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 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 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 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 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 Property Loss Prevention Data Sheet 7-31, *Storage of Aerosol Products*, when aerosols are being stored within an ASRS, or FM 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 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.

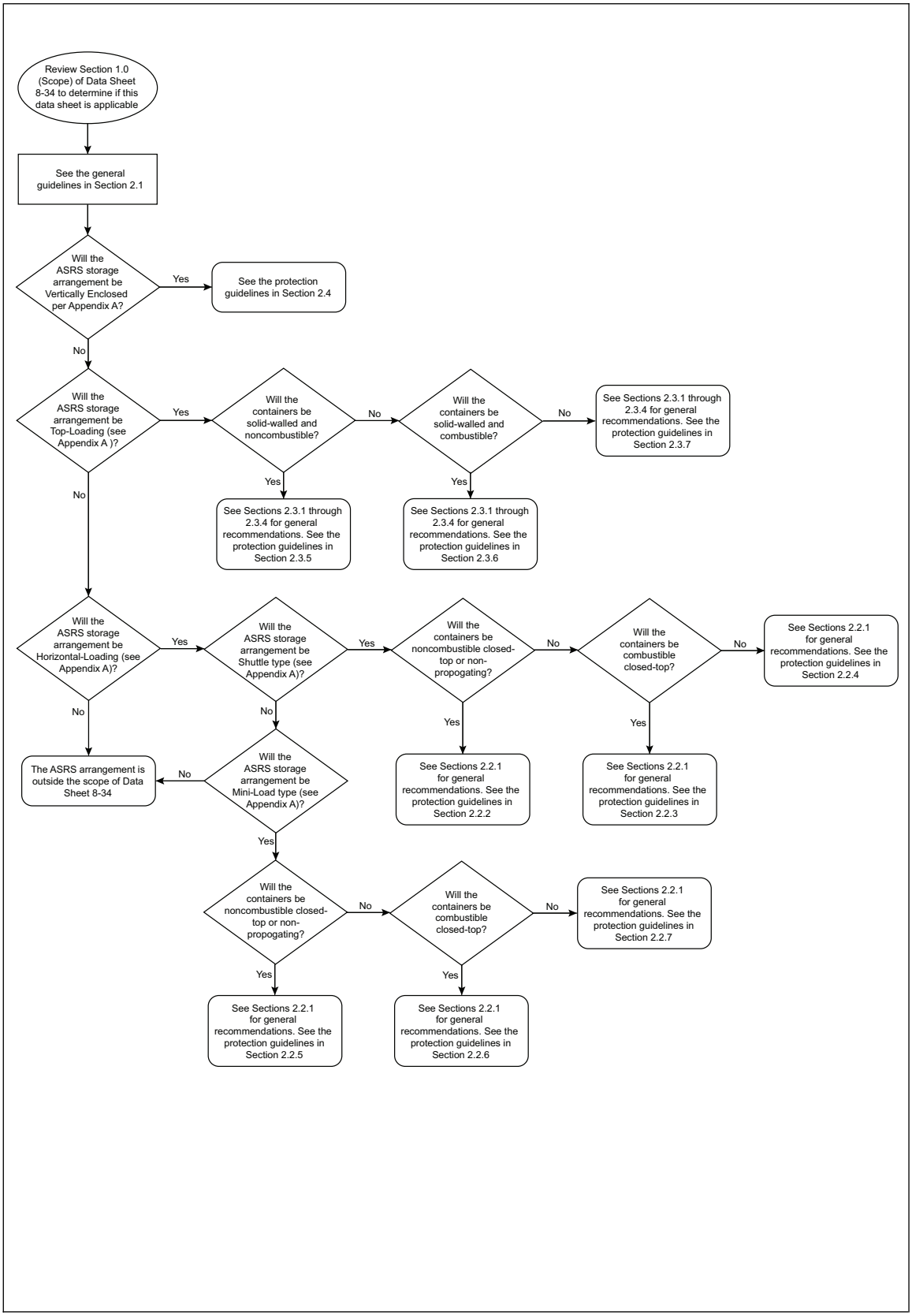

Fig. 1. Summarized guidance on how to navigate Data Sheet 8-34

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 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 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 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 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 gpm/psi$^{0.5}$ ([L/min]/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 ft^2 (53.5 m^2) when the number of sprinklers in the indicated design is 9
2. 640 ft^2 (59.5 m^2) when the number of sprinklers in the indicated design is 10
3. 768 ft^2 (71.3 m^2) 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 $\leq$ 1 in 12 = (1.2 / SAVG) x SQRT ([Number of Sprinklers in Ceiling Design x SAVG x 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 < Ceiling Slope $\leq$ 2 in 12 = (1.4 / SAVG) x SQRT ([Number of Sprinklers in Ceiling Design x SAVG x 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	Any	3
		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	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	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 Engineering Operations Center to address a means of achieving final extinguishment of a fire originating within the ASRS storage array. See FM 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 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 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 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 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 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 30º.

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 32ºF (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, 160ºF (70ºC) 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

Ceiling Sprinkler Type	*Number of Sprinklers in the Ceiling Sprinkler System Design*	*Hose Demand, gpm (L/min)*	*Water Supply Duration, min*
Standard-Coverage	12 or less	250 (950)	60
	13 to 19	500 (1,900)	90
	20 or more	500 (1,900)	120
Extended-Coverage	6 or less	250 (950)	60
	7 to 9	500 (1,900)	90
	10 or more	500 (1,900)	120

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 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

Material Handling Method	*Commodity Classification (No Open-Top Containers Permitted)*	*Ceiling Sprinkler System Type*	*Protection Table to Use*
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

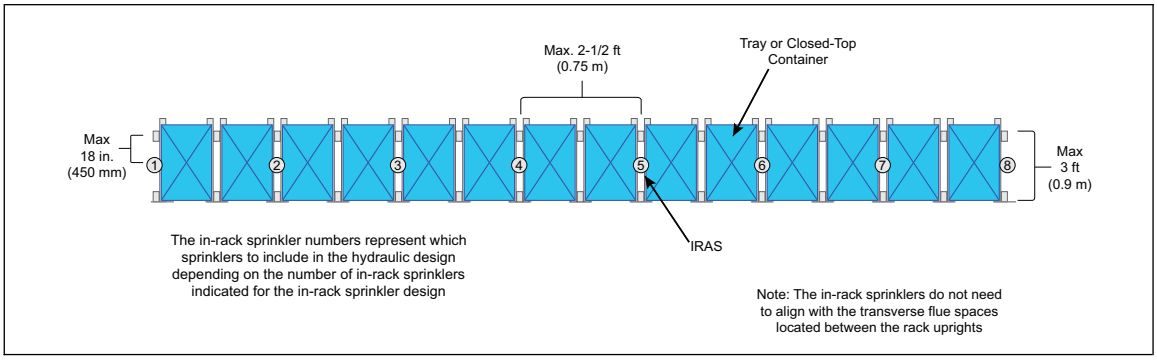

Fig. 4. Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage Trays within a Shuttle ASRS Where Rack Row Depths Do Not Exceed 3 ft (0.9 m) per Table 14 and the Maximum Allowable Horizontal Spacing is 2-1/2 ft (0.75 m)

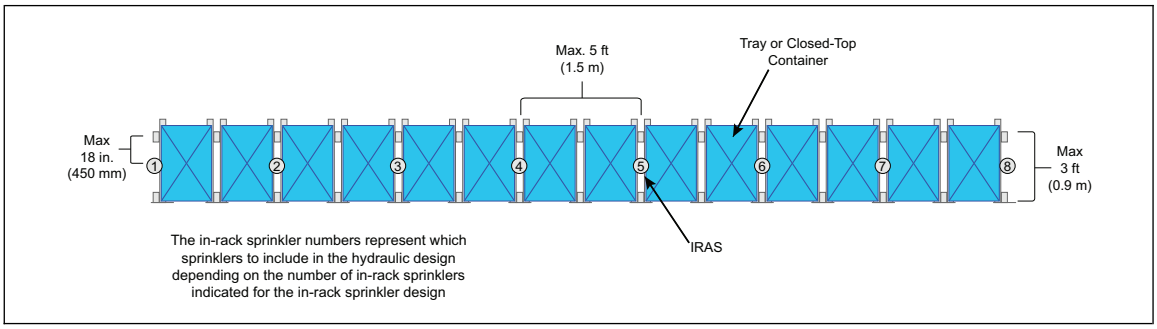

Fig. 5. Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Shuttle ASRS Where Rack Row Depths Do Not Exceed 3 ft (0.9 m) per Table 14, and the Maximum Allowable Horizontal Spacing is 5 ft (1.5 m)

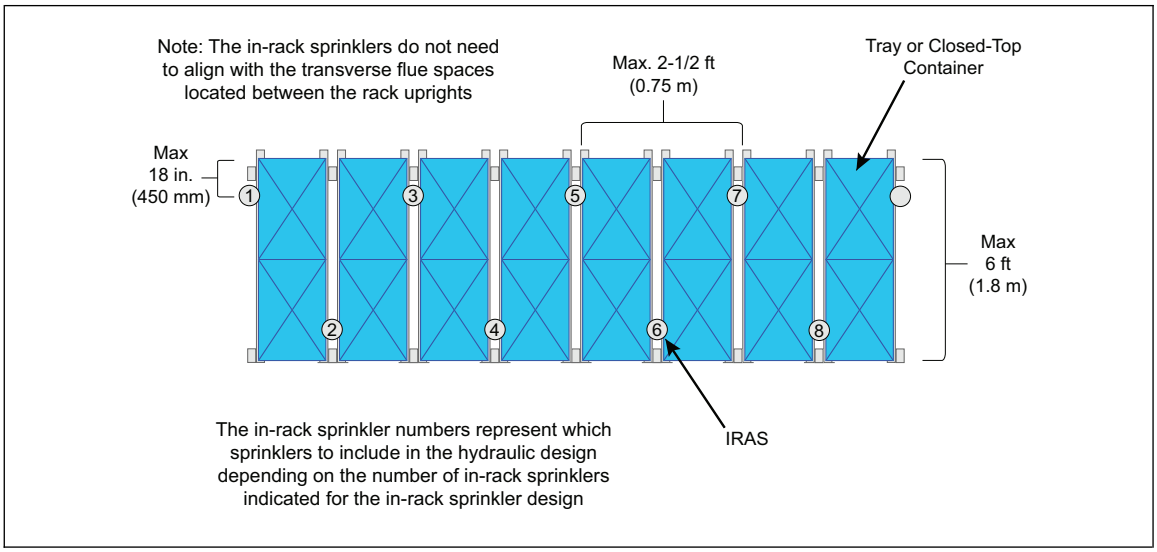

Fig. 6. Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Shuttle ASRS Where Rack Row Depths Do Not Exceed 6 ft (1.8 m) per Table 14 and the Maximum Allowable Horizontal Spacing is 2-1/2 ft (0.75 m)

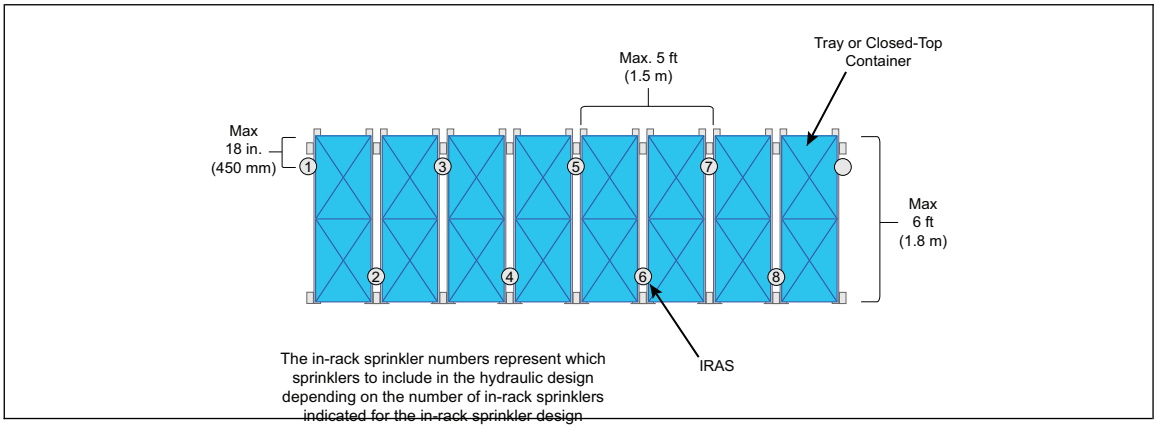

Fig. 7. Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Shuttle ASRS Where Rack Row Depths Do Not Exceed 6 ft (1.8 m) per Table 14 and the Maximum Allowable Horizontal Spacing is 5 ft (1.5 m)

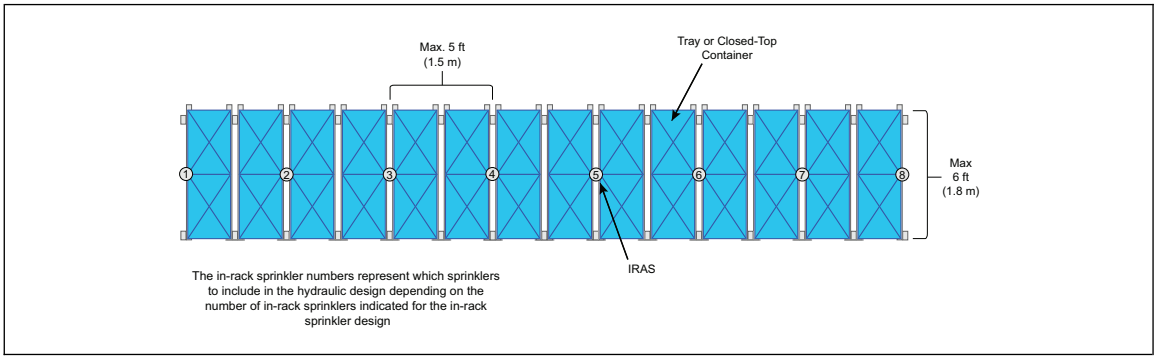

Fig. 8. Horizontal IRAS Arrangement Without Face Sprinklers for Closed-Top Combustible Containers, or Storage on Trays within a Shuttle ASRS Where Rack Row Depths Do Not Exceed 6 ft (1.8 m) per Table 14 and the Maximum Allowable Horizontal Spacing is 5 ft (1.5 m)

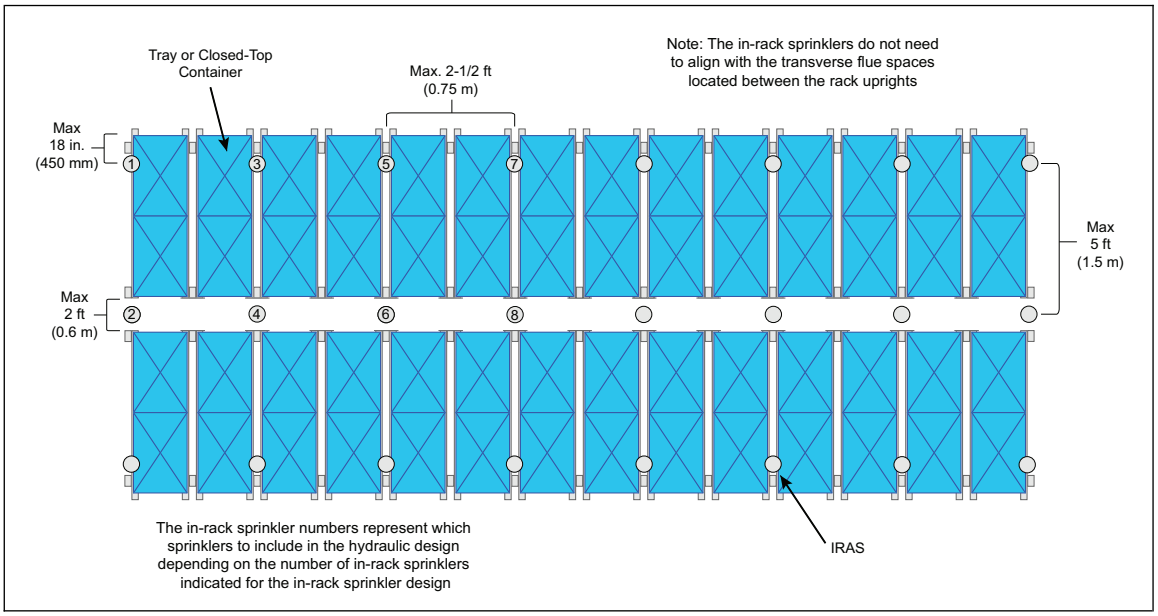

Fig. 9. Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Shuttle ASRS Where the Overall Rack Depths Do Not Exceed 14 ft (4.3 m) per Table 14 and the Maximum Allowable Horizontal Spacing is 2-1/2 ft (0.75 m)

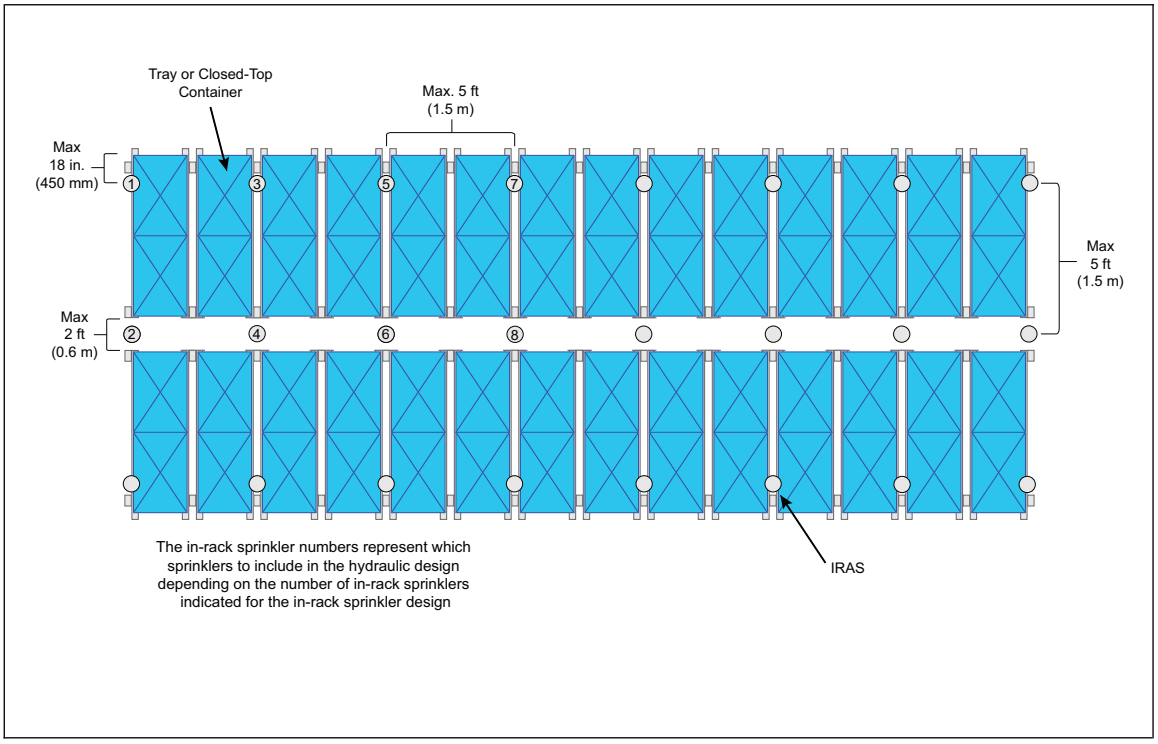

Fig. 10. Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Shuttle ASRS Where the Overall Rack Depths Do Not Exceed 14 ft (4.3 m) per Table 14 and the Maximum Allowable Horizontal Spacing is 5 ft (1.5 m)

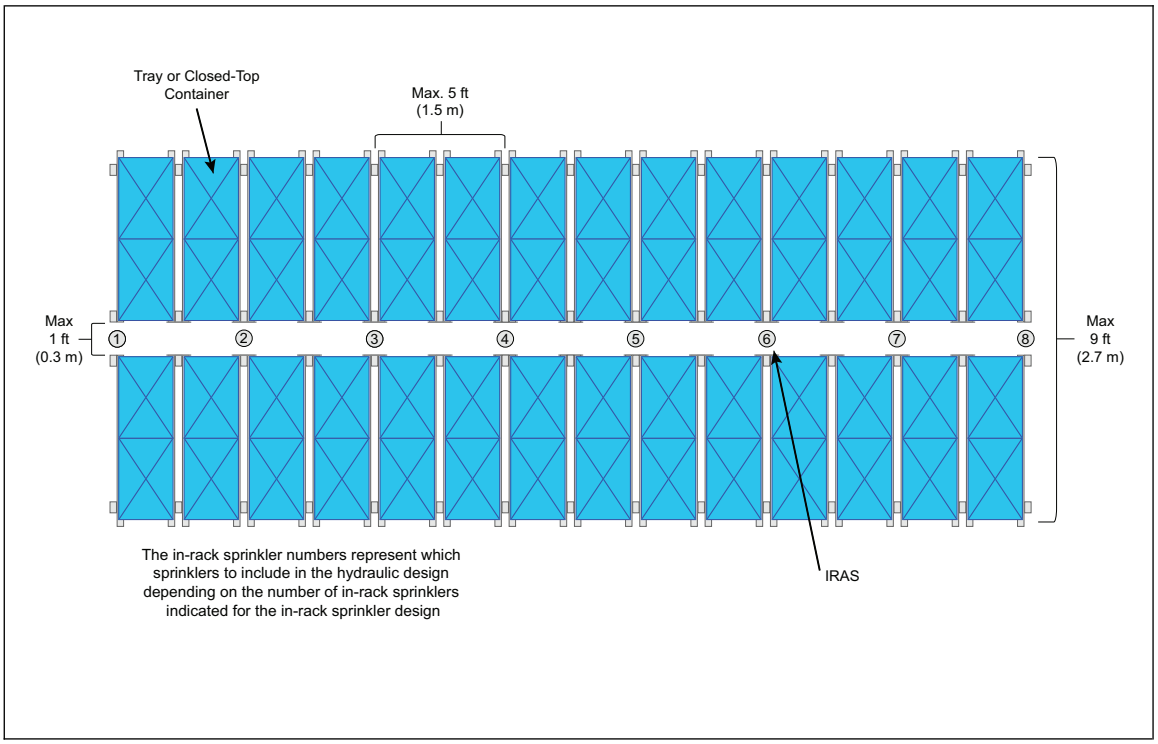

Fig. 11. Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Shuttle ASRS Where the Overall Rack Depths Do Not Exceed 9 ft (2.7 m) per Table 14 and the Maximum Allowable Horizontal Spacing is 5 ft (1.5 m)

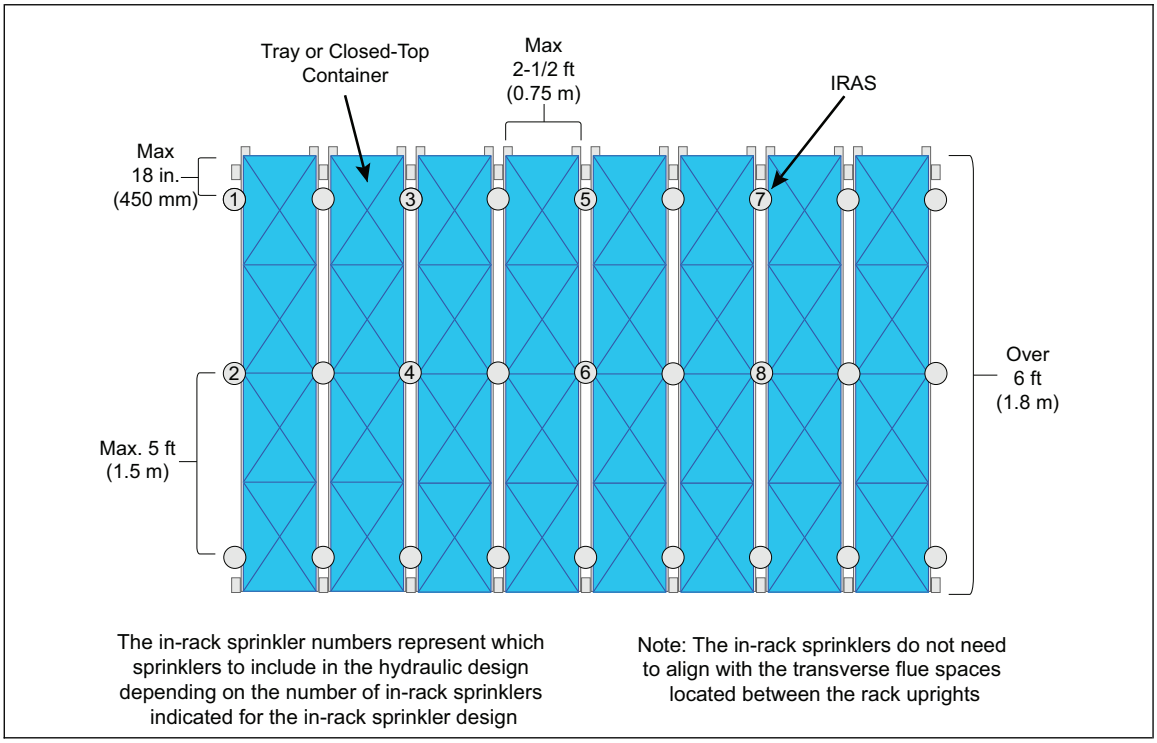

Fig. 12. Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Shuttle ASRS Where Rack Row Depths Exceed 6 ft (1.8 m) in Depth per Table 14 and the Maximum Allowable Horizontal Spacing is 2-1/2 ft (0.75 m)

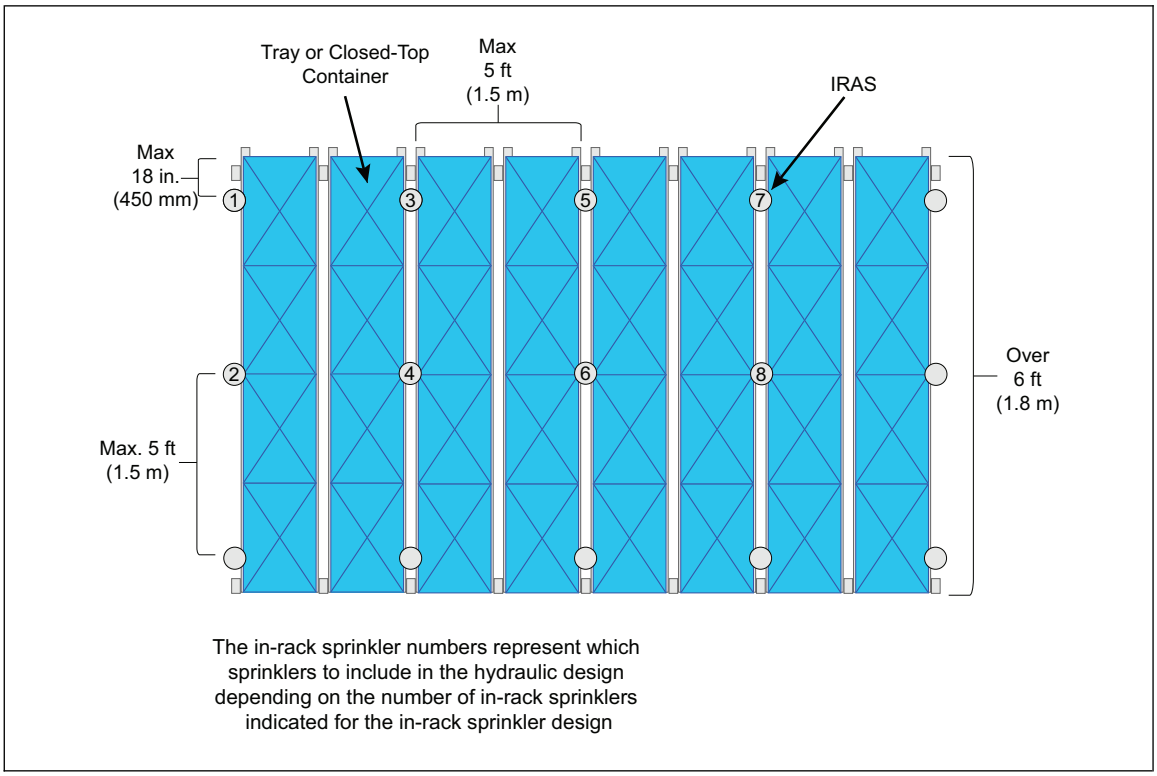

Fig. 13. Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Shuttle ASRS Where Rack Row Depths Exceed 6 ft (1.8 m) in Depth per Table 14 and the Maximum Allowable Horizontal Spacing is 5 ft (1.5 m)

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.

Table 15. Wet, In-Rack Sprinkler System Designs for the Protection of Closed-Top, Combustible Containers Stored in a Shuttle ASRS

Recommended Horizontal IRAS Arrangement per Table 14	*Maximum Commodity Hazard*	*Max. Vertical Distance Between IRAS, ft (m)*	*Max. Ceiling Height, ft (m)*	*Min. IRAS Flow Design, gpm (L/min)**	*Min. IRAS K-factor*	*No. of IRAS in Design*	*Hydraulically Balance IRAS System with Ceiling System?*
Figure 4	Class 3	10 (3.0)**	DNA	30 (115)	5.6 (80)	6 if one IRAS level or 10 (5 on top 2 levels)	Yes
				65 (250)	14.0 (200) Pendent	5 on top IRAS level	No
	Cartoned Unexpanded Plastics	10 (3.0)**	DNA	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
				65 (250)	14.0 (200) Pendent	5 on top IRAS level	No
	Cartoned Expanded Plastics	10 (3.0)**	DNA	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
				100 (380)	14.0 (200) Pendent	5 on top IRAS level	No
	Uncartoned Unexpanded Plastics	10 (3.0)**	DNA	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
				120 (455)	22.4 (320) Pendent	5 on top IRAS level	No
	Uncartoned Expanded Plastics	10 (3.0)**	DNA	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
				120 (455)	22.4 (320) Pendent	5 & 2 on top IRAS level***	No

Table 15. Wet, In-Rack Sprinkler System Designs for the Protection of Closed-Top, Combustible Containers Stored in a Shuttle ASRS (continued)

Recommended Horizontal IRAS Arrangement per Table 14	*Maximum Commodity Hazard*	*Max. Vertical Distance Between IRAS, ft (m)*	*Max. Ceiling Height, ft (m)*	*Min. IRAS Flow Design, gpm (L/min)**	*Min. IRAS K-factor*	*No. of IRAS in Design*	*Hydraulically Balance IRAS System with Ceiling System?*
Figures 5 or 7	Class 3	25 (7.6)**	DNA	30 (115)	5.6 (80)	6 if one IRAS level or 10 (5 on top 2 levels)	Yes
		30 (9.1)	DNA	65 (250)	14.0 (200) Pendent	4 on top IRAS level	No
		40 (12.2)	DNA	120 (455)	22.4 (320) Pendent	4 on top IRAS level	No
	Cartoned Unexpanded Plastics	20 (6.1)**	DNA	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
		30 (9.1)	DNA	65 (250)	14.0 (200) Pendent	4 on top IRAS level	No
		40 (12.2)	DNA	120 (455)	22.4 (320) Pendent	4 on top IRAS level	No
	Cartoned Expanded Plastics	15 (4.6)**	DNA	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
		30 (9.1)	DNA	100 (380)	14.0 (200) Pendent	4 on top IRAS level	No
	Uncartoned Unexpanded Plastics	10 (3.0)**	DNA	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
		30 (9.1)	DNA	120 (455)	22.4 (320) Pendent	4 on top IRAS level	No
	Uncartoned Expanded Plastics	10 (3.0)**	DNA	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
		30 (9.1)	DNA	120 (455)	22.4 (320) Pendent	4 & 2 on top IRAS level***	No

Table 15. Wet, In-Rack Sprinkler System Designs for the Protection of Closed-Top, Combustible Containers Stored in a Shuttle ASRS (continue)

Recommended Horizontal IRAS Arrangement per Table 14	*Maximum Commodity Hazard*	*Max. Vertical Distance Between IRAS, ft (m)*	*Max. Ceiling Height, ft (m)*	*Min. IRAS Flow Design, gpm (L/min)**	*Min. IRAS K-factor*	*No. of IRAS in Design*	*Hydraulically Balance IRAS System with Ceiling System?*
Figure 6	Class 3	10 (3.0)**	DNA	30 (115)	5.6 (80)	6 if one IRAS level or 10 (5 on top 2 levels)	Yes
				65 (250)	14.0 (200) Pendent	6 on top IRAS level	No
	Cartoned Unexpanded Plastics	10 (3.0)**	DNA	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
				65 (250)	14.0 (200) Pendent	6 on top IRAS level	No
	Cartoned Expanded Plastics	10 (3.0)**	DNA	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
				100 (380)	14.0 (200) Pendent	6 on top IRAS level	No
	Uncartoned Unexpanded Plastics	10 (3.0)**	DNA	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
				120 (455)	22.4 (320) Pendent	6 on top IRAS level	No
	Uncartoned Expanded Plastics	10 (3.0)**	DNA	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
				120 (455)	22.4 (320) Pendent	6 & 2 on top IRAS level***	No

*The indicated in-rack sprinkler design flow is based on a minimum 9 in. (225 mm) vertical distance between storage tier levels. If the vertical distance between vertical tier levels is less than 9 in. (225 mm), add 20 gpm (75 L/min) to the indicated design flow.
**The maximum storage height above the top in-rack sprinkler level is 10 ft (3.0 m)
***The design “X & Y” accounts for X in-rack sprinklers in the most remote storage rack as well as the most remote Y in-rack sprinklers in an adjacent storage rack. However, if the aisle width is 8 ft (2.4 m) or greater, the design does not have to account for the Y in-rack sprinklers in the adjacent rack.

