Table 11. Ceiling-Level Protection Guidelines on a Dry System for Uncartoned Unexpanded Plastic Commodities Stored in a Shuttle ASRS; No. of AS @ psi (bar)

Max. Ceiling Height, ft (m)	Dry System, 280°F (140°C) Nominally Rated, Upright Sprinklers			
	Standard-Response			
	K11.2 (K160)	K16.8 (K240)	K25.2 (K360)	K33.6 (K480)
10 (3.0)	20 @ 10 (0.7)	20 @ 7 (0.5)	20 @ 7 (0.5)	20 @ 50 (3.5)
15 (4.6)	20 @ 50 (3.5)	20 @ 22 (1.5)	20 @ 10 (0.7)	20 @ 50 (3.5)

Table 12. Ceiling-Level Protection Guidelines on a Wet System for Uncartoned Expanded Plastic Commodities Stored in a Shuttle ASRS; No. of AS @ psi (bar)

Max. Ceiling Height, ft (m)	Wet System, 160°F (70°C) Nominally Rated, Pendent Sprinklers												Wet System, 160°F (70°C) Nominally Rated, 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)	K28.0 (K400)	K33.6 (K480)	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)	15 @ 10 (0.7)	15 @ 7 (0.5)	15 @ 7 (0.5)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 20 (1.4)	9 @ 40 (2.8)	9 @ 55 (3.8)	15 @ 10 (0.7)	15 @ 7 (0.5)	12 @ 16 (1.1)	15 @ 7 (0.5)	15 @ 10 (0.7)	15 @ 7 (0.5)	15 @ 7 (0.5)	6 @ 20 (1.4)	15 @ 10 (0.7)	15 @ 7 (0.5)	15 @ 7 (0.5)	
15 (4.6)	15 @ 50 (3.5)	12 @ 32 (2.2)	12 @ 22 (1.5)	9 @ 25 (1.7)	9 @ 20 (1.4)	8 @ 35 (2.4)	9 @ 40 (2.8)	9 @ 55 (3.8)	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)	8 @ 35 (2.4)	15 @ 50 (3.5)	15 @ 22 (1.5)	15 @ 10 (0.7)	
25 (7.6)		12 @ 75 (5.2)	12 @ 52 (3.6)	9 @ 32 (2.2)	9 @ 25 (1.7)		9 @ 40 (2.8)	9 @ 55 (3.8)												
30 (9.1)		12 @ 100 (6.9)	12 @ 70 (4.8)	12 @ 50 (3.5)	12 @ 40 (2.8)		12 @ 40 (2.8)	12 @ 55 (3.8)												
40 (12.2)					20 @ 75 (5.2)		20 @ 61 (4.2)	20 @ 55 (3.8)												

Table 13. Ceiling-Level Protection Guidelines on a Dry System for Uncartoned Expanded Plastic Commodities Stored in a Shuttle ASRS; No. of AS @ psi (bar)

Max. Ceiling Height, ft (m)	Dry System, 280°F (140°C) Nominally Rated, Upright Sprinklers			
	Standard-Response			
	K11.2 (K160)	K16.8 (K240)	K25.2 (K360)	K33.6 (K480)
10 (3.0)	25 @ 10 (0.7)	25 @ 7 (0.5)	25 @ 7 (0.5)	25 @ 50 (3.5)
15 (4.6)	25 @ 50 (3.5)	25 @ 22 (1.5)	25 @ 10 (0.7)	25 @ 50 (3.5)

2.2.3.2 Ceiling and In-Rack Sprinkler System Design Criteria for Closed-Top Combustible Containers, or Storage on Trays

In-rack sprinklers are needed in combination with ceiling-level sprinklers when the guidelines from Section 2.2.3.1.1 are not met. Determine the recommended in-rack sprinkler horizontal arrangement in Section 2.2.3.2.1, the in-rack sprinkler vertical location and system design in Section 2.2.3.2.2, and the available ceiling-level sprinkler designs in Section 2.2.3.2.3.

