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

April 2026. Interim revision. Significant changes for this version of the data sheet include the following:

A. Section 2.2.1.4 has been updated to provide better clarification on how to measure the gross and net width of transverse flue spaces as well as what are the recommended net widths of the transverse flue spaces.

B. A new Section 2.2.1.5 has been created to indicate when vertical barriers are recommended for horizontal-loading ASRS arrangements.

C. The horizontal in-rack sprinkler arrangements in Sections 2.2.3.2.1, 2.2.4.2.1, 2.2.6.2.1, and 2.2.7.2.1 have been modified to provide for a more streamlined method of in-rack sprinkler installations.

D. Section 2.3 has been modified to (1) incorporate the guidelines specific to FM Approved Non-Flame Propagating Containers, (2) differentiate the guidelines for solid-walled containers when the ceiling height is either greater than 30 ft (9.1 m), or 30 ft (9.1 m) or less, (3) add a new ceiling-level sprinkler design based on a 28 ft (8.5 m) high ceiling, (4) address systems of limited size, and (5) address systems consisting of both plastic containers and FM Approved non-flame propagating containers.

E. The protection guidelines for vertically enclosed ASRS arrangements in Section 2.4 have been enhanced to address storage heights over 55 ft (16.8 m).

F. The format of Table 2.1.4.5.4 was updated to be consistent with the same table in Data Sheet 8-9.

G. Several editorial modifications were incorporated into this version of the data sheet including renumbering of the figures and the tables based on their section number.

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 1.2 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.

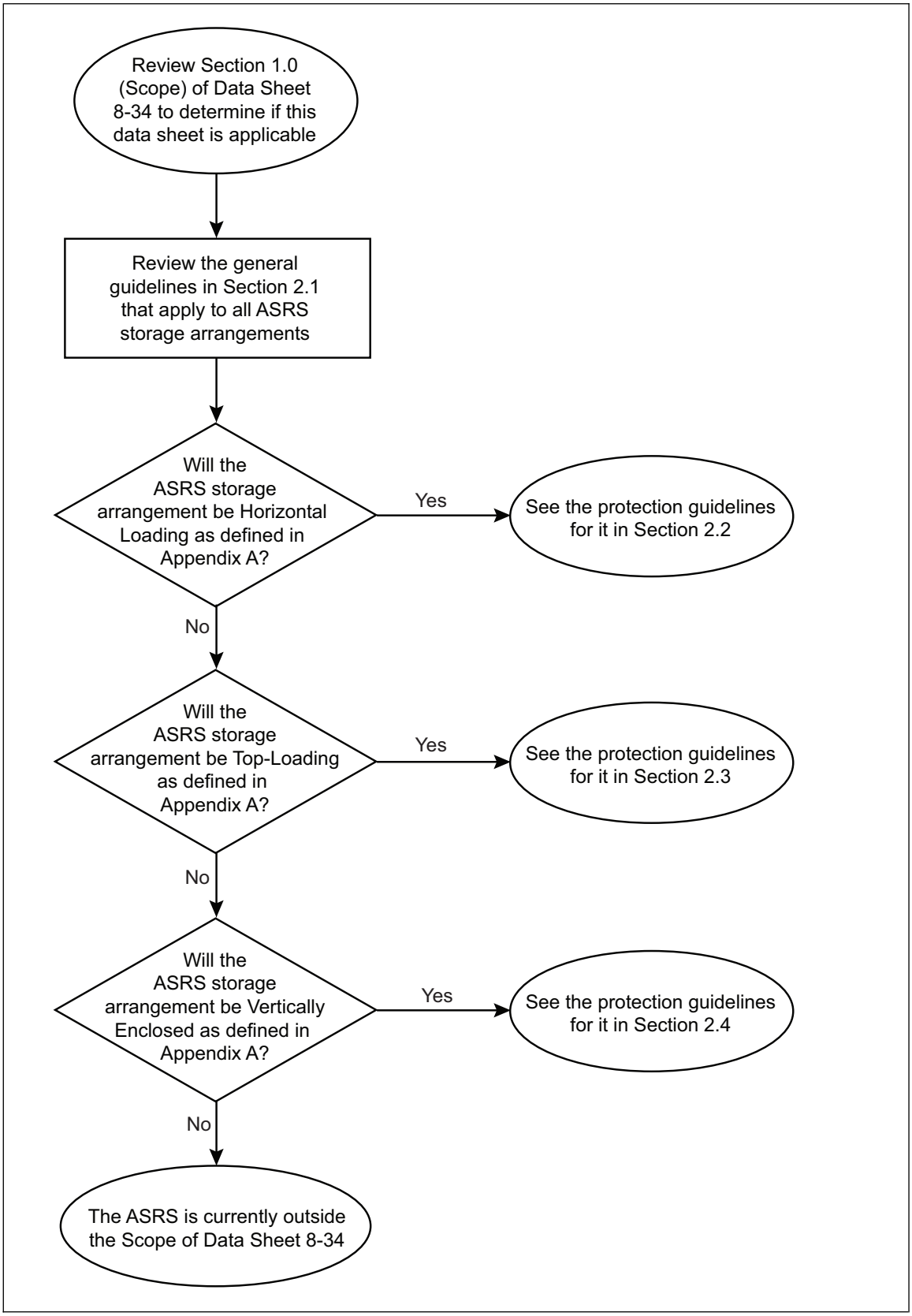

Fig. 1.2. Summarized guidance on how to navigate Data Sheet 8-34

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 Construction Related Recommendations per Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*

See Data Sheet 2-0 for guidelines specific to:

A. Heat and smoke vents

B. Natural draft exhaust vents

C. Mechanical exhaust vents

D. Ridge vents

E. Ceiling pockets

F. Airflow from ventilation systems

G. 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 Related Recommendations

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 Protection Related Recommendations per FM Data Sheet 2-0

2.1.4.1.1 In addition to the recommendations in this data sheet, follow the sprinkler, ceiling and in-rack, installation guidelines indicated for Storage sprinklers in Data Sheet 2-0, including recommendations specific to:

A. Temperature rating of the ceiling sprinklers based on the ambient temperature of the protected area

B. Linear and area spacing of the ceiling sprinklers based on unobstructed or obstructed ceiling construction

C. Mixing of ceiling sprinklers on the same sprinkler system

D. Obstruction of ceiling sprinkler discharge

E. Positioning of in-rack sprinklers

Note that when the slope of the ceiling over the ASRS storage area exceeds 2 in 12 (10º) and the ceiling construction is unobstructed, see DS 2-0 to determine if a 50 percent increase to the design area of the ceiling sprinkler system is recommended.

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 Protection Features per Data Sheet 3-0, Hydraulics of Fire Protection Systems

2.1.4.3.1 See Data Sheet 3-0, *Hydraulics of Fire Protection Systems*, for guidelines on calculating the required flow and pressure for the sprinkler designs obtained from this data sheet. See Section 2.1.4.5.5 to determine the number of sprinklers to account for per branch line for ceiling-level sprinkler system hydraulic calculation purposes.

2.1.4.4 Sprinkler Designations and Units

2.1.4.4.1 To distinguish between standard-coverage and extended-coverage sprinklers throughout this data sheet, sprinkler K-factor values that have an “EC” suffix associated with them represent extended-coverage sprinklers; sprinkler K-factor values without a suffix designation represent standard-coverage sprinklers.

2.1.4.4.2 Where ceiling sprinkler or in-rack sprinkler system designs are highlighted in green within a protection table, this represents a protection option where the hose stream demand is 250 gpm (950 L/min) and the sprinkler system duration is 1 hour.

2.1.4.4.3 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 Demand Area

2.1.4.5.2.1 Unobstructed Ceiling Construction

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

A. 384 ft² (35.7 m²) when the number of sprinklers in the indicated ceiling sprinkler design is 6

B. 576 ft^2 (53.5 m^2) when the number of sprinklers in the indicated ceiling sprinkler design is 9

C. 640 ft^2 (59.5 m^2) when the number of sprinklers in the indicated ceiling sprinkler design is 10

D. 768 ft^2 (71.3 m^2) when the number of sprinklers in the indicated ceiling sprinkler 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

A. When ceiling sprinklers can be installed under the ceiling structural members in the presence of obstructed ceiling construction, follow the guidelines for minimum ceiling demand area indicated in Section 2.1.4.5.2.1.

B. 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 demand 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 Hose Demand Design and Water Supply Duration for Horizontal-Loading ASRS Storage Arrangements

Unless indicated otherwise, see Table 2.1.4.5.4 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 2.1.4.5.4. 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

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

Use Table 2.1.4.5.5 to determine the number of ceiling-level sprinklers per branch line to include for hydraulic calculation purposes.

When using Equation 1 or Equation 2, if the calculated number from the applicable equation does not result in 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).

Table 2.1.4.5.5. Determining the Number of Ceiling Sprinklers Per Branch Line for Sprinkler System Hydraulic Calculation

Ceiling Sprinkler Coverage Type	*Number of Sprinklers in Ceiling Demand Area*	*Max. Ceiling Slope*	*Average Ceiling Sprinkler On-Line Spacing, ft (m)*	*Max. Number of Sprinklers per Branch Line in Demand Area*
Extended-Coverage	6 or less	4 in 12 (18.5º)	Any	3
	8	1 in 12 (5º)	< 12 (3.7)	4
			≥ 12 (3.7)	3
		4 in 12 (18.5º)	Any	4
	9	4 in 12 (18.5º)	Any	4
	10 or more	1 in 12 (5º)	Any	See Equation 1
		4 in 12 (18.5º)	Any	See Equation 1 if unobstructed construction, or Equation 2 if obstructed construction
Standard-Coverage	6	1 in 12 (5º)	Any	2
		4 in 12 (18.5º)	Any	3
	7 through 9	2 in 12 (10º)	Any	3
		4 in 12 (18.5º)	Any	See Equation 1
	10 through 12	1 in 12 (5º)	< 9 (2.7)	4
			≥ 9 (2.7)	3
		2 in 12 (10º)	< 10 (3.0)	4
			≥ 10 (3.0)	3
		4 in 12 (18.5º)	Any	4
	13 or more	1 in 12 (5º)	Any	See Equation 1
		4 in 12 (18.5º)	Any	See Equation 1 if unobstructed construction, or Equation 2 if obstructed construction

Equation 1:

Max. Number of Sprinklers per Branch Line in Demand Area = (1.2 / S_{AVG}) x SQRT ([Number of Sprinklers in Ceiling Demand Area x S_{AVG} x L_{AVG}])

Where:

S_{AVG} = Average on-line sprinkler spacing, ft (m)

L_{AVG} = Average between line sprinkler spacing, ft (m)

Equation 2:

Max. Number of Sprinklers per Branch Line in Demand Area =(1.4 / S_{AVG}) x SQRT ([Number of Sprinklers in Ceiling Demand Area x S_{AVG} x L_{AVG}])

Where:

S_{AVG} = Average on-line sprinkler spacing, ft (m)

L_{AVG} = Average between line sprinkler spacing, ft (m)

2.1.4.6 Oxygen Reduction Systems

An oxygen reduction system can be an acceptable alternative to automatic sprinkler protection when the following items are met:

1. The oxygen reduction system is FM Approved, and
2. The minimum value for the “limiting oxygen concentration for fire propagation (LOC_{FP})” is in accordance with the guidelines provided in FM Property Loss Prevention Data Sheet 4-13, *Oxygen Reduction Systems*, and
3. The installation and maintenance of the oxygen reduction system is in accordance with both Data Sheet 4-13 as well as the system manufacturer’s DIOM (design, installation, operation, and maintenance) manual.

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 or confirming 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

Section 2.2 provides protection guidelines for horizontal-loading automatic storage and retrieval systems (ASRS). Use the flowchart in Figure 2.2 to understand how best to navigate Section 2.2 based on the type of ASRS to be protected.