Table 15. Wet, In-Rack Sprinkler System Designs for the Protection of Closed-Top, Combustible Containers Stored in a Shuttle ASRS (continued)

Recommended Horizontal IRAS Arrangement per Table 14	*Maximum Commodity Hazard*	*Max. Vertical Distance Between IRAS, ft (m)*	*Max. Ceiling Height, ft (m)*	*Min. IRAS Flow Design, gpm (L/min)**	*Min. IRAS K-factor*	*No. of IRAS in Design*	*Hydraulically Balance IRAS System with Ceiling System?*
Figures 8 or 11	Class 3	10 (3.0)**	DNA	30 (115)	5.6 (80)	6 if one IRAS level or 10 (5 on top 2 levels)	Yes
		25 (7.6)**	30 (9.1)	30 (115)	5.6 (80)	6 if one IRAS level or 10 (5 on top 2 levels)	Yes
	Cartoned Unexpanded Plastics	10 (3.0)**	DNA	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
		20 (6.1)**	30 (9.1)	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
	Cartoned Expanded Plastics	15 (4.6)**	30 (9.1)	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
	Uncartoned Expanded Plastics	10 (3.0)**	30 (9.1)	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes

Table 15. Wet, In-Rack Sprinkler System Designs for the Protection of Closed-Top, Combustible Containers Stored in a Shuttle ASRS (continued)

Recommended Horizontal IRAS Arrangement per Table 14	*Maximum Commodity Hazard*	*Max. Vertical Distance Between IRAS, ft (m)*	*Max. Ceiling Height, ft (m)*	*Min. IRAS Flow Design, gpm (L/min)**	*Min. IRAS K-factor*	*No. of IRAS in Design*	*Hydraulically Balance IRAS System with Ceiling System?*
Figures 9 or 12	Class 3	10 (3.0)**	DNA	30 (115)	5.6 (80)	6 if one IRAS level or 10 (5 on top 2 levels)	Yes
				65 (250)	14.0 (200) Pendent	6 on top IRAS level	No
	Cartoned Unexpanded Plastics	10 (3.0)**	DNA	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
				65 (250)	14.0 (200) Pendent	6 on top IRAS level	No
	Cartoned Expanded Plastics	10 (3.0)**	DNA	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
				100 (380)	14.0 (200) Pendent	6 on top IRAS level	No
	Uncartoned Unexpanded Plastics	110 (3.0)**	DNA	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
				120 (455)	22.4 (320) Pendent	6 on top IRAS level	No
	Uncartoned Expanded Plastics	10 (3.0)**	DNA	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
				120 (455)	22.4 (320) Pendent	6 & 4 on top IRAS level***	No

Table 15. Wet, In-Rack Sprinkler System Designs for the Protection of Closed-Top, Combustible Containers Stored in a Shuttle ASRS (continued)

Recommended Horizontal IRAS Arrangement per Table 14	*Maximum Commodity Hazard*	*Max. Vertical Distance Between IRAS, ft (m)*	*Max. Ceiling Height, ft (m)*	*Min. IRAS Flow Design, gpm (L/min)**	*Min. IRAS K-factor*	*No. of IRAS in Design*	*Hydraulically Balance IRAS System with Ceiling System?*
Figures 10 or 13	Class 3	25 (7.6)**	DNA	30 (115)	5.6 (80)	6 if one IRAS level or 10 (5 on top 2 levels)	Yes
		30 (9.1)	DNA	65 (250)	14.0 (200) Pendent	6 on top IRAS level	No
		40 (12.2)	DNA	120 (455)	22.4 (320) Pendent	6 on top IRAS level	No
	Cartoned Unexpanded Plastics	20 (6.1)**	DNA	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
		30 (9.1)	DNA	65 (250)	14.0 (200) Pendent	6 on top IRAS level	No
		40 (12.2)	DNA	120 (455)	22.4 (320) Pendent	6 on top IRAS level	No
	Cartoned Expanded Plastics	15 (4.6)**	DNA	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
		30 (9.1)	DNA	100 (380)	14.0 (200) Pendent	6 on top IRAS level	No
	Uncartoned Unexpanded Plastics	10 (3.0)**	DNA	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
		30 (9.1)	DNA	120 (455)	22.4 (320) Pendent	6 on top IRAS level	No
	Uncartoned Expanded Plastics	10 (3.0)**	DNA	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
		30 (9.1)	DNA	120 (455)	22.4 (320) Pendent	6 & 4 on top IRAS level***	No

* The indicated in-rack sprinkler design flow is based on a minimum 9 in. (225 mm) vertical distance between storage tier levels. If the vertical distance between vertical tier levels is less than 9 in. (225 mm), add 20 gpm (75 L/min) to the indicated design flow.
** The maximum storage height above the top in-rack sprinkler level is 10 ft (3.0 m)
*** The design “X & Y” accounts for X in-rack sprinklers in the most remote storage rack as well as the most remote Y in-rack sprinklers in an adjacent storage rack. However, if the aisle width is 8 ft (2.4 m) or greater, the design does not have to account for the Y in-rack sprinklers in the adjacent rack.

Table 16. Dry, In-Rack Sprinkler Designs for the Protection of Closed-Top, Combustible Containers Stored in a Shuttle ASRS

Recommended IRAS Arrangement per Table 14	*Maximum Commodity Hazard*	*Max. Vertical Distance Between IRAS, ft (m)**	*Max. Ceiling Height, ft (m)*	*Min. IRAS Flow Design, gpm (L/min)***	*Min. IRAS K-factor*	*No. of IRAS in Design*	*Hydraulically Balance IRAS System with Ceiling System?*
Figures 4, 5, 6, 7, 9, 10, 12, or 13	Class 3	25 (7.6)	DNA	30 (115)	5.6 (80)	6 if one IRAS level or 10 (5 on top 2 levels)	Yes
	Cartoned Unexpanded Plastics	20 (6.1)	DNA	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
	Cartoned Expanded Plastics	15 (4.6)	DNA	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
	Uncartoned Expanded Plastics	10 (3.0)	DNA	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
Figures 8 or 11	Class 3	25 (7.6)	30 (9.1)	30 (115)	5.6 (80)	6 if one IRAS level or 10 (5 on top 2 levels)	Yes
	Cartoned Unexpanded Plastics	20 (6.1)	30 (9.1)	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
	Cartoned Expanded Plastics	15 (4.6)	30 (9.1)	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
	Uncartoned Expanded Plastics	10 (3.0)	30 (9.1)	30 (115)	5.6 (80)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes

*The maximum storage height above the top in-rack sprinkler level is 10 ft (3.0 m).
**The indicated in-rack sprinkler design flow is based on a minimum 9 in. (225 mm) vertical distance between storage tier levels. If the vertical distance between vertical tier levels is less than 9 in. (225 mm), add 20 gpm (75 L/min) to the indicated design flow.

2.2.3.2.3 Ceiling Sprinkler System Designs in Combination with In-Rack Sprinklers for the Protection of Closed-Top Combustible Containers, or Storage on Trays

2.2.3.2.3.1 For wet ceiling sprinkler systems, when Table 15 or Section 2.2.3.2.2.2 indicates the storage height above the top in-rack sprinkler level be limited to 10 ft (3.0 m), use Table 17 to determine how to obtain the ceiling sprinkler system design. If a protection option is not available from the applicable protection table, either:

1. Install a flat, continuous, noncombustible false ceiling capable of withstanding an uplift pressure of 3 lb./ft² (14.4 kg/m²) over, and for a minimum of 15 ft (4.6 m) beyond, the ASRS storage area in all directions, with sprinklers installed underneath the false ceiling in accordance with Table 17, or
2. Install in-rack sprinklers over the top of storage and design the ceiling sprinkler system per Table 17.

2.2.3.2.3.2 For wet ceiling sprinkler systems, when Section 2.2.3.2.2.2 is not applicable and Table 15 does not limit the storage height above the top in-rack sprinkler level, the ceiling sprinkler system can be designed using the applicable protection table (i.e., Tables 4, 6, 8, 10, and 12, depending on the commodity hazard being protected). The ceiling height to be used in the protection table is obtained by taking the vertical distance between the top in-rack sprinkler level and the ceiling. Note that if no storage is to be maintained above the top in-rack sprinkler level, the ceiling design can be determined using the lowest ceiling height given in the protection table.

2.2.3.2.3.3 For dry ceiling sprinkler systems, use Table 18 to determine how to obtain the ceiling sprinkler system design. If a protection option is not available from the applicable protection table, either:

1. Install a flat, continuous, noncombustible false ceiling, capable of withstanding an uplift pressure of 3 lb/ft² (14.4 kg/m²), over the ASRS storage area and for a minimum of 15 ft (4.6 m) beyond the ASRS area in all directions with sprinklers installed underneath the false ceiling in accordance with Table 18, or
2. Install in-rack sprinklers over the top of storage and design the ceiling sprinkler system per Table 18.

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

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

Table 17. Determining the Applicable Protection Table and Ceiling Height for Ceiling Sprinkler Designs when Wet Ceiling-Level Sprinkler Systems are Supplemented with In-Rack Sprinklers to Protect Closed-Top Combustible Containers, or Storage on Trays in a Shuttle ASRS

Maximum Commodity Hazard	*Material Handling Method*	*Max. Storage Height Above Top IRAS Level, ft (m)*	*Max. Clearance Between Top of Storage and Ceiling, ft (m)*	*Applicable Protection Table to Use*	*Applicable Ceiling Height to Use in Indicated Protection Table, ft (m)*
Class 3	Directly on Supporting Rails	0 (0)	Any	4	10 (3.0)
		5 (1.5)	5 (1.5)	4	10 (3.0)
			20 (6.1)	4	20 (6.1)
			> 20 (6.1)	4	Vertical distance between top IRAS level and ceiling
		10 (3.0)	Any	4	Vertical distance between top IRAS level and ceiling
	On Trays	0 (0)	Any	10	10 (3.0)
		5 (1.5)	5 (1.5)	10	10 (3.0)
			10 (3.0)	10	15 (4.6)
			20 (6.1)	10	20 (6.1)
			> 20 (6.1)	10	Vertical distance between top IRAS level and ceiling
		10 (3.0)	Any	10	Vertical distance between top IRAS level and ceiling
Cartoned Unexpanded Plastics	Directly on Supporting Rails	0 (0)	Any	6	10 (3.0)
		5 (1.5)	5 (1.5)	6	10 (3.0)
			10 (3.0)	6	15 (4.6)
			20 (6.1)	6	20 (6.1)
			> 20 (6.1)	6	Vertical distance between top IRAS level and ceiling
		10 (3.0)	Any	6	Vertical distance between top IRAS level and ceiling
	On Trays	0 (0)	Any	10	10 (3.0)
		5 (1.5)	5 (1.5)	10	10 (3.0)
			10 (3.0)	10	15 (4.6)
			20 (6.1)	10	20 (6.1)
			> 20 (6.1)	10	Vertical distance between top IRAS level and ceiling
		10 (3.0)	Any	10	Vertical distance between top IRAS level and ceiling
Cartoned Expanded Plastics	Directly on Supporting Rails	0 (0)	Any	8	10 (3.0)
		5 (1.5)	5 (1.5)	8	10 (3.0)
			20 (6.1)	8	20 (6.1)
			> 20 (6.1)	8	Vertical distance between top IRAS level and ceiling
		10 (3.0)	Any	8	Vertical distance between top IRAS level and ceiling
	On Trays	0 (0)	Any	10	10 (3.0)
		5 (1.5)	5 (1.5)	10	10 (3.0)
			10 (3.0)	10	15 (4.6)
			20 (6.1)	10	20 (6.1)
			> 20 (6.1)	10	Vertical distance between top IRAS level and ceiling
		10 (3.0)	Any	10	Vertical distance between top IRAS level and ceiling

Table 17. Determining the Applicable Protection Table and Ceiling Height for Ceiling Sprinkler Designs when Wet Ceiling-Level Sprinkler Systems are Supplemented with In-Rack Sprinklers to Protect Closed-Top, Combustible Containers Stored Directly on the Shuttle Rack's Horizontal Supporting Rails, or Non-Open Top Storage Maintained on Trays in a Shuttle ASRS (continued)

Maximum Commodity Hazard	*Material Handling Method*	*Max. Storage Height Above Top IRAS Level, ft (m)*	*Max. Clearance Between Top of Storage and Ceiling, ft (m)*	*Applicable Protection Table to Use*	*Applicable Ceiling Height to Use in Indicated Protection Table, ft (m)*
Uncartoned Unexpanded Plastics	Directly on Supporting Rails or On Trays	0 (0)	Any	10	10 (3.0)
		5 (1.5)	5 (1.5)	10	10 (3.0)
			10 (3.0)	10	15 (4.6)
			20 (6.1)	10	20 (6.1)
			> 20 (6.1)	10	Vertical distance between top IRAS level and ceiling
		10 (3.0)	Any	10	Vertical distance between top IRAS level and ceiling
Uncartoned Expanded Plastics	Directly on Supporting Rails or On Trays	0 (0)	Any	12	10 (3.0)
		5 (1.5)	5 (1.5)	12	10 (3.0)
			10 (3.0)	12	15 (4.6)
			20 (6.1)	12	25 (7.6)
			> 20 (6.1)	12	Vertical distance between top IRAS level and ceiling
		10 (3.0)	Any	12	Vertical distance between top IRAS level and ceiling

Table 18. Determining the Applicable Protection Table and Ceiling Height for Ceiling Sprinkler Designs when Dry Ceiling-Level Sprinkler Systems are Supplemented with In-Rack Sprinklers to Protect Closed-Top Combustible Containers, or Storage on Trays in a Shuttle ASRS

Maximum Commodity Hazard	*Material Handling Method*	*Max. Storage Height Above Top IRAS Level, ft (m)*	*Max. Clearance Between Top of Storage and Ceiling, ft (m)*	*Applicable Protection Table to Use*	*Applicable Ceiling Height to Use in Indicated Protection Table, ft (m)*
Class 3	Directly on Supporting Rails	0 (0)	Any	5	10 (3.0)
		5 (1.5)	5 (1.5)	5	20 (6.1)
			20 (6.1)	5	25 (7.6)
		10 (3.0)	5 (1.5)	5	25 (7.6)
			20 (6.1)	5	30 (9.1)
	On Trays	0 (0)	Any	5	20 (6.1)
		5 (1.5)	5 (1.5)	11	10 (3.0)
			10 (3.0)	11	15 (4.6)
		10 (3.0)	5 (1.5)	11	15 (4.6)
Cartoned Unexpanded Plastics	Directly on Supporting Rails	0 (0)	Any	7	10 (3.0)
		5 (1.5)	5 (1.5)	5	20 (6.1)
			10 (3.0)	7	15 (4.6)
			20 (6.1)	7	20 (6.1)
		10 (3.0)	5 (1.5)	7	20 (6.1)
			20 (6.1)	7	25 (7.6)
	On Trays	0 (0)	Any	5	20 (6.1)
		5 (1.5)	5 (1.5)	11	10 (3.0)
			10 (3.0)	11	15 (4.6)
		10 (3.0)	5 (1.5)	11	15 (4.6)
Cartoned Expanded Plastics	Directly on Supporting Rails	0 (0)	Any	5	20 (6.1)
		5 (1.5)	5 (1.5)	5	20 (6.1)
			20 (6.1)	9	20 (6.1)
		10 (3.0)	5 (1.5)	9	20 (6.1)
			10 (3.0)	7	25 (7.6)
	On Trays	(0)	Any	5	20 (6.1)
		5 (1.5)	5 (1.5)	11	10 (3.0)
			10 (3.0)	11	15 (4.6)
		10 (3.0)	5 (1.5)	11	15 (4.6)
Uncartoned Unexpanded Plastics	Directly on Supporting Rails or On Trays	0 (0)	Any	11	10 (3.0)
		5 (1.5)	5 (1.5)	11	10 (3.0)
			10 (3.0)	11	15 (4.6)
		10 (3.0)	5 (1.5)	11	15 (4.6)
Uncartoned Expanded Plastics	Directly on Supporting Rails or On Trays	0 (0)	Any	11	10 (3.0)
		5 (1.5)	5 (1.5)	13	10 (3.0)
			10 (3.0)	13	15 (4.6)
		10 (3.0)	5 (1.5)	13	15 (4.6)

2.2.4 Protection of Horizontal-Loading Shuttle ASRS Storage Arrangements Where Open-Top, Combustible Containers are Being Used

Note that the protection of expanded plastic containers is outside the scope of this data sheet.

Section 2.2.4 is organized as follows:

- Section 2.2.4.1 determines if a ceiling-only protection option is available and, if it is, the recommended ceiling-only protection designs.
- Section 2.2.4.2 determines the recommended designs when both ceiling and in-rack sprinklers are installed. This section is further broken down into the following subsections:
  - Section 2.2.4.2.1 provides acceptable horizontal in-rack sprinkler arrangements.
  - Section 2.2.4.2.2 provides both the acceptable vertical in-rack sprinkler arrangements as well as the corresponding in-rack sprinkler system design.
  - Section 2.2.4.2.3 provides the acceptable ceiling sprinkler system design with the chosen in-rack sprinkler system arrangement.

2.2.4.1 Ceiling-Only Sprinkler System Design Criteria for Horizontal-Loading Shuttle ASRS Storage Arrangements Using Open-Top, Combustible Containers

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

1. Adequate vertically aligned transverse flue spaces are provided as outlined in Section 2.2.1.4, and
2. The storage height does not exceed 10 ft (3.0 m), and
3. A ceiling-only protection is provided in the applicable protection table (Tables 20 and 21) for the specific sprinkler being installed at ceiling level, and
4. 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 (4) cannot be met, see Section 2.2.4.2 regarding the guidelines for installing in-rack sprinklers in combination with ceiling-level sprinklers.

2.2.4.1.2 When a ceiling-only protection scheme is acceptable per items (1) through (4) in Section 2.2.4.1.1, use Table 19 to determine which protection table to use for obtaining the recommended ceiling sprinkler design depending on the commodity hazard and the type of ceiling sprinkler system (i.e., wet or dry) being installed.

Table 19. Determining Which Ceiling Sprinkler Protection Table to Use for the Protection of Horizontal-Loading Shuttle ASRS Storage Arrangements Where Open-Top, Combustible Containers are Being Used

Commodity Classification	*Ceiling Sprinkler System Type*	*Protection Table to Use*
Class 1 through 4, Cartoned Plastics, and Uncartoned Plastics	Wet	20
	Dry	21

Note: In Table 20, 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 20. Wet Sprinkler System Ceiling-Level Protection Guidelines for Open-Top, Combustible Container Storage up to a Maximum of 10 ft (3.0 m) 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)	25 @ 50 (3.5)	12 @ 25 (1.7)	12 @ 18 (1.2)	9 @ 20 (1.4)	9 @ 20 (1.4)	12 @ 38 (2.6)	9 @ 40 (2.8)	9 @ 55 (3.8)	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 @ 18 (1.2)	12 @ 38 (2.6)	25 @ 50 (3.5)	25 @ 18 (1.2)	25 @ 10 (0.7)
15 (4.6)		12 @ 50 (3.5)	12 @ 35 (2.4)	12 @ 20 (1.4)	10 @ 20 (1.4)		9 @ 40 (2.8)	9 @ 55 (3.8)											
20 (6.1)		12 @ 75 (5.2)	12 @ 52 (3.6)	12 @ 29 (2.0)	12 @ 23 (1.6)		9 @ 40 (2.8)	9 @ 55 (3.8)											

Table 21. Dry Sprinkler System Ceiling-Level Protection Guidelines for Open-Top, Combustible Container Storage up to a Maximum of 10 ft (3.0 m) 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)	30 @ 50 (3.5)	30 @ 18 (1.2)	30 @ 10 (0.7)	30 @ 50 (3.5)

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

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

2.2.4.2 Ceiling and In-Rack Sprinkler System Design Criteria for Horizontal-Loading Shuttle ASRS Storage Arrangements Using Open-Top, Combustible Containers

In-rack sprinklers are needed in combination with ceiling-level sprinklers when the guidelines from Section 2.2.4.1.1 are not met. Determine the recommended in-rack sprinkler horizontal arrangement in Section 2.2.4.2.1, the in-rack sprinkler vertical location and system design in Section 2.2.4.2.2, and the available ceiling-level sprinkler designs in Section 2.2.4.2.3.

2.2.4.2.1 Horizontal Arrangement of In-Rack Sprinklers for the Protection of Open-Top, Combustible Containers in a Shuttle ASRS

Use Table 22 to determine the recommended horizontal in-rack sprinkler arrangement for the storage rack to be protected.

Table 22. Recommended Horizontal In-Rack Sprinkler Arrangements for the Protection of Open-Top, Combustible Containers in a Shuttle ASRS

Rack Row Depth, ft (m)	*Overall Maximum Rack Depth, ft (m)*	*Adequate Transverse Flue Spaces Provided per Section 2.2.1.4?*	*Open-Top Container Composition*	*Applicable Horizontal IRAS Arrangement Figures*
Up to 3 (0.9)	3 (0.9)	No	Cardboard or Unexpanded Plastic	14
		Yes	Cardboard	15
			Unexpanded Plastic	16
Up to 6 (1.8)	6 (1.8)	No	Cardboard or Unexpanded Plastic	17
		Yes	Cardboard	18
			Unexpanded Plastic	19
	14 (4.3)	No	Cardboard or Unexpanded Plastic	20
		Yes	Cardboard	21
			Unexpanded Plastic	22
Over 6 (1.8)	Over 6 (1.8)	No	Cardboard or Unexpanded Plastic	23 with Vertical Barriers
		Yes	Cardboard	24
			Unexpanded Plastic	25

2.2.4.2.2 Vertical Location of In-Rack Sprinklers and In-Rack Sprinkler System Designs for the Protection of Open-Top, Combustible Containers in a Shuttle ASRS

2.2.4.2.2.1 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 Table 23 to determine the allowable in-rack sprinkler vertical locations as well as the corresponding recommended in-rack sprinkler design.

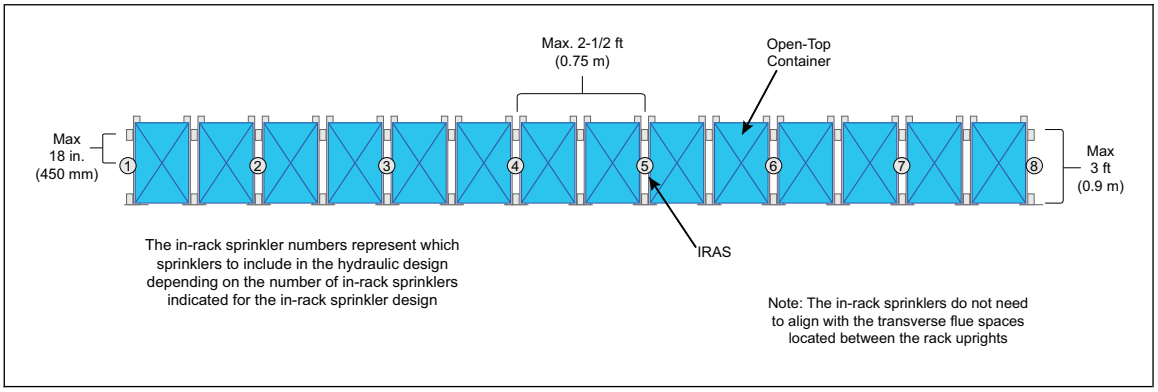

Fig. 14. Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Shuttle ASRS Where Rack Row Depths Do Not Exceed 3 ft (0.9 m) and the Maximum Horizontal Spacing is 2-1/2 ft (0.75 m) per Table 22

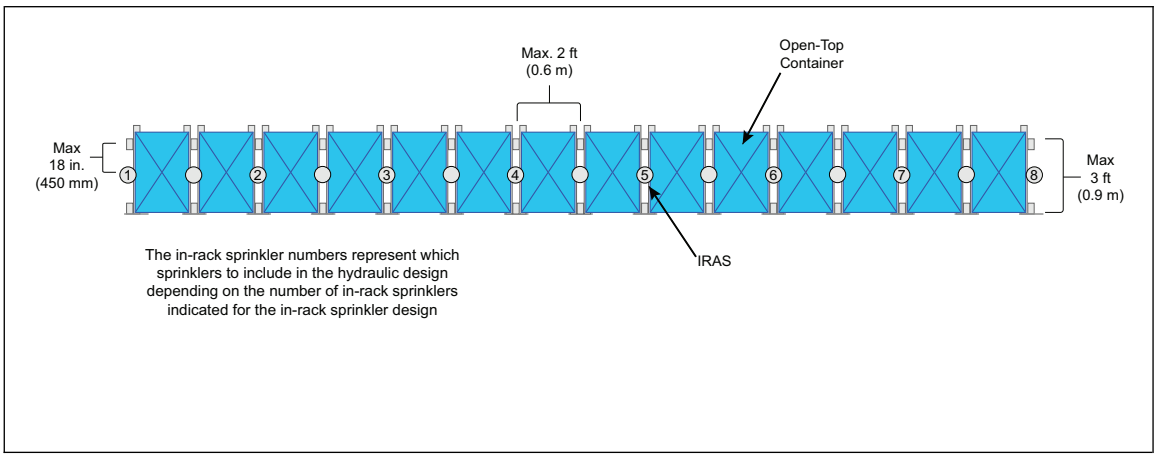

Fig. 15. Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Shuttle ASRS Where Rack Row Depths Do Not Exceed 3 ft (0.9 m) and the Maximum Horizontal Spacing is 2 ft (0.60 m) per Table 22

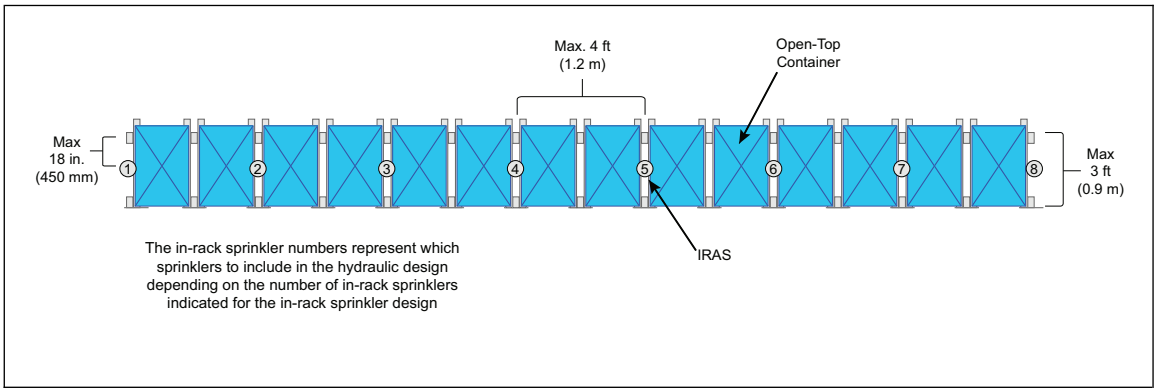

Fig. 16. Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Shuttle ASRS Where Rack Row Depths Do Not Exceed 3 ft (0.9 m) and the Maximum Horizontal Spacing is 4 ft (1.2 m) per Table 22

2. Limit the storage height above the top in-rack sprinkler level to a maximum height of 10 ft (3.0 m).
3. While the in-rack sprinkler designs given in Table 23 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.

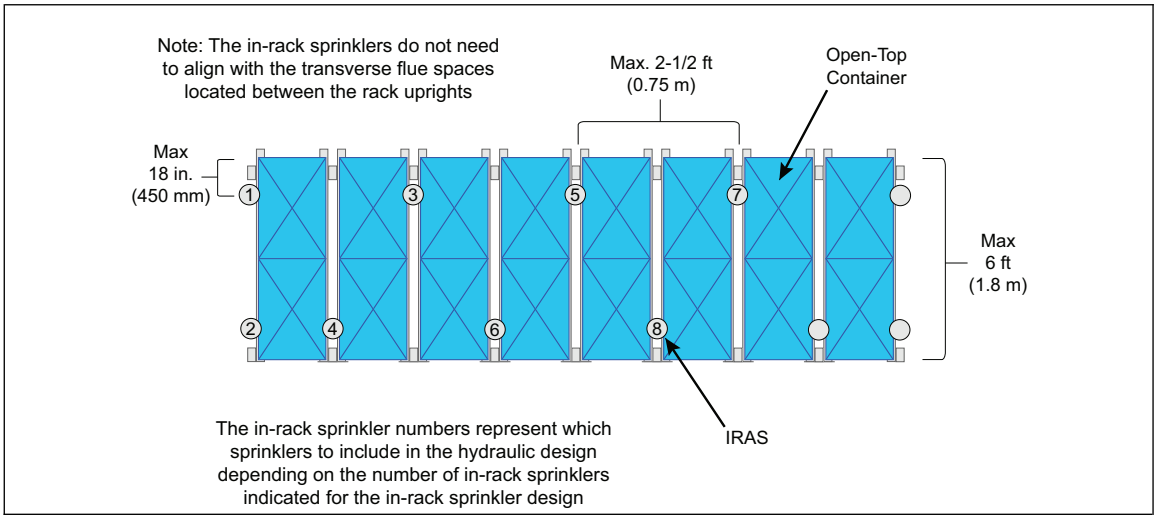

Fig. 17. Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Shuttle ASRS Where Rack Row Depths Do Not Exceed 6 ft (1.8 m) and the Maximum Horizontal Spacing is 2-1/2 ft (0.75 m) per Table 22

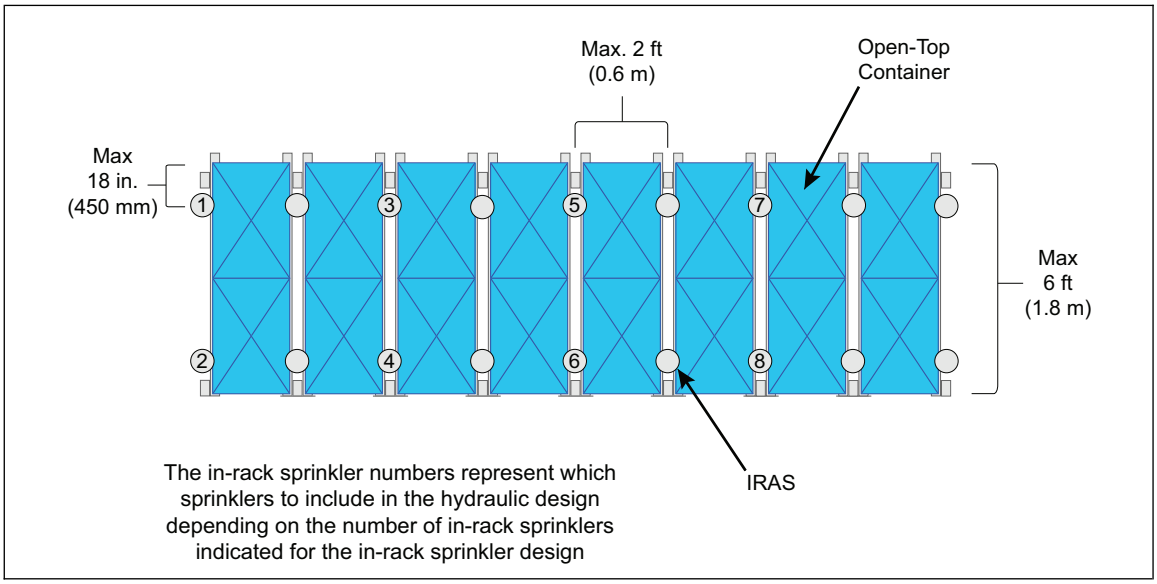

Fig. 18. Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Shuttle ASRS Where Rack Row Depths Do Not Exceed 6 ft (1.8 m) and the Maximum Horizontal Spacing is 2 ft (0.60 m) per Table 22

2.2.4.2.2.2 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 2.2.4.2.2.1. However, include all of 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 open-top, unexpanded plastic containers being stored within a shuttle ASRS which is to be protected with in-rack sprinklers per Figure 17, and the number of in-rack sprinklers between the vertical barriers is nine, then the design for the in-rack sprinkler system would be per Table 23 and would be based on 9 IRAS @ 100 gpm (380 L/min) instead of 6 IRAS @ 100 gpm (380 L/min).