2.2.3.2.1 Horizontal Arrangement of In-Rack Sprinklers for the Protection of Closed-Top Combustible Containers, or Storage on Trays in a Shuttle ASRS

Use Table 14 to determine the recommended horizontal in-rack sprinkler arrangements for the storage rack to be protected.

Table 14. Recommended Horizontal In-Rack Sprinkler (i.e., IRAS) Arrangements for Closed-Top Combustible Containers, or Storage on Trays

Rack Row Depth, ft (m)	Overall Maximum Rack Depth, ft (m)	Adequate Transverse Flue Spaces Provided per Section 2.2.1.4?	IRAS System Type	Commodity Hazards	Ceiling Height, ft (m)	Aisle Width, ft (m)	Applicable Horizontal IRAS Arrangement Figures
Up to 3 (0.9)	3 (0.9)	No	Wet or Dry	Any	Any	Any	4
		Yes	Wet or Dry	Any	Any	Any	4 or 5
Up to 6 (1.8)	6 (1.8)	No	Wet or Dry	Any	Any	Any	6
		Yes	Wet or Dry	Any	≤ 30 (9.1)	< 3.5 (1.1)	6 or 7
				Up to Cartoned Plastics	> 30 (9.1)	< 4 (1.2)	6 or 7
				Any	≤ 30 (9.1)	≥ 3.5 (1.1)	6, 7 or 8
				Up to Cartoned Plastics	> 30 (9.1)	≥ 4 (1.2)	6, 7 or 8
				Uncartoned Plastics	> 30 (9.1)	Any	6 or 7
	9 (2.7)	No	Wet or Dry	Any	Any	Any	9
		Yes	Wet	Up to Cartoned Plastics	≤ 30 (9.1)	< 3.5 (1.1)	9 or 10
					≥ 3.5 (1.1)	9, 10 or 11	
					> 30 (9.1)	< 4 (1.2)	9 or 10
					≥ 4 (1.2)	9, 10 or 11	
				Uncartoned Plastics	Any	Any	9 or 10
			Dry	Any	Any	Any	9 or 10
	14 (4.3)	No	Wet or Dry	Any	Any	Any	9
		Yes	Wet or Dry	Any	Any	Any	9 or 10
Over 6 (1.8)	Over 6 (1.8)	No	Wet or Dry	Any	Any	Any	12 with Vertical Barriers
		Yes	Wet or Dry	Any	Any	Any	13

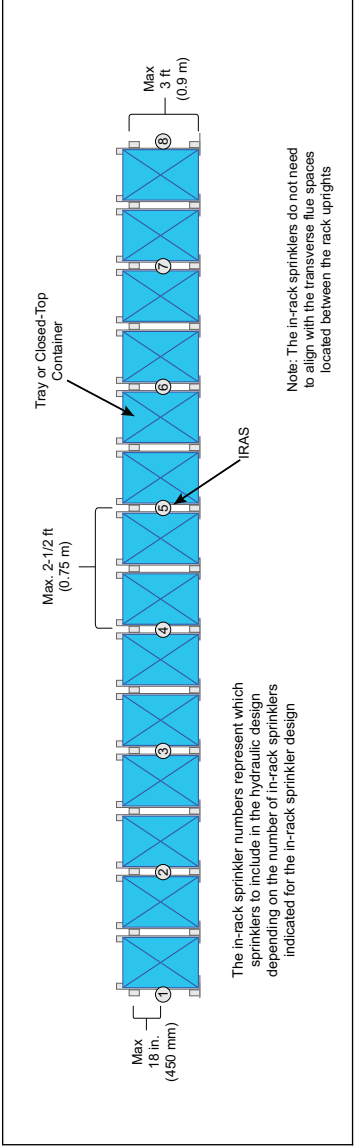


Fig. 4. Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage Trays within a Shuttle ASRS Where Rack Row Depths Do Not Exceed 3 ft (0.9 m) per Table 14 and the Maximum Allowable Horizontal Spacing is 2-1/2 ft (0.75 m)