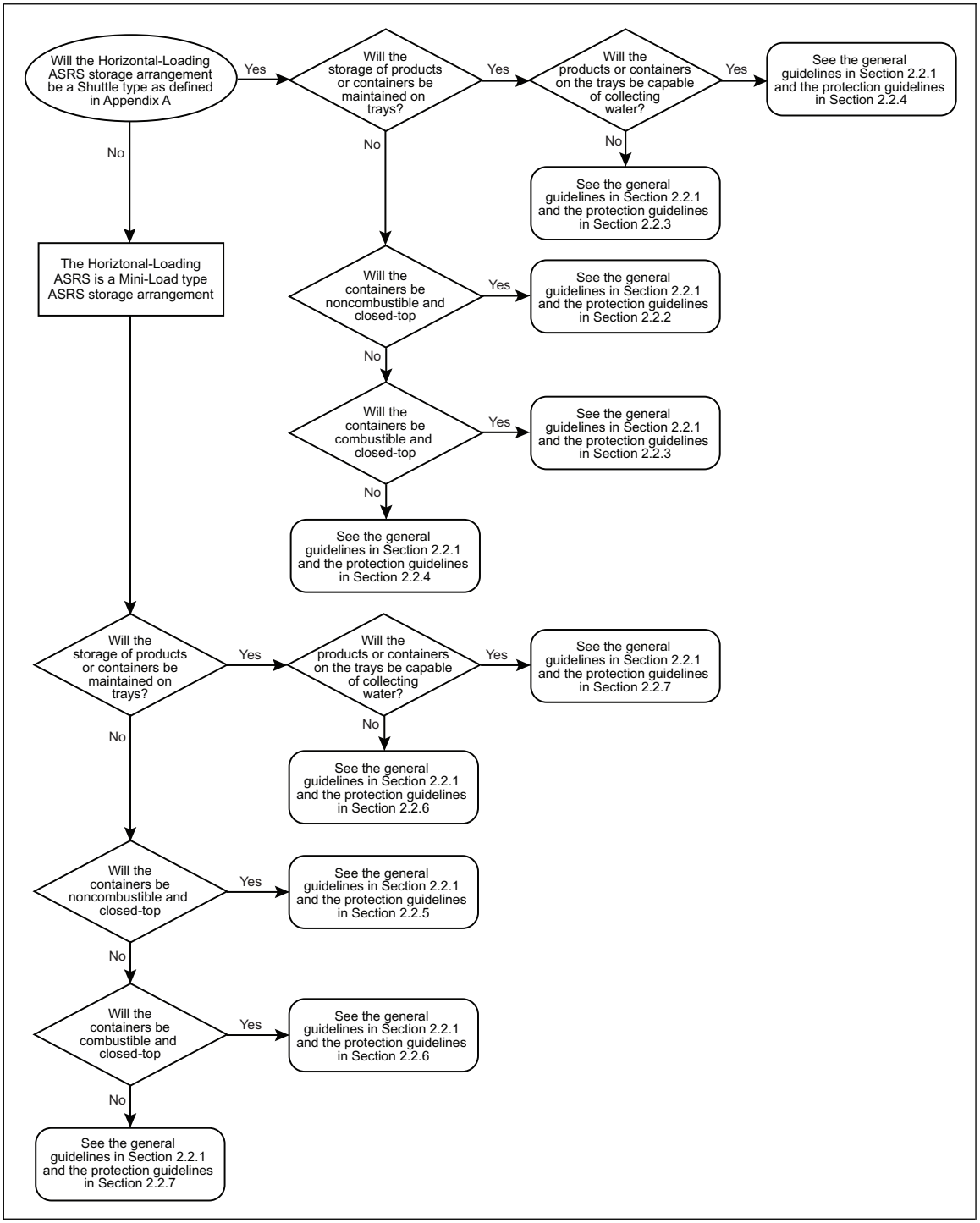

Fig. 2.2. Summarized guidance on how to navigate Section 2.2

2.2.1 General Guidelines for Horizontal-Loading ASRS Storage Arrangements

2.2.1.1 How to Use Section 2.2.1

Section 2.2.1 provides general guidelines for the protection of horizontal-lo ASRS. Use the flowchart in Figure 2.2.1.1 to determine how to navigate Section 2.2.1 to obtain the general recommendations offered for horizontal-loading ASRS.

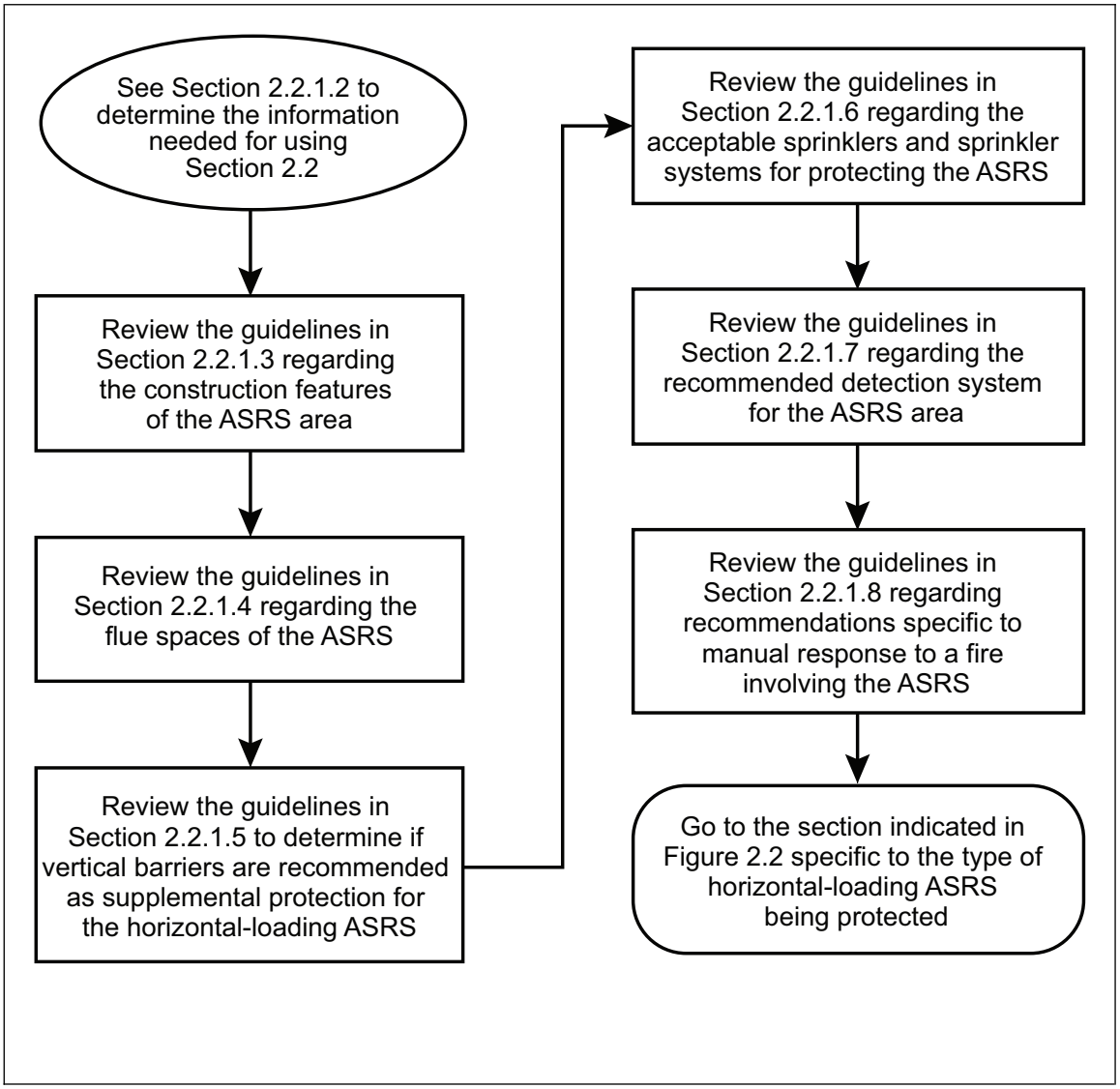

Fig. 2.2.1.1. Summarized guidance on how to navigate Section 2.2.1

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 Guidelines for Horizontal-Loading ASRS Storage Arrangements – Transverse Flue Spaces

2.2.1.4.1 Determining the Gross and Net Widths of Transverse Flue Spaces

2.2.1.4.1.1 The gross width of a transverse flue space is determined by taking the horizontal distance between containers and/or trays as demonstrated in Figure 2.2.1.4.1.1.

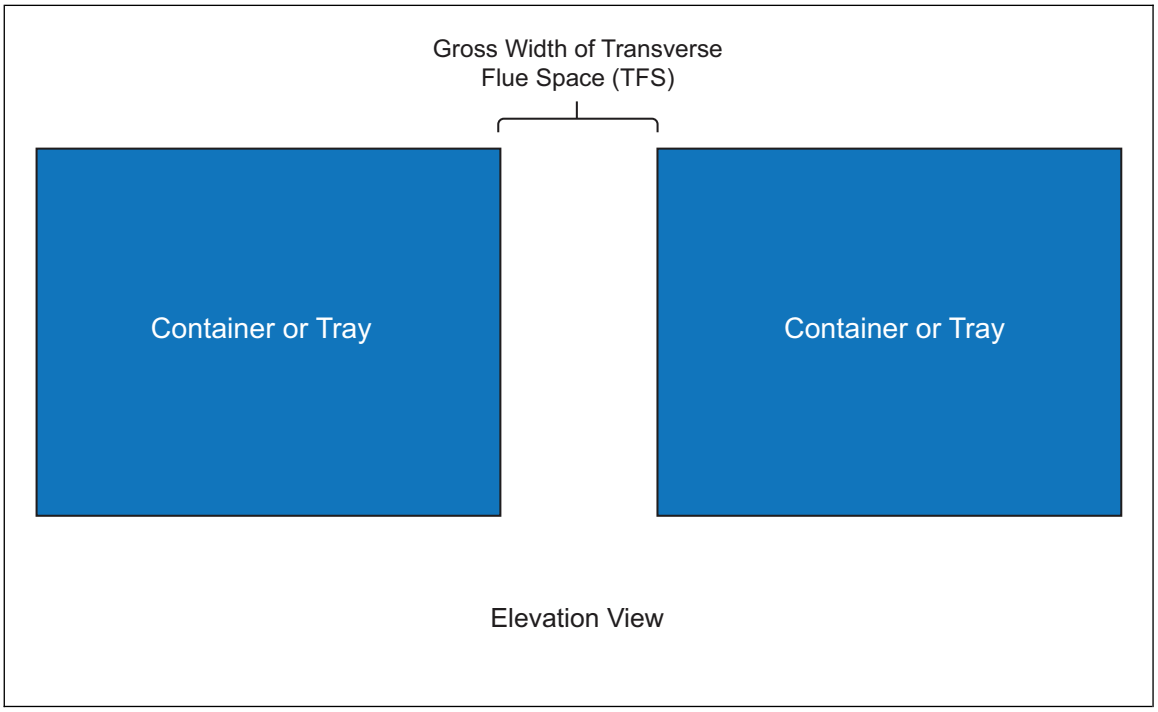

Fig. 2.2.1.4.1.1. How to determine the gross width of a transverse flue space within a horizontal-loading ASRS

2.2.1.4.1.2 The net width of a transverse flue space is determined by summing the horizontal openings available between containers and/or trays as measured on a vertical plane between tier levels as shown in Figure 2.2.1.4.1.2.

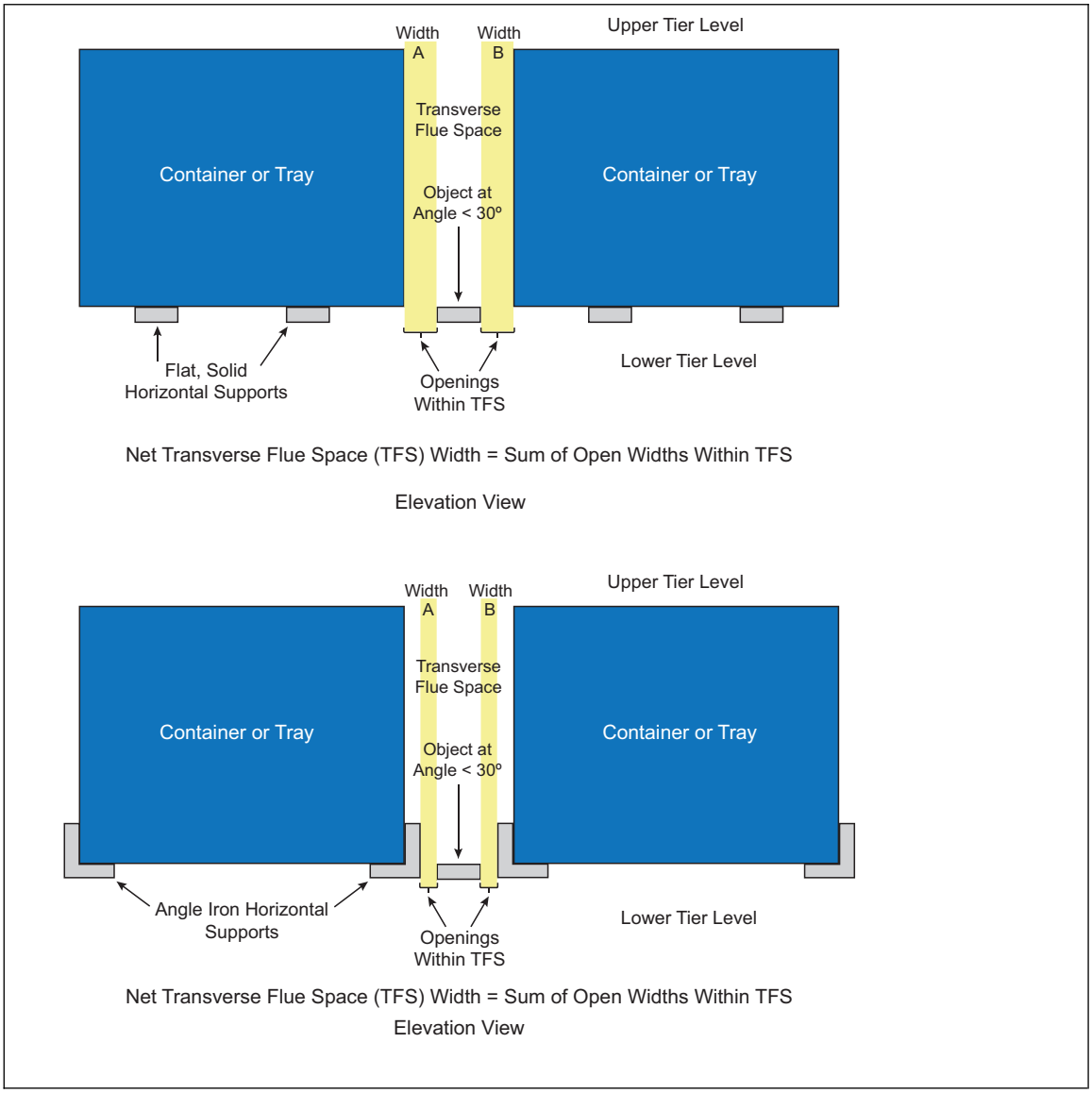

Fig. 2.2.1.4.1.2. Example of how to measure the net transverse flue space width in a shuttle or a mini-load ASRS

2.2.1.4.1.3 When determining the net width of a transverse flue space, an object located within the transverse flue space can be ignored when:

1. The object has a horizontal profile that is equal to or greater than 70% uniformly open (e.g., mesh shelving) as represented in Figure 2.2.1.4.1.3(a), or

2. The object is no wider than 4 in. (100 mm) and is at an angle of 30º or more (e.g., cross bracing within a rack upright) as represented in Figure 2.2.1.4.1.3(b).