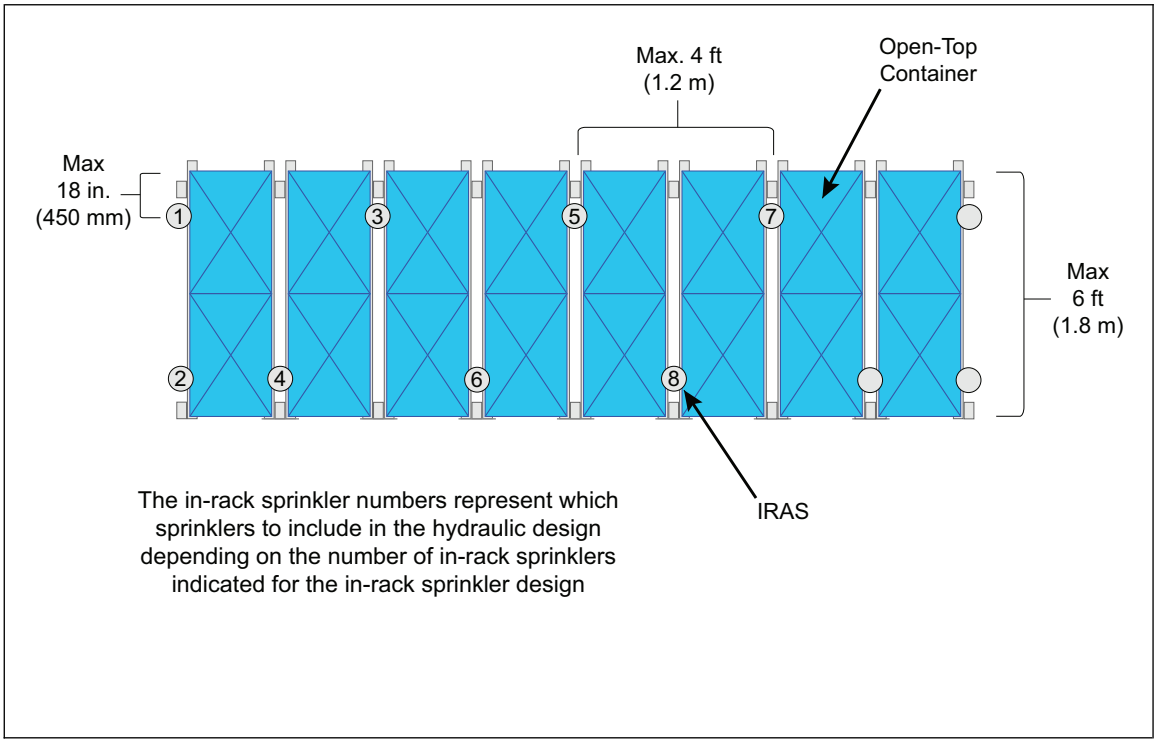

Fig. 19. Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Shuttle ASRS Where Rack Row Depths Do Not Exceed 6 ft (1.8 m) and the Maximum Horizontal Spacing is 4 ft (1.2 m) per Table 22

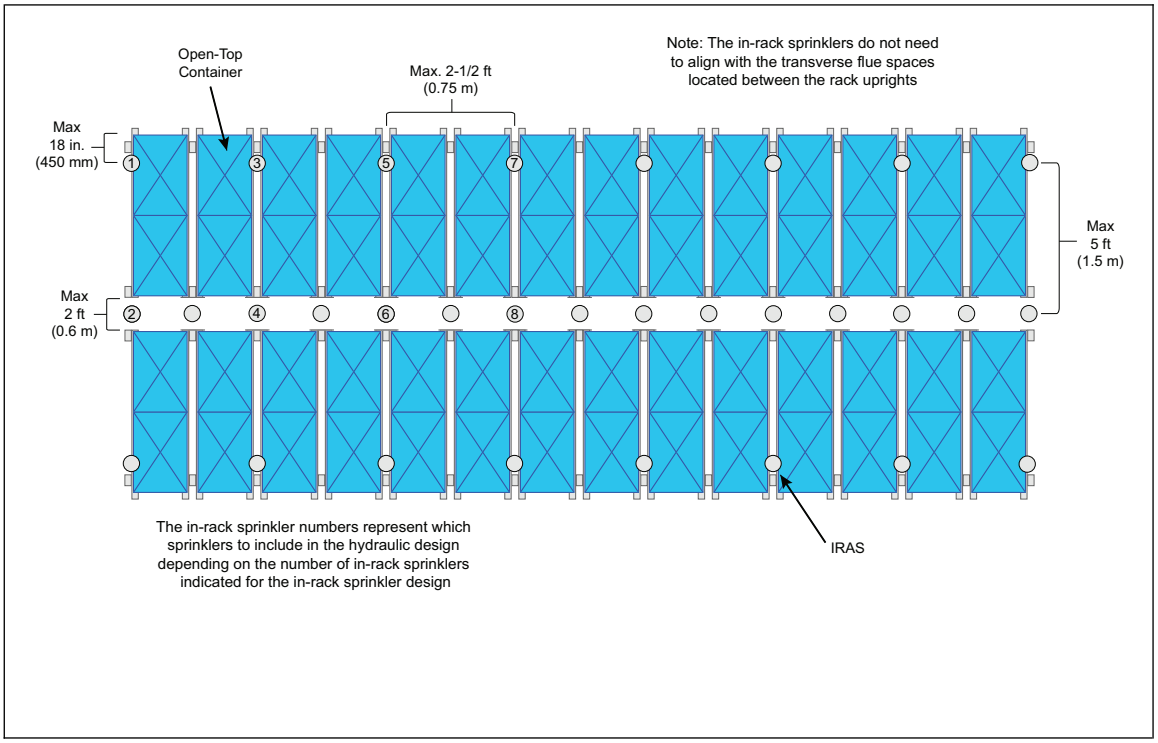

Fig. 20. Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Shuttle ASRS Where the Overall Rack Depths Do Not Exceed 14 ft (4.3 m) and the Maximum Horizontal Spacing is 2-1/2 ft (0.75 m) per Table 22

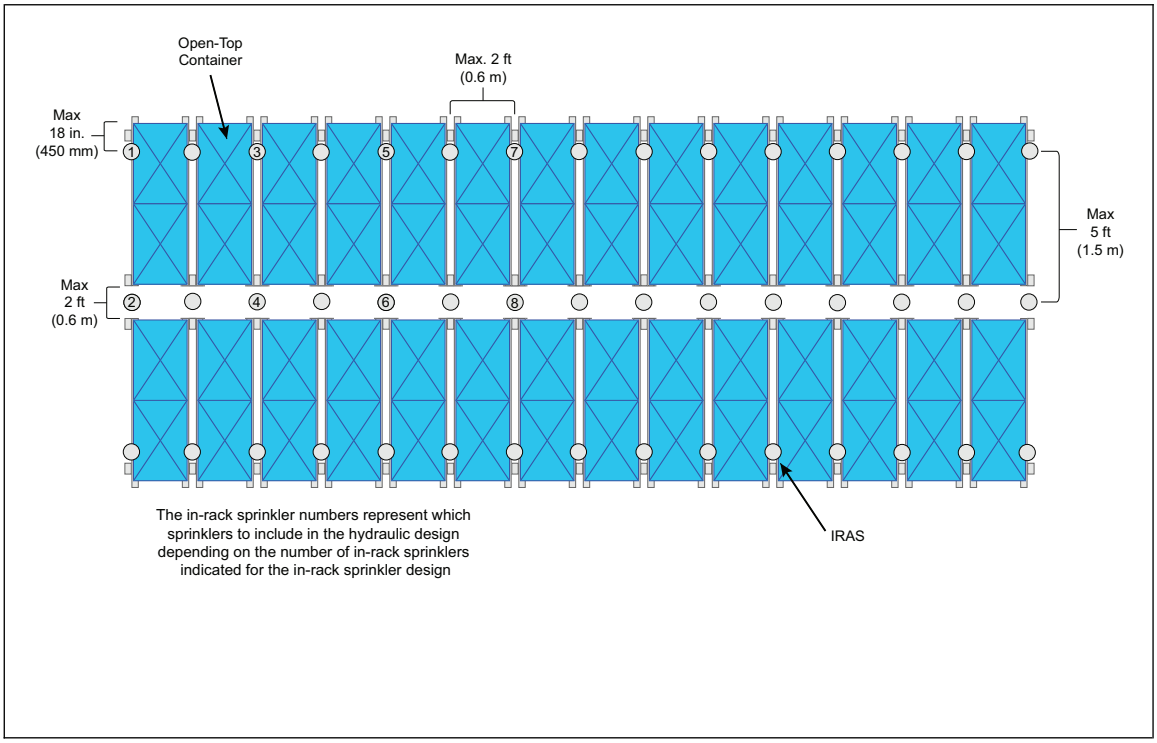

Fig. 21. Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Shuttle ASRS Where the Overall Rack Depths Do Not Exceed 14 ft (4.3 m) and the Maximum Horizontal Spacing is 2 ft (0.60 m) per Table 22

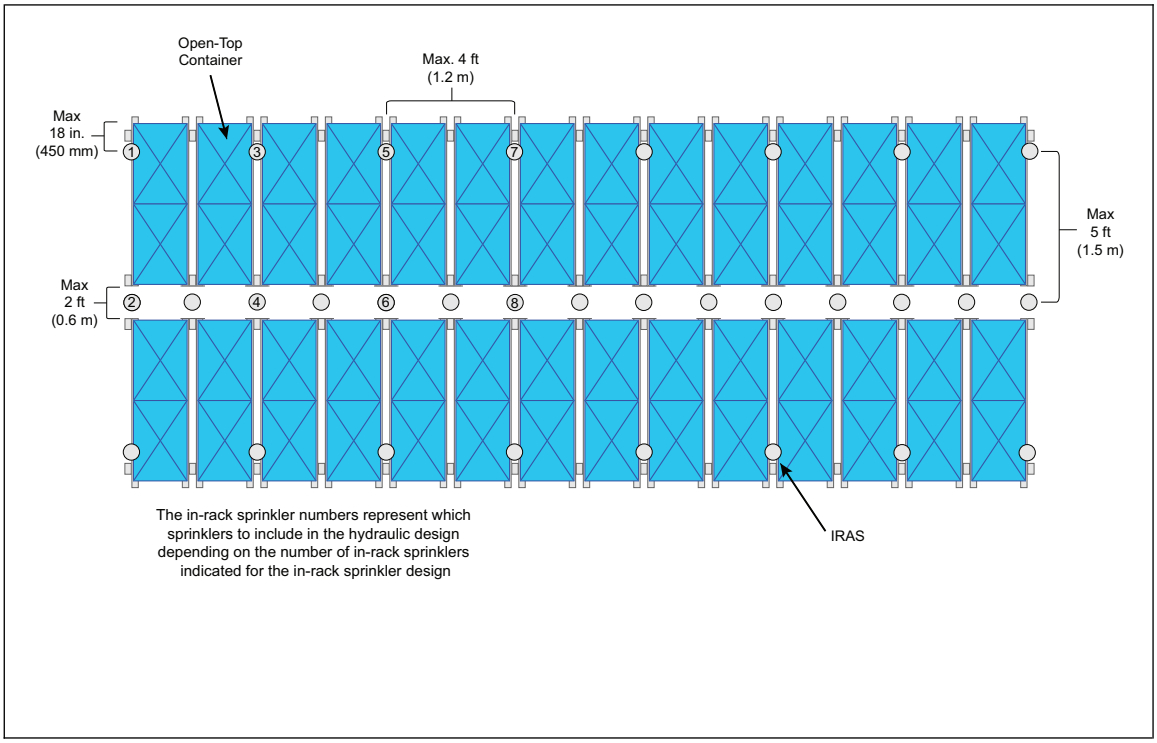

Fig. 22. Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Shuttle ASRS Where the Overall Rack Depths Do Not Exceed 14 ft (4.3 m) and the Maximum Horizontal Spacing is 4 ft (1.2 m) per Table 22

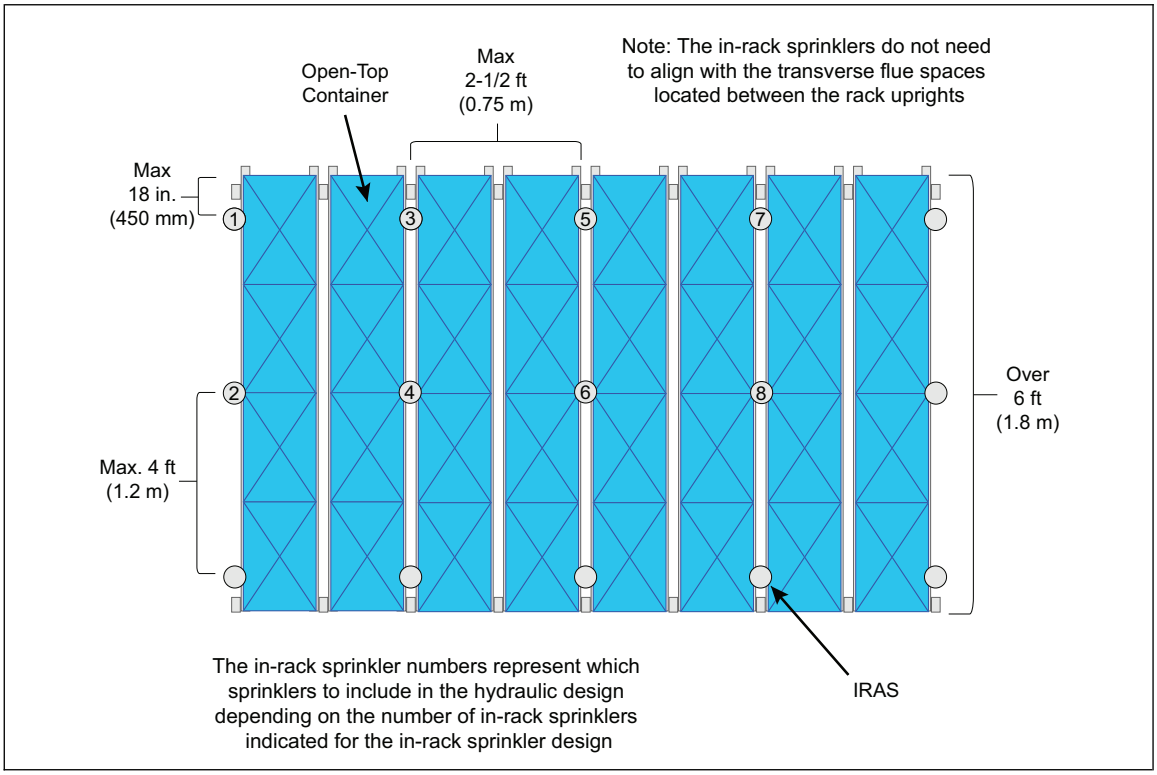

Fig. 23. Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Shuttle ASRS Where Rack Row Depths Exceed 6 ft (1.8 m) and the Maximum Horizontal Spacing is 2-1/2 ft (0.75 m) per Table 22

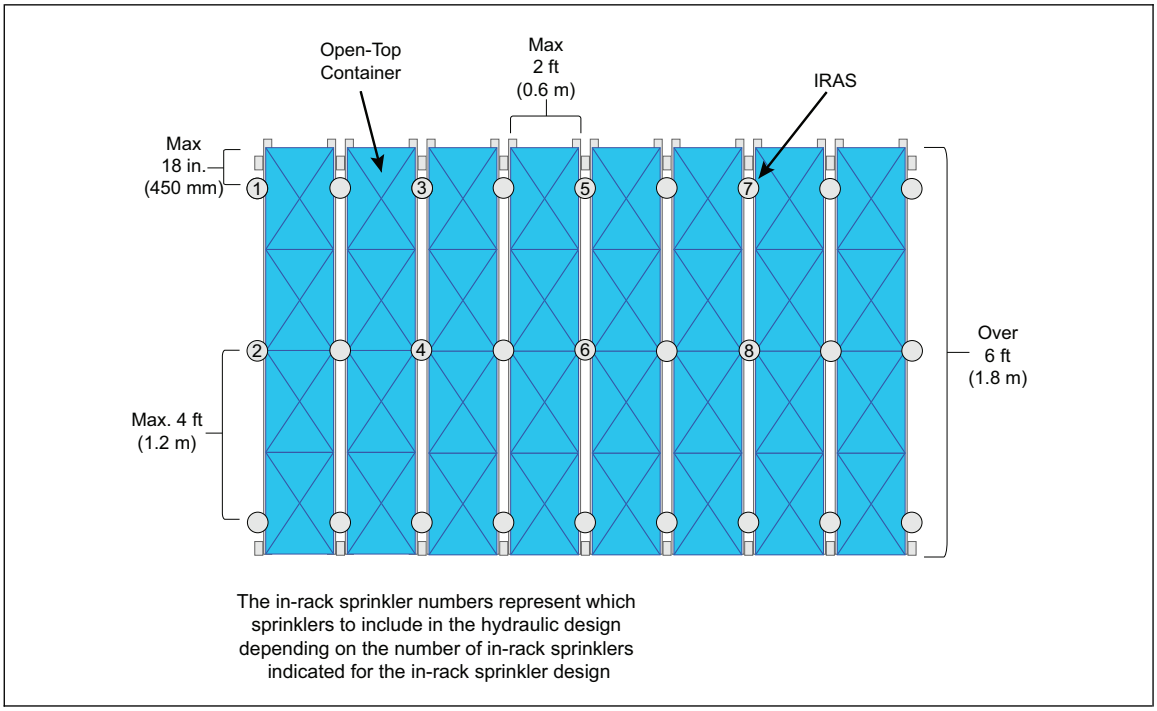

Fig. 24. Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Shuttle ASRS Where Rack Row Depths Exceed 6 ft (1.8 m) and the Maximum Horizontal Spacing is 2 ft (0.60 m) per Table 22

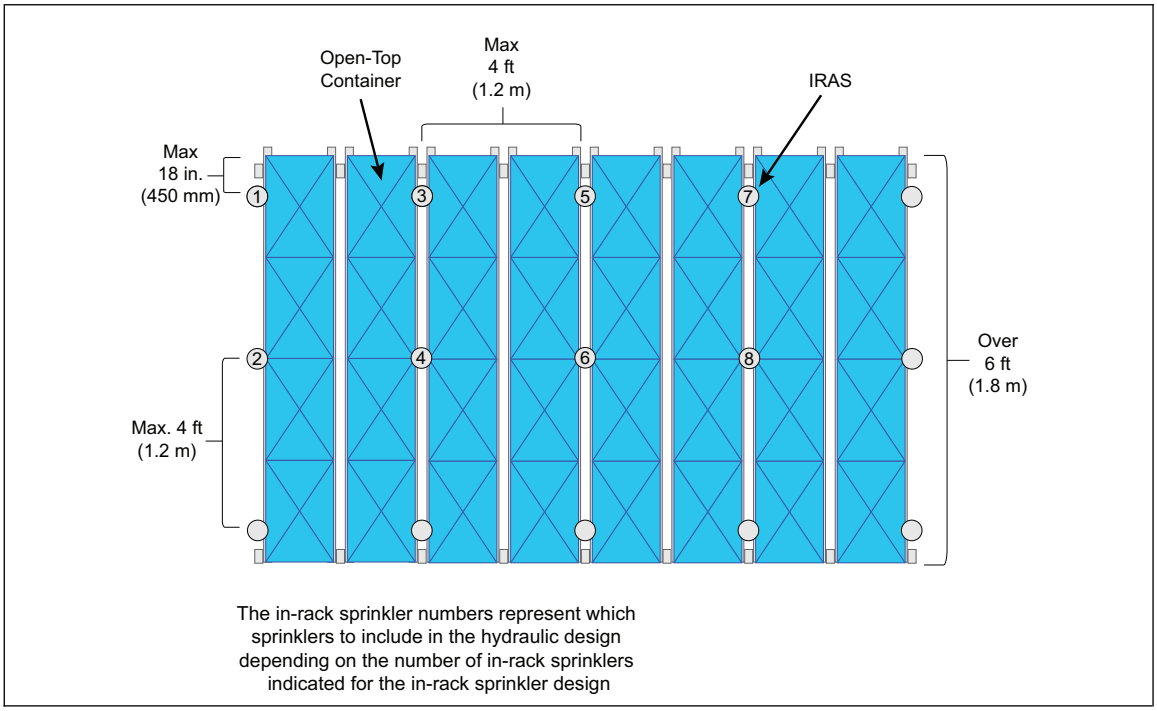

Fig. 25. Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Shuttle ASRS Where Rack Row Depths Exceed 6 ft (1.8 m) and the Maximum Horizontal Spacing is 4 ft (1.2 m) per Table 22

Table 23. Vertical In-Rack Sprinkler Locations and In-Rack Sprinkler Designs for the Protection of Open-Top, Combustible Containers Stored in a Shuttle System

Recommended IRAS Arrangement per Table 22	*Open-Top Container Composition*	*Maximum Commodity Classification*	*IRAS System Type*	*Maximum Vertical Distance Between IRAS, ft (m)*	*Minimum IRAS Design Flow, gpm (L/min)**	*Minimum IRAS K-factor*	*No. of IRAS in Design*	*Hydraulically Balance IRAS System with Ceiling System?*
Figure 14	Cardboard or Unexpanded Plastic	Any	Wet	10 (3.0)	100 (380)	11.2 (160)	4 on top IRAS level	No
			Dry	10 (3.0)	100 (380)	11.2 (160) Upright	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
Figure 15	Cardboard	Class 3	Wet	10 (3.0)	60 (230)	11.2 (160)	4 on top IRAS level	No
				15 (4.6)	100 (380)	14.0 (200) Pendent	6 on top IRAS level	No
			Dry	10 (3.0)	60 (230)	11.2 (160)	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
				15 (4.6)	100 (380)	14.0 (200) Upright	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
		Uncartoned Expanded Plastic	Wet	10 (3.0)	100 (380)	11.2 (160)	4 on top IRAS level	No
				15 (4.6)	140 (530)	22.4 (320) Pendent	6 on top IRAS level	No
			Dry	10 (3.0)	100 (380)	11.2 (160) Upright	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
Figure 16	Unexpanded Plastic	Any	Wet	10 (3.0)	100 (380)	11.2 (160)	4 on top IRAS level	No
				15 (4.6)	140 (530)	22.4 (320) Pendent	6 on top IRAS level	No
			Dry	10 (3.0)	100 (380)	11.2 (160) Upright	8 if one IRAS level or 14 (7 on top 2 levels)	Yes

* The indicated in-rack sprinkler design flow is based on a minimum 9 in. (225 mm) vertical distance between storage tier levels. If the vertical distance between vertical tier levels is less than 9 in. (225 mm), add 20 gpm (75 L/min) to the indicated design flow.

Table 23. Vertical In-Rack Sprinkler Locations and In-Rack Sprinkler Designs for the Protection of Open-Top, Combustible Containers Stored in a Shuttle System (continued)

Recommended IRAS Arrangement per Table 22	*Open-Top Container Composition*	*Maximum Commodity Classification*	*IRAS System Type*	*Maximum Vertical Distance Between IRAS, ft (m)*	*Minimum IRAS Design Flow, gpm (L/min)**	*Minimum IRAS K-factor*	*No. of IRAS in Design*	*Hydraulically Balance IRAS System with Ceiling System?*
Figures 17 or 20	Cardboard or Unexpanded Plastic	Any	Wet	10 (3.0)	100 (380)	11.2 (160)	6 on top IRAS level	No
			Dry	10 (3.0)	100 (380)	11.2 (160) Upright	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
Figures 18, 21, or 24	Cardboard	Class 3	Wet	10 (3.0)	60 (230)	11.2 (160)	6 on top IRAS level	No
				15 (4.6)	100 (380)	14.0 (200) Pendent	6 on top IRAS level	No
			Dry	10 (3.0)	60 (230)	11.2 (160) Upright	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
				15 (4.6)	100 (380)	14.0 (200) Upright	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
		Uncartoned Expanded Plastic	Wet	10 (3.0)	100 (380)	11.2 (160)	6 on top IRAS level	No
				15 (4.6)	140 (530)	22.4 (320) Pendent	6 on top IRAS level	No
			Dry	10 (3.0)	100 (380)	11.2 (160) Upright	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
Figures 19, 22, or 25	Unexpanded Plastic	Any	Wet	10 (3.0)	100 (380)	11.2 (160)	6 on top IRAS level	No
				15 (4.6)	140 (530)	22.4 (320) Pendent	6 on top IRAS level	No
			Dry	10 (3.0)	100 (380)	11.2 (160) Upright	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
Figure 23	Cardboard or Unexpanded Plastic	Any	Wet	10 (3.0)	100 (380)	11.2 (160)	8 on top IRAS level	No
			Dry	10 (3.0)	100 (380)	11.2 (160) Upright	8 if one IRAS level or 14 (7 on top 2 levels)	Yes

* The indicated in-rack sprinkler design flow is based on a minimum 9 in. (225 mm) vertical distance between storage tier levels. If the vertical distance between vertical tier levels is less than 9 in. (225 mm), add 20 gpm (75 L/min) to the indicated design flow.

2.2.4.2.3 Ceiling Sprinkler System Designs in Combination with In-Rack Sprinklers for the Protection of Open-Top, Combustible Containers in a Shuttle ASRS

2.2.4.2.3.1 Use Table 24 to determine the wet ceiling-level sprinkler system designs in combination with in-rack sprinklers. If a protection option is not available from the applicable protection table, either:

1. Install a flat, continuous, noncombustible false ceiling, capable of withstanding an uplift pressure of 3 lb/ft² (14.4 kg/m²), over the ASRS storage area and for a minimum of 15 ft (4.6 m) beyond the ASRS area in all directions with sprinklers installed underneath the false ceiling in accordance with Table 24, or
2. Install in-rack sprinklers over the top of storage and design the ceiling sprinkler system per Table 24.

2.2.4.2.3.2 Use Table 25 to determine the dry ceiling-level sprinkler system designs in combination with in-rack sprinklers. If a protection option is not available from the applicable protection table, either:

1. Install a flat, continuous, noncombustible false ceiling, capable of withstanding an uplift pressure of 3 lb/ft² (14.4 kg/m²), over the ASRS storage area and for a minimum of 15 ft (4.6 m) beyond the ASRS area in all directions with sprinklers installed underneath the false ceiling in accordance with Table 25, or
2. Install in-rack sprinklers over the top of storage and design the ceiling sprinkler system per Table 25.

2.2.4.2.3.3 The ceiling-level sprinkler system designs in Tables 24 and 25 are determined using the vertical distance between the top in-rack sprinkler level and the maximum ceiling height above the ASRS protected area.

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

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

Table 24. Wet System Ceiling-Level Sprinkler Protection Guidelines, in Combination with In-Rack Sprinklers, for the Protection of Open-Top, Combustible Containers in a Shuttle ASRS; No. of AS @ psi (bar)

Max. Storage Height Above Top IRAS Level, ft (m)	*Max. Vertical Distance Between Top IRAS Level and Ceiling, ft (m)*	*Ceiling-Level Sprinkler Protection Options for Shuttle ASRS Arrangements with Open-Top, Combustible Containers; No. of AS @ psi (bar)*																		
		Wet System, Pendent Storage Sprinklers, 160°F (70°C)												Wet System, Upright Storage Sprinklers, 160°F (70°C)						
		Quick-Response								Standard-Response				Quick-Response				Standard-Response		
		11.2 (160)	14.0 (200)	16.8 (240)	22.4 (320)	25.2 (360)	25.2EC (360EC)	28.0 (400)	33.6 (480)	11.2 (160)	14.0 (200)	19.6 (280)	25.2 (360)	11.2 (160)	14.0 (200)	16.8 (240)	25.2EC (360EC)	11.2 (160)	16.8 (240)	25.2 (360)
0 (0)	Any	20 @ 7 (0.5)	9 @ 20 (1.4)	9 @ 20 (1.4)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 20 (1.4)	9 @ 40 (2.8)	9 @ 55 (3.8)	20 @ 7 (0.5)	9 @ 20 (1.4)	9 @ 16 (1.1)	9 @ 7 (0.5)	20 @ 7 (0.5)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 20 (1.4)	20 @ 7 (0.5)	9 @ 20 (1.4)	9 @ 7 (0.5)
5 (1.5)	10 (3.0)	20 @ 30 (2.1)	12 @ 25 (1.7)	12 @ 18 (1.2)	9 @ 20 (1.4)	9 @ 20 (1.4)	10 @ 22 (1.0)	9 @ 40 (2.8)	9 @ 55 (3.8)	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 (1.0)	20 @ 30 (2.1)	20 @ 13 (0.9)	20 @ 7 (0.5)
	15 (4.6)	25 @ 50 (3.5)	10 @ 35 (2.4)	10 @ 25 (1.7)	9 @ 20 (1.4)	9 @ 20 (1.4)	12 @ 38 (2.6)	9 @ 40 (2.8)	9 @ 55 (3.8)	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 (6.1)		12 @ 50 (3.5)	12 @ 35 (2.4)	12 @ 20 (1.4)	12 @ 20 (1.4)		9 @ 40 (2.8)	9 @ 55 (3.8)											
10 (3.0)	15 (4.6)	25 @ 50 (3.5)	10 @ 35 (2.4)	10 @ 25 (1.7)	9 @ 20 (1.4)	9 @ 20 (1.4)	12 @ 38 (2.6)	9 @ 40 (2.8)	9 @ 55 (3.8)	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 (6.1)		12 @ 50 (3.5)	12 @ 35 (2.4)	12 @ 20 (1.4)	12 @ 20 (1.4)		9 @ 40 (2.8)	9 @ 55 (3.8)											

Note: 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 25. Dry System Ceiling-Level Sprinkler Protection Guidelines, in Combination with In-Rack Sprinklers, for the Protection of Open-Top, Combustible Containers in a Shuttle ASRS; No. of AS @ psi (bar)

Max. Storage Height Above Top IRAS Level, ft (m)	*Max. Vertical Distance Between Top IRAS Level and Ceiling, ft (m)*	*Ceiling-Level Sprinkler Protection Options for Shuttle ASRS Arrangements with Open-Top, Combustible Containers; No. of AS @ psi (bar)*			
		Dry System, Upright Storage Sprinklers, 280°F (140°C)			
		Standard-Response			
		11.2 (160)	16.8 (240)	25.2 (360)	33.6 (480)
0 (0)	Any	25 @ 7 (0.5)	25 @ 7 (0.5)	25 @ 7 (0.5)	25 @ 50 (3.5)
5 (1.5)	10 (3.0)	25 @ 30 (2.1)	25 @ 13 (0.9)	25 @ 7 (0.5)	25 @ 50 (3.5)
	15 (4.6)	30 @ 50 (3.5)	30 @ 22 (1.5)	30 @ 10 (0.7)	30 @ 50 (3.5)
10 (3.0)	15 (4.6)	30 @ 50 (3.5)	30 @ 22 (1.5)	30 @ 10 (0.7)	30 @ 50 (3.5)

2.2.5 Protection of Horizontal-Loading, Mini-Load ASRS Storage Arrangements Where Closed-Top, Noncombustible, Solid-Walled Containers, or FM Approved, Non-Propagating, Open-Top Containers are Being Used

2.2.5.1 Protection of Horizontal-Loading, Mini-Load ASRS Storage Arrangements Where Closed-Top, Noncombustible, Solid-Walled Containers are Being Used

2.2.5.1.1 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.

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

2.2.5.2 Protection of Horizontal-Loading, Mini-Load 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 an FM Approval Standard specific to these types of containers.

2.2.6 Protection of Horizontal-Loading Mini-Load 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 2.2.6 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 2.2.6 as “storage on trays”. If the product or containers allow for water collection, use the protection guidelines provided in Section 2.2.7.

Section 2.2.6 is organized as follows:

- Section 2.2.6.1 determines if a ceiling-only protection option is available and, if it is, the recommended ceiling-only protection designs.
- Section 2.2.6.2 determines the recommended designs when both ceiling and in-rack sprinklers are installed. This section is further broken down into the following subsections:
  - Section 2.2.6.2.1 provides acceptable horizontal in-rack sprinkler arrangements.
  - Section 2.2.6.2.2 provides both the acceptable vertical in-rack sprinkler arrangements as well as the corresponding in-rack sprinkler system design.
  - Section 2.2.6.2.3 provides the acceptable ceiling sprinkler system design with the chosen in-rack sprinkler system arrangement.

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

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

1. Adequately aligned transverse flue spaces are provided as outlined in Section 2.2.1.4, 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 protection table), and

4. Uncartoned plastic products are not stored directly on the mini-load rack's horizontal supporting rails (i.e., the products are being stored on trays), and

5. For the given material handling scenario outlined in this section, a ceiling-only protection option is provided in the applicable protection table (Tables 27 through 30) for the specific sprinkler being installed at ceiling level, and

6. 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 (6) cannot be met, see Section 2.2.6.2 regarding the guidelines for installing in-rack sprinklers in combination with ceiling-level sprinklers.

2.2.6.1.2 When a ceiling-only protection scheme is acceptable per items (1) through (6) in Section 2.2.6.1.1, use Table 26 to determine which protection table to use for obtaining the recommended ceiling sprinkler design, depending on the commodity hazard, the type of material handling being used (i.e., directly on the mini-load rack's horizontal supporting rails or on trays), and the type of ceiling sprinkler system (i.e., wet or dry) being installed.

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

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

Table 26. Determining Which Ceiling Sprinkler Protection Table to Use for the Protection of Closed-Top Combustible Containers, or Storage on Trays in a Mini-Load ASRS

Material Handling Method	*Commodity Classification (No Open-Top Containers Permitted)*	*Ceiling Sprinkler System Type*	*Protection Table to Use*
Directly on Supporting Rails or On Trays	Class 1 through 4, Cartoned Plastics, and Uncartoned Unexpanded Plastics	Wet	27
		Dry	28
	Uncartoned Expanded Plastics	Wet	29
		Dry	30

Note 1. In Tables 27 and 29, 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 27. Ceiling-Level Protection Guidelines on a Wet System for Class 1 - 4, Cartoned Plastics, and Uncartoned Unexpanded Plastic Commodities Stored in a Mini-Load 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 28. Ceiling-Level Protection Guidelines on a Dry System for Class 1 - 4, Cartoned Plastics, and Uncartoned Unexpanded Plastic Commodities Stored in a Mini-Load 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 29. Ceiling-Level Protection Guidelines on a Wet System for Uncartoned Expanded Plastic Commodities Stored in a Mini-Load Type 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 30. Ceiling-Level Protection Guidelines on a Dry System for Uncartoned Expanded Plastic Commodities Stored in a Mini-Load 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)

2.2.6.2 Ceiling and In-Rack Sprinkler System Design Criteria for Closed-Top Containers, or Storage on Trays in a Mini-Load ASRS

In-rack sprinklers are needed in combination with ceiling-level sprinklers when the guidelines from Section 2.2.6.1.1 are not met. Determine the recommended in-rack sprinkler horizontal arrangement in Section 2.2.6.2.1, the in-rack sprinkler vertical location and system design in Section 2.2.6.2.2, and the available ceiling-level sprinkler designs in Section 2.2.6.2.3.

2.2.6.2.1 Horizontal Arrangement of In-Rack Sprinklers for Closed-Top Containers, or Storage on Trays in a Mini-Lad ASRS

Use Table 31 to determine the recommended horizontal in-rack sprinkler arrangements for the storage rack to be protected.