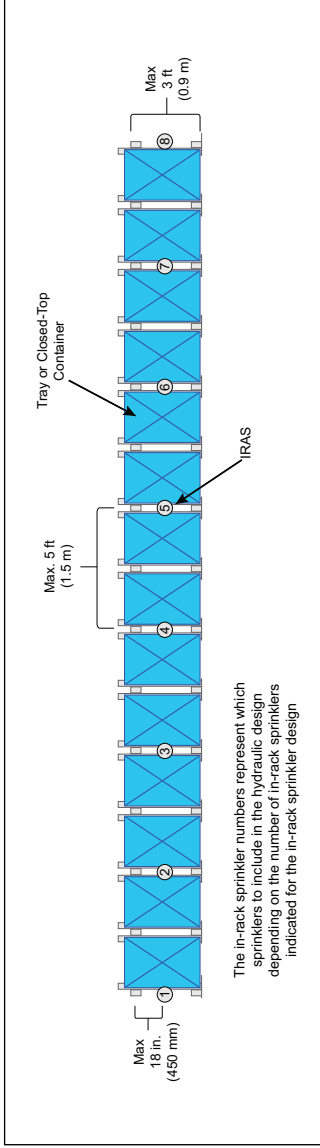


Fig. 5. Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Shuttle ASRS Where Rack Row Depths Do Not Exceed 3 ft (0.9 m) per Table 14, and the Maximum Allowable Horizontal Spacing is 5 ft (1.5 m)

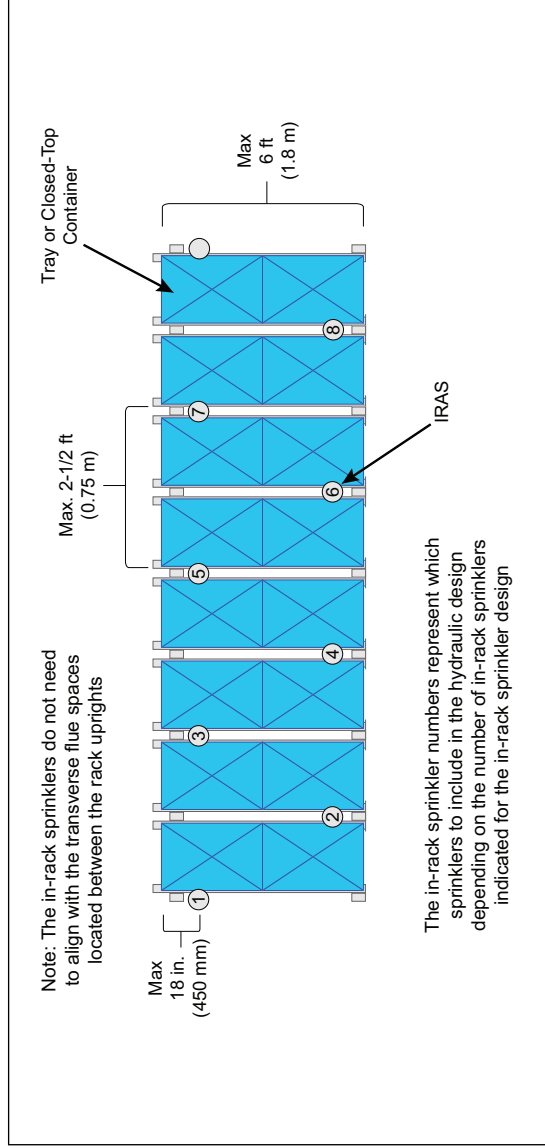


Fig. 6. Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Shuttle ASRS Where Rack Row Depths Do Not Exceed 6 ft (1.8 m) per Table 14 and the Maximum Allowable Horizontal Spacing is 2-1/2 ft (0.75 m)