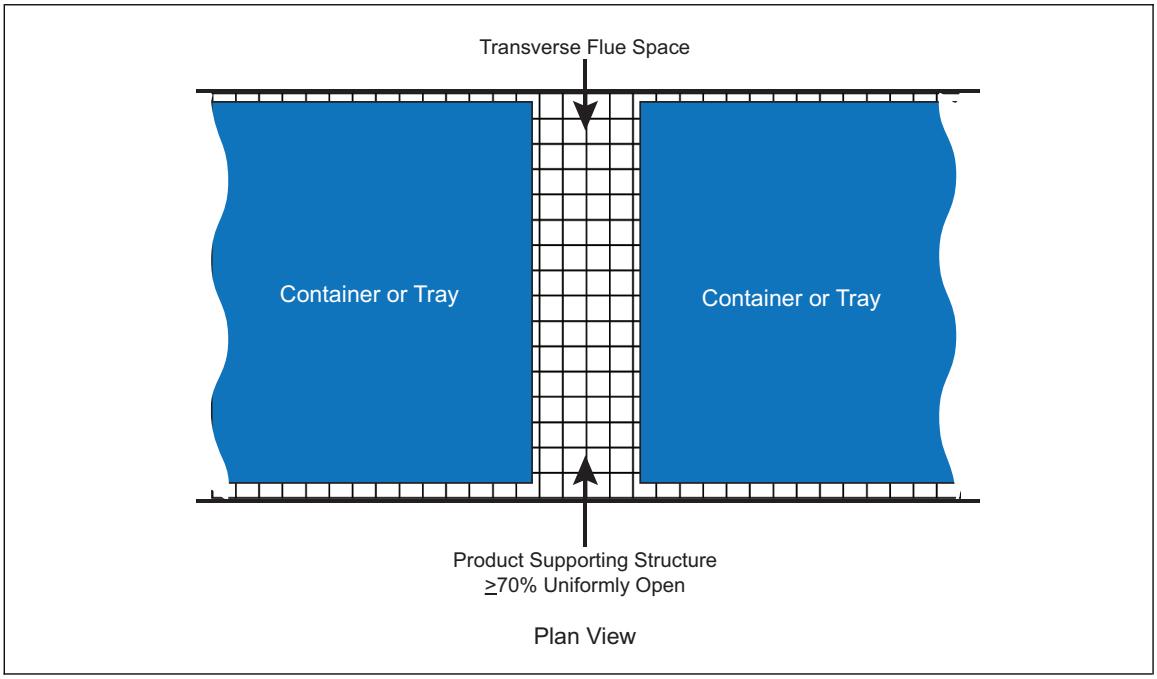

Fig. 2.2.1.4.1.3(a). Example of an object within the transverse flue space having a horizontal profile ≥ 70% uniformly open

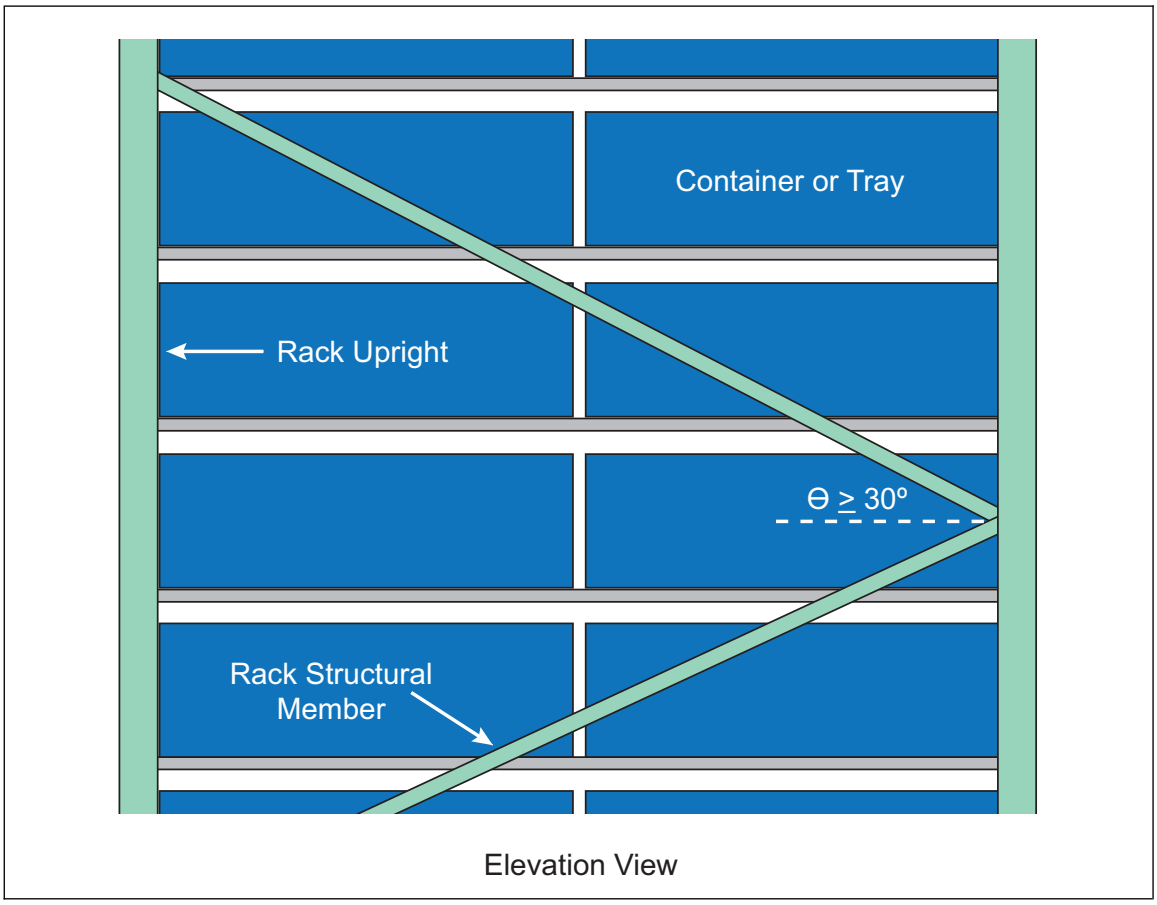

Fig. 2.2.1.4.1.3(b). Example of an object no wider than 4 in. (100 mm) within the transverse flue space at an angle ≥ 30°

2.2.1.4.2 Recommended Minimum Transverse Flue Space Widths

2.2.1.4.2.1 See Table 2.2.1.4.2.1 to determine the recommended minimum net transverse flue space widths depending on the horizontal distance between transverse flue spaces having a minimum net width of 1.5 in. (38 mm). Do not treat any gaps less than 1.5 in. (38 mm) wide as transverse flue spaces. See Figure 2.2.1.4.2.1 for a visual demonstration of how to measure the nominal horizontal distance between transverse flue spaces.

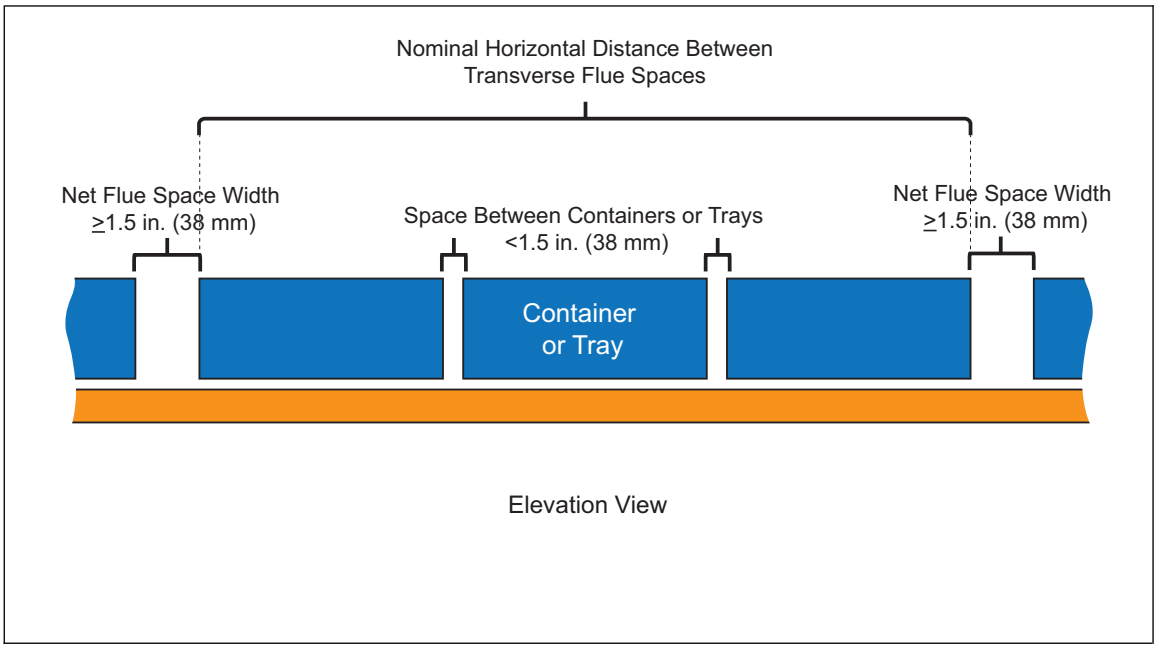

Fig. 2.2.1.4.2.1. Example of how to measure the nominal horizontal distance between transverse flue spaces that are at least 1.5 in. (38 mm) wide

Table 2.2.1.4.2.1. Recommended Minimum Net Transverse Flue Space Widths within a Horizontal-Loading ASRS

Nominal Horizontal Distance Between Transverse Flue Spaces, ft (m)	*Recommended Minimum Nominal Net Transverse Flue Space Width, in. (mm)*
2 (0.6)	1.5 (38)
2.5 (0.75)	2 (50)
5 (1.5)	3 (75)
10 (3.0)	6 (150)
> 10 (3.0)	In-rack sprinklers are needed. See Section 2.2.1.5 to see if vertical barriers are needed too

2.2.1.4.2.2 Transverse flue spaces are considered adequate when:

1. They meet the guidelines indicated in Table 2.2.1.4.2.1, and
2. They are vertically aligned and not obstructed throughout the height of the horizontal-loading ASRS storage array as demonstrated in Figure 2.2.1.4.2.2.

2.2.1.4.2.3 When transverse flue spaces are not in compliance with Table 2.2.1.4.2.1 and Section 2.2.1.4.2.2, in-rack sprinklers will be needed and the vertical distance between in-rack sprinklers will be limited to 10 ft (3.0 m).

2.2.1.4.2.4 When there are transverse flue spaces between rack uprights that have a minimum gross width of 1.5 in. (38 mm) but have a maximum net width of 0.5 in. (13 mm), see Section 2.2.1.5 to determine if vertical barriers will be needed in addition to in-rack sprinklers.