Table 31. Recommended Horizontal In-Rack Sprinkler (i.e., IRAS) Arrangements for Closed-Top Combustible Containers, or Storage on Trays in a Mini-Load ASRS

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	26
		Yes	Wet or Dry	Any	Any	Any	26 or 27
Up to 6 (1.8)	6 (1.8)	No	Wet or Dry	Any	Any	Any	28
		Yes	Wet or Dry	Any	Any	Any	28 or 29
	14 (4.3)	No	Wet or Dry	Any	Any	Any	30
		Yes	Wet or Dry	Any	Any	Any	30 or 31
Over 6 (1.8)	Over 6 (1.8)	No	Wet or Dry	Any	Any	Any	32 with Vertical Barriers
		Yes	Wet or Dry	Any	Any	Any	33

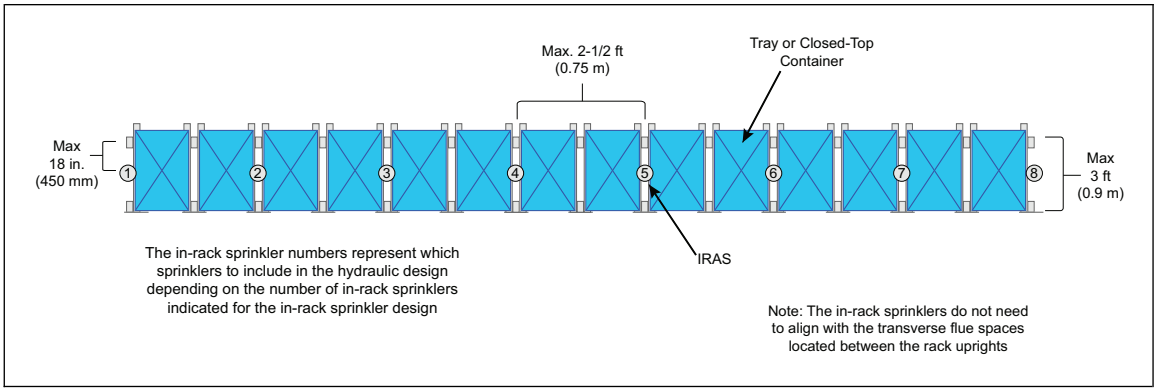

Fig. 26. Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Mini-Load ASRS Where Rack Row Depths Do Not Exceed 3 ft (0.9 m) and the Maximum Horizontal Spacing is 2-1/2 ft (0.75 m) per Table 31

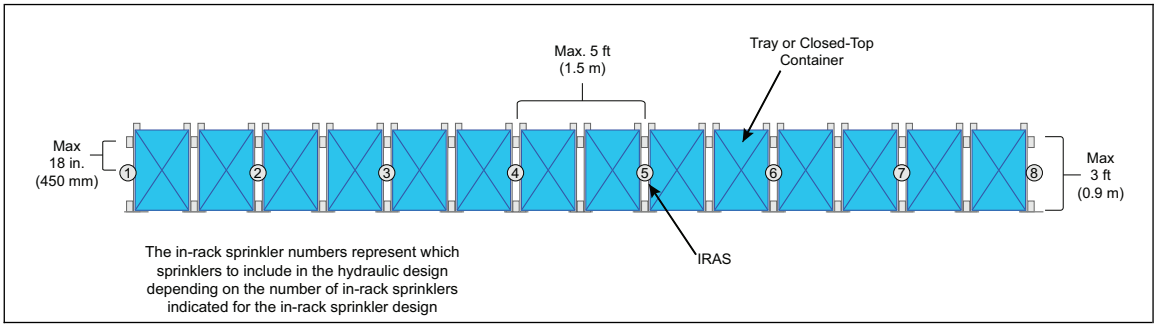

Fig. 27. Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Mini-Load ASRS Where Rack Row Depths Do Not Exceed 3 ft (0.9 m) and the Maximum Horizontal Spacing is 5 ft (1.5 m) per Table 31

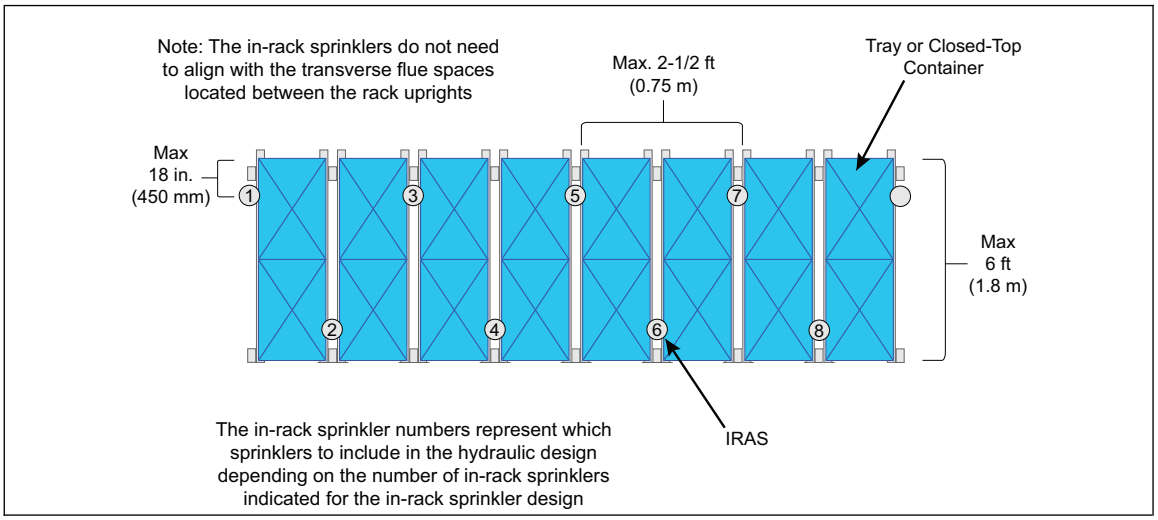

Fig. 28. Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Mini-Load ASRS Where Rack Row Depths Do Not Exceed 6 ft (1.8 m) and the Maximum Horizontal Spacing is 2-1/2 ft (0.75 m) per Table 31

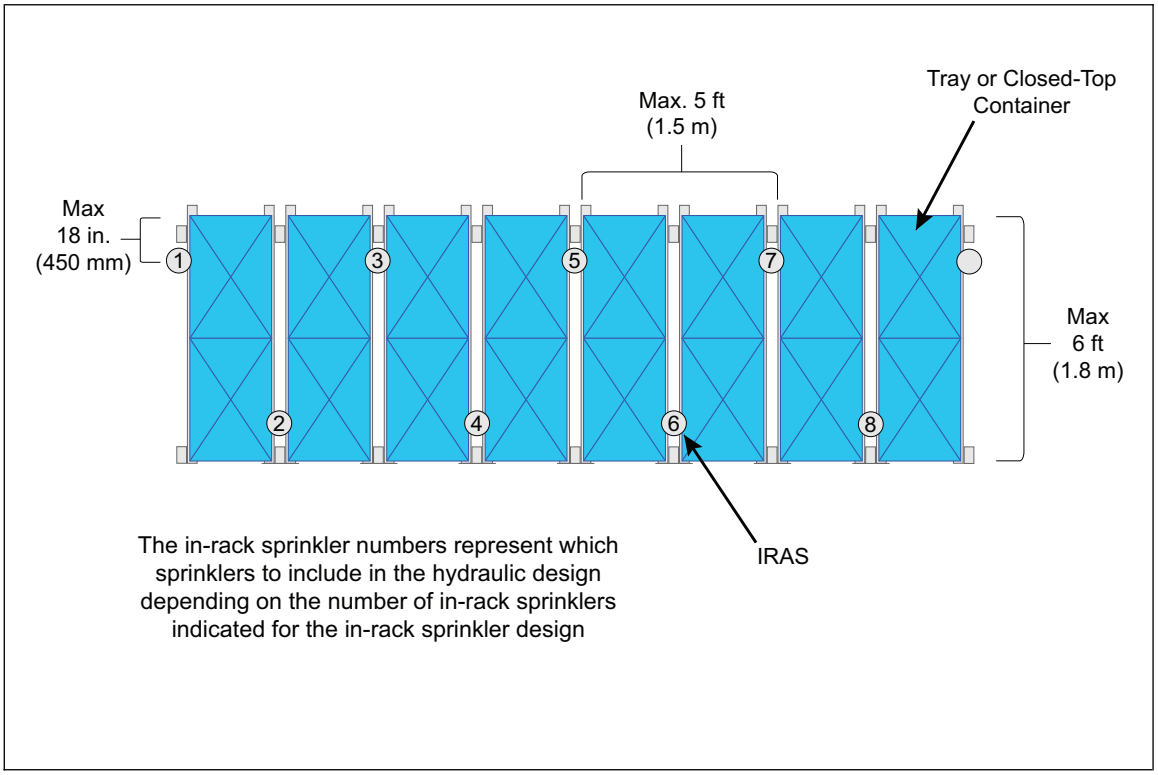

Fig. 29. Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Mini-Load ASRS Where Rack Row Depths Do Not Exceed 6 ft (1.8 m) and the Maximum Horizontal Spacing is 5 ft (1.5 m) per Table 31

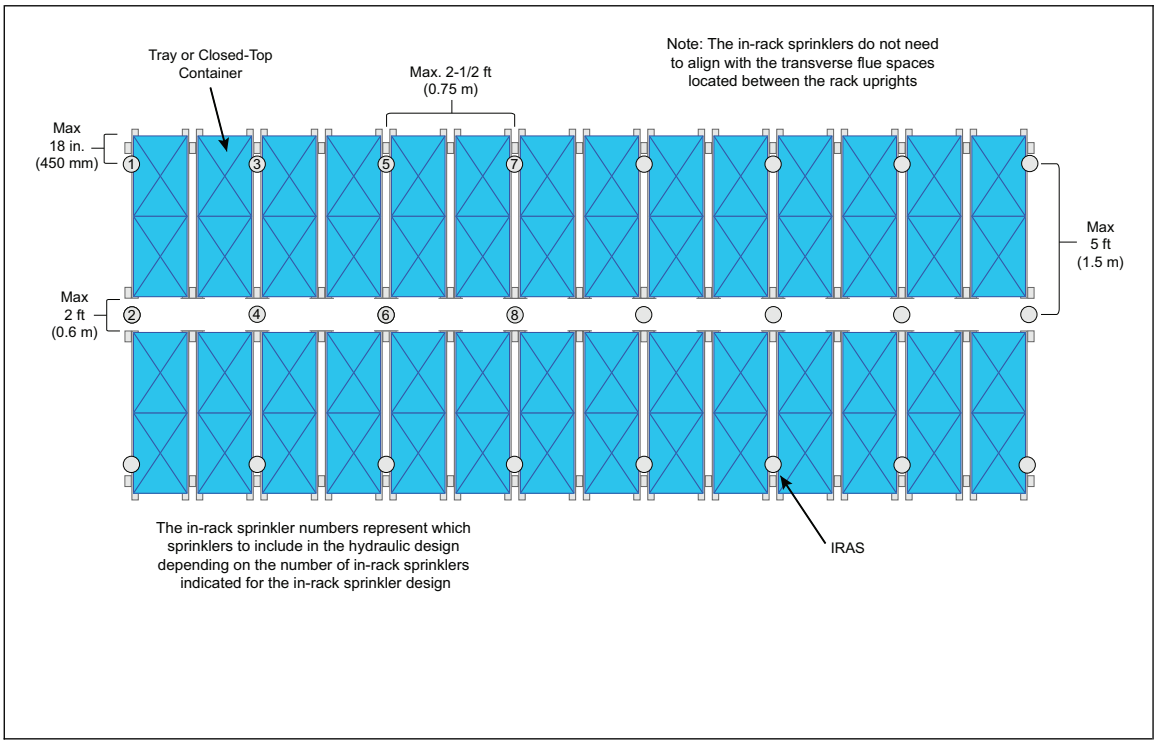

Fig. 30. Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Mini-Load ASRS Where the Overall Rack Depths Do Not Exceed 14 ft (4.3 m) and the Maximum Horizontal Spacing is 2-1/2 ft (0.75 m) per Table 31

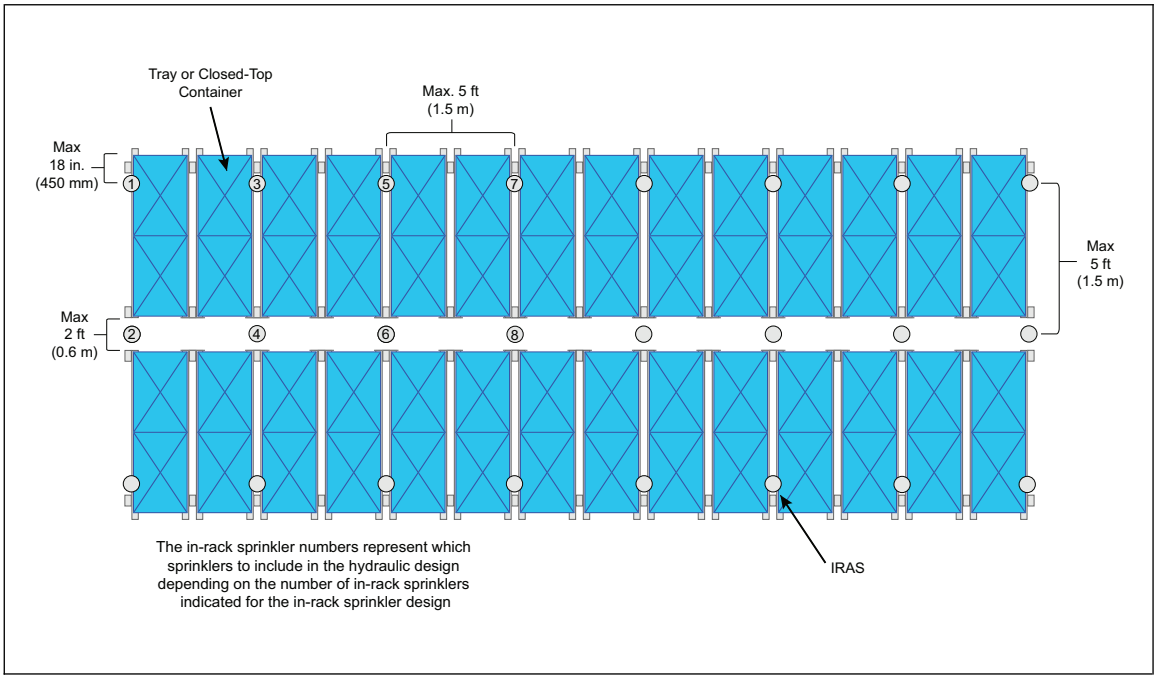

Fig. 31. Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Mini-Load ASRS Where the Overall Rack Depths Do Not Exceed 14 ft (4.3 m) and the Maximum Horizontal Spacing is 5 ft (1.5 m) per Table 31

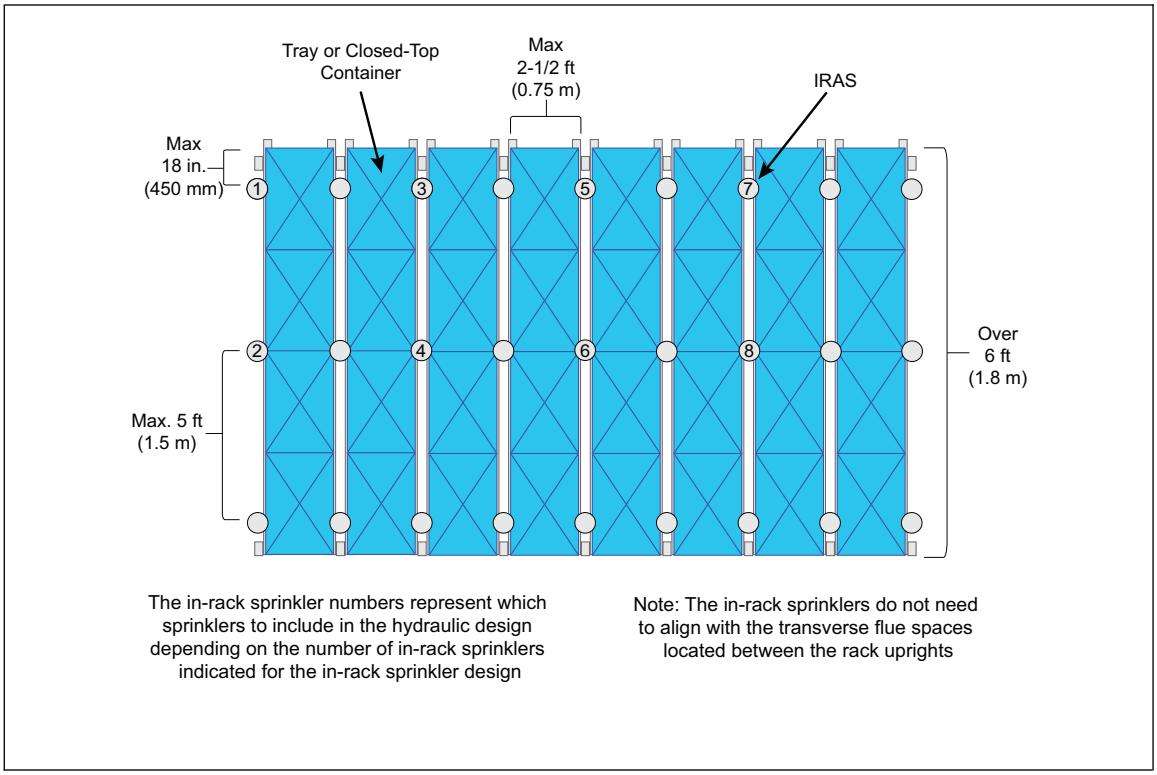

Fig. 32. Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Mini-Load ASRS Where Rack Row Depths Exceed 6 ft (1.8 m) in Depth and the Maximum Horizontal Spacing is 2-1/2 ft (0.75 m) per Table 31

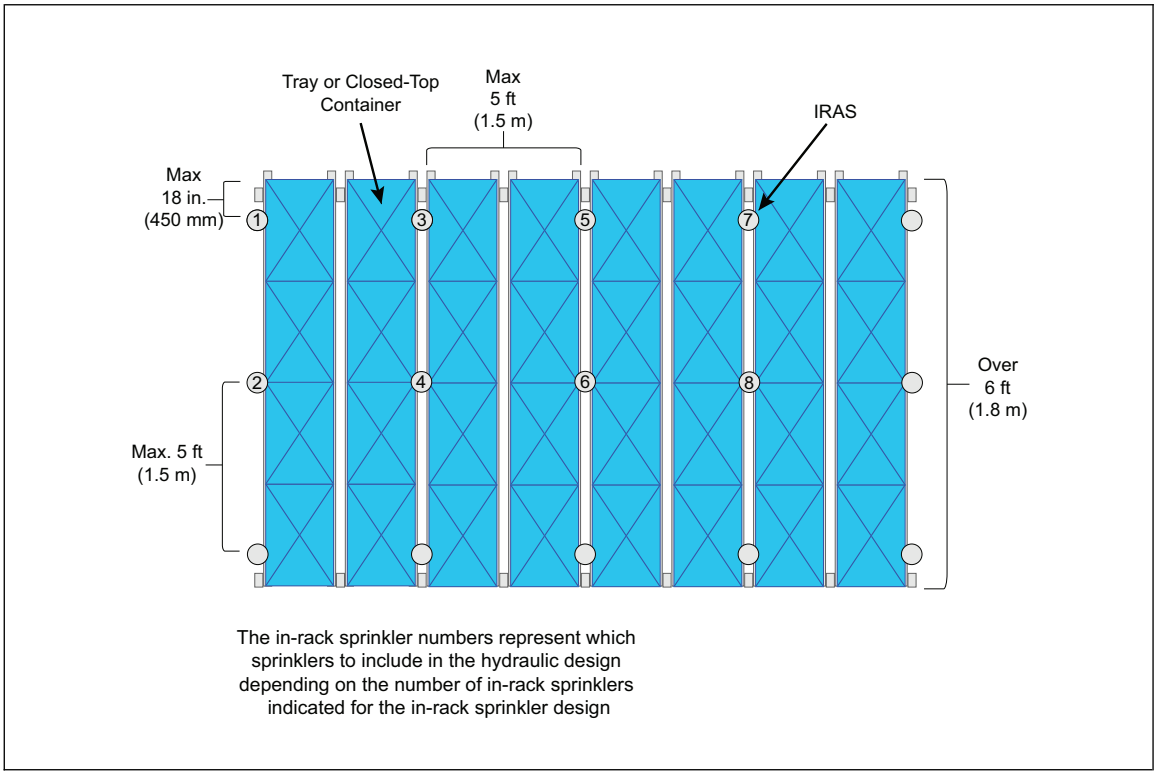

Fig. 33 Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Mini-Load ASRS Where Rack Row Depths Exceed 6 ft (1.8 m) in Depth and the Maximum Horizontal Spacing is 5 ft (1.5 m) per Table 31

2.2.6.2.2 Vertical Location of In-Rack Sprinklers and In-Rack Sprinkler System Designs for the Protection of Closed-Top Combustible Containers, or Storage on Trays in a Mini-Load ASRS

2.2.6.2.2.1 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 32: Wet, In-Rack sprinkler system protecting a mini-load type ASRS, or

   B. Table 33: Dry, In-Rack sprinkler system protecting a mini-load type ASRS

2. The maximum storage height above the top in-rack sprinkler level is 10 ft (3.0 m).

3. While the in-rack sprinkler designs given in Tables 32 and 33 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.

2.2.6.2.2.2 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 2.2.6.2.2.1. However, include all of 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 cartoned unexpanded plastic commodity being stored within a mini-load ASRS which is to be protected with in-rack sprinklers per Figure 28, and the number of in-rack sprinklers between the vertical barriers is 9, then the design for the in-rack sprinkler system would be per Table 32 and would be designed for (1) 9 IRAS @ 60 gpm (230 L/min) as opposed to 6 IRAS @ 60 gpm (230 L/min).

Table 32. Wet, In-Rack Sprinkler Designs for the Protection of Closed-Top, Combustible Containers Stored in a Mini-Load Type ASRS

Recommended IRAS Arrangement per Table 31	*Maximum Commodity Hazard*	*Material Handling Method*	*Max. Vertical Distance Between IRAS, ft (m)**	*Min. IRAS Flow Design, gpm (L/min)***	*Min. IRAS K-factor*	*No. of IRAS in Design*	*Hydraulically Balance IRAS System with Ceiling System?*
Figure 26	Cartoned Unexpanded Plastics	Directly on Rails or On Trays	10 (3.0)	60 (230)	11.2 (160)	5 on top IRAS level	No
			15 (4.6)	100 (380)	14.0 (200)	6 on top IRAS level	No
	Cartoned Expanded Plastics	Directly on Rails	10 (3.0)	60 (230)	11.2 (160)	5 on top IRAS level	No
		On Trays	10 (3.0)	60 (230)	11.2 (160)	5 on top IRAS level	No
			15 (4.6)	100 (380)	14.0 (200)	6 on top IRAS level	No
	Uncartoned Expanded Plastics	On Trays	10 (3.0)	60 (230)	11.2 (160)	5 on top IRAS level	No
Figure 27	Cartoned Unexpanded Plastics	Directly on Rails or On Trays	10 (3.0)	60 (230)	11.2 (160)	4 on top IRAS level	No
			15 (4.6)	100 (380)	14.0 (200)	6 on top IRAS level	No
	Cartoned Expanded Plastics	Directly on Rails	10 (3.0)	60 (230)	11.2 (160)	4 on top IRAS level	No
		On Trays	10 (3.0)	60 (230)	11.2 (160)	4 on top IRAS level	No
			15 (4.6)	100 (380)	14.0 (200)	6 on top IRAS level	No
	Uncartoned Expanded Plastics	On Trays	10 (3.0)	60 (230)	11.2 (160)	4 on top IRAS level	No
Figures 28, 30, or 32	Cartoned Expanded Plastics	Directly on Rails or On Trays	10 (3.0)	60 (230)	11.2 (160)	6 on top IRAS level	No
	Uncartoned Expanded Plastics	On Trays	10 (3.0)	60 (230)	11.2 (160)	6 on top IRAS level	No
Figures 29, 31, or 33	Cartoned Unexpanded Plastics	Directly on Rails or On Trays	10 (3.0)	60 (230)	11.2 (160)	6 on top IRAS level	No
			15 (4.6)	100 (380)	14.0 (200)	8 on top IRAS level	No
	Cartoned Expanded Plastics	Directly on Rails	10 (3.0)	60 (230)	11.2 (160)	6 on top IRAS level	No
		On Trays	10 (3.0)	60 (230)	11.2 (160)	6 on top IRAS level	No
			15 (4.6)	100 (380)	14.0 (200)	8 on top IRAS level	No
	Uncartoned Expanded Plastics	On Trays	10 (3.0)	60 (230)	11.2 (160)	6 on top IRAS level	No

*The maximum storage height above the top in-rack sprinkler level is 10 ft (3.0 m).
**The indicated in-rack sprinkler design flow is based on a minimum 9 in. (225 mm) vertical distance between storage tier levels. If the vertical distance between vertical tier levels is less than 9 in. (225 mm), add 20 gpm (75 L/min) to the indicated design flow.

Table 33. Dry, In-Rack Sprinkler Designs for the Protection of Closed-Top, Combustible Containers Stored in a Mini-Load Type ASRS

Recommended IRAS Arrangement per Table 31	*Maximum Commodity Hazard*	*Material Handling Method*	*Max. Vertical Distance Between IRAS, ft (m)**	*Min. IRAS Flow Design, gpm (L/min)***	*Min. IRAS K-factor*	*No. of IRAS in Design*	*Hydraulically Balance IRAS System with Ceiling System?*
Figure 26	Cartoned Unexpanded Plastics	Directly on Rails or On Trays	10 (3.0)	60 (230)	11.2 (160) Upright	6 if one IRAS level or 10 (5 on top 2 levels)	Yes
			15 (4.6)	100 (380)	14.0 (200) Upright	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
	Cartoned Expanded Plastics	Directly on Rails	10 (3.0)	60 (230)	11.2 (160) Upright	6 if one IRAS level or 10 (5 on top 2 levels)	Yes
		On Trays	10 (3.0)	60 (230)	11.2 (160) Upright	6 if one IRAS level or 10 (5 on top 2 levels)	Yes
			15 (4.6)	100 (380)	14.0 (200) Upright	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
	Uncartoned Expanded Plastics	On Trays	10 (3.0)	60 (230)	11.2 (160) Upright	6 if one IRAS level or 10 (5 on top 2 levels)	Yes
Figure 27	Cartoned Unexpanded Plastics	Directly on Rails or On Trays	10 (3.0)	60 (230)	11.2 (160) Upright	4 if one IRAS level or 8 (4 on top 2 levels)	Yes
			15 (4.6)	100 (380)	14.0 (200) Upright	6 if one IRAS level or 10 (5 on top 2 levels)	Yes
	Cartoned Expanded Plastics	Directly on Rails	10 (3.0)	60 (230)	11.2 (160) Upright	4 if one IRAS level or 8 (4 on top 2 levels)	Yes
		On Trays	10 (3.0)	60 (230)	11.2 (160) Upright	4 if one IRAS level or 8 (4 on top 2 levels)	Yes
			15 (4.6)	100 (380)	14.0 (200) Upright	6 if one IRAS level or 10 (5 on top 2 levels)	Yes
	Uncartoned Expanded Plastics	On Trays	10 (3.0)	60 (230)	11.2 (160) Upright	6 if one IRAS level or 10 (5 on top 2 levels)	Yes
Figures 28, 29, 30, 31, 32, or 33	Cartoned Unexpanded Plastics	Directly on Rails or On Trays	10 (3.0)	60 (230)	11.2 (160) Upright	6 if one IRAS level or 10 (5 on top 2 levels)	Yes
			15 (4.6)	100 (380)	14.0 (200) Upright	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
	Cartoned Expanded Plastics	Directly on Rails	10 (3.0)	60 (230)	11.2 (160) Upright	6 if one IRAS level or 10 (5 on top 2 levels)	Yes
		On Trays	10 (3.0)	60 (230)	11.2 (160) Upright	6 if one IRAS level or 10 (5 on top 2 levels)	Yes
			15 (4.6)	100 (380)	14.0 (200) Upright	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
	Uncartoned Expanded Plastics	On Trays	10 (3.0)	60 (230)	11.2 (160) Upright	8 if one IRAS level or 14 (7 on top 2 levels)	Yes

*The maximum storage height above the top in-rack sprinkler level is 10 ft (3.0 m).
**The indicated in-rack sprinkler design flow is based on a minimum 9 in. (225 mm) vertical distance between storage tier levels. If the vertical distance between vertical tier levels is less than 9 in. (225 mm), add 20 gpm (75 L/min) to the indicated design flow.

2.2.6.2.3 Ceiling Sprinkler System Designs in Combination with In-Rack Sprinklers for the Protection of Closed-Top Combustible Containers, or Storage on Trays in a Mini-Load ASRS

2.2.6.2.3.1 Use Table 34 to determine how to obtain the ceiling sprinkler system design for a wet ceiling sprinkler system protecting a mini-load type ASRS. If a protection option is not available from the applicable protection table, either:

1. Install a flat, continuous, noncombustible false ceiling, capable of withstanding an uplift pressure of 3 lb/ft² (14.4 kg/m²), over the ASRS storage area and for a minimum of 15 ft (4.6 m) beyond the ASRS area in all directions with sprinklers installed underneath the false ceiling in accordance with Table 34, or
2. Install in-rack sprinklers over the top of storage and design the ceiling sprinkler system per Table 34.

2.2.6.2.3.2 Use Table 35 to determine how to obtain the ceiling sprinkler system design for a dry ceiling sprinkler system protecting a mini-load type ASRS. If a protection option is not available from the applicable protection table, either:

1. Install a flat, continuous, noncombustible false ceiling, capable of withstanding an uplift pressure of 3 lb/ft² (14.4 kg/m²), over the ASRS storage area and for a minimum of 15 ft (4.6 m) beyond the ASRS area in all directions with sprinklers installed underneath the false ceiling in accordance with Table 35, or
2. Install in-rack sprinklers over the top of storage and design the ceiling sprinkler system per Table 35.

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

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

Table 34. Determining the Applicable Protection Table and Ceiling Height for Ceiling Sprinkler Designs when Wet Ceiling-Level Sprinkler Systems are Supplemented with In-Rack Sprinklers to Protect Closed-Top Combustible Containers, or Storage on Trays in a Mini-Load Type ASRS

Maximum Commodity Hazard	*Material Handling Method*	*Max. Storage Height Above Top IRAS Level, ft (m)*	*Max. Clearance Between Top of Storage and Ceiling, ft (m)*	*Applicable Protection Table to Use*	*Applicable Ceiling Height to Use in Indicated Protection Table, ft (m)*
Cartoned Unexpanded Plastics	Directly on Supporting Rails or On Trays	0 (0)	Any	27	10 (3.0)
		5 (1.5)	5 (1.5)	27	10 (3.0)
			10 (3.0)	27	15 (4.6)
			20 (6.1)	27	20 (6.1)
			> 20 (6.1)	27	Vertical distance between top IRAS level and ceiling
		10 (3.0)	Any	27	Vertical distance between top IRAS level and ceiling
Cartoned Expanded Plastics	Directly on Supporting Rails	0 (0)	Any	29	10 (3.0)
		5 (1.5)	5 (1.5)	29	10 (3.0)
			10 (3.0)	29	15 (4.6)
			20 (6.1)	29	25 (7.6)
			> 20 (6.1)	29	Vertical distance between top IRAS level and ceiling
		0 (3.0)	Any	29	Vertical distance between top IRAS level and ceiling
	On Trays	0 (0)	Any	27	10 (3.0)
		5 (1.5)	5 (1.5)	27	10 (3.0)
			10 (3.0)	27	15 (4.6)
			20 (6.1)	27	20 (6.1)
			> 20 (6.1)	27	Vertical distance between top IRAS level and ceiling
		10 (3.0)	Any	27	Vertical distance between top IRAS level and ceiling
Uncartoned Unexpanded Plastics	Directly on Supporting Rails	0 (0)	Any	27	10 (3.0)
	On Trays	0 (0)	Any	27	10 (3.0)
		5 (1.5)	5 (1.5)	27	10 (3.0)
			10 (3.0)	27	15 (4.6)
			20 (6.1)	27	20 (6.1)
			> 20 (6.1)	27	Vertical distance between top IRAS level and ceiling
		10 (3.0)	Any	27	Vertical distance between top IRAS level and ceiling
Uncartoned Expanded Plastics	Directly on Supporting Rails	0 (0)	Any	29	10 (3.0)
	On Trays	0 (0)	Any	29	10 (3.0)
		5 (1.5)	5 (1.5)	29	10 (3.0)
			10 (3.0)	29	15 (4.6)
			20 (6.1)	29	25 (7.6)
			> 20 (6.1)	29	Vertical distance between top IRAS level and ceiling
		10 (3.0)	Any	29	Vertical distance between top IRAS level and ceiling

Table 35. Determining the Applicable Protection Table and Ceiling Height for Ceiling Sprinkler Designs when Dry Ceiling-Level Sprinkler Systems are Supplemented with In-Rack Sprinklers to Protect Closed-Top Combustible Containers, or Storage on Trays in a Mini-Load Type ASRS

Maximum Commodity Hazard	*Material Handling Method*	*Max. Storage Height Above Top IRAS Level, ft (m)*	*Max. Clearance Between Top of Storage and Ceiling, ft (m)*	*Applicable Protection Table to Use*	*Applicable Ceiling Height to Use in Indicated Protection Table, ft (m)*
Cartoned Unexpanded Plastics	Directly on Supporting Rails or On Trays	0 (0)	Any	28	10 (3.0)
		5 (1.5)	5 (1.5)	28	10 (3.0)
			10 (3.0)	28	15 (4.6)
		10 (3.0)	5 (1.5)	28	15 (4.6)
Cartoned Expanded Plastics	Directly on Supporting Rails	0 (0)	Any	30	10 (3.0)
		5 (1.5)	5 (1.5)	30	10 (3.0)
			10 (3.0)	30	15 (4.6)
		10 (3.0)	5 (1.5)	30	15 (4.6)
	On Trays	0 (0)	Any	28	10 (3.0)
		5 (1.5)	5 (1.5)	28	10 (3.0)
			10 (3.0)	28	15 (4.6)
		10 (3.0)	5 (1.5)	28	15 (4.6)
Uncartoned Unexpanded Plastics	Directly on Supporting Rails	0 (0)	Any	28	10 (3.0)
	On Trays	0 (0)	Any	28	10 (3.0)
		5 (1.5)	5 (1.5)	28	10 (3.0)
			10 (3.0)	28	15 (4.6)
		10 (3.0)	5 (1.5)	28	15 (4.6)
Uncartoned Expanded Plastics	Directly on Supporting Rails	0 (0)	Any	30	10 (3.0)
	On Trays	0 (0)	Any	30	10 (3.0)
		5 (1.5)	5 (1.5)	30	10 (3.0)
			10 (3.0)	30	15 (4.6)
		10 (3.0)	5 (1.5)	30	15 (4.6)

2.2.7 Protection of Horizontal-Loading, Mini-Load ASRS Storage Arrangements Where Open-Top, Combustible Containers are Being Used

Note that the protection of expanded plastic containers is outside the scope of this data sheet.