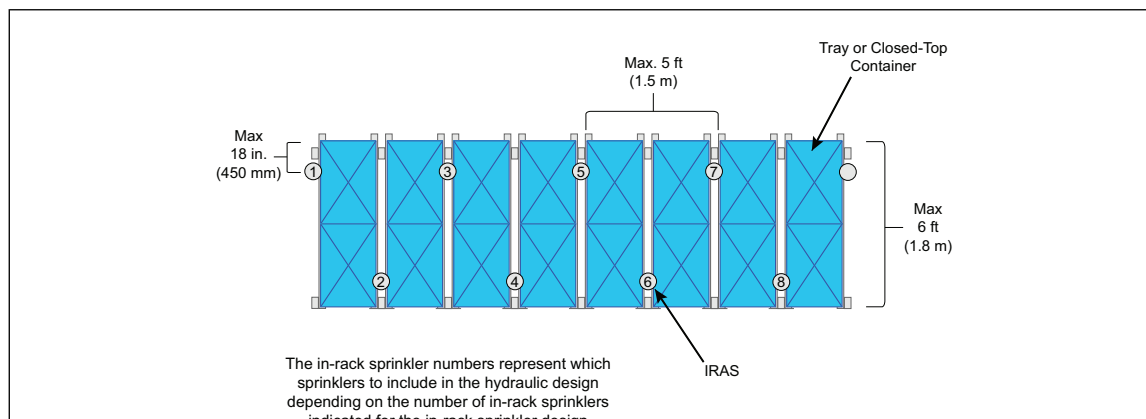


Fig. 7. Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Shuttle ASRS Where Rack Row Depths Do Not Exceed 6 ft (1.8 m) per Table 14 and the Maximum Allowable Horizontal Spacing is 5 ft (1.5 m)

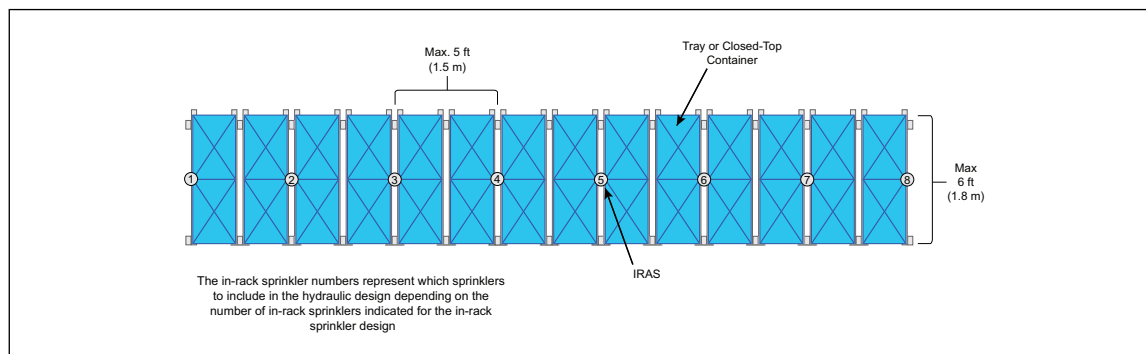


Fig. 8. Horizontal IRAS Arrangement Without Face Sprinklers for Closed-Top Combustible Containers, or Storage on Trays within a Shuttle ASRS Where Rack Row Depths Do Not Exceed 6 ft (1.8 m) per Table 14 and the Maximum Allowable Horizontal Spacing is 5 ft (1.5 m)