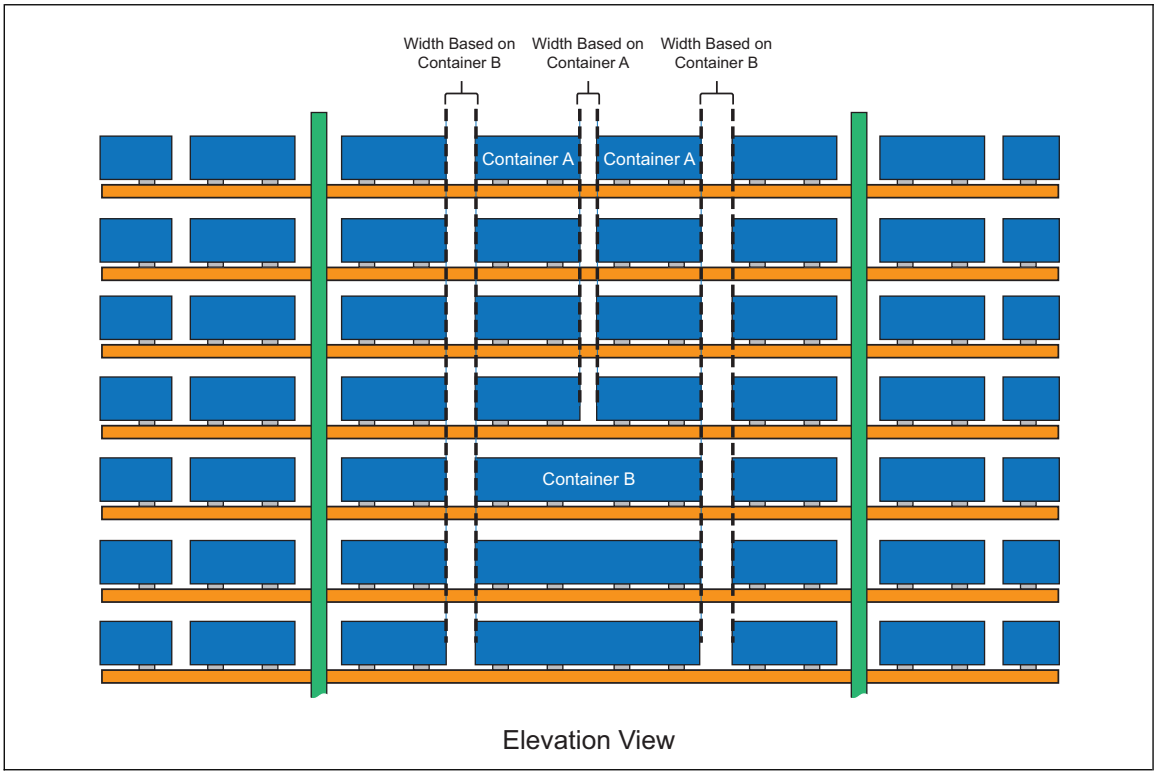

Fig. 2.2.1.4.2.2. Example of transverse flue spaces that are vertically aligned in a horizontal-loading ASRS

2.2.1.5 Vertical Barriers for Horizontal-Loading ASRS Storage Arrangements

2.2.1.5.1 Vertical barriers are recommended at rack uprights on spacing not exceeding 12 ft (3.7 m) when:

1. Transverse flue spaces between rack uprights have a minimum gross width of 1.5 in. (38 mm), and

2. Material handling supports within the rack structure, such as vertical alignment guides or similar, result in the transverse flue spaces between rack uprights having a maximum net width of 0.5 in. (13 mm), and

3. The horizontal distance between the affected transverse flue spaces outlined above is greater than 10 ft (3.0 m)

See Figure 2.2.1.5.1 for a visual demonstration of this guidance.

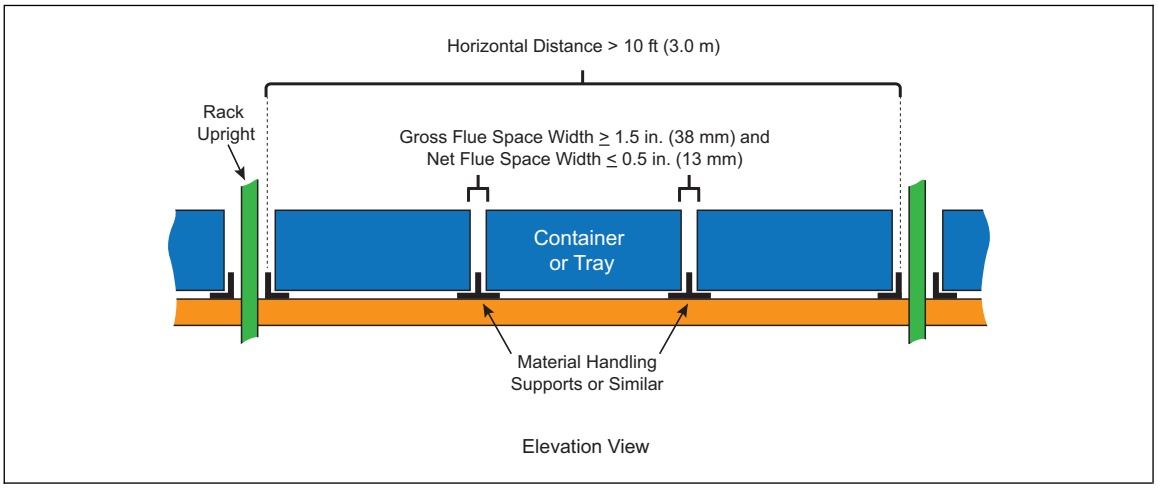

Fig. 2.2.1.5.1. Example of material handling supports creating a condition where vertical barriers would be needed

2.2.1.5.2 Arrange the vertical barriers to span the entire depth of the rack row as well as the entire storage height located between each vertical level of in-rack sprinklers.

2.2.1.5.3 The vertical barriers do not need to extend up into the horizontal space where the in-rack sprinklers are being installed.

2.2.1.6 General Protection Guidelines for Horizontal-Loading ASRS Storage Arrangements

2.2.1.6.1 Sprinkler System Types

2.2.1.6.1.1 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.

2.2.1.6.1.2 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.

2.2.1.6.2 Sprinklers

2.2.1.6.2.1 Ceiling-Level Sprinklers

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

2.2.1.6.2.2 In-Rack Sprinklers

a. 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.

b. Use in-rack sprinklers equipped with water shields when 2 levels of in-rack sprinklers are indicated for the in-rack sprinkler system design.

c. The use of water shields for in-rack sprinklers as outlined in Section 2.2.1.6.2.2(b) can be avoided when in-rack sprinklers are installed in the presence of horizontal barriers or solid shelves that block water from discharging on the in-rack sprinklers.

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 are Being Used

2.2.2.1 When noncombustible closed-top containers are used throughout the horizontal-loading ASRS storage area, install ceiling-level sprinkler protection over the horizontal-loading ASRS storage area using a design that, as a minimum, will be acceptable for the protection of the occupancies adjacent to the horizontal-loading ASRS storage area.

2.2.2.2 When the horizontal-loading ASRS storage area will not consist entirely of noncombustible closed-top containers, design and install sprinkler protection for the horizontal-loading ASRS storage area designed for the protection of the worst-case container being used.

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 supporting 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.

See the flowchart in Figure 2.2.3 for guidance on how to navigate this section.

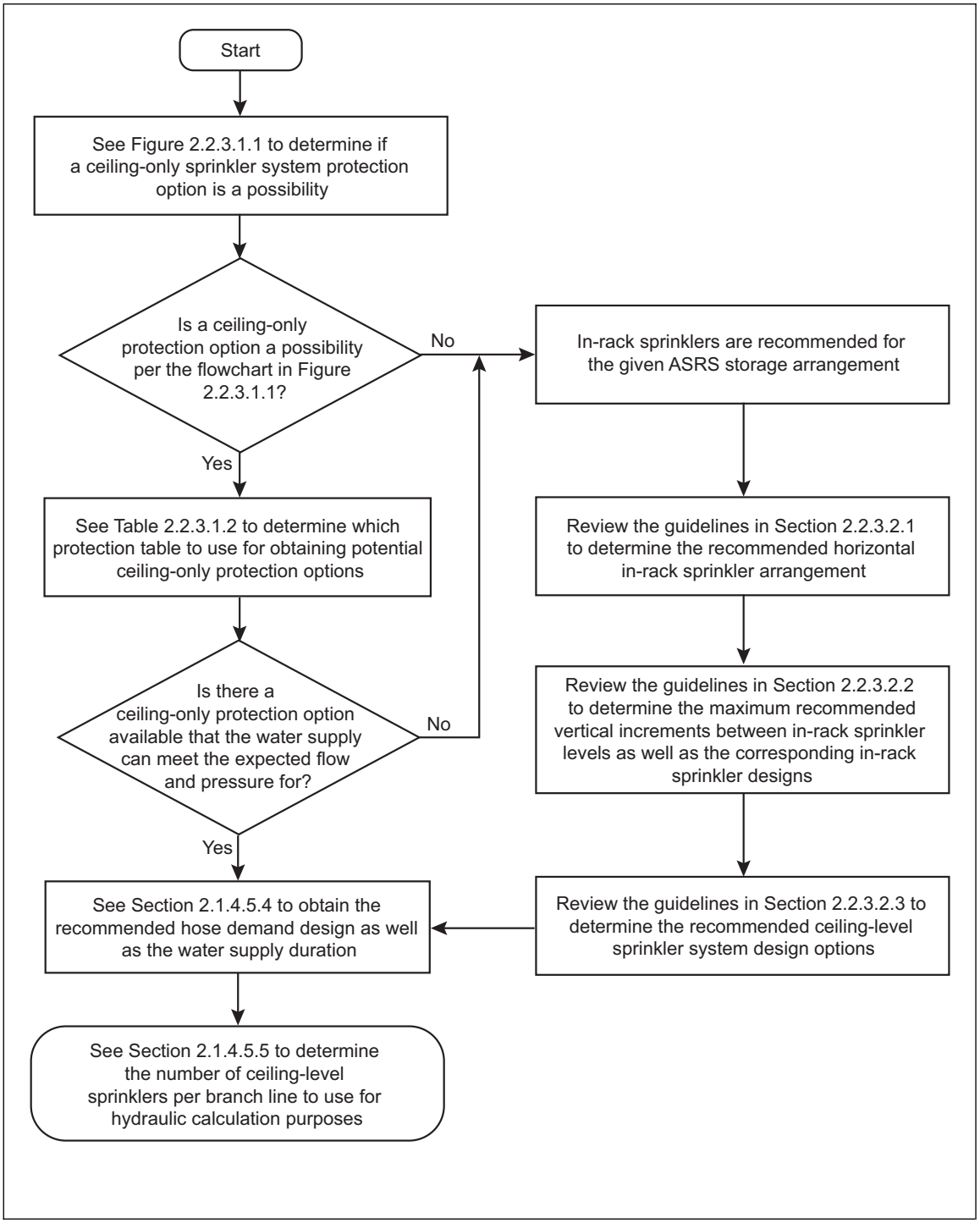

Fig. 2.2.3. Flowchart for how to navigate Section 2.2.3

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

2.2.3.1.1 See the flowchart in Figure 2.2.3.1.1 to determine if a ceiling-only sprinkler system protection scheme is a potential option.

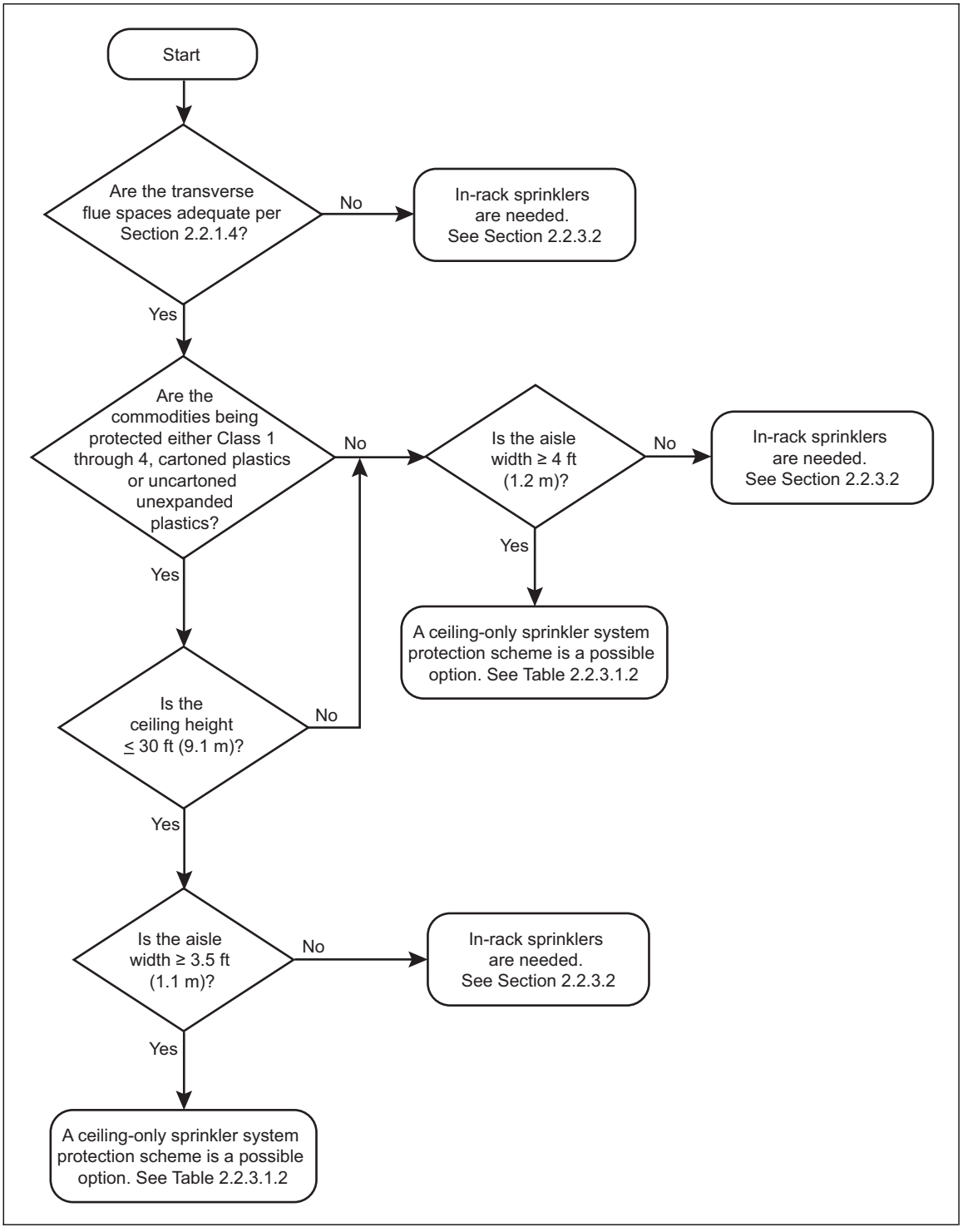

Fig. 2.2.3.1.1. Flowchart to determine if a ceiling-only sprinkler system protection scheme is a potential option

2.2.3.1.2 When a ceiling-only protection scheme is a potential option per the flowchart in Figure 2.2.3.1.1, use Table 2.2.3.1.2 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.