Section 2.2.7 is organized as follows:

- Section 2.2.7.1 determines if a ceiling-only protection option is available and, if it is, the recommended ceiling-only protection designs.
- Section 2.2.7.2 determines the recommended designs when both ceiling and in-rack sprinklers are installed. This section is further broken down into the following subsections:
  - Section 2.2.7.2.1 provides acceptable horizontal in-rack sprinkler arrangements.
  - Section 2.2.7.2.2 provides both the acceptable vertical in-rack sprinkler arrangements as well as the corresponding in-rack sprinkler system design.
  - Section 2.2.7.2.3 provides the acceptable ceiling sprinkler system design with the chosen in-rack sprinkler system arrangement.

2.2.7.1 Ceiling-Only Sprinkler System Design Criteria for Horizontal-Loading, Mini-Load ASRS Storage Arrangements Using Open-Top, Combustible Containers

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

1. Adequate vertically aligned transverse flue spaces are provided as outlined in Section 2.2.1.4, and
2. The storage height does not exceed 10 ft (3.0 m), and
3. A ceiling-only protection option is provided in the applicable protection table (Tables 37 and 38) for the specific sprinkler being installed at ceiling level, and

4. 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 (4) cannot be met, see Section 2.2.7.2 regarding the guidelines for installing in-rack sprinklers in combination with ceiling-level sprinklers.

2.2.7.1.2 When a ceiling-only protection scheme is acceptable per items (1) through (4) in Section 2.2.7.1.1, use Table 36 to determine which protection table to use for obtaining the recommended ceiling sprinkler design, depending on the type of ceiling sprinkler system (i.e., wet or dry) being installed.

Table 36. Determining Which Ceiling Sprinkler Protection Table to Use for the Protection of Horizontal-Loading, Mini-Load ASRS Storage Arrangements Where Open-Top, Combustible Containers are Being Used

Commodity Classification	*Ceiling Sprinkler System Type*	*Protection Table to Use*
Class 1 through 4, Cartoned Plastics, and Uncartoned Plastics	Wet	37
	Dry	38

Note: In Table 37, 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 37. Ceiling-Level Protection Guidelines on a Wet System for Storage in Open-Top, Combustible Containers in a Mini-Load ASRS up to a Maximum of 10 ft (3.0 m); 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				tandard-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)	25 @ 50 (3.5)	12 @ 25 (1.7)	12 @ 18 (1.2)	9 @ 20 (1.4)	9 @ 20 (1.4)	12 @ 38 (2.6)	9 @ 40 (2.8)	9 @ 55 (3.8)	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 @ 18 (1.2)	12 @ 38 (2.6)	25 @ 50 (3.5)	25 @ 18 (1.2)	25 @ 10 (0.7)
15 (4.6)		12 @ 50 (3.5)	12 @ 35 (2.4)	12 @ 20 (1.4)	10 @ 20 (1.4)		9 @ 40 (2.8)	9 @ 55 (3.8)											
20 (6.1)		12 @ 75 (5.2)	12 @ 52 (3.6)	12 @ 29 (2.0)	12 @ 23 (1.6)		9 @ 40 (2.8)	9 @ 55 (3.8)											

Table 38. Ceiling-Level Protection Guidelines on a Dry System for Storage in Open-Top, Combustible Containers in a Mini-Load ASRS up to a Maximum of 5 ft (1.5 m); 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)	30 @ 50 (3.5)	30 @ 18 (1.2)	30 @ 10 (0.7)	30 @ 50 (3.5)

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

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

2.2.7.2 Ceiling and In-Rack Sprinkler System Design Criteria for Horizontal-Loading, Mini-Load ASRS Storage Arrangements Using Open-Top, Combustible Containers

In-rack sprinklers are needed in combination with ceiling-level sprinklers when the guidelines from Section 2.2.7.1.1 are not met. Determine the recommended in-rack sprinkler horizontal arrangement in Section 2.2.7.2.1, the in-rack sprinkler vertical location and system design in Section 2.2.7.2.2, and the available ceiling-level sprinkler designs in Section 2.2.7.2.3.

2.2.7.2.1 Horizontal Arrangement of In-Rack Sprinklers for the Protection of Open-Top, Combustible Containers in a Mini-Load ASRS

Use Table 39 to determine the recommended horizontal in-rack sprinkler arrangement for the storage rack to be protected.

Table 39. Recommended Horizontal In-Rack Sprinkler Arrangements for the Protection of Open-Top, Combustible Containers in a Mini-Load ASRS

Rack Row Depth, ft (m)	*Overall Maximum Rack Depth, ft (m)*	*Adequate Transverse Flue Spaces Provided per Section 2.2.1.4?*	*Open-Top Container Composition*	*Applicable Horizontal IRAS Arrangement Figures*
Up to 3 (0.9)	3 (0.9)	No	Cardboard or Unexpanded Plastic	34
		Yes	Cardboard	35
			Unexpanded Plastic	36
Up to 6 (1.8)	6 (1.8)	No	Cardboard or Unexpanded Plastic	37
		Yes	Cardboard	38
			Unexpanded Plastic	39
	14 (4.3)	No	Cardboard or Unexpanded Plastic	40
		Yes	Cardboard	41
			Unexpanded Plastic	42
Over 6 (1.8)	Over 6 (1.6)	No	Cardboard or Unexpanded Plastic	43 with Vertical Barriers
		Yes	Cardboard	44
			Unexpanded Plastic	45

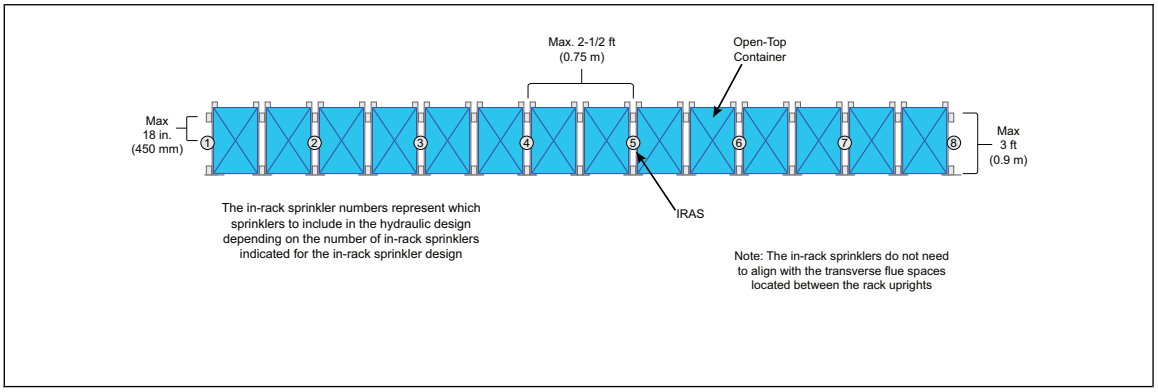

Fig. 34. Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Mini-Load ASRS Where Rack Row Depths Do Not Exceed 3 ft (0.9 m) and the Maximum Horizontal Spacing is 2-1/2 ft (0.75 m) per Table 39

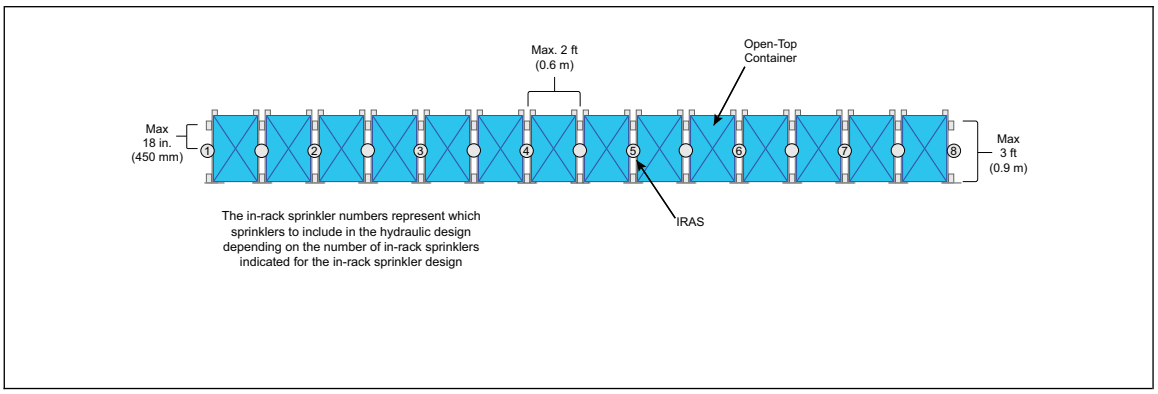

Fig. 35. Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Mini-Load ASRS Where Rack Row Depths Do Not Exceed 3 ft (0.9 m) and the Maximum Horizontal Spacing is 2 ft (0.60 m) per Table 39

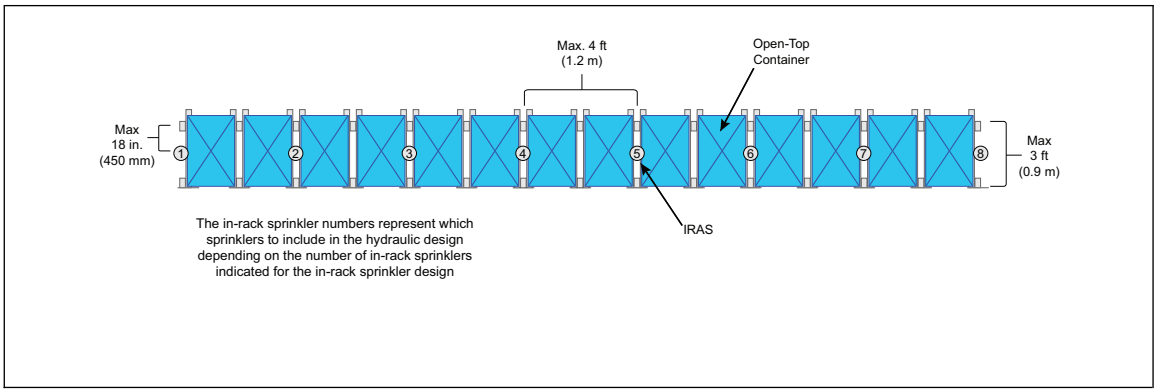

Fig. 36. Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Mini-Load ASRS Where Rack Row Depths Do Not Exceed 3 ft (0.9 m) and the Maximum Horizontal Spacing is 4 ft (1.2 m) per Table 39

2.2.7.2.2 Vertical Location of In-Rack Sprinklers and In-Rack Sprinkler System Designs for the Protection of Open-Top, Combustible Containers in a Mini-Load ASRS

2.2.7.2.2.1 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 Table 40 to determine the allowable in-rack sprinkler vertical locations as well as the corresponding recommended in-rack sprinkler design.
2. Limit the storage height above the top in-rack sprinkler level to a maximum height of 10 ft (3.0 m).

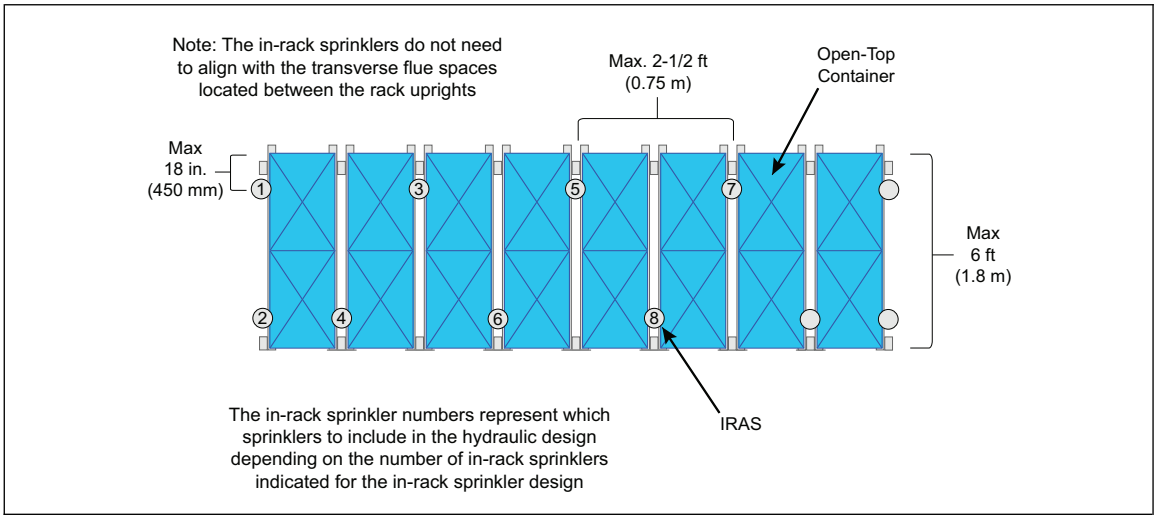

Fig. 37. Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Mini-Load ASRS Where Rack Row Depths Do Not Exceed 6 ft (1.8 m) and the Maximum Horizontal Spacing is 2-1/2 ft (0.75 m) per Table 39

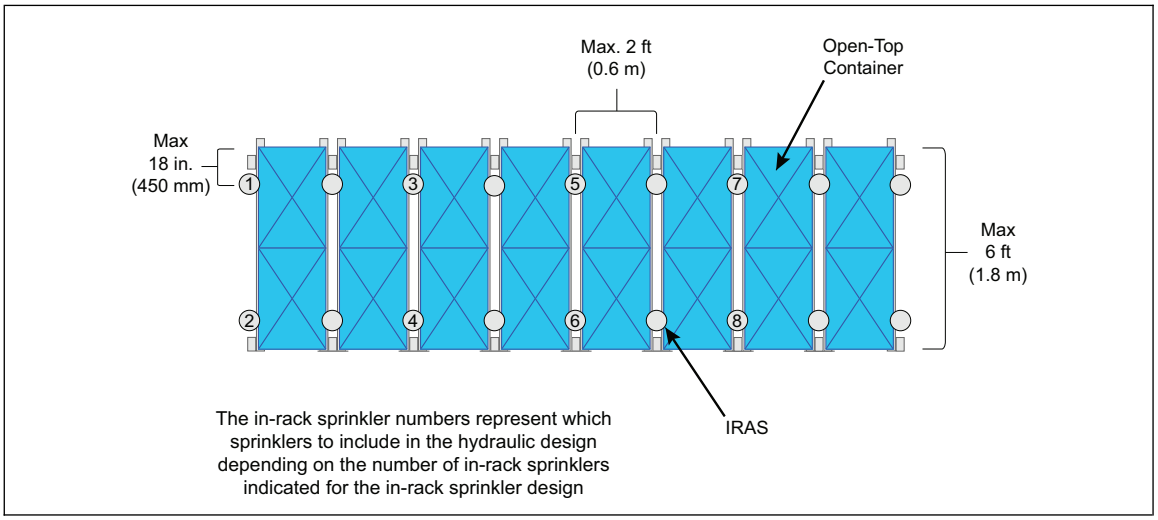

Fig. 38. Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Mini-Load ASRS Where Rack Row Depths Do Not Exceed 6 ft (1.8 m) and the Maximum Horizontal Spacing is 2 ft (0.60 m) per Table 39

3. While the in-rack sprinkler designs given in Table 40 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.

2.2.7.2.2.2 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 2.2.7.2.2.1. However, include all of 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 open-top, unexpanded plastic containers being stored within a mini-load ASRS which is to be protected with in-rack sprinklers per Figure 37, and the number of in-rack sprinklers between the vertical barriers is 9, then the design for the in-rack sprinkler system would be per Table 40 and would be based on 9 IRAS @ 100 gpm (380 L/min) instead of 6 IRAS @ 100 gpm (380 L/min).

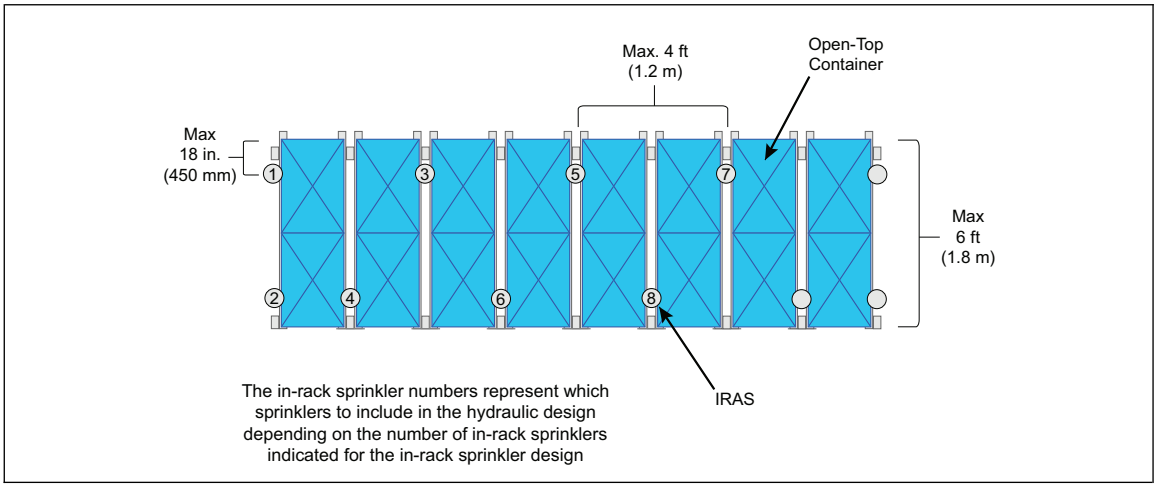

Fig. 39. Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Mini-Load ASRS Where Rack Row Depths Do Not Exceed 6 ft (1.8 m) and the Maximum Horizontal Spacing is 4 ft (1.2 m) per Table 39

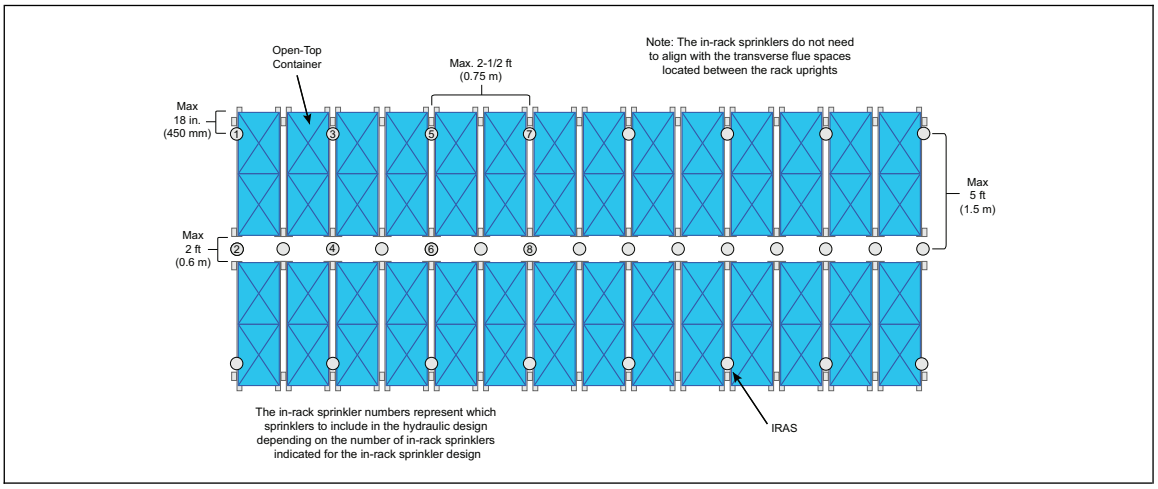

Fig. 40. Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Mini-Load ASRS Where the Overall Rack Depths Do Not Exceed 14 ft (4.3 m) and the Maximum Horizontal Spacing is 2-1/2 ft (0.75 m) per Table 39

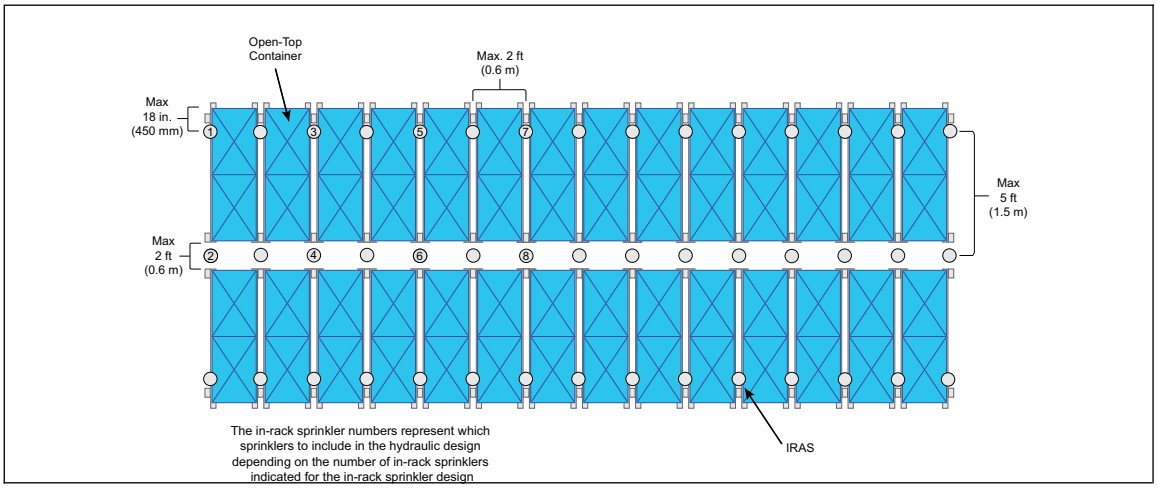

Fig. 41. Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Mini-Load ASRS Where the Overall Rack Depths Do Not Exceed 14 ft (4.3 m) and the Maximum Horizontal Spacing is 2 ft (0.60 m) per Table 39

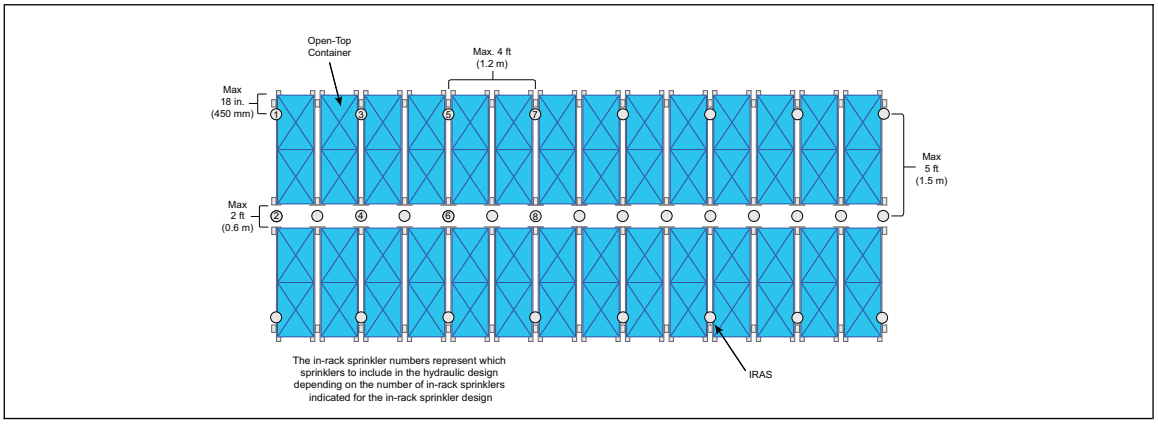

Fig. 42. Horizontal IRAS for Open-Top Combustible Containers within a Mini-Load ASRS Where the Overall Rack Depths Do Not Exceed 14 ft (4.3 m) and the Maximum Horizontal Spacing is 4 ft (1.2 m) per Table 39

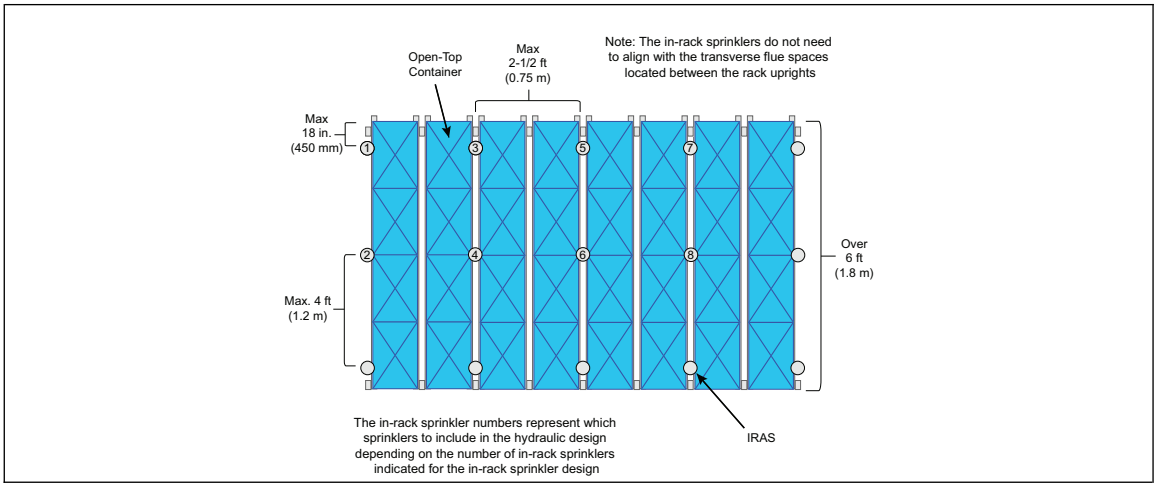

Fig. 43. Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Mini-Load ASRS Where Rack Row Depths Exceed 6 ft (1.8 m) and the Maximum Horizontal Spacing is 2-1/2 ft (0.75 m) per Table 39

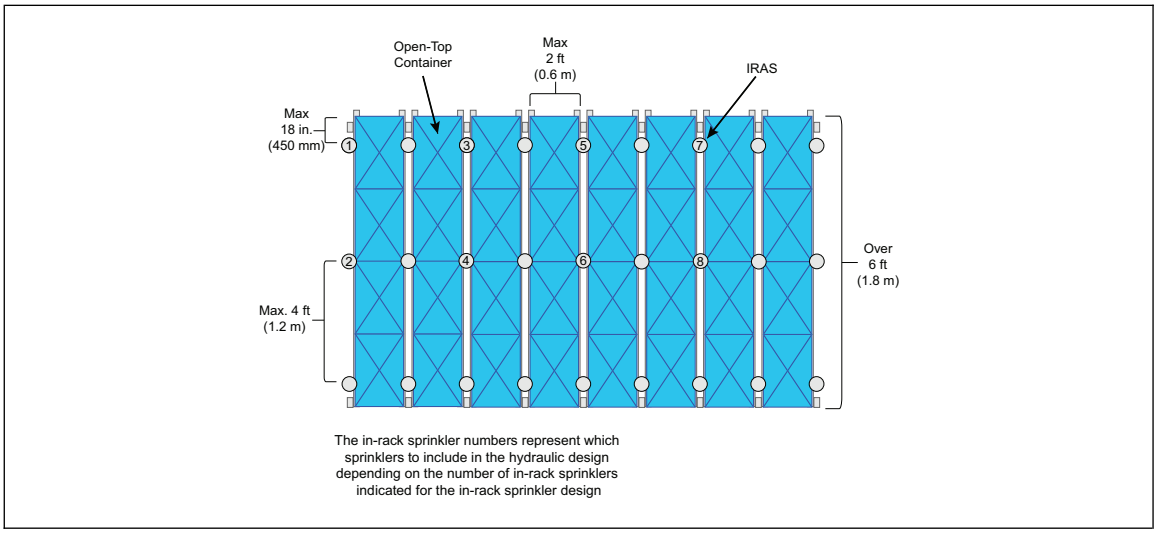

Fig. 44. Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Mini-Load ASRS Where Rack Row Depths Exceed 6 ft (1.8 m) and the Maximum Horizontal Spacing is 2 ft (0.60 m) per Table 39

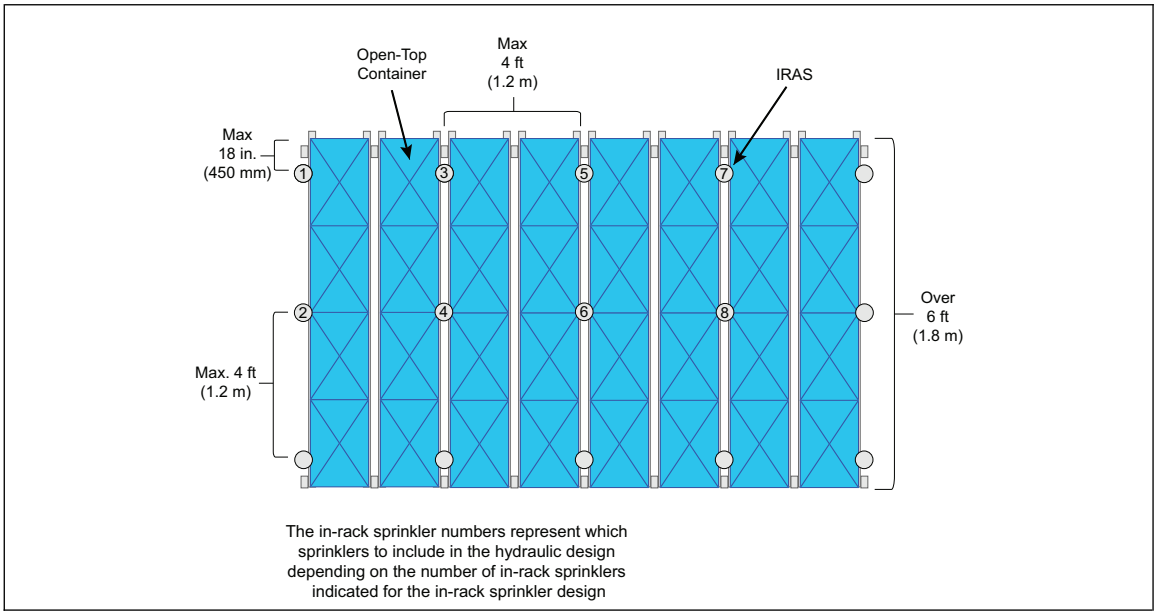

Fig. 45. Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Mini-Load ASRS Where Rack Row Depths Exceed 6 ft (1.8 m) and the Maximum Horizontal Spacing is 4 ft (1.2 m) per Table 39

Table 40. Vertical In-Rack Sprinkler Locations and In-Rack Sprinkler Designs for the Protection of Open-Top, Combustible Containers Stored in a Mini-Load Type System

Recommended IRAS Arrangement per Table 39	*Open-Top Container Composition*	*Maximum Commodity Classification*	*IRAS System Type*	*Maximum Vertical Distance Between IRAS, ft (m)*	*Minimum IRAS Design Flow, gpm (L/min)**	*Minimum IRAS K-factor*	*No. of IRAS in Design*	*Hydraulically Balance IRAS System with Ceiling System?*
Figure 34	Cardboard or Unexpanded Plastic	Any	Wet	10 (3.0)	100 (380)	11.2 (160)	4 on top IRAS level	No
			Dry	10 (3.0)	100 (380)	11.2 (160) Upright	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
Figure 35	Cardboard	Any	Wet	10 (3.0)	100 (380)	11.2 (160)	4 on top IRAS level	No
				15 (4.6)	140 (530)	22.4 (320) Pendent	6 on top IRAS level	No
			Dry	10 (3.0)	100 (380)	11.2 (160) Upright	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
Figure 36	Unexpanded Plastic	Any	Wet	10 (3.0)	100 (380)	11.2 (160)	4 on top IRAS level	No
				15 (4.6)	140 (530)	22.4 (320) Pendent	6 on top IRAS level	No
			Dry	10 (3.0)	100 (380)	11.2 (160) Upright	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
Figures 37 or 40	Cardboard or Unexpanded Plastic	Any	Wet	10 (3.0)	100 (380)	11.2 (160)	6 on top IRAS level	No
			Dry	10 (3.0)	100 (380)	11.2 (160) Upright	8 if one IRAS level or 14 (7 on top 2 levels)	Yes

* The indicated in-rack sprinkler design flow is based on a minimum 9 in. (225 mm) vertical distance between storage tier levels. If the vertical distance between vertical tier levels is less than 9 in. (225 mm), add 20 gpm (75 L/min) to the indicated design flow.