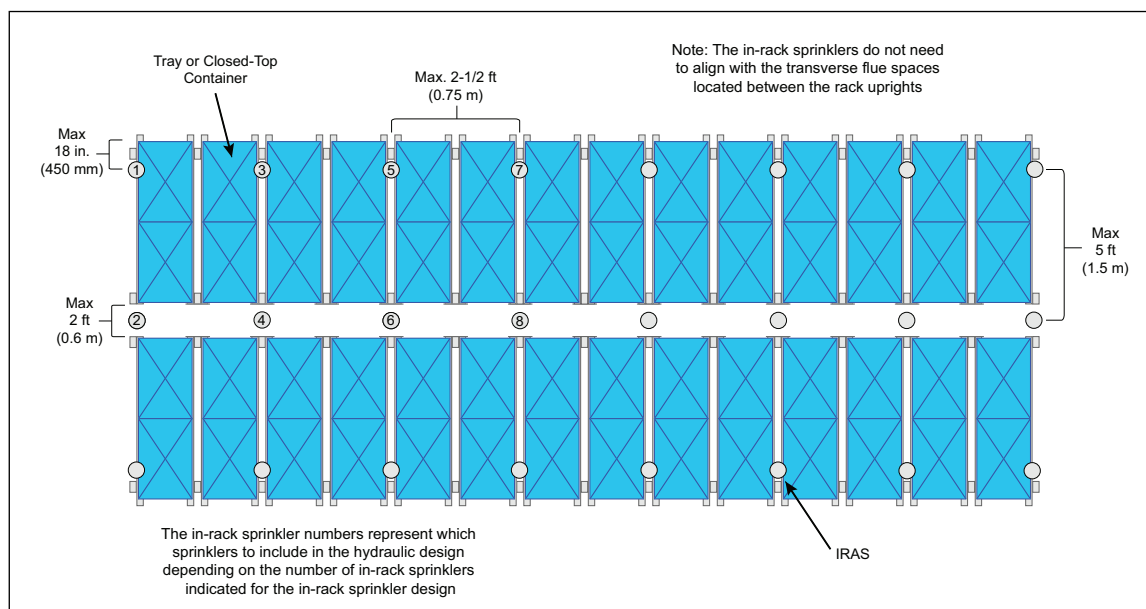


Fig. 9. Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Shuttle ASRS Where the Overall Rack Depths Do Not Exceed 14 ft (4.3 m) per Table 14 and the Maximum Allowable Horizontal Spacing is 2-1/2 ft (0.75 m)

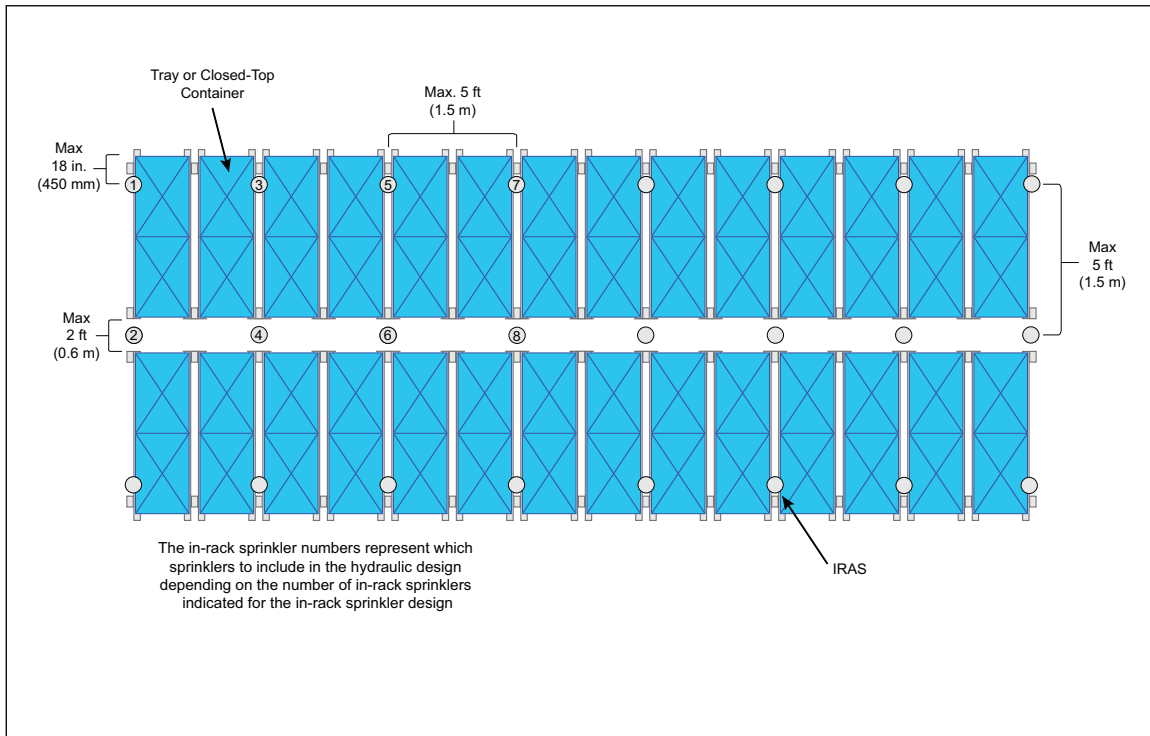


Fig. 10. Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Shuttle ASRS Where the Overall Rack Depths Do Not Exceed 14 ft (4.3 m) per Table 14 and the Maximum Allowable Horizontal Spacing is 5 ft (1.5 m)