Table 2.2.3.1.2. 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	2.2.3.1.2(a)
		Dry	2.2.3.1.2(f)
	Class 4 and Cartoned Unexpanded Plastics	Wet	2.2.3.1.2(b)
		Dry	2.2.3.1.2(g)
	Cartoned Expanded Plastics	Wet	2.2.3.1.2(c)
		Dry	2.2.3.1.2(h)
	Uncartoned Unexpanded Plastics	Wet	2.2.3.1.2(d)
		Dry	2.2.3.1.2(i)
	Uncartoned Expanded Plastics	Wet	2.2.3.1.2(e)
		Dry	2.2.3.1.2 (j)
On Trays	Class 1 through 4, Cartoned Plastics, and Uncartoned Unexpanded Plastics	Wet	2.2.3.1.2(d)
		Dry	2.2.3.1.2(i)
	Uncartoned Expanded Plastics	Wet	2.2.3.1.2(e)
		Dry	2.2.3.1.2(j)

Note: In Tables 2.2.3.1.2(a) through 2.2.3.1.2(e), 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 2.2.3.1.2(a). Ceiling-Level Sprinkler Protection Guidelines on a Wet System for the Protection of 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 2.2.3.1.2(b). Ceiling-Level Sprinkler Protection Guidelines on a Wet System for the Protection of 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 2.2.3.1.2(c). Ceiling-Level Sprinkler Protection Guidelines on a Wet System for the Protection of 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 2.2.3.1.2(d). Ceiling-Level Sprinkler Protection Guidelines on a Wet System for the Protection of 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 2.2.3.1.2(e). Ceiling-Level Sprinkler Protection Guidelines on a Wet System for the Protection of 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 2.2.3.1.2(f). Ceiling-Level Sprinkler Protection Guidelines on a Dry System for the Protection of 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 2.2.3.1.2(g). Ceiling-Level Sprinkler Protection Guidelines on a Dry System for the Protection of 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 2.2.3.1.2(h). Ceiling-Level Sprinkler Protection Guidelines on a Dry System for the Protection of 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 2.2.3.1.2(i). Ceiling-Level Sprinkler Protection Guidelines on a Dry System for the Protection of 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 2.2.3.1.2(j). Ceiling-Level Sprnkler Protection Guidelines on a Dry System for the Protection of 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)

2.2.3.1.3 See Section 2.1.4.5.4 to determine the ceiling sprinkler's hose demand design and water supply duration.

2.2.3.1.4 See Section 2.1.4.5.5 to determine the number of sprinklers per branch line for ceiling-level sprinkler calculations.

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 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 2.2.3.2.1 to determine the recommended horizontal in-rack sprinkler arrangements for the storage rack to be protected.

Table 2.2.3.2.1. Recommended Horizontal In-Rack Sprinkler (i.e., IRAS) Arrangements for Closed-Top Combustible Containers, or Storage on Trays

Overall Maximum Rack Depth, ft (m)	*IRAS System Type*	*Commodity Hazards*	*Ceiling Height, ft (m)*	*Aisle Width, ft (m)*	*Applicable Horizontal IRAS Arrangement Figures*
3 (0.9)	Wet or Dry	Any	Any	Any	2.2.3.2.1(a)
8 (2.4)	Wet or Dry	Any	≤ 30 (9.1)	< 3.5 (1.1)	2.2.3.2.1(b)
				≥ 3.5 (1.1)	2.2.3.2.1(b) or 2.2.3.2.1(c)
		Up to Cartoned Plastics	> 30 (9.1)	< 4 (1.2)	2.2.3.2.1(b)
				≥ 4 (1.2)	2.2.3.2.1(b) or 2.2.3.2.1(c)
		Uncartoned Plastics	> 30 (9.1)	Any	2.2.3.2.1(b)
9 (2.7)	Wet	Up to Cartoned Plastics	≤ 30 (9.1)	< 3.5 (1.1)	2.2.3.2.1(d)
				≥ 3.5 (1.1)	2.2.3.2.1(c) or 2.2.3.2.1(d)
			> 30 (9.1)	< 4 (1.2)	2.2.3.2.1(d)
				≥ 4 (1.2)	2.2.3.2.1(c) or 2.2.3.2.1(d)
		Uncartoned Plastics	Any	Any	2.2.3.2.1(d)
	Dry	Any	Any	Any	2.2.3.2.1(d)
13 (4.0)	Wet or Dry	Any	Any	Any	2.2.3.2.1(d)
Over 13 (4.0)	Wet or Dry	Any	Any	Any	2.2.3.2.1(e)

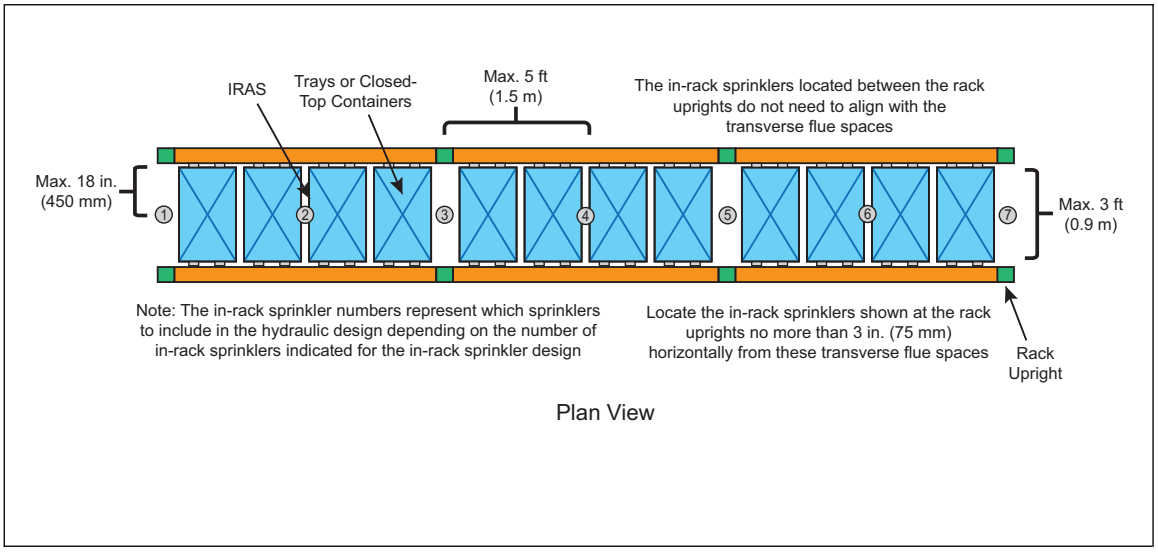

Fig. 2.2.3.2.1(a). Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Shuttle ASRS Where Rack Row Depths Do Not Exceed 3 ft (0.9 m) per Table 2.2.3.2.1

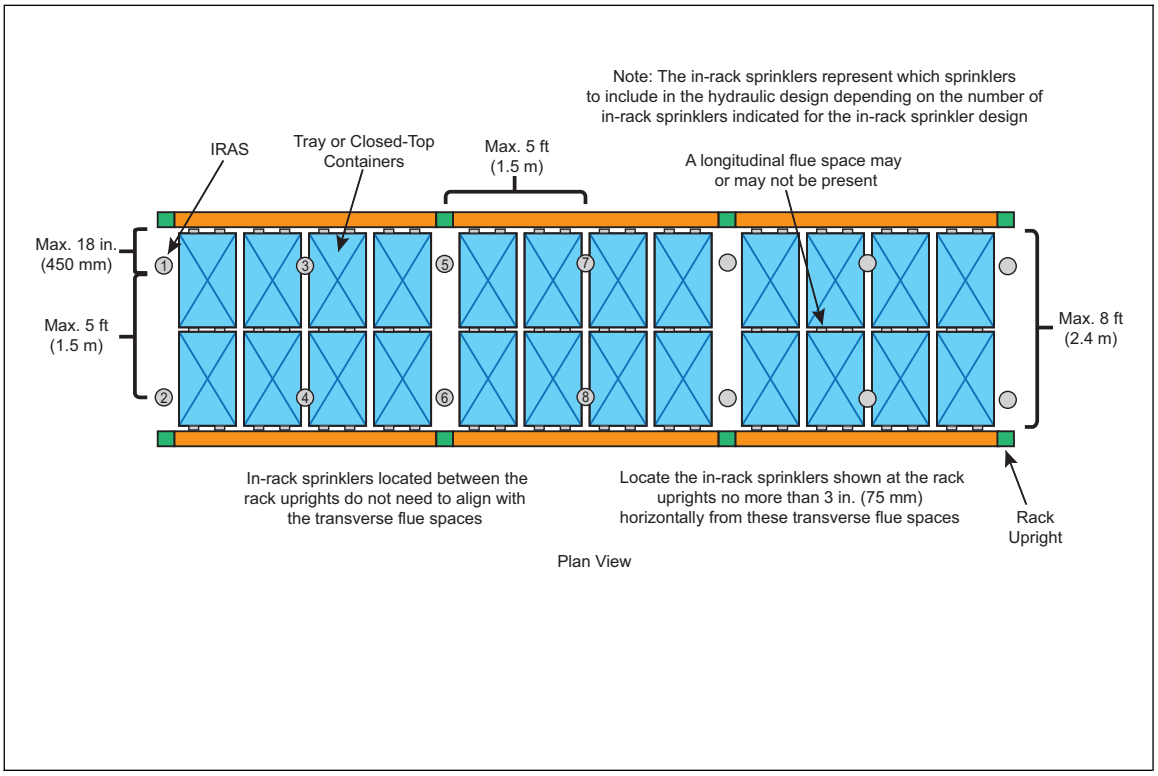

Fig. 2.2.3.2.1(b). Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Shuttle ASRS Where the Overall Rack Depths Do Not Exceed 8 ft (2.4 m) per Table 2.2.3.2.1

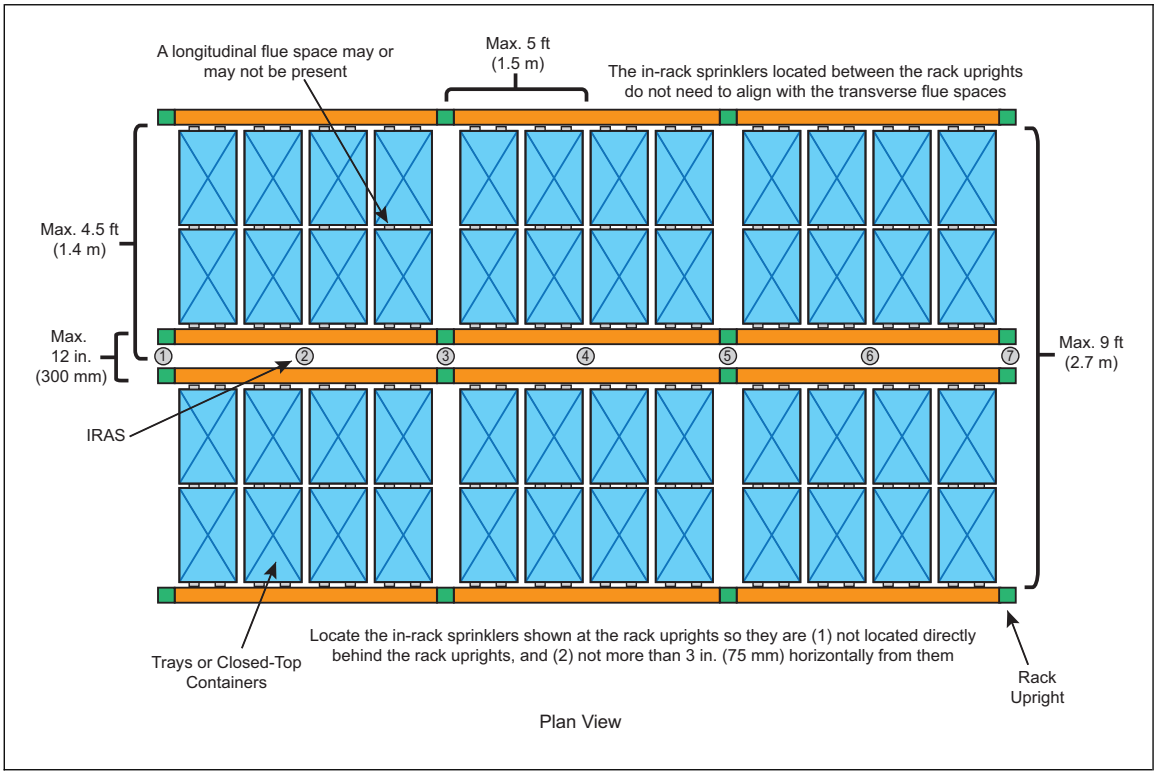

Fig. 2.2.3.2.1(c). Horizontal IRAS Arrangement Without Face Sprinklers for Closed-Top Combustible Containers, or Storage on Trays within a Shuttle ASRS Where the Overall Rack Depths Do Not Exceed 9 ft (2.7 m) per Table 2.2.3.2.1