Table 40. Vertical In-Rack Sprinkler Locations and In-Rack Sprinkler Designs for the Protection of Open-Top, Combustible Containers Stored in a Mini-Load Type System (continued)

Recommended IRAS Arrangement per Table 39	*Open-Top Container Composition*	*Maximum Commodity Classification*	*IRAS System Type*	*Maximum Vertical Distance Between IRAS, ft (m)*	*Minimum IRAS Design Flow, gpm (L/min)**	*Minimum IRAS K-factor*	*No. of IRAS in Design*	*Hydraulically Balance IRAS System with Ceiling System?*
Figures 38, 41, or 44	Cardboard	Any	Wet	10 (3.0)	100 (380)	11.2 (160)	6 on top IRAS level	No
				15 (4.6)	140 (530)	22.4 (320) Pendent	6 on top IRAS level	No
			Dry	10 (3.0)	100 (380)	11.2 (160) Upright	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
Figures 39, 42, or 45	Unexpanded Plastic	Any	Wet	10 (3.0)	100 (380)	11.2 (160)	6 on top IRAS level	No
				15 (4.6)	140 (530)	22.4 (320) Pendent	6 on top IRAS level	No
			Dry	10 (3.0)	100 (380)	11.2 (160) Upright	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
Figure 43	Cardboard or Unexpanded Plastic	Any	Wet	10 (3.0)	100 (380)	11.2 (160)	8 on top IRAS level	No
			Dry	10 (3.0)	100 (380)	11.2 (160) Upright	8 if one IRAS level or 14 (7 on top 2 levels)	Yes

* The indicated in-rack sprinkler design flow is based on a minimum 9 in. (225 mm) vertical distance between storage tier levels. If the vertical distance between vertical tier levels is less than 9 in. (225 mm), add 20 gpm (75 L/min) to the indicated design flow.

2.2.7.2.3 Ceiling Sprinkler System Designs in Combination with In-Rack Sprinklers for the Protection of Open-Top, Combustible Containers in a Mini-Load ASRS

2.2.7.2.3.1 Use Table 41 to determine the wet ceiling-level sprinkler system designs in combination with in-rack sprinklers. If a protection option is not available from the applicable protection table, either:

1. Install a flat, continuous, noncombustible false ceiling, capable of withstanding an uplift pressure of 3 lb/ft² (14.4 kg/m²), over the ASRS storage area and for a minimum of 15 ft (4.6 m) beyond the ASRS area in all directions with sprinklers installed underneath the false ceiling in accordance with Table 41, or
2. Install in-rack sprinklers over the top of storage and design the ceiling sprinkler system per Table 41.

2.2.7.2.3.2 Use Table 42 to determine the dry ceiling-level sprinkler system designs in combination with in-rack sprinklers. If a protection option is not available from the applicable protection table, either:

1. Install a flat, continuous, noncombustible false ceiling, capable of withstanding an uplift pressure of 3 lb/ft² (14.4 kg/m²), over the ASRS storage area and for a minimum of 15 ft (4.6 m) beyond the ASRS area in all directions with sprinklers installed underneath the false ceiling in accordance with Table 42, or
2. Install in-rack sprinklers over the top of storage and design the ceiling sprinkler system per Table 42.

2.2.7.2.3.3 The ceiling-level sprinkler system designs in Tables 41 and 42 are determined using the vertical distance between the top in-rack sprinkler level and the maximum ceiling height above the ASRS protected area.

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

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

Table 41. Wet System Ceiling-Level Sprinkler Protection Guidelines, in Combination with In-Rack Sprinklers, for the Protection of Open-Top Combustible Containers in a Mini-Load ASRS; No. of AS @ psi (bar)

Max. Storage Height Above Top IRAS Level, ft (m)	*Max. Vertical Distance Between Top IRAS Level and Ceiling, ft (m)*	*Ceiling-Level Sprinkler Protection Options for Mini-Load ASRS Arrangements with Open-Top Combustible Containers; No. of AS @ psi (bar)*																		
		Wet System, Pendent Storage Sprinklers, 160°F (70°C)												Wet System, Upright Storage Sprinklers, 160°F (70°C)						
		Quick-Response								Standard-Response				Quick-Response				Standard-Response		
		11.2 (160)	14.0 (200)	16.8 (240)	22.4 (320)	25.2 (360)	25.2EC (360EC)	28.0 (400)	33.6 (480)	11.2 (160)	14.0 (200)	19.6 (280)	25.2 (360)	11.2 (160)	14.0 (200)	16.8 (240)	25.2EC (360EC)	11.2 (160)	16.8 (240)	25.2 (360)
0 (0)	Any	20 @ 7 (0.5)	9 @ 20 (1.4)	9 @ 20 (1.4)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 20 (1.4)	9 @ 40 (2.8)	9 @ 55 (3.8)	20 @ 7 (0.5)	9 @ 20 (1.4)	9 @ 16 (1.1)	9 @ 7 (0.5)	20 @ 7 (0.5)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 20 (1.4)	20 @ 7 (0.5)	9 @ 20 (1.4)	9 @ 7 (0.5)
5 (1.5)	10 (3.0)	20 @ 30 (2.1)	12 @ 25 (1.7)	12 @ 18 (1.2)	9 @ 20 (1.4)	9 @ 20 (1.4)	10 @ 22 (1.5)	9 @ 40 (2.8)	9 @ 55 (3.8)	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 (1.0)	20 @ 30 (2.1)	20 @ 13 (0.9)	20 @ 7 (0.5)
	15 (4.6)	25 @ 50 (3.5)	10 @ 35 (2.4)	10 @ 25 (1.7)	9 @ 20 (1.4)	9 @ 20 (1.4)	12 @ 38 (2.6)	9 @ 40 (2.8)	9 @ 55 (3.8)	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 (6.1)		12 @ 50 (3.5)	12 @ 35 (2.4)	12 @ 20 (1.4)	12 @ 20 (1.4)		9 @ 40 (2.8)	9 @ 55 (3.8)											
10 (3.0)	15 (4.6)	25 @ 50 (3.5)	10 @ 35 (2.4)	10 @ 25 (1.7)	9 @ 20 (1.4)	9 @ 20 (1.4)	12 @ 38 (2.6)	9 @ 40 (2.8)	9 @ 55 (3.8)	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 (6.1)		12 @ 50 (3.5)	12 @ 35 (2.4)	12 @ 20 (1.4)	12 @ 20 (1.4)		9 @ 40 (2.8)	9 @ 55 (3.8)											

Note: 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 42. Dry System Ceiling-Level Sprinkler Protection Guidelines, in Combination with In-Rack Sprinklers, for the Protection of Open-Top Combustible Containers in a Mini-Load ASRS; No. of AS @ psi (bar)

Max. Storage Height Above Top IRAS Level, ft (m)	*Max. Vertical Distance Between Top IRAS Level and Ceiling, ft (m)*	*Ceiling-Level Sprinkler Protection Options for Mini-Load ASRS Arrangements with Open-Top Combustible Containers; No. of AS @ psi (bar)*			
		Dry System, Upright Storage Sprinklers, 280°F (140°C)			
		Standard-Response			
		11.2 (160)	16.8 (240)	25.2 (360)	33.6 (480)
0 (0)	Any	25 @ 7 (0.5)	25 @ 7 (0.5)	25 @ 7 (0.5)	25 @ 50 (3.5)
5 (1.5)	10 (3.0)	25 @ 30 (2.1)	25 @ 13 (0.9)	25 @ 7 (0.5)	25 @ 50 (3.5)
	15 (4.6)	30 @ 50 (3.5)	30 @ 22 (1.5)	30 @ 10 (0.7)	30 @ 50 (3.5)
10 (3.0)	15 (4.6)	30 @ 50 (3.5)	30 @ 22 (1.5)	30 @ 10 (0.7)	30 @ 50 (3.5)

2.3 Top-Loading Automatic Storage and Retrieval Systems (TL-ASRS)

2.3.1 General Guidelines for TL-ASRS Storage Arrangements

2.3.1.1 This section provides protection guidelines for TL-ASRS storage arrangements that use open-top, solid-bottomed containers. It is further subdivided into sections specific to noncombustible open-top, solid-bottom, solid-walled containers in Section 2.3.5, combustible open-top, solid-bottom, solid-walled containers in Section 2.3.6, and open-top, solid-bottom, non-solid-walled containers in Section 2.3.7.

2.3.1.2 What differentiates this storage arrangement from other ASRS storage arrangements is that the containers are loaded and unloaded vertically from the storage array using automated robots that move about the storage area on an elevated gridded track network. Since material handling is done in a vertical manner, traditional material-handling equipment, such as fork-lifts, are not required, eliminating the need for aisles between storage arrays.

2.3.2 Drainage

2.3.2.1 Due to the expected water application duration during a fire event, when possible provide minimum 4 in. (100 mm) high curbing at the perimeter of the storage array in combination with properly designed floor drainage (account for both ceiling sprinkler discharge and an additional 500 gpm [1900 L/min] for manual firefighting efforts).

2.3.2.2 The guidelines for drainage in Section 2.3.2.1 are not required when noncombustible solid-walled containers are used throughout the ASRS storage array.

2.3.3 Robots and Robot Holding Areas

2.3.3.1 Robots

Arrange the robots so they are void of as much exterior combustible materials as possible. Use noncombustible materials whenever decorative covers, sidings or other similar identification methods are needed for the robots.

2.3.3.2 Robot Holding Areas

2.3.3.2.1 Establish designated “Robot Holding Areas” anywhere on the storage grid to which all robots can move upon the activation of the fire detection system outlined in Section 2.3.4. See Figure 46 for an example of this arrangement.

2.3.3.2.2 Do not designate areas directly above storage grid area access points as Robot Holding Areas.

2.3.3.2.3 Maintain the storage columns directly below the Robot Holding Areas free of combustible storage.

2.3.3.2.4 The guidelines for Robot Holding Areas are not required when noncombustible solid-walled containers are used throughout the ASRS storage array.

2.3.4 Fire Detection

2.3.4.1 Install a FM Approved ceiling-level very early warning fire detection system over the storage array accordance with Data Sheet 5-48, *Automatic Fire Detection*.

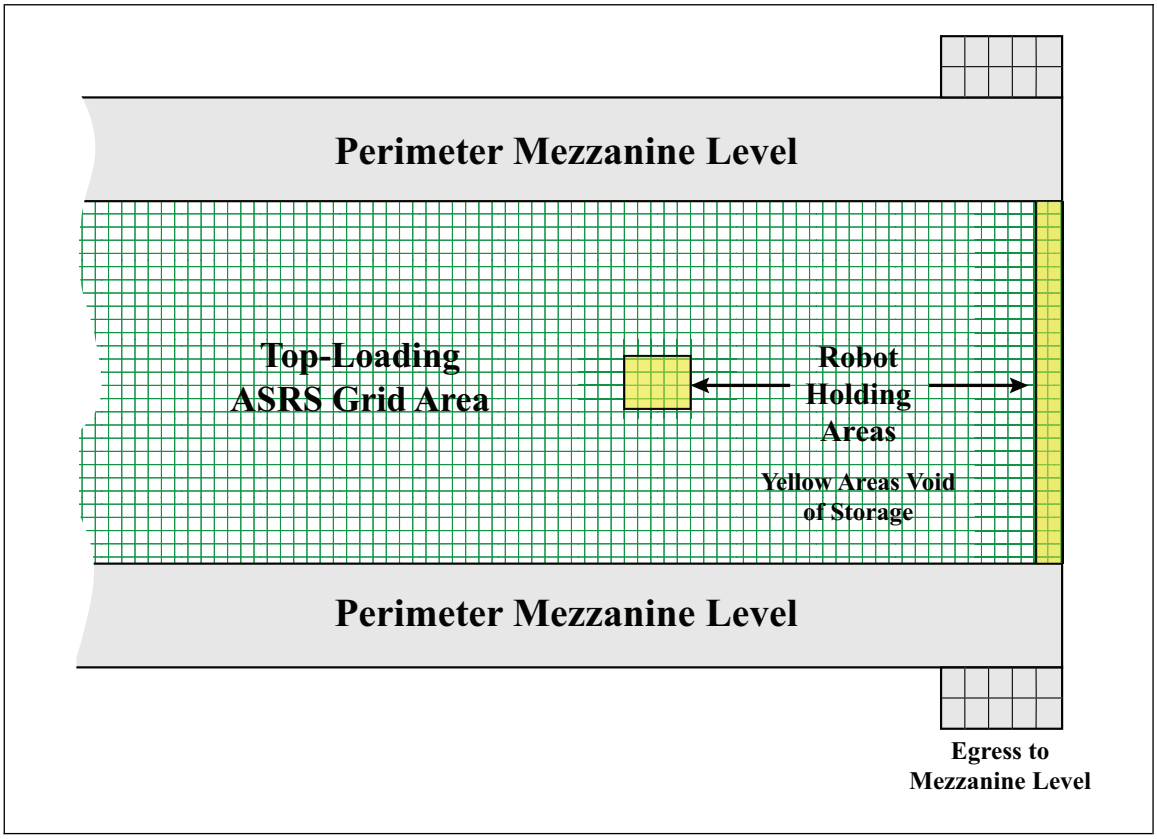

Fig. 46. Examples of Potential Robot Holding Areas

2.3.4.2 When the ceiling construction over the storage array is considered unobstructed per Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*, install the detectors on a spacing that does not exceed 50% of the maximum allowable spacing indicated in the *Approval Guide* using an obscuration rate that is in accordance with the detection system manufacturer's guidelines.

2.3.4.3 When the ceiling construction over the storage array is considered obstructed per Data Sheet 2-0, install the detectors using the same spacing as the ceiling-level sprinklers using selecting an obscuration rate that is in accordance with the detection system manufacturer's guidelines.

2.3.4.4 Arrange the fire detection system upon activation to:

1. Send an alarm to a constantly attended location, and
2. Automatically send the robots to the Robot Holding Area, and
3. Deactivate the robot charging stations

2.3.4.5 The guidelines for fire detection as outlined in Sections 2.3.4.1 through 2.3.4.4 are not required when noncombustible solid-walled containers are used throughout the ASRS storage array.

2.3.5 Protection of Noncombustible Solid-Walled Containers

2.3.5.1 Ceiling-Level Sprinkler System Types

2.3.5.1.1 Depending on the ambient temperature of the ASRS area being protected, ceiling-level sprinkler systems can be one of the following:

A. Wet-pipe sprinkler systems

B. Dry-pipe sprinkler systems

C. Non-interlocked or single-interlocked preaction sprinkler systems

D. Refrigerated area sprinkler systems

E. Antifreeze solution sprinkler systems consisting of a 20% to 30% propylene glycol concentration in water

2.3.5.1.2 The maximum water delivery time for all dry-pipe and similar sprinkler systems is 40 seconds upon the operation of the hydraulically most remote 4 sprinklers (2 sprinklers on 2 lines).

2.3.5.1.3 When installing a preaction or refrigerated area sprinkler system, see Data Sheet 5-48, *Automatic Fire Detection*, for recommendations pertaining to the sprinkler system's activating detection system.

2.3.5.1.4 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 5-48 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 in Table 43 when the detection installation is not in compliance with the recommendations provided in Data Sheet 5-48 for a wet-pipe sprinkler system design.

2.3.5.1.5 A ceiling-level sprinkler system consisting of 20% to 30% concentration of propylene glycol in water is acceptable for ambient temperatures between 32ºF (0ºC) and 40ºF (4ºC).

2.3.5.1.6 When installing an antifreeze sprinkler system consisting of a 20% to 30% concentration of propylene glycol in water, the ceiling designs indicated for a wet-pipe sprinkler system can be used.

2.3.5.1.7 See Data Sheet 2-0 for additional recommendations related to the installation of all sprinkler system types and when a refrigerated area sprinkler system is installed.

2.3.5.2 Ceiling-Level Sprinklers

2.3.5.2.1 For ceiling heights up to 55 ft (16.8 m), install FM Approved Storage ceiling-level sprinklers in accordance with the design guidelines offered in Table 43.

2.3.5.2.2 For ceiling heights over 55 ft (16.8 m), install a flat, continuous noncombustible false ceiling over the ASRS storage area and for a minimum of 15 ft (4.6 m) beyond it in all directions. Design the false ceiling to be capable of withstanding a minimum uplift pressure of 3 lb/ft^2 (14.4 kg/m^2). Provide sprinkler protection under this false ceiling in accordance with Table 43.

2.3.5.2.3 When elevated mezzanines are present, provide sprinkler protection under them in accordance with Data Sheet 2-0.

2.3.5.3 Ceiling-Level Sprinkler System Design Criteria

2.3.5.3.1 Use Table 43 to determine the ceiling-level sprinkler system designs for TL-ASRS storage arrangements using solid-walled noncombustible containers.

Table 43. Ceiling-Level Protection Guidelines for TL-ASRS Storage Arrangements Using Open-Top Solid-Walled Noncombustible Containers

Max. Ceiling Height, ft (m)	*Ceiling-Level Sprinkler Protection Options for Top-Loading ASRS Arrangements; No. of AS @ psi (bar)*																						
	Wet System, Pendent Storage Sprinklers, 160°F (70°C)												Wet System, Upright Storage Sprinklers, 160°F (70°C)							Dry System, Upright Storage Sprinklers, 280°F (140°C)			
	Quick-Response								Standard-Response				Quick-Response				Standard-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)	K11.2 (K160)	K16.8 (K240)	K25.2 (K360)	K33.6 (K480)
20 (6.1)	12 @ 10 (0.7)	12 @ 7 (0.5)	12 @ 7 (0.5)	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 @ 7 (0.5)	12 @ 10 (0.7)	12 @ 7 (0.5)	12 @ 7 (0.5)	6 @ 20 (1.4)	12 @ 10 (0.7)	12 @ 7 (0.5)	9 @ 7 (0.5)	16 @ 10 (0.7)	16 @ 7 (0.5)	16 @ 7 (0.5)	12 @ 50 (3.5)
25 (7.6)	10 @ 30 (2.1)	10 @ 20 (1.4)	10 @ 13 (0.9)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 20 (1.4)	9 @ 40 (2.8)	9 @ 55 (3.8)	10 @ 30 (2.1)	10 @ 20 (1.4)	9 @ 16 (1.1)	10 @ 7 (0.5)	10 @ 30 (2.1)	10 @ 20 (1.4)	10 @ 13 (0.9)	6 @ 20 (1.4)	10 @ 30 (2.1)	10 @ 13 (0.9)	10 @ 7 (0.5)	20 @ 16 (1.1)	20 @ 7 (0.5)	20 @ 7 (0.5)	12 @ 50 (3.5)
30 (9.1)	18 @ 50 (3.5)	12 @ 50 (3.5)	12 @ 35 (2.4)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 25 (1.7)	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 @ 25 (1.7)	18 @ 50 (3.5)	18 @ 22 (1.5)	12 @ 20 (1.4)	20 @ 25 (1.7)	20 @ 10 (0.7)	20 @ 7 (0.5)	12 @ 50 (3.5)
35 (10.7)		9 @ 75 (5.2)	9 @ 52 (3.6)	9 @ 28 (1.9)	9 @ 22 (1.5)	6 @ 60 (4.1)	9 @ 40 (2.8)	9 @ 55 (3.8)			15 @ 25 (1.7)	9 @ 30 (2.1)		9 @ 75 (5.2)	9 @ 52 (3.6)	8 @ 40 (2.8)				20 @ 25 (1.7)	20 @ 10 (0.7)	20 @ 7 (0.5)	12 @ 50 (3.5)
40 (12.2)		9 @ 75 (5.2)	9 @ 52 (3.6)	9 @ 28 (1.9)	9 @ 22 (1.5)		9 @ 40 (2.8)	9 @ 55 (3.8)				9 @ 30 (2.1)								36 @ 55 (3.8)	36 @ 22 ((1.5)	12 @ 50 (3.5)	12 @ 50 (3.5)
45 (13.7)				10 @ 63 (4.3)	10 @ 50 (3.5)		10 @ 40 (2.8)	9 @ 55 (3.8)														12 @ 50 (3.5)	12 @ 50 (3.5)
50 (15.2)				10 @ 63 (4.3)	10 @ 50 (3.5)		10 @ 40 (2.8)	9 @ 55 (3.8)															15 @ 50 (3.5)
55 (16.8)							9 @ 80 (5.5)	9 @ 55 (3.8)															16 @ 50 (3.5)

2.3.5.3.2 Hose Demand Design Guidelines

Include a minimum flow of 250 gpm (950 L/min) for the hose demand design.

2.3.5.3.3 Water Supply Duration

Size the water supply feeding the ceiling sprinkler system and the hose stream demand, when taken from the same water supply, for a minimum of 60 minutes.

2.3.6 Protection of Combustible Solid-Walled Containers

2.3.6.1 Final Extinguishment

2.3.6.1.1 General

2.3.6.1.1.1 Due to the lack of direct access by the local fire service to the fire area, review the recommendations in this section that are intended to establish a means by which final extinguishment can be achieved.

2.3.6.1.1.2 At a minimum, implement the recommendations in Sections 2.3.6.1.2, 2.3.6.1.3, and 2.3.6.1.4, unless indicated otherwise in Section 2.3.6.1.5.

2.3.6.1.1.3 See Section 2.3.6.1.5 for ceiling-level protection options that will allow for the elimination of some recommendations offered for final extinguishment.

2.3.6.1.1.4 When the guidelines of Section 2.3.6.1.5 are not met, see Sections 2.3.6.1.6 through 2.3.6.1.9 for recommendations to review and discuss with the local fire service to potentially assist with achieving final extinguishment. Implement those recommendations deemed necessary by either the authority having jurisdiction or the appropriate representatives from the local fire service.

2.3.6.1.2 Pre-Incident Plan

2.3.6.1.2.1 For TL-ASRS storage arrangements that use solid-walled containers, establish a pre-incident plan with the local fire service that takes into consideration how the local fire service will gain access to any point of the ASRS storage grid for final extinguishment purposes. Items to consider, at a minimum, are:

A. Access to the storage grid itself (i.e., removal of any separating walls or fences),

B. A plan to remove storage containers along with a place to put them, and

C. A means of preventing robots from falling from the grid into the storage area.

2.3.6.1.2.2 See Section 2.1.5 for additional guidance on pre-incident planning.

2.3.6.1.3 Storage Arrangement

To allow local fire service access to the fire area, arrange the TL-ASRS storage arrangement as follows:

1. Establish readily accessible, clearly marked designated locations along the side walls of the ASRS unit that can be used as access points to the storage area. Provide as many access points as possible to limit the horizontal distance between the access point and the potential fire area within the storage area.
2. Consider limiting the horizontal distance between one end of the storage array and the opposite end to a maximum of 100 ft (30 m).

2.3.6.1.4 Mezzanines and/or Platforms

2.3.6.1.4.1 To allow local fire service access adjacent to the top of the storage grid where strategic planning can occur and hose streams can potentially be applied, install mezzanines and/or platforms at a minimum, along the longer walls of the ASRS unit at a height equal to or above the storage grid. See Figure 47 for examples of mezzanines and/or platforms. Note that if the maximum width of the storage array is 50 ft (15 m), then only a single mezzanine and/or platform would be needed. Determine from the local authority having jurisdiction the minimum width of the mezzanine and/or platform they would require and the minimum number of access points for each mezzanine and/or platform area.

2.3.6.1.4.2 If the horizontal distances between the ends of the storage array will exceed 100 ft (30 m) in both directions, in addition to mezzanines and/or platforms install solid-floored elevated mezzanine levels

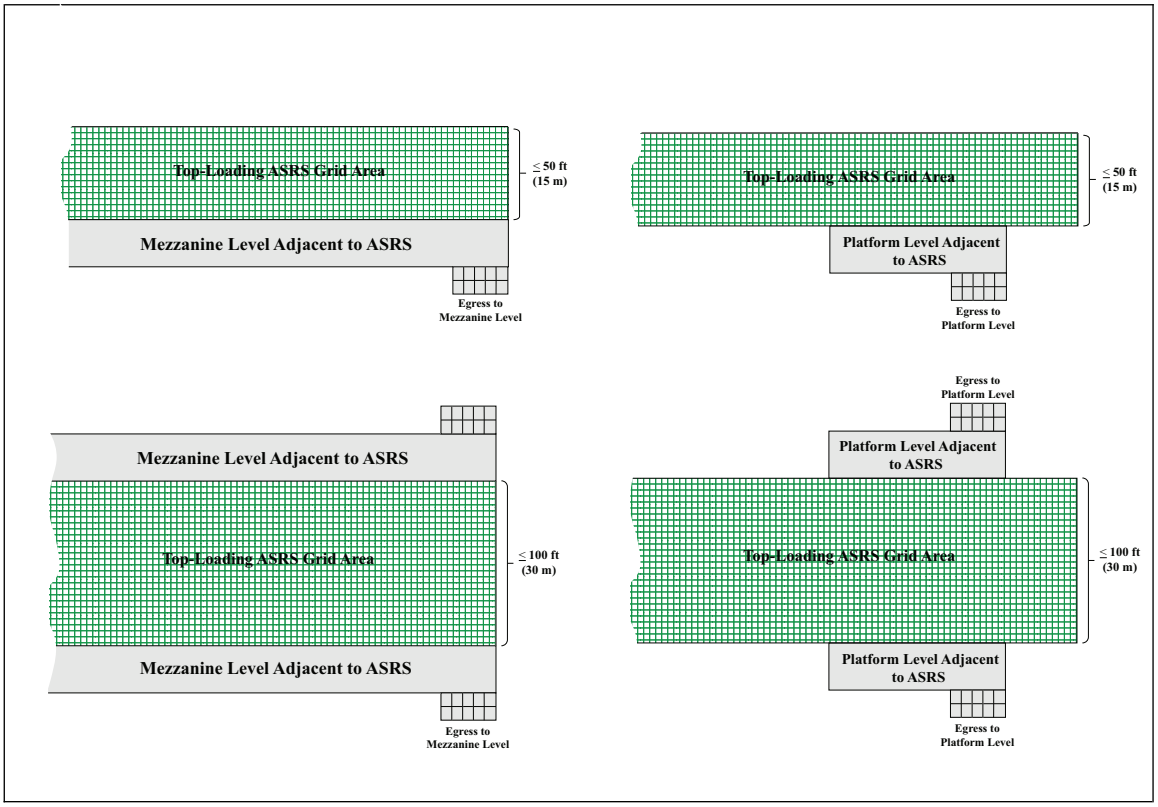

Fig. 47. Examples of a TL-ASRS arrangement showing maximum 100 ft (30 m) depth in one direction

at maximum horizontal distances of 100 ft (30 m) as demonstrated in Figure 48. Arrange the elevated mezzanines to allow robots the ability to pass underneath them.

2.3.6.1.4.3 The installation of elevated mezzanines can be avoided when:

1. The recommendations outlined in Section 2.3.6.1.5 for ceiling sprinkler designs are met, or
2. Fixed-in-place monitor nozzles and their associated monitoring cameras are installed over the storage grid area at ceiling level and in accordance with Sections 2.3.6.1.8 and 2.3.6.1.9.

2.3.6.1.4.4 The installation of mezzanines and/or platforms, as well as elevated mezzanines, can be avoided (if so chosen by the end user) by obtaining written confirmation from the local authority having jurisdiction and/or local fire service that they would not plan to use these mezzanines during a fire event.

2.3.6.1.5 Alternative Ceiling-Level Sprinkler Protection Options for Final Extinguishment

2.3.6.1.5.1 The recommendations offered in Section 2.3.6.1.4.2 regarding elevated mezzanines as well as Sections 2.3.6.1.7 through 2.3.6.1.9 (i.e., vertical barriers and fixed-in-place monitor nozzles) can be ignored when the ceiling sprinkler system is designed and installed in accordance with this section.

2.3.6.1.5.2 Install a wet ceiling sprinkler system. Dry, pre-action, and anti-freeze solution sprinkler systems are not acceptable.

2.3.6.1.5.3 Install FM Approved storage ceiling-level sprinklers in accordance with the design guidelines offered in Table 44.

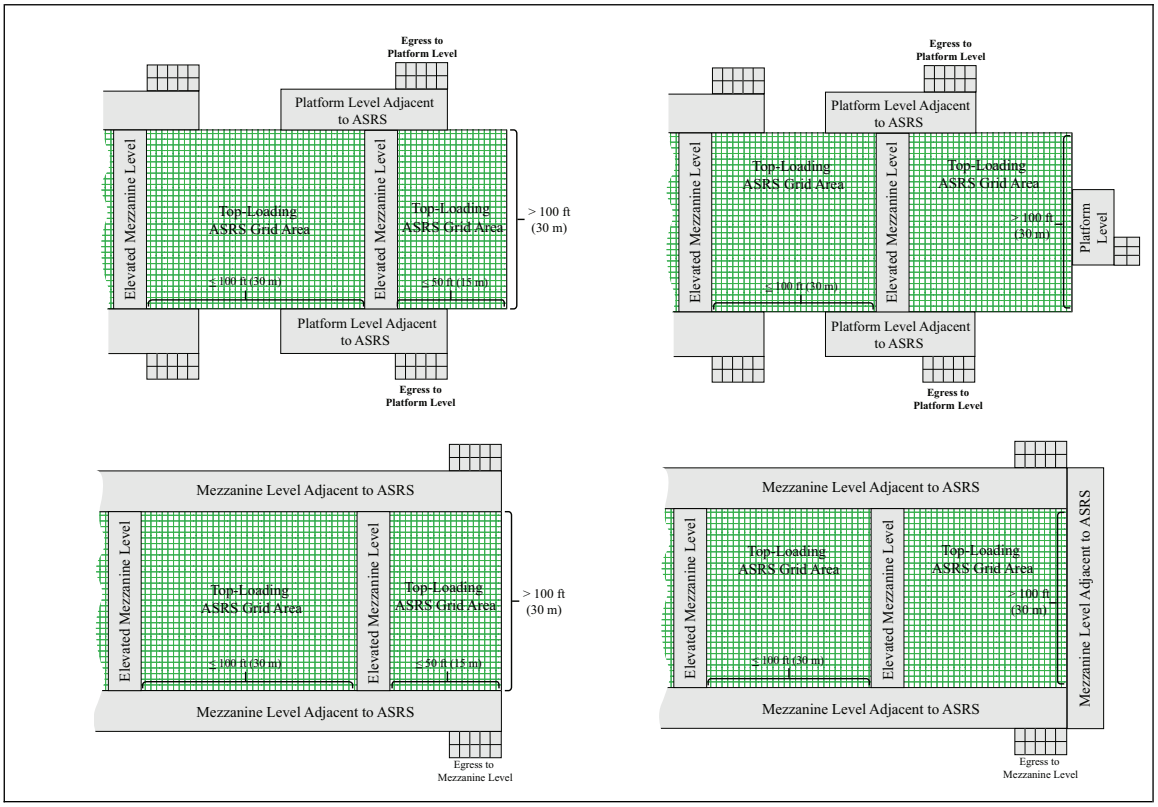

Fig. 48. Example of solid-floored elevated mezzanine levels when span of TL-ASRS exceeds 100 ft (30 m) in each direction

Table 44. Alternative Ceiling-Level Sprinkler Protection Options for Top-Loading ASRS Arrangements that Address Final Extinguishment; Maximum Storage Height up to and Including 20 ft (6.1 m)

Max. Ceiling Height, ft (m)	*Maximum Vertical Distance of Sprinkler Thermal Element Below Ceiling, in. (mm)*	*Alternative Ceiling-Level Sprinkler Protection Options for Top-Loading ASRS Arrangements that Address Final Extinguishment; No. of AS @ psi (bar)*					
		Wet Sprinkler System Using Quick-Response 160°F (70°C) Pendent Storage Sprinklers					
		K14.0 (K200)	K16.8 (K240)	K22.4 (K320)	K25.2 (K360)	K28.0 (K400)	K33.6 (K480)
25 (7.6)	13 (325)	9 @ 50 (3.5)	9 @ 35 (2.4)	9 @ 20 (1.4)	9 @ 20 (1.4)	9 @ 40 (2.8)	9 @ 55 (3.8)
30 (9.1)	13 (325)				6 @ 120 (8.3)	6 @ 95 (6.6)	6 @ 65 (4.5)

2.3.6.1.5.4 Include a minimum flow of 250 gpm (950 L/min) for hose demand design.

2.3.6.1.5.5 Size the water supply feeding the ceiling sprinkler system for a minimum duration of two hours. Include the hose stream demand (inside and outside) for water sizing purposes when it is taken from the same water supply feeding the ceiling sprinkler system.

2.3.6.1.5.6 For ceiling sprinkler designs from Table 44 that consist of six sprinklers, base the hydraulic calculation on the operation of two sprinklers flowing on three lines. For ceiling sprinkler designs from Table 44 that consist of nine sprinklers, base the hydraulic calculation on the operation of three sprinklers flowing on three lines.

2.3.6.1.5.7 As part of the Pre-Incident Plan, arrange for the local fire service and facility personnel to allow the sprinkler system to operate continuously for a minimum duration of two hours, or until the fire is confirmed to be extinguished by accessing the fire area within the storage array.

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

2.3.6.1.6 Small Hose Connection Stations

2.3.6.1.6.1 To aid in manual fire-fighting efforts and after-extinguishment mop-up operations, consider the installation of small hose connection stations near the floor-level access points established for the local fire service and on the mezzanine levels (perimeter and elevated), if provided. Consult with the local fire service or authority having jurisdiction to determine their recommendations regarding:

A. The use of wet- or dry-barrel stations, and

B. The size of the hose connections, and

C. The horizontal distance between stations

2.3.6.1.6.2 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).

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

A. A piping system dedicated solely for the small hose connection stations, or

B. Piping that connects the stations to a sprinkler system that is different than the one protecting the ASRS storage area

2.3.6.1.6.4 The installation of small hose connection stations can be avoided (if so chosen by the end user) by obtaining written confirmation from the local authority having jurisdiction and/or local fire service that they would not plan to use the small hose connection stations during a fire event.