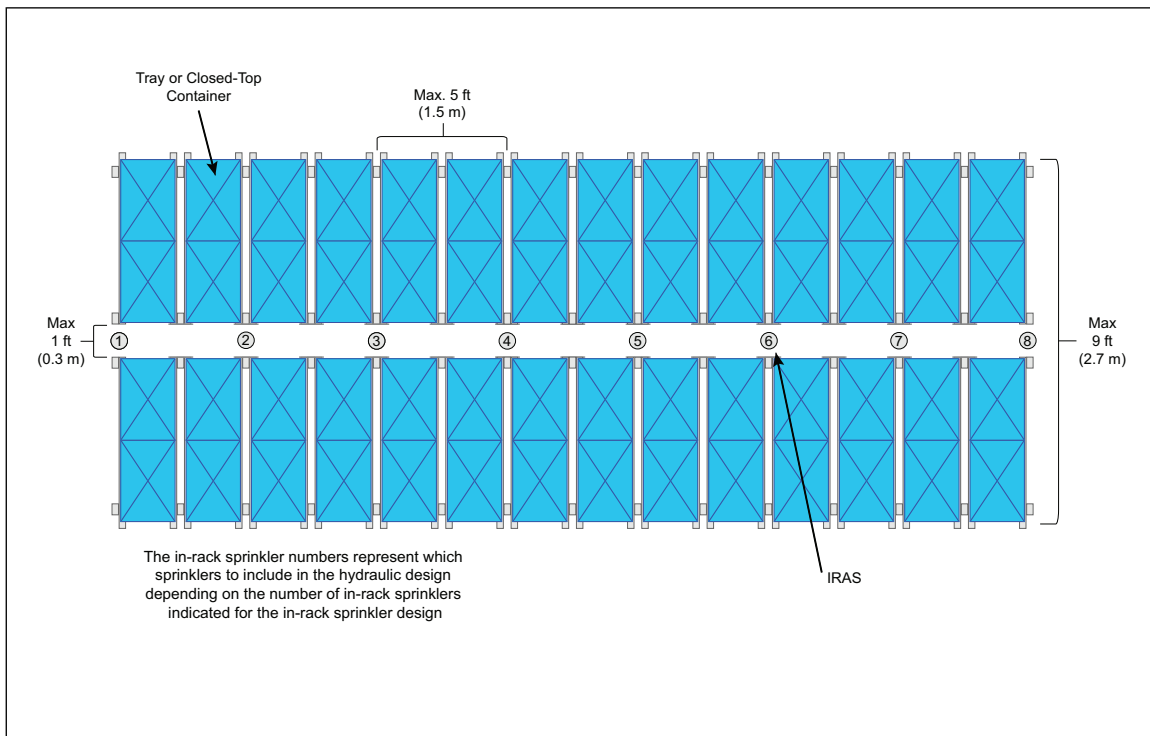


Fig. 11. Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Shuttle ASRS Where the Overall Rack Depths Do Not Exceed 9 ft (2.7 m) per Table 14 and the Maximum Allowable Horizontal Spacing is 5 ft (1.5 m)