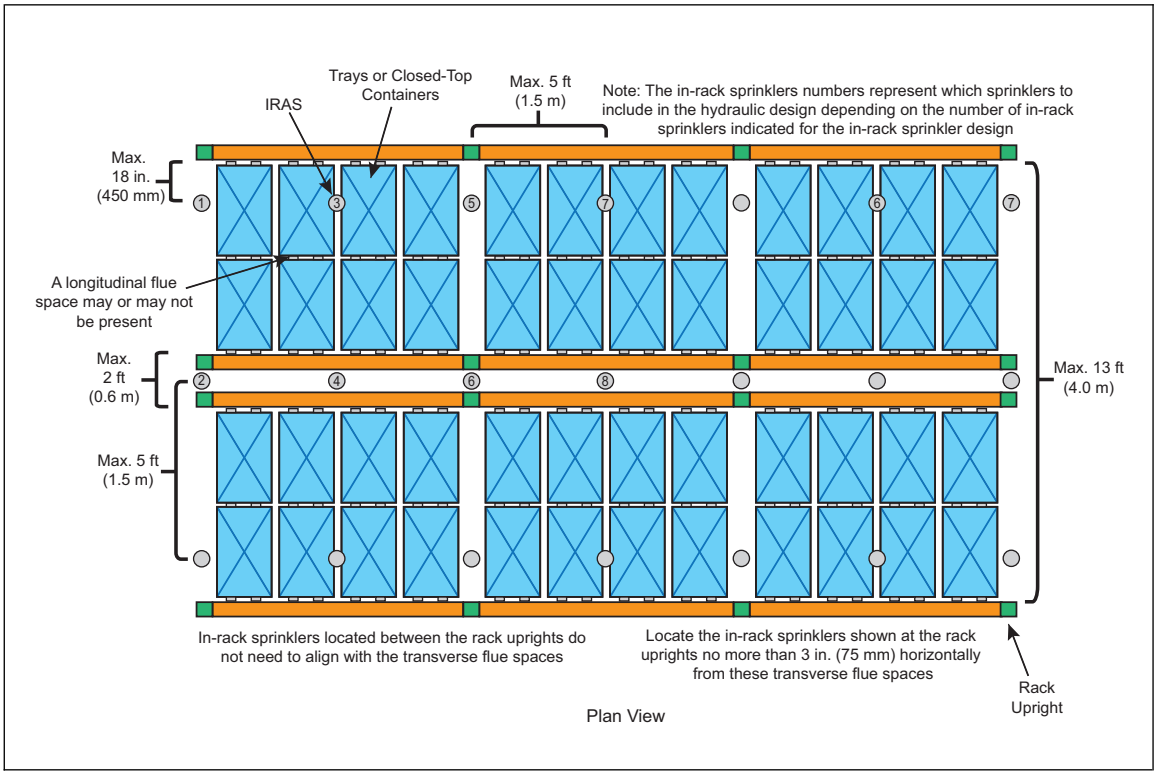

Fig. 2.2.3.2.1(d). Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Shuttle ASRS Where the Overall Rack Depths Do Not Exceed 13 ft (4.0 m) per Table 2.2.3.2.1

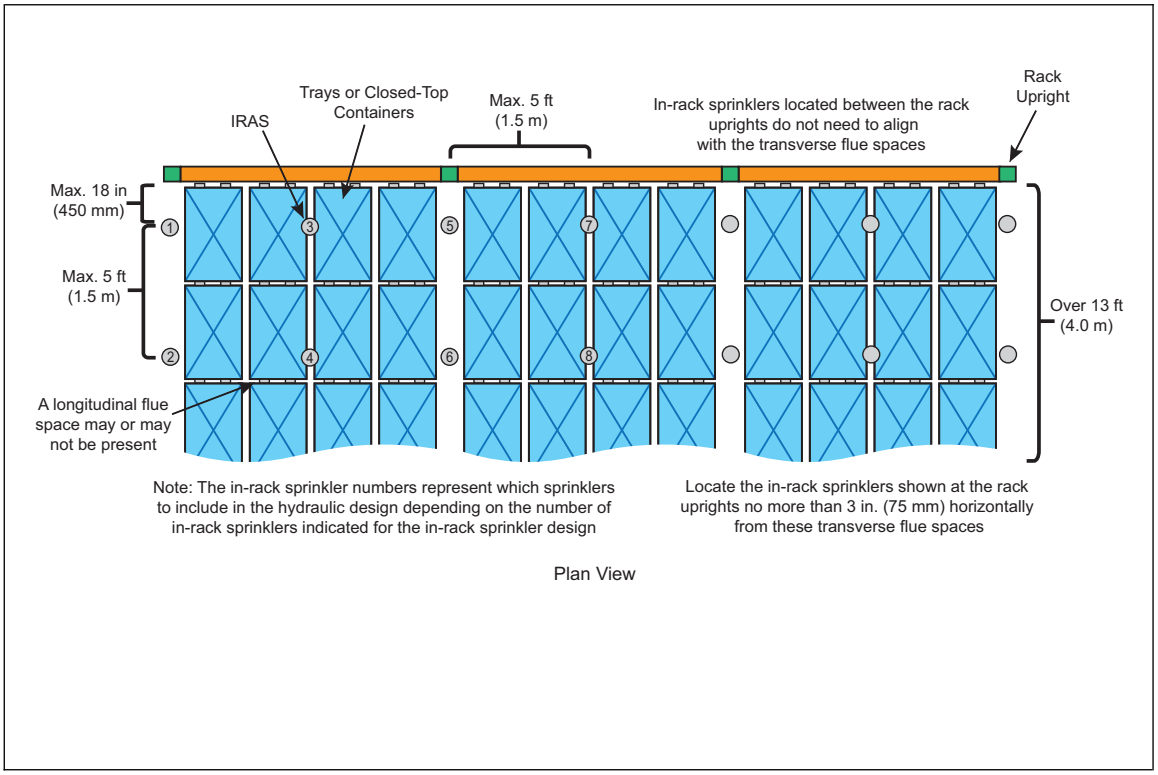

Fig. 2.2.3.2.1(e). Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Shuttle ASRS Where the Overall Rack Depths Exceed 13 ft (4.0 m) per Table 2.2.3.2.1

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 See the flowchart in Figure 2.2.3.2.2.1 to determine which protection table to use for obtaining the allowable in-rack sprinkler vertical locations, as well as the corresponding recommended in-rack sprinkler design.

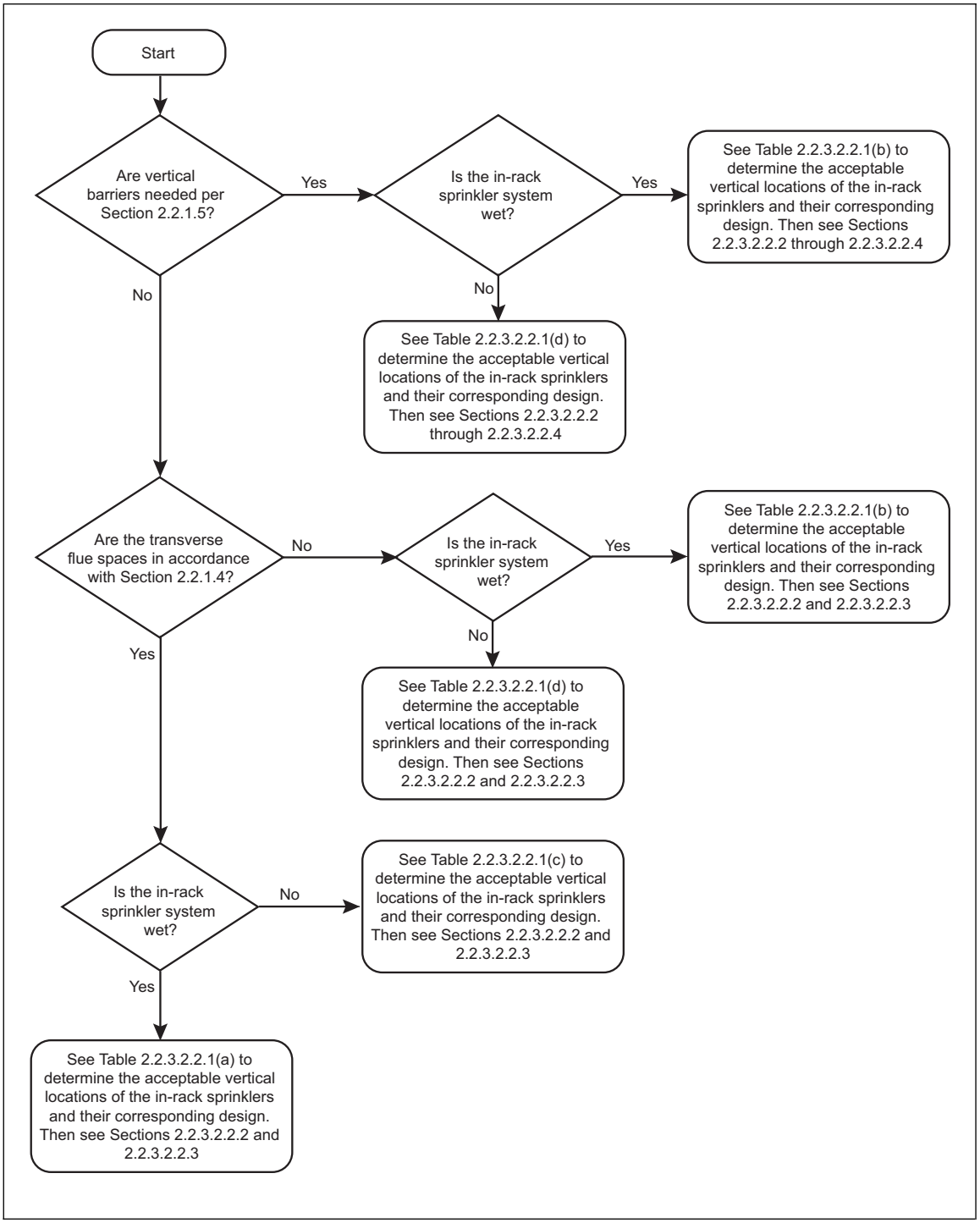

Fig. 2.2.3.2.2.1. Flowchart to determine which table to use to find the acceptable vertical locations and designs of in-rack sprinklers.

Table 2.2.3.2.2.1(a). Wet, In-Rack Sprinkler System Designs for the Protection of Closed-Top Combustible Containers, or Storage on Trays, Stored in a Shuttle ASRS with Flue Spaces in Accordance with Section 2.2.1.4

Recommended Horizontal IRAS Arrangement per Table 2.2.3.2.1	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 2.2.3.2.1(a) or 2.2.3.2.1(b)	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

*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 2.2.3.2.2.1(a). Wet, In-Rack Sprinkler System Designs for the Protection of Closed-Top Combustible Containers, or Storage on Trays, Stored in a Shuttle ASRS with Flue Spaces in Accordance with Section 2.2.1.4 (continued)

Recommended Horizontal IRAS Arrangement per Table 2.2.3.2.1	*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 2.2.3.2.1(c)	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

* 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 2.2.3.2.2.1(a). Wet, In-Rack Sprinkler System Designs for the Protection of Closed-Top Combustible Containers, or Storage on Trays, Stored in a Shuttle ASRS with Flue Spaces in Accordance with Section 2.2.1.4 (continued)

Recommended Horizontal IRAS Arrangement per Table 2.2.3.2.1	*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 2.2.3.2.1(d) or 2.2.3.2.1(e)	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 2.2.3.2.2.1(b). Wet, In-Rack Sprinkler System Designs for the Protection of Closed-Top Combustible Containers, or Storage on Trays, Stored in a Shuttle ASRS with Flue Spaces Not in Accordance with Section 2.2.1.4

Recommended Horizontal IRAS Arrangement per Table 2.2.3.2.1	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 2.2.3.2.1(a) through 2.2.3.2.1(e)	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)	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)	8 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
				100 (380)	14.0 (200)	8 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)	8 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 5 ft (1.5 m).

Table 2.2.3.2.2.1(c). Dry, In-Rack Sprinkler System Designs for the Protection of Closed-Top Combustible Containers, or Storage on Trays, Stored in a Shuttle ASRS with Flue Spaces in Accordance with Section 2.2.1.4

Recommended IRAS Arrangement per Table 2.2.3.2.1	*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 2.2.3.2.1(a), 2.2.3.2.1(b), 2.2.3.2.1(d), or 2.2.3.2.1(e)	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
Figure 2.2.3.2.1(c)	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.

Table 2.2.3.2.2.1(d). Dry, In-Rack Sprinkler System Designs for the Protection of Closed-Top Combustible Containers, or Storage on Trays, Stored in a Shuttle ASRS with Flue Spaces Not in Accordance with Section 2.2.1.4

Recommended Horizontal IRAS Arrangement per Table 2.2.3.2.1	*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 2.2.3.2.1(a) through 2.2.3.2.1(e)	Class 3	10 (3.0)**	DNA	30 (115)	5.6 (80)	6 if one IRAS level or 10 (5 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

* 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 5 ft (1.5 m)

2.2.3.2.2.2 Any green highlighted protection cell within Table 2.2.3.2.2.1(a) 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 2.2.3.1.2(b) through 2.2.3.1.2(k), 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.