2.3.6.1.7 Vertical Barriers

2.3.6.1.7.1 To assist with firefighting efforts, consider the installation of vertical barriers throughout the ASRS storage area. When vertical barriers are to be provided throughout the storage area, install them as follows:

A. Use minimum 20-gauge (0.9 mm) sheet metal for the vertical barriers

B. Install the barriers from floor level to the top of the storage array

C. Attach the vertical barriers to each of the storage columns with a minimum of 3 tech screws per column (near the top, middle, and bottom)

D. Provide a minimum 3 in. (75 mm) overlap, sealed with fire-rated silicone, of the barriers with the floor and all sheet metal joints

E. Where the vertical barriers are required at corners, bend the sheet metal around the corner to avoid any seams at these locations

2.3.6.1.7.2 Arrange the vertical barriers to limit the subdivided storage area to a maximum size of 1,000 ft^2 (93 m^2).

2.3.6.1.7.3 Maintain one row of storage on one side and adjacent to each of the vertical barriers free of combustibles as shown in Figure 49.

2.3.6.1.7.4 To aid with access to the fire area, limit the number of vertical barriers for each subdivided area to 3 or less as demonstrated in Figure 49.

2.3.6.1.7.5 Vertical barriers would be considered redundant with protection installed in accordance with Section 2.3.6.1.5, Sections 2.3.6.1.8 and 2.3.6.1.9. As a result, if the protection outlined in Section 2.3.6.1.5 regarding ceiling sprinkler protection, or Sections 2.3.6.1.8 and 2.3.6.1.9 regarding fixed-in-place monitor nozzles, are implemented, the installation of vertical barriers would not be needed.

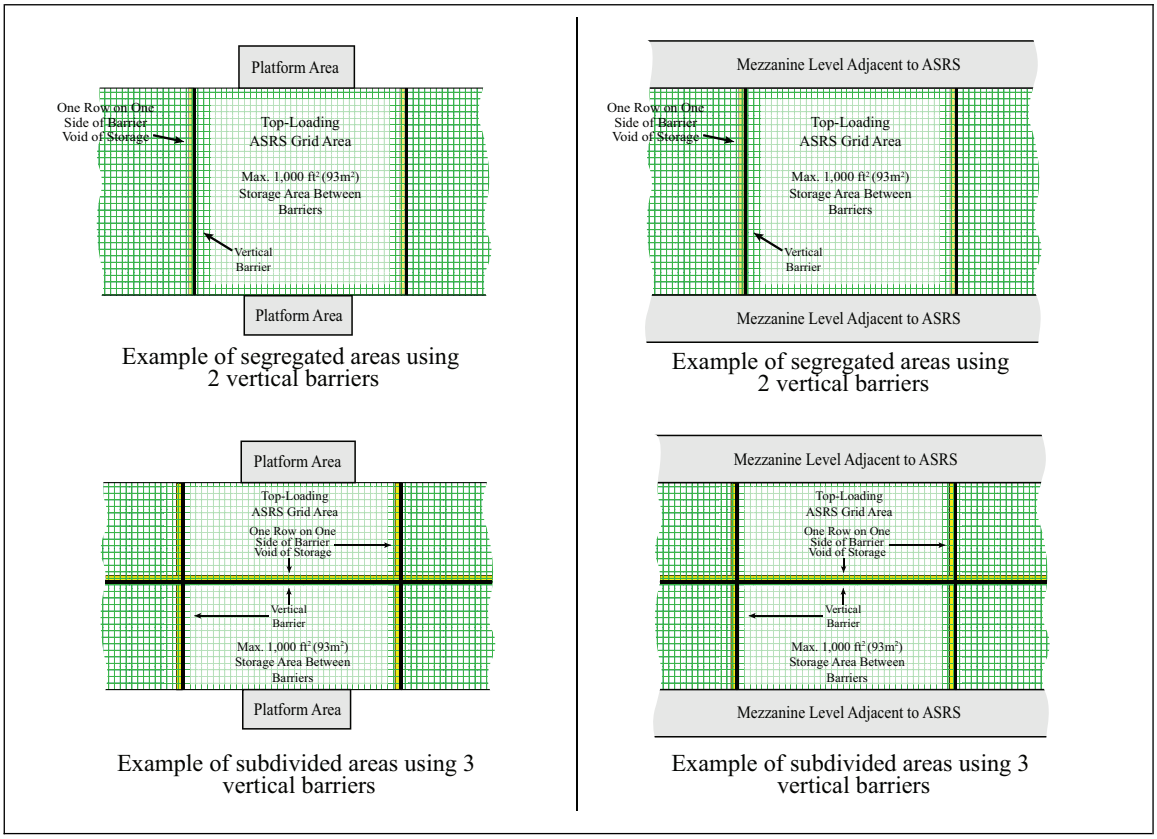

Fig. 49. Examples showing the use of vertical barriers within a TL-ASRS arrangement

2.3.6.1.8 Fixed-In-Place Monitor Nozzle Protection

2.3.6.1.8.1 To assist with firefighting efforts, consider the installation of fixed-in-place monitor nozzles throughout the ASRS storage area.

2.3.6.1.8.2 The monitor nozzles can be fixed-in-place either to the mezzanines and/or to the overhead ceiling structure.

A. When the monitor nozzles are fixed-in-place on the mezzanine structure, position the monitor nozzles a minimum 7 ft (2.1 m) above the top of the ASRS grid as well at a minimum of 2 ft (0.6 m) below the underside of the ceiling.

B. When the monitor nozzles are fixed-in-place to the overhead ceiling structure, position the monitor nozzles so they do not obstruct ceiling sprinkler discharge.

2.3.6.1.8.3 Space the monitor nozzles horizontally as follows:

A. A maximum of 100 ft (30 m) between monitor nozzles, and

B. A maximum of 50 ft (15 m) between a monitor nozzle and the nearest corner of the storage array

See Figures 50 and 51 for an example of this arrangement.

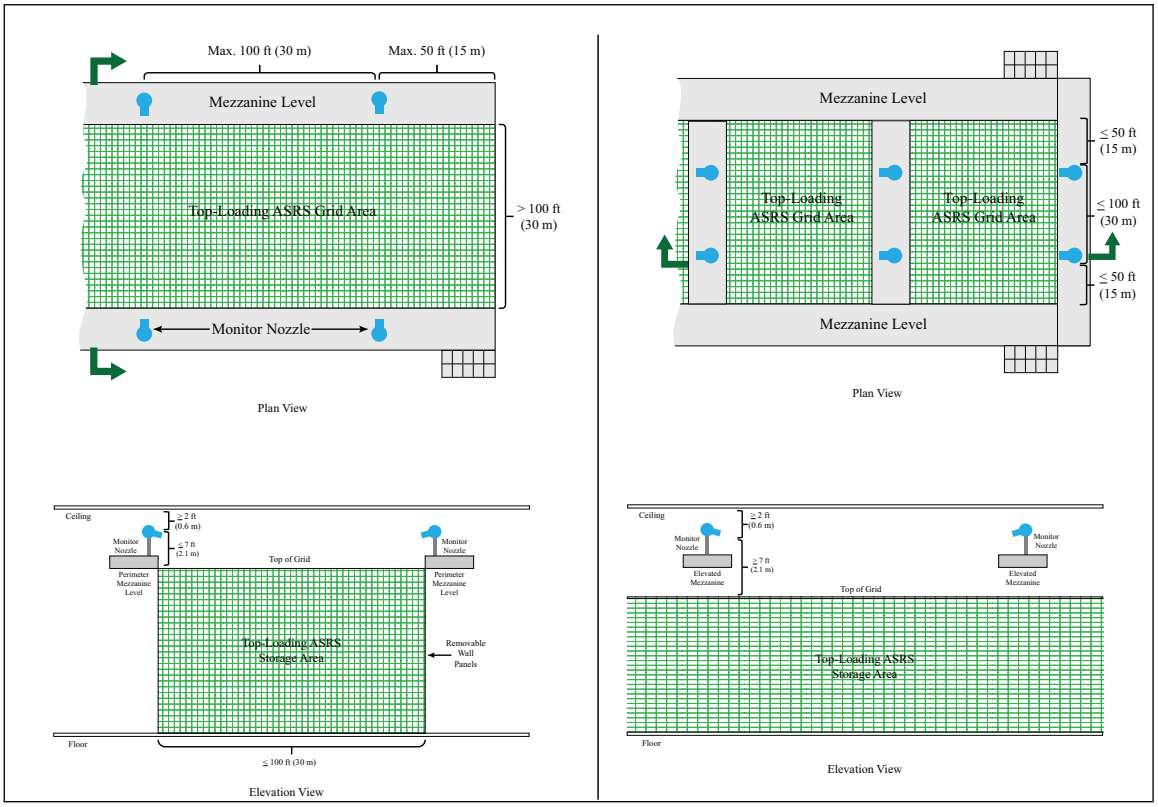

Fig. 50. Example of TL-ASRS arrangement protected by fixed-in-place monitor nozzles installed on the mezzanines

2.3.6.1.8.4 Arrange the monitor nozzles to be capable of:

A. Being operated remotely from a dedicated location that will not be affected by a fire involving the ASRS storage area, and

B. Being operated manually at the monitor nozzle when the monitor nozzles are installed on mezzanines

2.3.6.1.8.5 Design the monitor nozzle system to provide a minimum flow of 200 gpm (760 L/min) from each of the two most hydraulically remote monitor nozzles (400 gpm [1,520 L/min] total).

2.3.6.1.8.6 Water supplies for the monitor nozzles can be arranged in one of the following methods:

A. A piping system dedicated solely for the monitor nozzles, or
B. From sprinkler systems that are different than the one protecting the ASRS storage area

2.3.6.1.8.7 Fixed-in-place monitor nozzles would be considered redundant with ceiling sprinkler protection installed in accordance with Section 2.3.6.1.5. As a result, the installation of fixed-in-place monitor nozzles would not be needed (if so chosen by the end user) when:

A. The recommendations outlined in Section 2.3.6.1.5 are met, or

B. Written confirmation has been obtained from the local authority having jurisdiction and/or local fire service that they would not plan to use the monitor nozzles during a fire event.

2.3.6.1.9 Visible or Infrared Camera Installation for Fixed-In-Place Monitor Nozzle Operation

2.3.6.1.9.1 To allow for guided discharge of the monitor nozzles to the point of fire origin, install infrared (IR) cameras over the entire storage grid, in accordance with this section, using dedicated feeds to the remote location designated for monitor nozzle operation.

2.3.6.1.9.2 Arrange the IR cameras as follows:

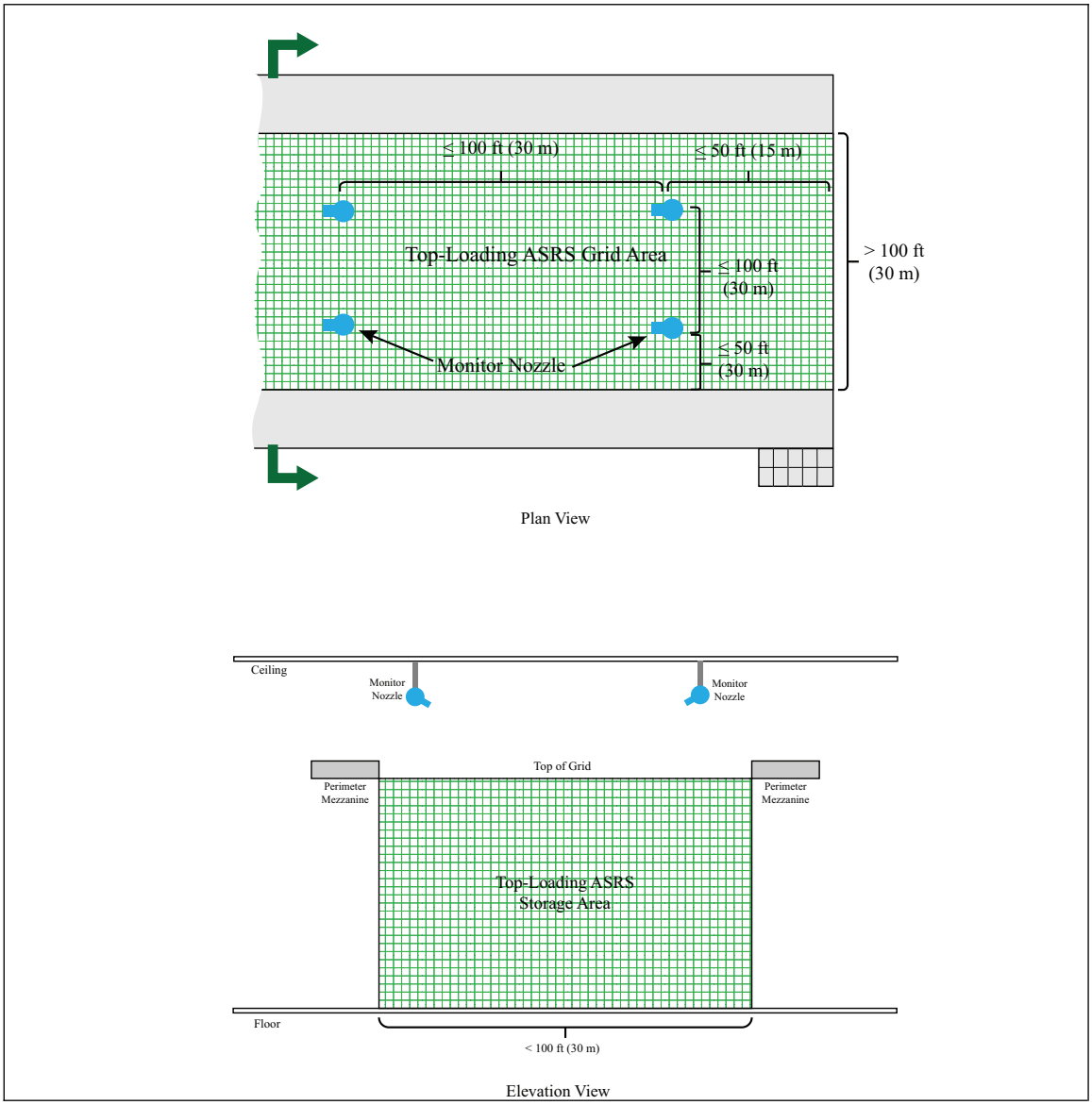

Fig. 51. Example of TL-ASRS arrangement protected by fixed-in-place monitor nozzles installed at ceiling level

A. Install longwave infrared (LWIR) cameras, capable of panning and tilting, that have a spectral range of 8-12 µm, a minimum spatial resolution of 15 pixels/ft (45 pixels/m), measured at the farthest position from the camera along the top surface of the storage array, and a field of view (FOV) that does not exceed 25°. Avoid the use of IR cameras that use charge-coupled device (CCD) sensors.

B. Locate the cameras vertically as high as possible over the storage grid while also avoiding obstruction to the camera's view. Position the cameras horizontally as close as possible to the halfway mark in-between the locations of the fixed-in-place monitor nozzles. Maintain a minimum horizontal distance of 10 ft (3.0 m) from any camera to the nearest fixed-in-place monitor nozzle.

C. Install the cameras so that every column of the storage array can be viewed by a minimum of two cameras.

D. When possible, incorporate data into the camera view that can communicate to the remote location operator the specific location of the storage grid the camera is viewing.

2.3.6.1.9.3 The installation of visible imaging cameras can be used in lieu of infrared cameras when:

A. The space between the top of the storage grid and the ceiling will be (1) unconfined so that smoke can readily escape the ASRS storage area, and (2) the ceiling-level sprinklers will be quick-response, minimum K14.0 (K200) standard-coverage pendent Storage sprinklers, or

B. The space between the top of the storage grid and the ceiling will be (1) confined so that smoke cannot readily escape the ASRS storage area, and (2) manually-operated ceiling-level ventilation will be provided that can be turned on upon fire service arrival to clear the storage grid area of visible smoke.

2.3.6.1.9.4 When permitted by Section 2.3.6.1.8.3, install visible imaging cameras over the entire storage grid, using dedicated feeds to the remote location designated for monitor nozzle operation, as follows:

A. Install cameras, capable of panning and tilting, that have a minimum spatial resolution of 15 pixels/ft (45 pixels/m), measured at the farthest position from the camera along the top surface of the storage array.

B. Locate the cameras vertically as high as possible over the storage grid while also avoiding obstruction to the camera's view. Position the cameras horizontally as close as possible to the halfway mark in-between the locations of the fixed-in-place monitor nozzles. Maintain a minimum horizontal distance of 10 ft (3.0 m) from any camera to the nearest fixed-in-place monitor nozzle.

C. Install the cameras so that every column of the storage array can be viewed by a minimum of two cameras.

D. When possible, incorporate data into the camera view that can communicate to the remote location operator the specific location of the storage grid the camera is viewing.

E. Arrange the recording equipment so that review of the video is possible to help identify where flames have been visually observed.

2.3.6.1.9.5 When fixed-in-place monitor nozzles are being installed, the installation of IR or visible cameras can be avoided (if so chosen by the end user) at the written discretion of the local authority having jurisdiction when all the fixed-in-place monitor nozzles are readily accessible during a fire event.

2.3.6.2 Ceiling-Level Sprinkler System Types

2.3.6.2.1 Depending on the ambient temperature of the ASRS area being protected, ceiling-level sprinkler systems can be:

A. Wet-pipe sprinkler systems

B. Single-interlocked preaction sprinkler systems

C. Antifreeze solution sprinkler systems consisting of a 20% to 30% propylene glycol concentration in water

2.3.6.2.2 When installing a single-interlocked preaction sprinkler system, install the detection system used for tripping the sprinkler system on the same spacing as the ceiling sprinklers. See Data Sheet 5-48 for other recommendations pertaining to the preaction sprinkler system's detection.

2.3.6.2.3 A ceiling-level sprinkler system consisting of 20% to 30% concentration of propylene glycol in water is acceptable for ambient temperatures between 32ºF (0ºC) and 40ºF (4ºC).

2.3.6.2.4 When installing an antifreeze sprinkler system consisting of a 20% to 30% concentration of propylene glycol in water, the ceiling designs indicated for a wet-pipe sprinkler system can be used.

2.3.6.2.5 See Data Sheet 2-0 for additional recommendations related to the installation of all sprinkler system types.

2.3.6.3 Ceiling-Level Sprinklers

2.3.6.3.1 For ceiling heights up to 45 ft (13.7 m), install FM Approved, Storage ceiling-level sprinklers in accordance with the design guidelines offered in Tables 45 and 46.

2.3.6.3.2 For ceiling heights over 45 ft (13.7 m), install a flat, continuous noncombustible false ceiling over the ASRS storage area and for a minimum of 15 ft (4.6 m) beyond it in all directions. Design the false ceiling to be capable of withstanding a minimum uplift pressure of 3 lb/ft^2 (14.4 kg/m^2). Provide sprinkler protection under this false ceiling in accordance with the height above the floor the ceiling is installed.

2.3.6.3.3 When elevated mezzanines are present, provide sprinkler protection under them in accordance with Data Sheet 2-0.

2.3.6.4 Ceiling-Level Sprinkler System Design Criteria

2.3.6.4.1 Use Table 45 to determine the ceiling-level sprinkler system designs for TL-ASRS storage arrangements using solid-walled combustible containers having a maximum storage height of 20 ft (6.1 m).

2.3.6.4.2 Use Table 46 to determine the ceiling-level sprinkler system designs for TL-ASRS storage arrangements using solid-walled combustible containers having a storage height that exceeds 20 ft (6.1 m).

Table 45. Ceiling-Level Protection Guidelines for TL-ASRS Storage Arrangements Using Open-Top Solid-Walled Unexpanded Plastic Containers; Storage Height up to and Including 20 ft (6.1 m)

Max. Ceiling Height, ft (m)	*Ceiling-Level Sprinkler Protection Options for Top-Loading ASRS Arrangements; No. of AS @ psi (bar)*																		
	Wet System, Pendent Storage Sprinklers, 160°F (70°C)												Wet System, Upright Storage Sprinklers, 160°F (70°C)						
	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)
20 (6.1)	15 @ 25 (1.7)	9@ 50 (3.5)	9@ 35 (2.4)	9@ 20 (1.4)	9@ 20 (1.4)	7@ 19 (1.3)	9@ 40 (2.8)	9@ 55 (3.8)	15@ 25 (1.7)	15@ 16 (1.1)	15@ 16 (1.1)	15@ 7 (0.5)	15@ 25 (1.7)	10@ 50 (3.5)	10@ 35 (2.4)	7@ 19 (1.3)	15 @ 25 (1.7)	15@ 11 (0.8)	15 @ 7 (0.5)
25 (7.6)	15 @ 50 (3.5)	9@ 50 (3.5)	9@ 35 (2.4)	9@ 20 (1.4)	9@ 20 (1.4)	7@ 38 (2.6)	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)	10@ 50 (3.5)	10@ 35 (2.4)	7@ 38 (2.6)	15 @ 50 (3.5)	15@ 22 (1.5)	15 @ 10 (0.7)
30 (9.1)	20 @ 50 (3.5)	9@ 50 (3.5)	9@ 35 (2.4)	9@ 20 (1.4)	9@ 20 (1.4)	10@ 38 (2.6)	9@ 40 (2.8)	9@ 55 (3.8)	20@ 50 (3.5)	20@ 32 (2.2)	20@ 16 (1.1)	20@ 10 (0.7)	20@ 50 (3.5)	10@ 50 (3.5)	10@ 35 (2.4)	10@ 38 (2.6)	20 @ 50 (3.5)	20@ 22 (1.5)	20 @ 10 (0.7)
35 (10.7)		9 @ 75 (5.2)	9@ 52 (3.6)	9@ 29 (2.0)	9@ 23 (1.6)		9@ 40 (2.8)	9@ 55 (3.8)											
40 (12.2)		9 @ 75 (5.2)	9@ 52 (3.6)	9@ 29 (2.0)	9@ 23 (1.6)		9@ 40 (2.8)	9@ 55 (3.8)											
45 (13.7)				9 @ 75 (5.2)	9@ 60 (4.1)		9@ 50 (3.5)	9@ 55 (3.8)											

Table 46. Ceiling-Level Protection Guidelines for TL-ASRS Storage Arrangements Using Open-Top Solid-Walled Unexpanded Plastic Containers; Storage Height in Excess of 20 ft (6.1 m)

Max. Ceiling Height, ft (m)	*Ceiling-Level Sprinkler Protection Options for Top-Loading ASRS Arrangements; No. of AS @ psi (bar)*																		
	Wet System, Pendent Storage Sprinklers, 160°F (70°C)												Wet System, Upright Storage Sprinklers, 160°F (70°C)						
	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)
25 (7.6)	15 @ 50 (3.5)	10@ 50 (3.5)	10@ 35 (2.4)	10@ 20 (1.4)	10@ 20 (1.4)	7 @ 38 (2.6)	10 @ 40 (2.8)	10 @ 55 (3.8)	15@ 50 (3.5)	15@ 32 (2.2)	15@ 16 (1.1)	15@ 10 (0.7)	15@ 50 (3.5)	12@ 50 (3.5)	12@ 35 (2.4)	7 @ 38 (2.6)	15 @ 50 (3.5)	15@ 22 (1.5)	15 @ 10 (0.7)
30 (9.1)	20 @ 50 (3.5)	12@ 50 (3.5)	12@ 35 (2.4)	12@ 20 (1.4)	12@ 20 (1.4)	10@ 38 (2.6)	12@ 40 (2.8)	12@ 55 (3.8)	20@ 50 (3.5)	20@ 32 (2.2)	20@ 16 (1.1)	20@ 10 (0.7)	20@ 50 (3.5)	12@ 50 (3.5)	12@ 35 (2.4)	10@ 38 (2.6)	20@ 50 (3.5)	20@ 22 (1.5)	20 @ 10 (0.7)
35 (10.7)				12 @ 29 (2.0)	12@ 23 (1.6)		12@ 40 (2.8)	12@ 55 (3.8)											
40 (12.2)				12 @ 29 (2.0)	12@ 23 (1.6)		12@ 40 (2.8)	12@ 55 (3.8)											
45 (13.7)				12 @ 75 (5.2)	12@ 60 (4.1)		12@ 50 (3.5)	12@ 55 (3.8)											

2.3.6.4.3 Hose Demand Design Guidelines

A. Include a minimum flow of 500 gpm (1,900 L/min) for the hose demand design.

B. When both fixed-in-place monitor nozzles are provided in accordance with Section 2.3.6.1.8 and small hose connection stations are provided in accordance with Section 2.3.6.1.6, account for the 500 gpm (1,900 L/min) hose demand design as follows:

1. Include a flow of 200 gpm (760 L/min) from each of the two most remote monitor nozzles (400 gpm [1,520 L/min] total) as part of the hose demand design, and
2. Include a flow of 50 gpm (190 L/min) from each of the two most remote small hose connection stations

C. When only fixed-in-place monitor nozzles are provided in accordance with Section 2.3.6.1.8, account for a flow of 200 gpm (760 L/min) from each of the two most remote monitor nozzles (400 gpm [1,520 L/min] total) as part of the hose demand design. Account for the remaining 100 gpm (380 L/min) hose demand by adding it to the overall ceiling sprinkler system demand at the point of its connection to the water supply.

D. When only small hose connection stations are provided in accordance with Section 2.3.6.1.6, account for a flow of 50 gpm (190 L/min) from each of the two most remote small hose connection stations. Account for the remaining 400 gpm (1,520 L/min) hose stream allowance by adding it to the overall ceiling sprinkler system demand at the point of its connection to the water supply.

2.3.6.4.4 Water Supply Duration

Size the water supply feeding the ceiling sprinkler system, the monitor nozzles, and the hose stream demand (inside and outside), when taken from the same water supply, for the following durations:

A. A minimum of 2 hours for ceiling heights less than or equal to 25 ft (7.6 m), or

B. A minimum of 4 hours for ceiling heights over 25 ft (7.6 m)

2.3.7 Protection of Non-Solid-Walled Containers

2.3.7.1 Storage Arrangement

2.3.7.1.1 Create individual storage subdivisions within the ASRS storage array whose storage footprints are defined entirely or by a combination of any of the following:

A. A minimum 4 ft (1.2 m) wide void space, or

B. A wall that defines the extent of the ASRS storage array, or

C. An adjacent area where containers can be stored only one high and on the same plane that represents the maximum storage height within the storage array.

See Figure 52 for a visual representation of these arrangements.

2.3.7.1.2 Determine the size of the storage subdivisions based on the number of operating sprinklers the water supply can support. See Section 2.3.7.4 for more information on the sprinkler system design.

2.3.7.1.3 Arrange the void spaces between storage subdivisions so ceiling sprinklers are aligned, as close as possible, over the center of them as shown in Figure 53.

2.3.7.1.4 Limit the storage within each subdivision to a maximum height of 25 ft (7.6 m).

2.3.7.2 Ceiling-Level Sprinkler System Types

2.3.7.2.1 Depending on the ambient temperature of the ASRS area being protected, ceiling-level sprinkler systems can be one of the following:

A. Wet-pipe sprinkler system

B. Antifreeze solution sprinkler system consisting of a 20% to 30% propylene glycol concentration in water

2.3.7.2.2 A ceiling-level sprinkler system consisting of 20% to 30% concentration of propylene glycol in water is acceptable for ambient temperatures between 32ºF (0ºC) and 40ºF (4ºC).

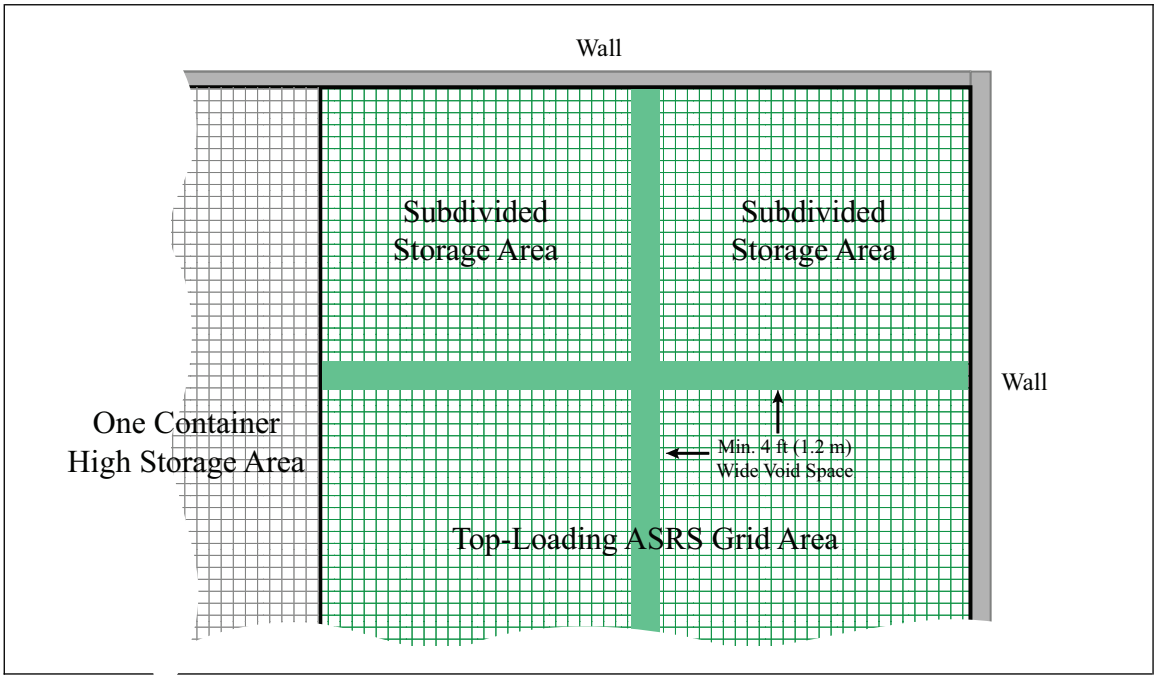

Fig. 52. Establishing storage subdivisions within TL-ASRS

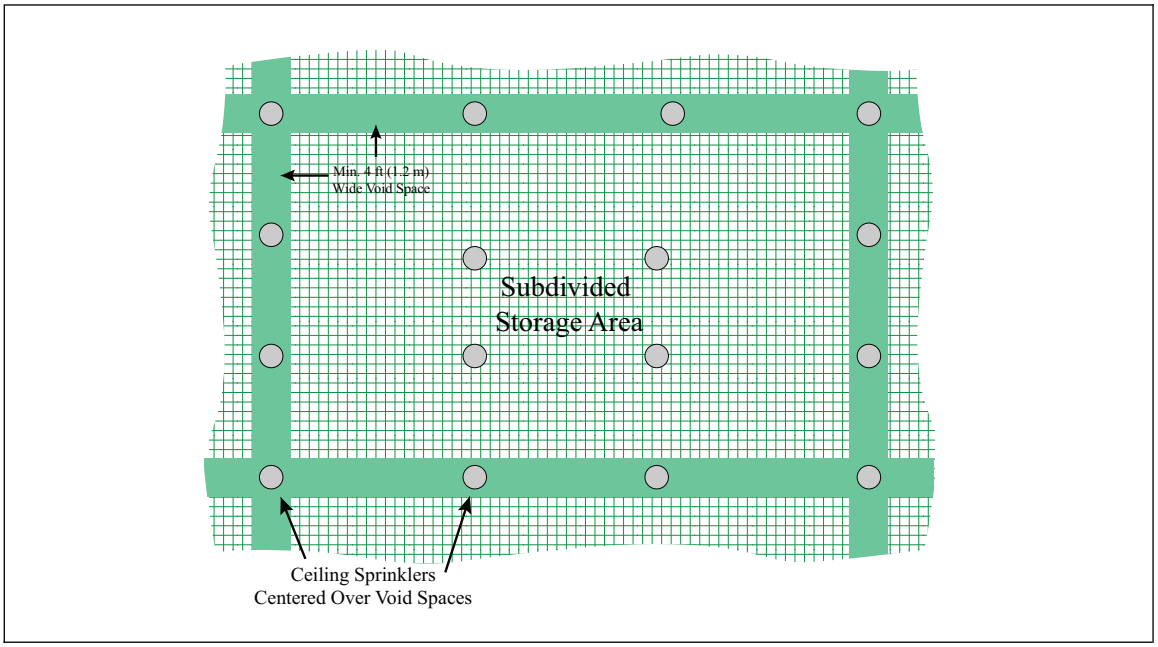

Fig. 53. Positioning of void spaces under ceiling sprinklers

2.3.7.2.3 When installing an antifreeze sprinkler system consisting of a 20% to 30% concentration of propylene glycol in water, the ceiling designs indicated for a wet-pipe sprinkler system can be used.

2.3.7.2.4 See Data Sheet 2-0 for additional recommendations related to the installation of these type sprinkler systems.

2.3.7.3 Ceiling-Level Sprinklers

2.3.7.3.1 For ceiling heights up to 40 ft (12.2 m), install FM Approved, quick-response, minimum K14.0 (K200) pendent Storage ceiling-level sprinklers.

2.3.7.3.2 For ceiling heights over 40 ft (12.2 m) and up to 45 ft (13.7 m), install FM Approved, quick-response, minimum K22.4 (K360) pendent Storage ceiling-level sprinklers.

2.3.7.3.3 For ceiling heights over 45 ft (13.7 m), install a flat, continuous noncombustible false ceiling over the ASRS storage area and for a minimum of 15 ft (4.6 m) beyond it in all directions. Design the false ceiling to be capable of withstanding a minimum uplift pressure of 3 lb/ft^2 (14.4 kg/m^2). Provide sprinkler protection under this false ceiling in accordance with the height above the floor the ceiling is installed.

2.3.7.3.4 When elevated mezzanines are present, provide sprinkler protection under them in accordance with Data Sheet 2-0.

2.3.7.4 Ceiling-Level Sprinkler System Design Criteria

2.3.7.4.1 For ceiling heights up to and including 45 ft (13.7 m), provide a minimum flow of 120 gpm (455 L/min) from the most hydraulically remote operating sprinkler over the storage subdivision.