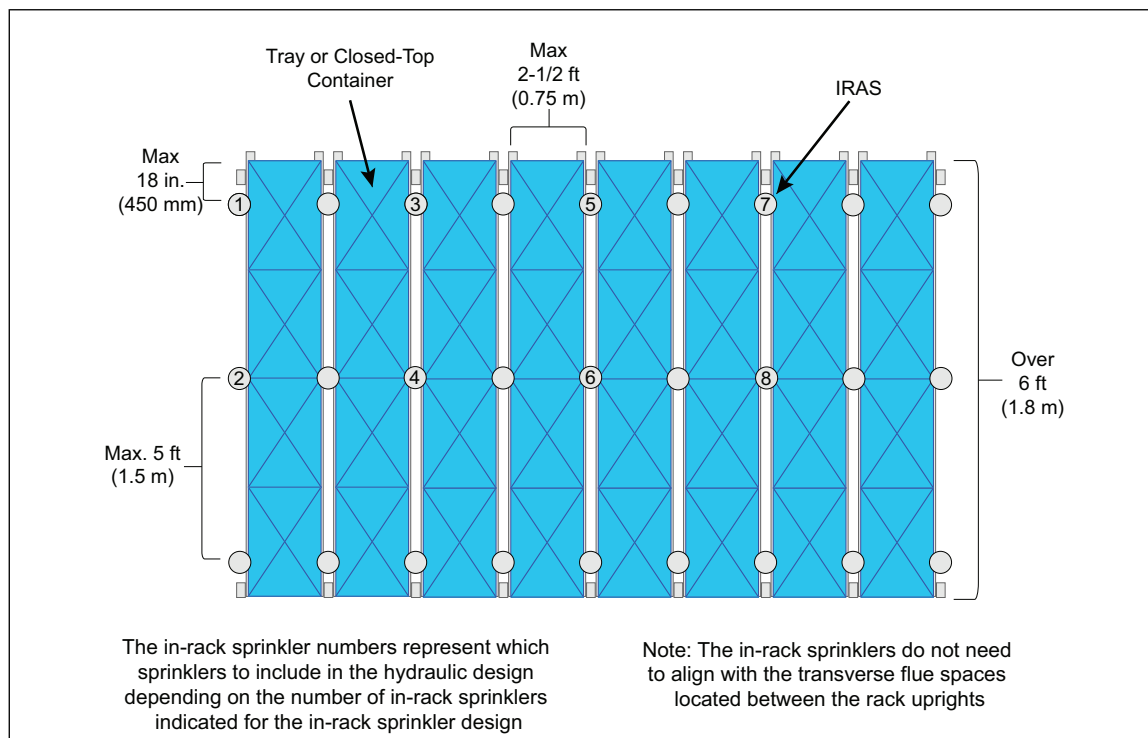


Fig. 12. Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Shuttle ASRS Where Rack Row Depths Exceed 6 ft (1.8 m) in Depth per Table 14 and the Maximum Allowable Horizontal Spacing is 2-1/2 ft (0.75 m)