2.2.3.2.2.3 While the in-rack sprinkler designs given in Tables 2.2.3.2.2.1(a) through 2.2.3.2.2.1(d) 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.

2.2.3.2.2.4 When Section 2.2.1.5 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 2.2.3.2.1(d), 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 2.2.3.2.2.1(b) and could use either (1) 9 IRAS if one IRAS level (or 18 on top 2 levels) @ 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.

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 2.2.3.2.2.1(a) 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 2.2.3.2.3.1 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 2.2.3.2.3.1, or
2. Install in-rack sprinklers over the top of storage and design the ceiling sprinkler system per Table 2.2.3.2.3.1.

Table 2.2.3.2.3.1. 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	2.2.3.1.2(a)	10 (3.0)
		5 (1.5)	5 (1.5)	2.2.3.1.2(a)	10 (3.0)
			20 (6.1)	2.2.3.1.2(a)	20 (6.1)
			> 20 (6.1)	2.2.3.1.2(a)	Vertical distance between top IRAS level and ceiling
		10 (3.0)	Any	2.2.3.1.2(a)	Vertical distance between top IRAS level and ceiling
	On Trays	0 (0)	Any	2.2.3.1.2(d)	10 (3.0)
		5 (1.5)	5 (1.5)	2.2.3.1.2(d)	10 (3.0)
			10 (3.0)	2.2.3.1.2(d)	15 (4.6)
			20 (6.1)	2.2.3.1.2(d)	20 (6.1)
			> 20 (6.1)	2.2.3.1.2(d)	Vertical distance between top IRAS level and ceiling
		10 (3.0)	Any	2.2.3.1.2(d)	Vertical distance between top IRAS level and ceiling
Cartoned Unexpanded Plastics	Directly on Supporting Rails	0 (0)	Any	2.2.3.1.2(b)	10 (3.0)
		5 (1.5)	5 (1.5)	2.2.3.1.2(b)	10 (3.0)
			10 (3.0)	2.2.3.1.2(b)	15 (4.6)
			20 (6.1)	2.2.3.1.2(b)	20 (6.1)
			> 20 (6.1)	2.2.3.1.2(b)	Vertical distance between top IRAS level and ceiling
		10 (3.0)	Any	2.2.3.1.2(b)	Vertical distance between top IRAS level and ceiling
	On Trays	0 (0)	Any	2.2.3.1.2(d)	10 (3.0)
		5 (1.5)	5 (1.5)	2.2.3.1.2(d)	10 (3.0)
			10 (3.0)	2.2.3.1.2(d)	15 (4.6)
			20 (6.1)	2.2.3.1.2(d)	20 (6.1)
			> 20 (6.1)	2.2.3.1.2(d)	Vertical distance between top IRAS level and ceiling
		10 (3.0)	Any	2.2.3.1.2(d)	Vertical distance between top IRAS level and ceiling
Cartoned Expanded Plastics	Directly on Supporting Rails	0 (0)	Any	2.2.3.1.2(c)	10 (3.0)
		5 (1.5)	5 (1.5)	2.2.3.1.2(c)	10 (3.0)
			20 (6.1)	2.2.3.1.2(c)	20 (6.1)
			> 20 (6.1)	2.2.3.1.2(c)	Vertical distance between top IRAS level and ceiling
		10 (3.0)	Any	2.2.3.1.2(c)	Vertical distance between top IRAS level and ceiling
	On Trays	0 (0)	Any	2.2.3.1.2(d)	10 (3.0)
		5 (1.5)	5 (1.5)	2.2.3.1.2(d)	10 (3.0)
			10 (3.0)	2.2.3.1.2(d)	15 (4.6)
			20 (6.1)	2.2.3.1.2(d)	20 (6.1)
			> 20 (6.1)	2.2.3.1.2(d)	Vertical distance between top IRAS level and ceiling
		10 (3.0)	Any	2.2.3.1.2(d)	Vertical distance between top IRAS level and ceiling

Table 2.2.3.2.3.1. 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	2.2.3.1.2(d)	10 (3.0)
		5 (1.5)	5 (1.5)	2.2.3.1.2(d)	10 (3.0)
			10 (3.0)	2.2.3.1.2(d)	15 (4.6)
			20 (6.1)	2.2.3.1.2(d)	20 (6.1)
			> 20 (6.1)	2.2.3.1.2(d)	Vertical distance between top IRAS level and ceiling
		10 (3.0)	Any	2.2.3.1.2(d)	Vertical distance between top IRAS level and ceiling
Uncartoned Expanded Plastics	Directly on Supporting Rails or On Trays	0 (0)	Any	2.2.3.1.2(e)	10 (3.0)
		5 (1.5)	5 (1.5)	2.2.3.1.2(e)	10 (3.0)
			10 (3.0)	2.2.3.1.2(e)	15 (4.6)
			20 (6.1)	2.2.3.1.2(e)	25 (7.6)
			> 20 (6.1)	2.2.3.1.2(e)	Vertical distance between top IRAS level and ceiling
		10 (3.0)	Any	2.2.3.1.2(e)	Vertical distance between top IRAS level and ceiling

2.2.3.2.3.2 For wet ceiling sprinkler systems, when Section 2.2.3.2.2.2 is not applicable and Table 2.2.3.2.2.1(a) 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 2.2.3.1.2(b), 2.2.3.1.2(c), 2.2.3.1.2(d), 2.2.3.1.2(e), and 2.2.3.1.2(f) , 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 2.2.3.2.3.3 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 2.2.3.2.3.3, or
2. Install in-rack sprinklers over the top of storage and design the ceiling sprinkler system per Table 2.2.3.2.3.3.

Table 2.2.3.2.3.3. 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	2.2.3.1.2(f)	10 (3.0)
		5 (1.5)	5 (1.5)	2.2.3.1.2(f)	20 (6.1)
			20 (6.1)	2.2.3.1.2(f)	25 (7.6)
		10 (3.0)	5 (1.5)	2.2.3.1.2(f)	25 (7.6)
			20 (6.1)	2.2.3.1.2(f)	30 (9.1)
	On Trays	0 (0)	Any	2.2.3.1.2(f)	20 (6.1)
		5 (1.5)	5 (1.5)	2.2.3.1.2(i)	10 (3.0)
			10 (3.0)	2.2.3.1.2(i)	15 (4.6)
		10 (3.0)	5 (1.5)	2.2.3.1.2(i)	15 (4.6)
Cartoned Unexpanded Plastics	Directly on Supporting Rails	0 (0)	Any	2.2.3.1.2(g)	10 (3.0)
		5 (1.5)	5 (1.5)	2.2.3.1.2(f)	20 (6.1)
			10 (3.0)	2.2.3.1.2(g)	15 (4.6)
			20 (6.1)	2.2.3.1.2(g)	20 (6.1)
		10 (3.0)	5 (1.5)	2.2.3.1.2(g)	20 (6.1)
			20 (6.1)	2.2.3.1.2(g)	25 (7.6)
	On Trays	0 (0)	Any	2.2.3.1.2(f)	20 (6.1)
		5 (1.5)	5 (1.5)	2.2.3.1.2(i)	10 (3.0)
			10 (3.0)	2.2.3.1.2(i)	15 (4.6)
		10 (3.0)	5 (1.5)	2.2.3.1.2(i)	15 (4.6)
Cartoned Expanded Plastics	Directly on Supporting Rails	0 (0)	Any	2.2.3.1.2(f)	20 (6.1)
		5 (1.5)	5 (1.5)	2.2.3.1.2(f)	20 (6.1)
			20 (6.1)	2.2.3.1.2(h)	20 (6.1)
		10 (3.0)	5 (1.5)	2.2.3.1.2(h)	20 (6.1)
			10 (3.0)	2.2.3.1.2(g)	25 (7.6)
	On Trays	(0)	Any	2.2.3.1.2(f)	20 (6.1)
		5 (1.5)	5 (1.5)	2.2.3.1.2(i)	10 (3.0)
			10 (3.0)	2.2.3.1.2(i)	15 (4.6)
		10 (3.0)	5 (1.5)	2.2.3.1.2(i)	15 (4.6)
Uncartoned Unexpanded Plastics	Directly on Supporting Rails or On Trays	0 (0)	Any	2.2.3.1.2(i)	10 (3.0)
		5 (1.5)	5 (1.5)	2.2.3.1.2(i)	10 (3.0)
			10 (3.0)	2.2.3.1.2(i)	15 (4.6)
		10 (3.0)	5 (1.5)	2.2.3.1.2(i)	15 (4.6)
Uncartoned Expanded Plastics	Directly on Supporting Rails or On Trays	0 (0)	Any	2.2.3.1.2(i)	10 (3.0)
		5 (1.5)	5 (1.5)	2.2.3.1.2(j)	10 (3.0)
			10 (3.0)	2.2.3.1.2(j)	15 (4.6)
		10 (3.0)	5 (1.5)	2.2.3.1.2(j)	15 (4.6)

2.2.3.2.3.4 See Section 2.1.4.5.4 to determine the ceiling sprinkler's hose demand design and water supply duration.

2.2.3.2.3.5 See Section 2.1.4.5.5 to determine the number of sprinklers per branch line for ceiling-level sprinkler calculations.

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

See the flowchart in Figure 2.2.4 for guidance on how to navigate this section. Note that the protection of expanded plastic containers is outside the scope of this data sheet.

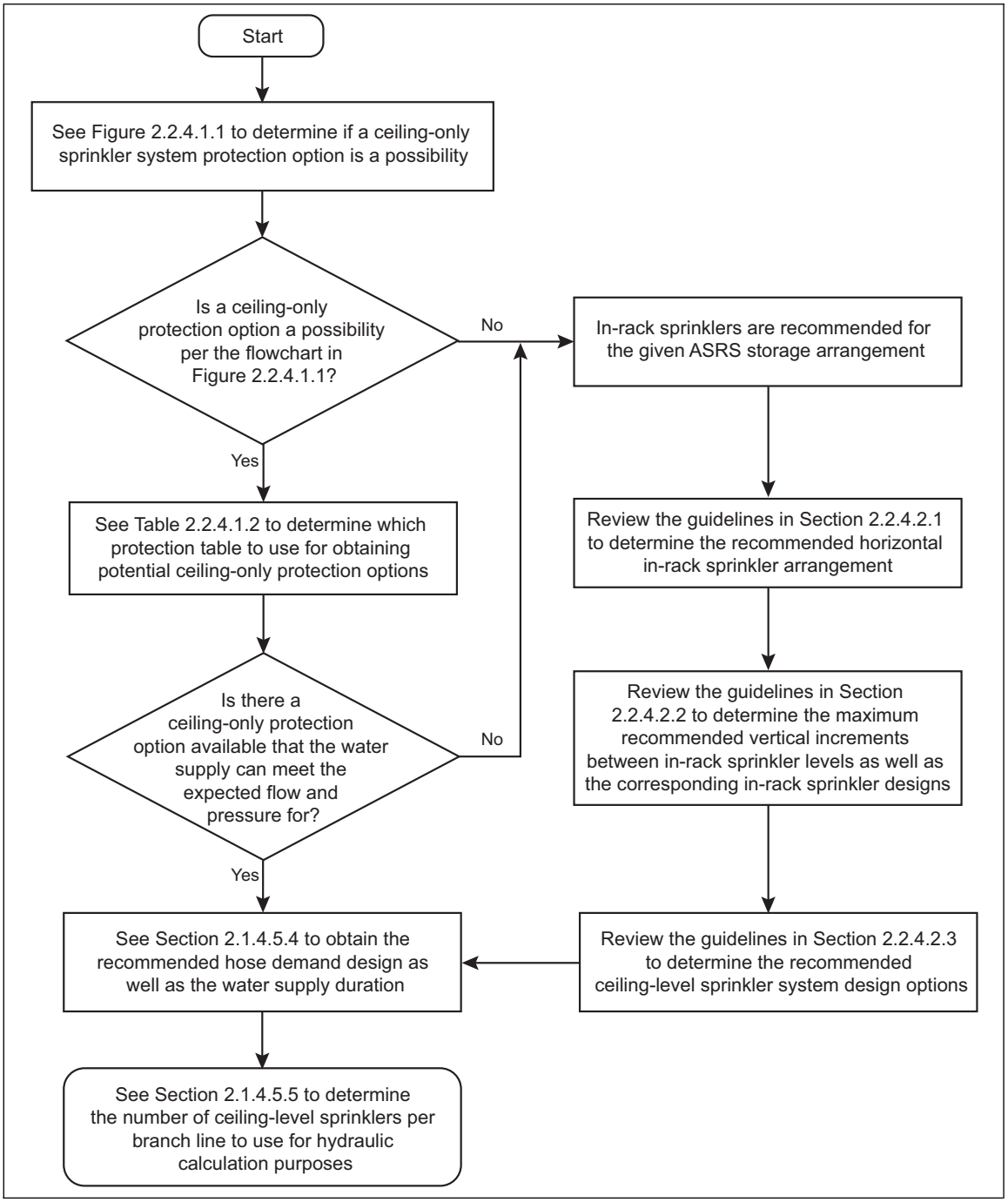

Fig. 2.2.4. Flowchart for how to navigate Section 2.2.4

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 See the flowchart in Figure 2.2.4.1.1 to determine if a ceiling-only sprinkler system protection scheme is a potential option.