2.3.7.4.2 Size the ceiling sprinkler demand area as follows:

A. For ceiling heights up to and including 40 ft (12.2 m), the demand area includes the sprinklers located directly over and within 4 ft (1.2 m) horizontally of each subdivided storage area.

B. For ceiling heights over 40 ft (12.2 m) and up to and including 45 ft (13.7 m), the demand area includes 5 more sprinklers than the sprinklers located directly over and within 4 ft (1.2 m) horizontally of each subdivided storage area.

2.3.7.4.3 When determining the ceiling sprinkler demand area in accordance with Section 2.3.7.4.2, sprinklers on the opposite side of a full height wall, or on the opposite side of a minimum 2 ft (0.6 m) deep draft curtain that is installed at the perimeter of the ASRS storage area, do not have to be accounted for in the ceiling sprinkler design.

2.3.7.5 Hose Demand Design Guidelines

2.3.7.5.1 Include a minimum flow of 500 gpm (1,900 L/min) for the hose demand design.

2.3.7.5.2 When small hose connection stations are provided in accordance with Section 2.3.7.6.2, account for a flow of 50 gpm (190 L/min) from each of the two most remote small hose connection stations. Account for the remaining 400 gpm (1,515 L/min) hose stream allowance by adding it to the overall ceiling sprinkler system demand at the point of its connection to the water supply.

2.3.7.6 Water Supply Duration

Size the water supply feeding the ceiling sprinkler system and the hose stream demand (inside and outside), when taken from the same water supply, for a minimum 4-hour duration.

2.3.7.7 Final Extinguishment

Due to the lack of direct access by the local fire services to the fire area, recommendations in this section are intended to establish a means by which final extinguishment can be achieved.

2.3.7.7.1 Storage Arrangement and Mezzanines

A. To allow the fire service to access the top of the storage grid where hose streams can be applied, arrange the TL-ASRS storage as follows:

1. Limit the horizontal distance between one end of the storage array and the opposite end to a maximum of 100 ft (30 m) as shown in Figure 54.
2. Install perimeter mezzanines, at a minimum, along the longer walls of the ASRS unit at a height equal to or above the storage grid as shown in Figure 54. Determine from the local authority having jurisdiction the minimum width of the mezzanine they would require and the minimum number of access points for each perimeter mezzanine area.

3. Establish readily accessible, clearly marked designated locations along the side walls of the ASRS unit that can be used as access points to the storage area. Provide as many access points as possible to limit the horizontal distance between the access point and the potential fire area within the storage area. See Figure 54 for an example of this arrangement.

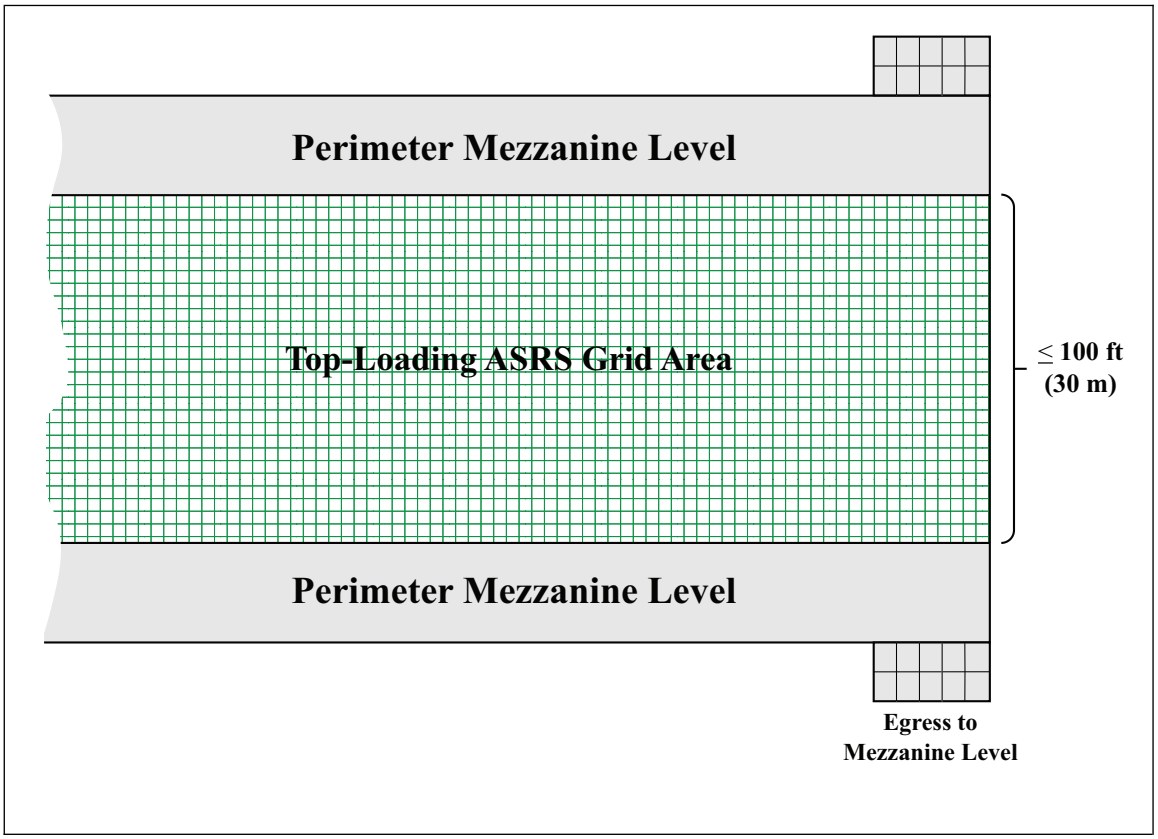

Fig. 54. Example of a TL-ASRS arrangement showing maximum 100 ft (30 m) depth in one direction

B. If the horizontal distances between the ends of the storage array will exceed 100 ft (30 m) in both directions, install solid-floored elevated mezzanine levels that will limit the horizontal distances between mezzanines to 100 ft (30 m) and the maximum horizontal distances for hose stream application to 50 ft (15 m). Arrange the elevated mezzanines to allow robots the ability to pass underneath them. See Figure 55 for an example of this arrangement.

C. The installation of elevated mezzanines, as outlined in Section 2.3.7.7.1(B), can be avoided at the written discretion of the local authority having jurisdiction.

2.3.7.7.2 Small Hose Connection Stations

A. To aid in manual fire fighting efforts and after-extinguishment mop-up operations, install small hose connection stations near the floor-level access points established for the local fire service and on the mezzanine levels (perimeter and elevated). Consult with the local fire service or authority having jurisdiction to determine their recommendations regarding the following:

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

B. 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).

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

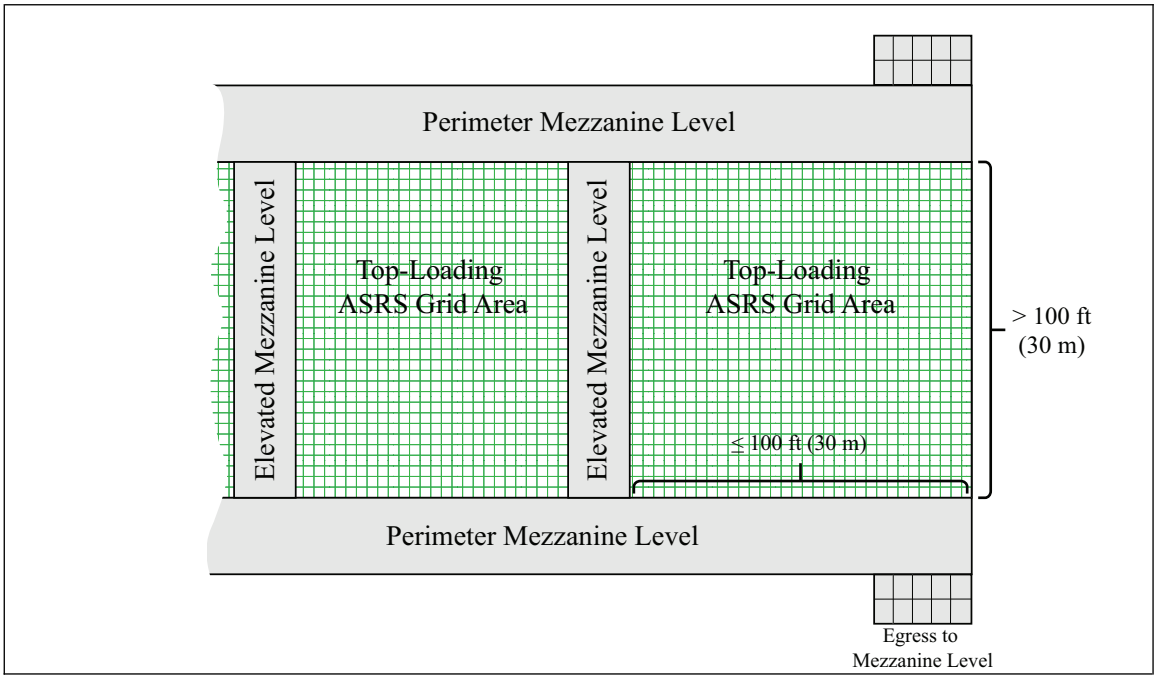

Fig. 55. Example of solid-floored elevated mezzanine levels when span of TL-ASRS exceeds 100 ft (30 m) in each direction

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

D. The installation of small hose connection stations can be avoided at the documented discretion of the local authority having jurisdiction.

2.3.7.7.3 Pre-Incident Plan

For TL-ASRS storage arrangements that use non-solid-walled containers, establish a pre-incident plan with the local fire service that takes into consideration how the local fire service will gain access to any point of the ASRS storage grid for final extinguishment purposes. Items to consider, at a minimum, are:

A. Access to the storage grid itself (i.e., removal of any separating walls or fences),

B. A plan to remove storage containers along with a place to put them, and

C. A means of preventing robots from falling from the grid into the storage area.

See Section 2.1.5 for additional guidance on pre-incident planning.

2.4 Vertically Enclosed Automatic Storage and Retrieval System Storage Arrangements

2.4.1 General

2.4.1.1 Section 2.4 provides protection guidelines for vertically enclosed automatic storage and retrieval systems (ASRS) storage arrangements. See Figure 56 for an example of this type of storage arrangement.

2.4.1.2 The protection options in this section for a vertically enclosed ASRS storage unit focus solely on the protection provided within the unit itself. See the applicable FM Data Sheet for the surrounding occupancy hazard to determine recommendations pertaining to the construction, occupancy, and protection of the area in which the vertically enclosed ASRS storage unit is located.

2.4.2 Storage Trays for Vertically Enclosed Storage Units

2.4.2.1 To help reduce the fire load within a vertically enclosed ASRS storage unit, use trays that are noncombustible.

Fig. 56. Example of a vertically enclosed ASRS storage unit

2.4.2.2 To aid in water penetration throughout the vertical height of the vertically enclosed ASRS unit, consider the use of either trays with gridded bottoms, or trays that are provided with a minimum 10% venting area uniformly around the sides of the trays a maximum 1 in. (25 mm) above the bottom of the tray.

2.4.3 Protection Options for Vertically Enclosed Storage Units

2.4.3.1 General

2.4.3.1.1 Arrange the vertically enclosed ASRS storage unit for automatic shutdown upon fire/smoke detection or sprinkler activation.

2.4.3.1.2 If the materials being maintained within the vertically enclosed ASRS storage 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 4-Series Data Sheet to supplement the sprinkler protection recommended in Section 2.4.3.3.

2.4.3.2 Sprinkler System Types

2.4.3.2.1 Depending on the ambient temperature of the area being protected, the sprinkler system protecting the vertically enclosed ASRS storage unit can be wet-pipe, dry-pipe, preaction, a maximum 30% propylene glycol antifreeze solution, or a deluge sprinkler system.

2.4.3.2.2 When installing a dry-pipe or similar ceiling-level sprinkler system, the maximum water delivery time is 40 seconds based on a maximum operation of the most remote 4 sprinklers.

2.4.3.2.3 See Data Sheet 2-0 for additional recommendations related to the installation of the sprinkler system.

2.4.3.3 Protection of Vertically Enclosed ASRS Units

2.4.3.3.1 Vertically Enclosed ASRS Storage Units up to 25 ft (7.6 m) Tall

A. Provide sprinkler protection at the top of a closed-top ASRS unit using minimum K11.2 (K160) Storage sprinklers on maximum 8 ft (2.4 m) linear spacing and maximum 64 ft^2 (6.0 m^2) area spacing.

B. If the top of the ASRS unit is open to the surrounding area, reduce the sprinkler spacing to a maximum 4 ft (1.2 m) linear spacing and a maximum 16 ft^2 (1.5 m^2) area spacing.

C. Design the sprinkler system to account for all sprinklers within the vertically enclosed ASRS storage unit operating at a minimum flow of 30 gpm (115 L/min) from the most remote sprinkler.

2.4.3.3.2 Vertically Enclosed ASRS Storage Units Over 25 ft (7.6 m) Tall

A. Protection with Sprinklers at the Top of the ASRS Unit Only

1. For closed-top vertically enclosed ASRS units over 25 ft (7.6 m) and up to a maximum height of 55 ft (16.8 m) tall protected by sprinklers only at the top of the ASRS unit, install quick-response, standard-coverage, 160°F (70°C) nominally rated, minimum K14.0 (K200) pendent Storage sprinklers on maximum 8 ft (2.4 m) linear spacing and maximum 64 ft^2 (6.0 m^2) area spacing.
2. For open-top vertically enclosed ASRS units over 25 ft (7.6 m) and up to a maximum height of 55 ft (16.8 m) tall protected by sprinklers only at the top of the ASRS unit, install quick-response, standard-coverage, 160°F (70°C) nominally rated, minimum K14.0 (K200) pendent Storage sprinklers on maximum 4 ft (1.2 m) linear spacing and maximum 16 ft^2 (1.5 m^2) area spacing.
3. Design the sprinkler system accounting for all sprinklers within the vertically enclosed ASRS unit operating at the minimum design pressure indicated in Table 47.

Table 47. Sprinkler Pressure Requirements for the Protection of Vertically Enclosed ASRS Storage Units Over 25 ft (7.6 m) and up to 55 ft (16.8 m) Tall

Maximum Ceiling Height of Vertically Enclosed ASRS Unit, ft (m)	*Wet System, Quick Response, 160°F (70°C), Pendent Storage Sprinklers; Pressure, psi (bar)*					
	K14.0 (K200)	K16.8 (K240)	K22.4 (K320)	K25.2 (K360)	K28.0 (K400)	K33.6 (K480)
30 (9.1)	50 (3.4)	35 (2.4)	20 (1.4)	20 (1.4)	40 (2.8)	55 (3.8)
35 (10.7)	75 (5.2)	52 (3.6)	30 (2.1)	30 (2.1)	40 (2.8)	55 (3.8)
40 (12.2)	75 (5.2)	52 (3.6)	40 (2.8)	40 (2.8)	40 (2.8)	55 (3.8)
45 (13.7)			50 (3.4)	50 (3.4)	40 (2.8)	55 (3.8)
50 (15.2)			63 (4.3)	50 (3.4)	40 (2.8)	55 (3.8)
55 (16.8)					80 (5.5)	55 (3.8)

B. Protection with Ceiling- and Intermediate-Level Sprinklers

1. For closed-top vertically enclosed ASRS units over 25 ft (7.6 m) and up to a maximum height of 55 ft (16.8 m) tall protected by both ceiling- and intermediate-level sprinklers, provide sprinkler protection within the ASRS unit as follows:

   a. Install sprinklers at the top of the ASRS unit using minimum K11.2 (K160) Storage sprinklers on maximum 8 ft (2.4 m) linear spacing and maximum 64 ft^2 (6.0 m^2) area spacing, and

   b. Install intermediate levels of quick response, 160°F (70°C) nominally rated, minimum K8.0 (K115) Nonstorage sidewall or extended-coverage sidewall sprinklers installed at both ends of the ASRS unit. Locate the intermediate levels of sprinklers on a maximum vertical spacing of 10 ft (3.0 m) while leaving no more than 15 ft (4.6 m) of storage above the top level of intermediate sprinklers.

   c. Design the sprinkler system to account for all sprinklers (ceiling and intermediate) within the vertically enclosed ASRS storage unit operating at a minimum flow of 30 gpm (115 L/min) from the most remote sprinkler.

2. If the top of the ASRS unit is open to the surrounding area, reduce the sprinkler spacing indicated in Section 2.4.3.3.2(B)(1)(a) to a maximum 4 ft (1.2 m) linear spacing and a maximum 16 ft^2 (1.5 m^2) area spacing.

2.4.3.4 Hose Demand and System Duration

2.4.3.4.1 Hose Demand Design

As part of the overall sprinkler system design, include a hose demand allowance of 250 gpm (950 L/min) for manual intervention.

2.4.3.4.2 System Duration

Size the water supply for the sprinkler system and the hose demand design, when taken from the same water supply source, for a minimum duration of 60 minutes.

2.4.4 Final Extinguishment – Small Hose Connection Stations

2.4.4.1 To aid in manual fire fighting efforts and after-extinguishment mop-up operations, install small hose connection stations near the vertically enclosed ASRS unit. Consult with the local fire service or authority having jurisdiction to determine their recommendations regarding:

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

2.4.4.2 Design the small hose connection stations 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).

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

A. A piping system dedicated solely for the small hose connection stations, or

B. Piping that connects the stations to a sprinkler system that is different than the one protecting the vertically enclosed ASRS storage unit

2.4.4.4 The installation of small hose connection stations can be avoided at the documented discretion of the local authority having jurisdiction.

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 that use angle irons for material handling support (see Figure 57). 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 58), 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. 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 59) and thus can be very tall.

Trays or containers used for product handling are removed from the rack by a motorized automated picking robot (see Figure 60). 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. The picking robot, located in the aisle on a set of rails, is typically operated via a computer terminal. The robot 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 robot 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: noncombustible containers, cellulosic containers, and plastic containers.

Fig. 57. Example of open-top plastic containers in mini-load ASRS storage arrangementi

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 typically 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 non-solid, then heat transfer is more readily achieved and the protection needed is driven 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. 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 recommended for them is appropriate to avoid the fire from growing vertically past the in-rack sprinklers when installed on a wet sprinkler system. 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 Unexpanded Plastic Containers

These containers are typically constructed using injection molded plastic; however, containers are sometimes made of expanded or corrugated plastic. Expanded plastic containers are currently outside the scope of the data sheet. 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 provided that the hinge is located close enough to the bottom of the container and the product inside the container will not block the water from escaping.

Fig. 58. Example of an empty mini-load ASRS storage arrangement where rack uprights are about 2 to 3 in. (50 to 75 mm) wide and about 2 ft (0.6 m) horizontally apart

Fig. 59. Example of rack-supported ASRS storage arrangement

Fig. 60. Example of motorized automated picking robot in a mini-load ASRS storage arrangement with open-top unexpanded plastic containers

3.1.2 Top-Loading ASRS Storage Arrangements

3.1.2.1 General

A top-loading ASRS (TL-ASRS) storage arrangement consists of an open metal grid structure that is supported by metal columns located at the corner of each of the grid openings. Under each grid opening is a solid-piled column of storage containers that are vertically aligned due to the angle irons provided on the metal support columns. The containers used in TL-ASRS storage arrangements are almost always open-top and made from various plastics, such as polyethylene (HDPE) or polypropylene. The top of the grid acts as a track across which remotely operated robots transverse; the robots are used to either remove containers from the storage grid for picking operations, or are used to return containers to their designated storage location. The track that the robots operate on is about the same width as the flue spaces surrounding each container.

3.1.2.2 Robot Charging Systems

Robot chargers are connected to AC or DC supply networks. Multiple chargers exist at various locations around the grid, requiring extensive runs of cables around the grid. The chargers condition the power (rectification/step down) to a level that is acceptable for the robot. The robots' batteries may be fixed to chassis or removable for charging. In designs with fixed batteries, the robot is stationary at the charging station while the batteries are being charged. In the case of removable batteries, robots deposit the batteries at the charging station for charging and acquire a fully charged battery at another station to continue operation. The robot may be powered by an ultra-capacitor during this transition. This leads to a system with higher uptimes and overall productivity per robot.

3.1.2.3 Batteries

In general, the batteries in use are one of two types: lead-acid or lithium-ion with the latter gaining more popularity in recent times. For designs with Li-ion batteries, charging rates could be substantially higher than for the lead acid counterparts. This can put additional stress on the current carrying parts of the battery pack and charger in addition to the batteries themselves, which tend to heat at higher current levels. A Battery Management System (BMS) is provided for the safe operation of the Li-ion battery pack.

Batteries use different chemistries. As indicated above, the chemistries typically observed in top-loading ASRS robots are lead-acid and lithium-ion batteries. Lead-acid batteries are typically of the sealed type. Li-ion batteries consist of several Li-ion cells (cylindrical or prismatic) connected in series/parallel combination to meet the voltage, power, and capacity requirements of the application. The battery pack also consist of the BMS and instrumentation to continuously monitor the battery state of charge, state of health. The BMS also provides safety operation limits on charge/discharge voltage and currents. The chargers for these Li-ion batteries follow specific charging profiles depending on the Li-ion chemistry used in the cells.

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. 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.

3.2 Loss History of Automatic Storage and Retrieval Systems (ASRS)

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 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

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 2-1, *Corrosion in Automatic Sprinkler Systems*
Data Sheet 2-8, *Earthquake Protection for Water-Based Fire Protection Systems*
Data Sheet 3-0, *Hydraulics of Fire Protection Systems*
Data Sheet 5-48, *Automatic Fire Detection*
Data Sheet 7-43, *Process Safety*
Data Sheet 7-110, *Industrial Control Systems*
Data Sheet 8-1, *Commodity Classification*
Data Sheet 8-9, *Storage of Class 1, 2, 3, 4 and Plastic Commodities*
Data Sheet 10-1, *Pre-Incident Planning*
Data Sheet 10-8, *Operators*

4.2 Other

International Electrotechnical Commission (IEC). IEC 60950-1, *Information Technology Equipment - Safety - Part 1: General Requirements.*

International Electrotechnical Commission (IEC). IEC 62619, *Secondary Cells and Batteries Containing Alkaline or Other Non-acid Electrolytes - Safety Requirements for Secondary Lithium Cells and Batteries, for Use in Industrial Applications.*

APPENDIX A GLOSSARY OF TERMS

ASRS rack row depth: The horizontal length of storage within a mini-load ASRS storage arrangement, measured perpendicular to the loading aisle, between (1) the face of the rack, and (2) either the longitudinal flue space or the back face of the rack when a longitudinal flue space is not provided. See Figure A-1 for a visual representation of this term.

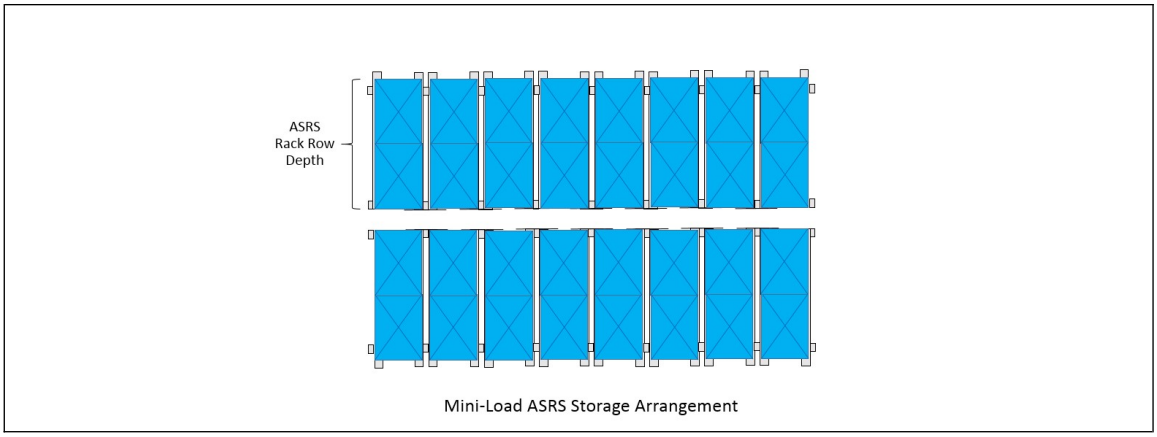

Fig. A-1. ASRS rack row depth

Automatic Storage and Retrieval System (ASRS): A storage system in which an automated picker (or robot) retrieves an otherwise stationary shelf, tray or container and brings it to a delivery platform or operator.

Carousel Storage and Retrieval System: A rotating storage system that uses vertically or horizontally rotating carriers on tracks or chains to move the entire array of stored items, where a summoned shelf or container stops at a designated access point for the storage or retrieval of goods. See Data Sheet 8-33, *Carousel Storage and Retrieval Systems*, for protection guidelines involving these types of storage arrangements.

Closed-top container: A container equipped with a solid cover that will prevent water from entering the top. The cover can be an integral part of container, such as a corrugated cardboard box with folding flaps that are then sealed closed (typically with glue or packing tape). It can also be a fixed-in-place lid. If a fixed-in-place lid is used, it needs to be expected to stay in place during a fire event and not allow water to enter the top of the container.

Fixed-in-place monitor nozzle: A non-portable monitor nozzle that is attached directly to either a floor or a ceiling structure. The nozzle itself, however, can be moved as needed to direct water discharge to the fire area.

Horizontal-loading ASRS storage arrangement: An automatic storage and retrieval system where material handling is conducted in a horizontal plane, similar to standard storage racks, but with robots that load and unload small containers or trays. There are two types of horizontal-loading ASRS storage arrangements currently addressed in this standard, which are mini-load and shuttle type ASRS arrangements.

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$^{0.5}$).

Local fire service: The responding personnel, paid or volunteer, whose assigned task would be to provide final extinguishment of a fire that originates within an ASRS storage array.

Longitudinal flue space: A flue space that is parallel to the loading aisle having a minimum width of 3 in. (75 mm) and a maximum width of 24 in. (600 mm). Note that any flue space that is parallel to the loading aisle having a minimum width over 24 in. (600 mm) as an aisle for in-rack sprinkler location purposes.

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. They are differentiated from other storage racks due to the presence of angle irons, which result in the diversion of sprinkler discharge toward the face of the rack and away from both the longitudinal and transverse flue spaces. 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 3).

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.

Monitor nozzle: A nozzle used for water discharge to a fire area that can turn 360º in a horizontal plane while also having a limited play in a vertical plane.

Non-solid-walled container (top-loading ASRS): A container that has openings on any of its side walls. The protection requirements for these types of containers differ from those for solid-walled containers when maintained in a TL-ASRS storage arrangement.

Open-top container: A container with walls higher than 1 in. (25 mm) that either does not have a top cover or is not equipped with a cover capable of preventing water from entering the container. Note that this includes open-top containers filled with product to any height within the container.

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. Protection guidelines for these storage arrangements are provided in Data Sheet 8-9, *Storage of Class 1, 2, 3, 4 and Plastic Commodities.*

Shuttle-type ASRS storage arrangement: An automatic storage and retrieval system that uses trays or small totes/containers (as opposed to traditional pallet loads) for material handling. What differentiates these ASRS storage arrangements from mini-load ASRS storage arrangements is the storage racks typically use slatted shelving (that are void of vertical alignment guides) on which the materials, trays, or containers rest. As a result, the rack structure does not inherently divert water away from the flue spaces that surround the stored product, provided the slats do not result in a blocked transverse flue space. Shuttle-type ASRS rack structures typically use rack uprights that are about 8 to 10 ft (2.4 to 3.0 m) horizontally apart and are about 3 in. (75 mm) in width. Tier heights are roughly 1 to 2 ft (0.3 to 0.6 m).

Small container: A container used in an ASRS storage arrangement, having walls more than 1.25 in. (32 mm) in height, that is typically either roughly (1) 16 x 24 x 15 in. tall (400 x 600 x 375 mm tall) in size, or (2) slightly wider in footprint but does not exceed 18 in. (450 mm) in height.

Small tray (i.e., tray): A flat product material handling platform typically about 16 x 24 in. (400 x 600 mm) in size, that has a vertical lip around its perimeter that does not exceed more than 1.25 in. (32 mm) in height.

Solid-walled open-top container (top-loading ASRS): A container that has no openings on any of its side walls. The protection requirements for these types of containers differ from those for non-solid-walled containers when maintained in a TL-ASRS storage arrangement.

Top-loading ASRS (TL-ASRS): An automatic storage and retrieval system that consists of a metal grid structure under which containers, usually open-top and made of unexpanded plastic, are stacked one on top of another in vertically aligned columns. They are accessed from the top of the grid by service robots that have been programmed to either retrieve a specific container for commodity picking purposes, or for replenishing the amount of commodity maintained within the storage container.

Vertical barrier: A barrier that is typically 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. When used in a mini-load ASRS storage arrangement, the vertical barrier can consist of either minimum 22-gauge (0.7 mm) sheet metal or minimum 3/8 in. (10 mm) plywood. For vertical barriers installed in a top-loading ASRS storage arrangement, see the guidelines specified for the barrier in Section 2.3.6.1.7.

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

The purpose of this appendix is to capture the changes that were made to this document each time it was published. Please note that section numbers refer specifically to those in the version published on the date shown (i.e., the section numbers are not always the same from version to version).

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

July 2023. Interim revision. Significant changes include the following:

A. The scope of this data sheet was modified to indicate that it applies to material handling of small containers and small trays; (see Appendix A for a definition of these terms).

B. The generic term horizontal-loading has been introduced to address both mini-load and shuttle type (i.e., shuttle) ASRS storage arrangements.

C. Previously, this data sheet referenced FM Global Property Loss Prevention Data Sheet 8-9, *Storage of Class 1, 2, 3, 4, and Plastic Commodities*, for protection guidelines of (1) closed-top containers stored directly on the rail supports of a shuttle ASRS and (2) closed-top storage maintained on trays within a shuttle or mini-load type ASRS. Those protection guidelines have now been added to this data sheet, so

the user can obtain the needed recommendations here.

D. The guidelines for adequately vented open-top containers used in horizontal-loading ASRS storage arrangements have been removed from this data sheet based on recent successful test results with solid-walled, open-top plastic containers.

E. Guidelines for open-top noncombustible containers in a horizontal-loading ASRS storage arrangement have been temporarily removed. Once an Approval Standard for FM Approved “non-propagating containers” specific to horizontal-loading ASRS arrangements is developed, protection guidelines for these containers will be reintroduced into the data sheet.

January 2023. Interim revision. Significant changes include the following:

A. The Final Extinguishment section for top-loading ASRS storage arrangements (former Section 2.3.6.4) was relocated to the beginning of this section and is now Section 2.3.6.1, with the previous sections and subsections renumbered.

B. A new ceiling sprinkler system design for ceiling heights up to and including 30 ft (9.1 m) was added in the Final Extinguishment section for top-loading ASRS storage arrangements where final extinguishment without manual intervention is a possibility.

C. The guidelines in Section 2.2.3 for storage of products on trays within a mini-load type of ASRS storage arrangement were clarified to apply only to those products that are not maintained in open-top containers.

D. The intended goal of an adequately vented open-top container and how it can potentially be achieved when used in a top-loading ASRS storage arrangement was added to Section 2.2.4 and Appendix A.

E. Section 2.3.4 was updated to clarify that a very early warning detection system is recommended over the storage array of a top-loading ASRS storage arrangement.

F .New figures were added to Section 2.3.6 to clarify that the recommended mezzanines did not have to extend along the entire perimeter of the storage array.

October 2020. Interim revision. Significant changes include the following:

A. The following changes were made to the entire document:

1. Reformatted the sections so Section 2.2 is specific to mini-load ASRS storage arrangements, Section 2.3 is specific to TL-ASRS storage arrangements, and Section 2.4 is specific to vertically enclosed storage arrangements.

2. Added instructions for users to see Data Sheet 8-9 for the protection of rack structure ASRS storage arrangements.

3. Noted that protection options for open-top, gridded-bottom containers used within either mini-load or top-loading ASRS storage arrangements are outside the scope of this data sheet.

B. The following changes were made specific to mini-load ASRS storage arrangements:

1. Moved all the protection options specific to mini-load ASRS storage arrangements to this document (i.e., users no longer referred to Data Sheet 8-9 for certain storage arrangements)

2. Added new guidelines for solid-walled noncombustible containers.

3. Added dry-pipe sprinkler protection options.

4. Noted that protection options for expanded plastic trays and containers are outside the scope of this data sheet.

5. Added information on shuttle-type ASRS storage arrangements in Section 2.1 and Appendix A.

C. The following changes were made specific to top-loading ASRS storage arrangements:

1. Noted that protection options for open-top, gridded-bottom containers are outside the scope of this data sheet.

2. Added protection options for open-top, non-solid walled containers to this data sheet.

3. Added protection options for noncombustible open-top, solid-walled containers to this data sheet.

D. Clarified TL-ASRS storage arrangements regarding what is needed for sprinkler protection (suppression or control) and what is needed for final extinguishment. Added new sections for each ASRS storage arrangement specific to final extinguishment.

E. Added definitions to Appendix A to clarify guidance for the various types of containers described in this data sheet.

January 2020. Interim revision. Significant changes include the following:

A. Added loss prevention guidelines for top-loading ASRS arrangements that use solid-walled (open- and closed-top containers).

B. Reformatted the document so each ASRS storage arrangement now has its own section.

C. Incorporated the results of recent full-scale fire testing of top-loading automatic storage and retrieval systems using solid-walled plastic containers.

January 2018. Interim revision. Clarifications were made to section 2.2.4.2, Longitudinal Flue Spaces, corrected reference to the table in sections 2.2.4.1.3 and 2.3.4.1.2. Also corrections were made to Table 11, IRAS Design Guidelines.

October 2017. Interim revision. Minor editorial changes were made.

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.