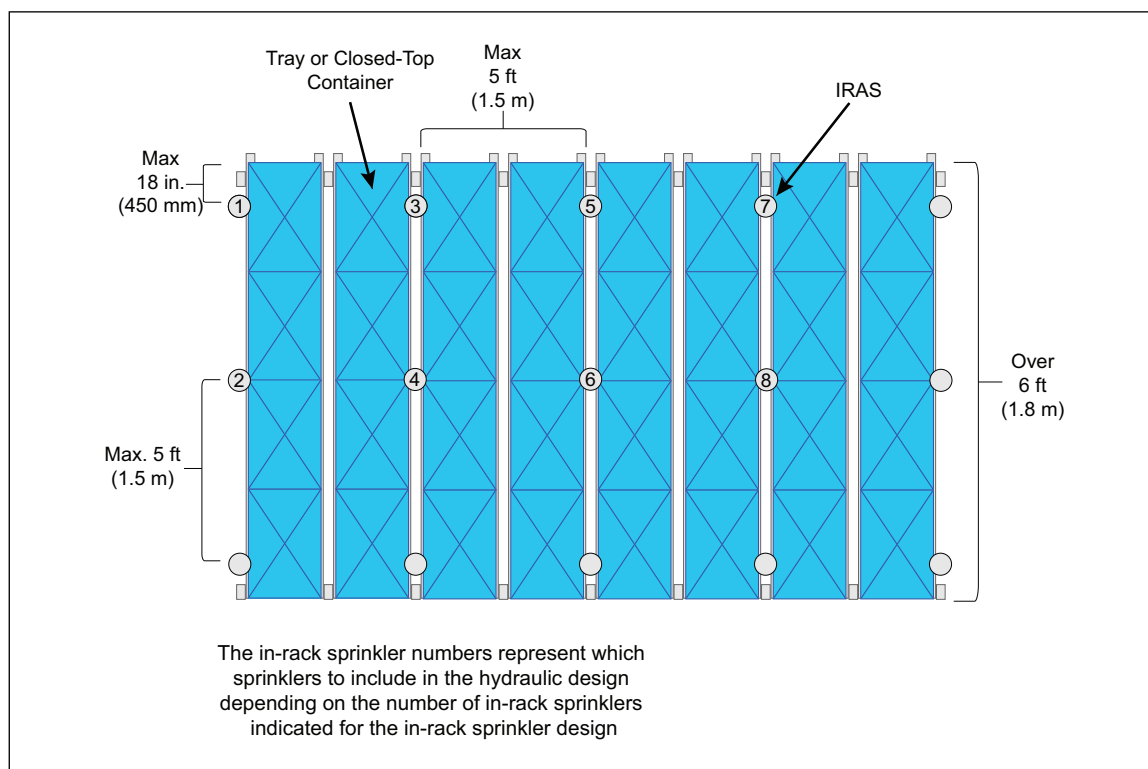


Fig. 13. Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Shuttle ASRS Where Rack Row Depths Exceed 6 ft (1.8 m) in Depth per Table 14 and the Maximum Allowable Horizontal Spacing is 5 ft (1.5 m)

2.2.3.2.2 Vertical Location of In-Rack Sprinklers and In-Rack Sprinkler System Designs for the Protection of Closed-Top Combustible Containers, or Storage on Trays**2.2.3.2.2.1 Storage Racks Not Requiring Vertical Barriers**

1. When Section 2.2.1.4 indicates that vertical barriers are not required due to transverse flue spaces being provided, use the following tables to determine the allowable in-rack sprinkler vertical locations, as well as the corresponding recommended in-rack sprinkler design:
 - A. Table 15: Wet, In-Rack sprinkler system protecting a shuttle ASRS, or
 - B. Table 16: Dry, In-Rack sprinkler system protecting a shuttle ASRS
2. Any green highlighted protection cell within Table 15 represents (1) an arrangement where the in-rack sprinkler system and the ceiling sprinkler system do not need to be hydraulically balanced at their point of connection, and (2) a potential design where the top in-rack sprinkler tier level can represent a virtual floor. The ceiling sprinkler system can be designed using the applicable protection table (i.e., Tables 4 through 13, depending on the commodity hazard being protected) with a ceiling height obtained by taking the vertical distance between the top level of in-rack sprinklers and the actual ceiling above. However, for this option to be applicable, the aisle width must be acceptable for a ceiling-only protection option as indicated in Section 2.2.3.1.1.
3. While the in-rack sprinkler designs given in Tables 15 and 16 are based on flow, the corresponding design pressure for the chosen in-rack sprinkler cannot be less than 7 psi (0.5 bar). When the design pressure will be less than 7 psi (0.5 bar), use a minimum pressure of 7 psi (0.5 bar) for design purposes, regardless of the in-rack sprinkler's K-factor value.

2.2.3.2.2.2 Storage Racks Requiring Vertical Barriers

When Section 2.2.1.4 indicates that vertical barriers are required due to the lack of acceptable transverse flue spaces, install the in-rack sprinklers vertically using the design guidelines indicated in Section 2.2.3.2.2.1. However, include all the in-rack sprinklers installed between the vertical barriers in the in-rack sprinkler design.

For example, if a wet, in-rack sprinkler system is being used to protect Class 3 commodity being stored within a shuttle ASRS protected with in-rack sprinklers per Figure 6, and the number of in-rack sprinklers between the vertical barriers is 9; the design for the in-rack sprinkler system would be per Table 15 and could use either (1) 9 IRAS @ 30 gpm (115 L/min), which would require the ceiling and in-rack system to be hydraulically balanced, or (2) 9 IRAS @ 65 gpm (250 L/min), which would avoid the need for the ceiling and in-rack sprinkler system to be hydraulically balanced.