2.2.4.1.2 When a ceiling-only protection scheme is acceptable per the flowchart in Figure 2.2.4.1.1 use Table 2.2.4.1.2 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.

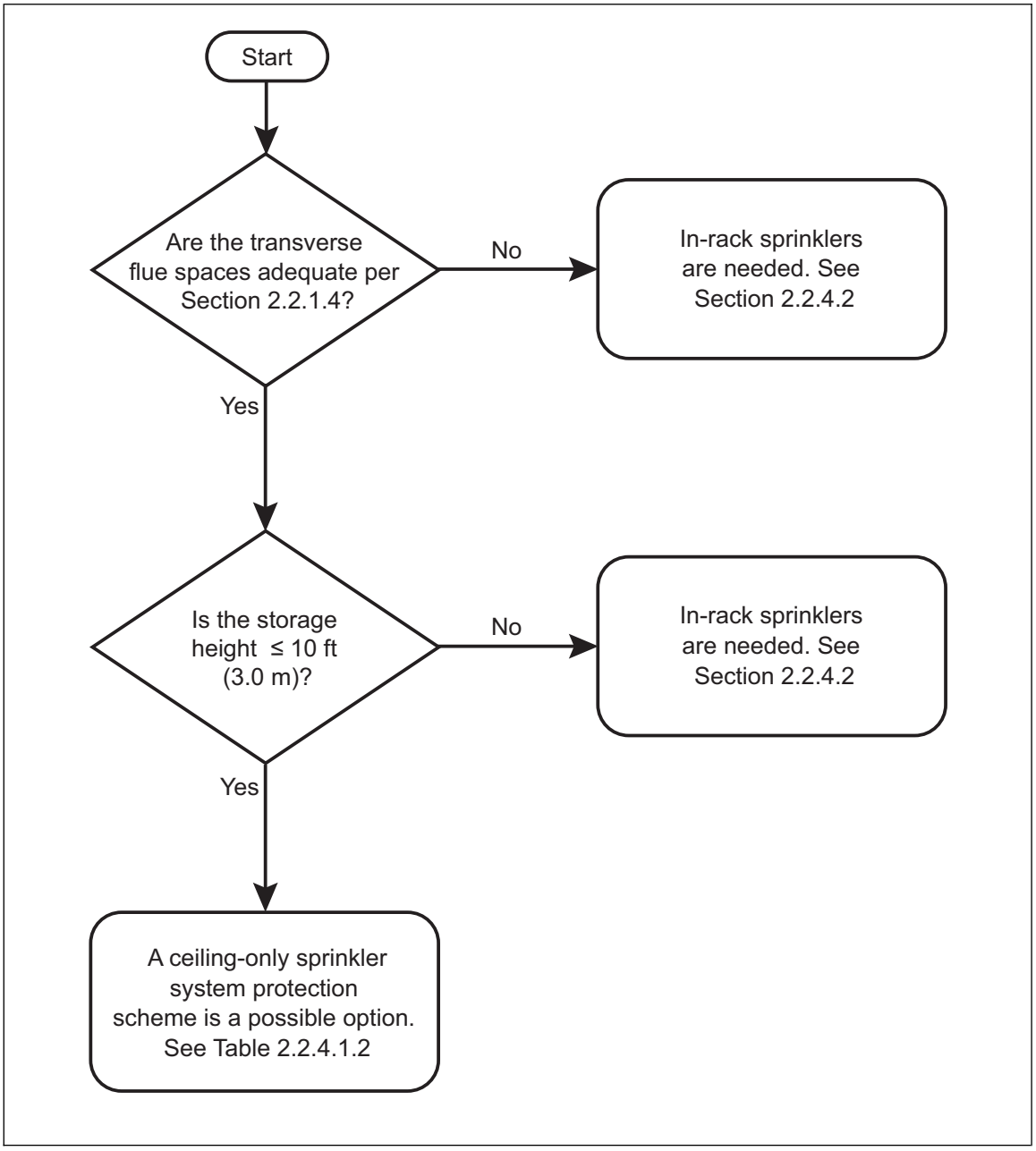

Fig. 2.2.4.1.1. Flowchart to determine if a ceiling-only sprinkler system protection scheme is a potential option

Table 2.2.4.1.2. 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	2.2.4.1.2(a)
	Dry	2.2.4.1.2(b)

Note: In Table 2.2.4.1.2(a), 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 2.2.4.1.2(a). Ceiling-Level Sprinkler Protection Guidelines on a Wet System for the Protection of 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 2.2.4.1.2(b). Ceiling-Level Sprinkler Protection Guidelines on a Dry System for the Protection of 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 2.1.4.5.4 to determine the ceiling sprinkler's hose demand design and water supply duration.

2.2.4.1.4 See Section 2.1.4.5.5 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 2.2.4.2.1 to determine the recommended horizontal in-rack sprinkler arrangement for the storage rack to be protected.

Table 2.2.4.2.1. Recommended Horizontal In-Rack Sprinkler Arrangements for the Protection of Open-Top, Combustible Containers in a Shuttle ASRS

Overall Maximum Rack Depth, ft (m)	*In-Rack Sprinkler Type*	*Applicable Horizontal IRAS Arrangement Figures*
3 (0.9)	Wet or Dry	2.2.4.2.1(a)
8 (2.4)	Wet or Dry	2.2.4.2.1(b)
13 (4.0)	Wet	2.2.4.2.1(c)
	Dry	2.2.4.2.1(d)
Over 13 (4.0)	Wet or Dry	2.2.4.2.1(e)

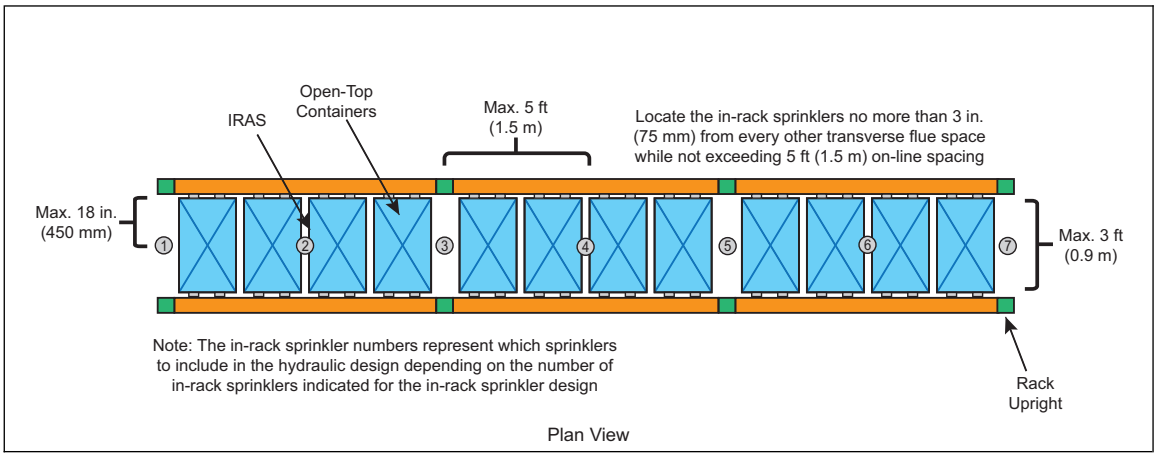

Fig. 2.2.4.2.1(a). Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Shuttle ASRS Where Rack Row Depths Do Not Exceed 3 ft (0.9 m) per Table 2.2.4.2.1

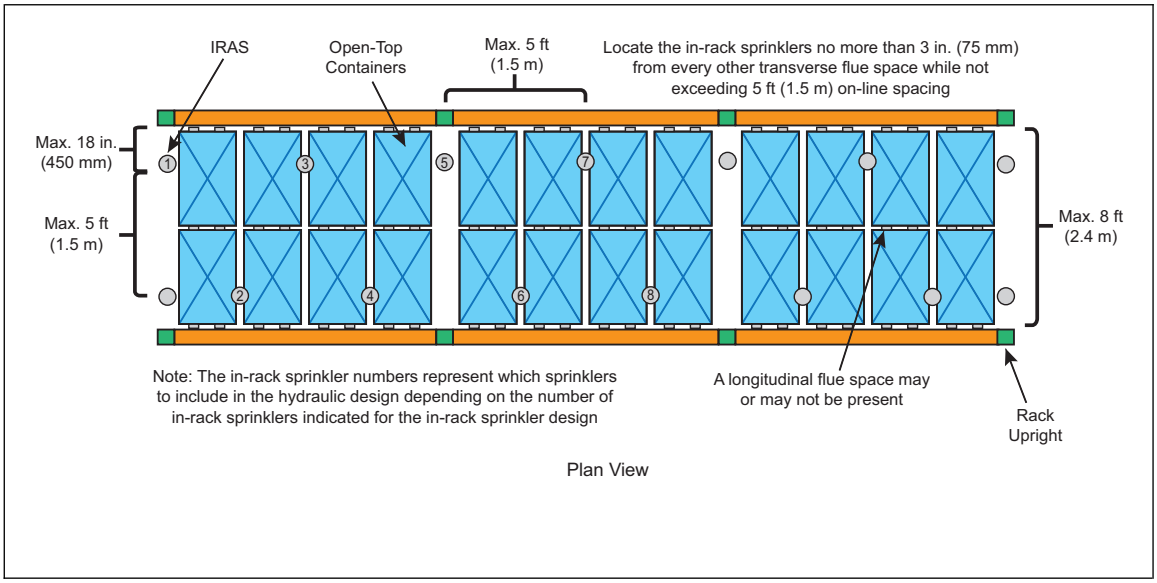

Fig. 2.2.4.2.1(b). Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Shuttle ASRS Where the Overall Rack Depths Do Not Exceed 8 ft (2.4) per Table 2.2.4.2.1

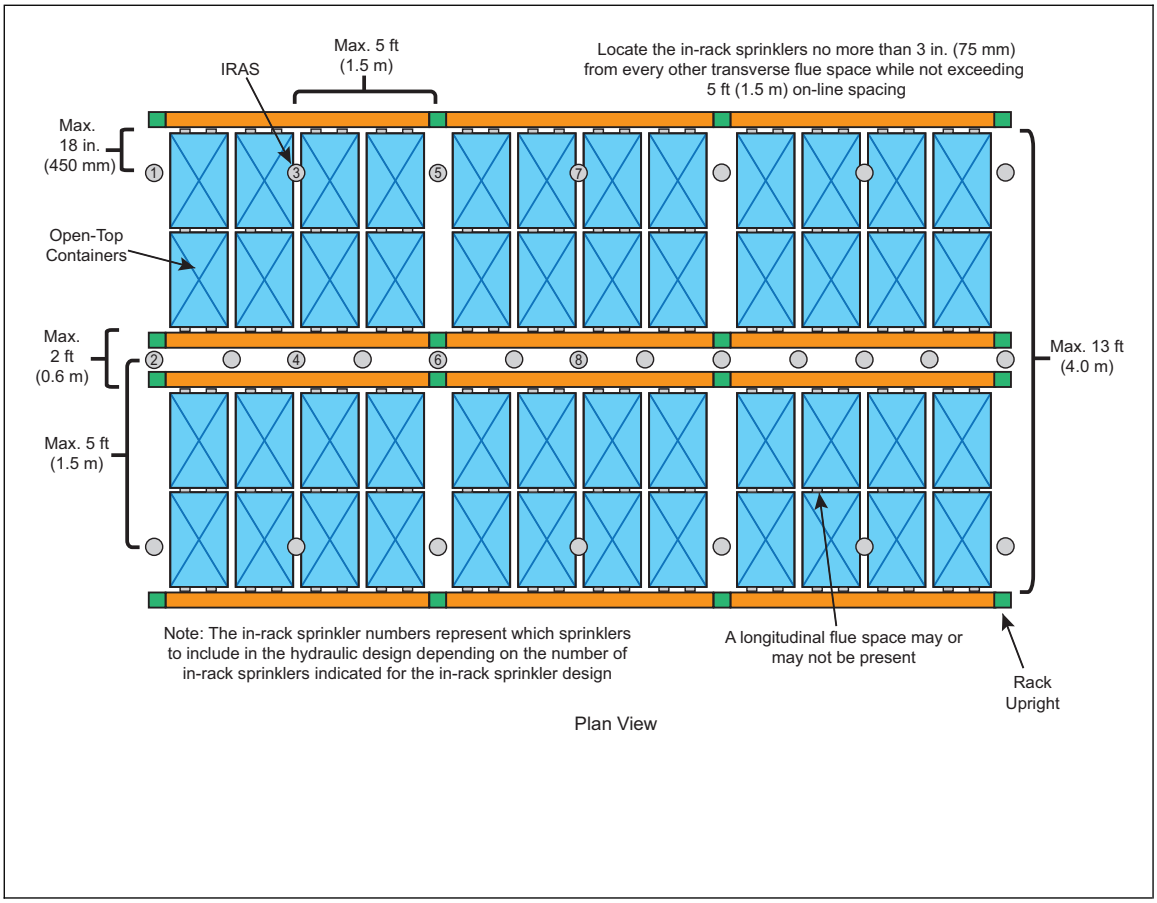

Fig. 2.2.4.2.1(c). Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Shuttle ASRS Where the Overall Rack Depths Do Not Exceed 13 ft (4.0 m) per Table 2.2.4.2.1

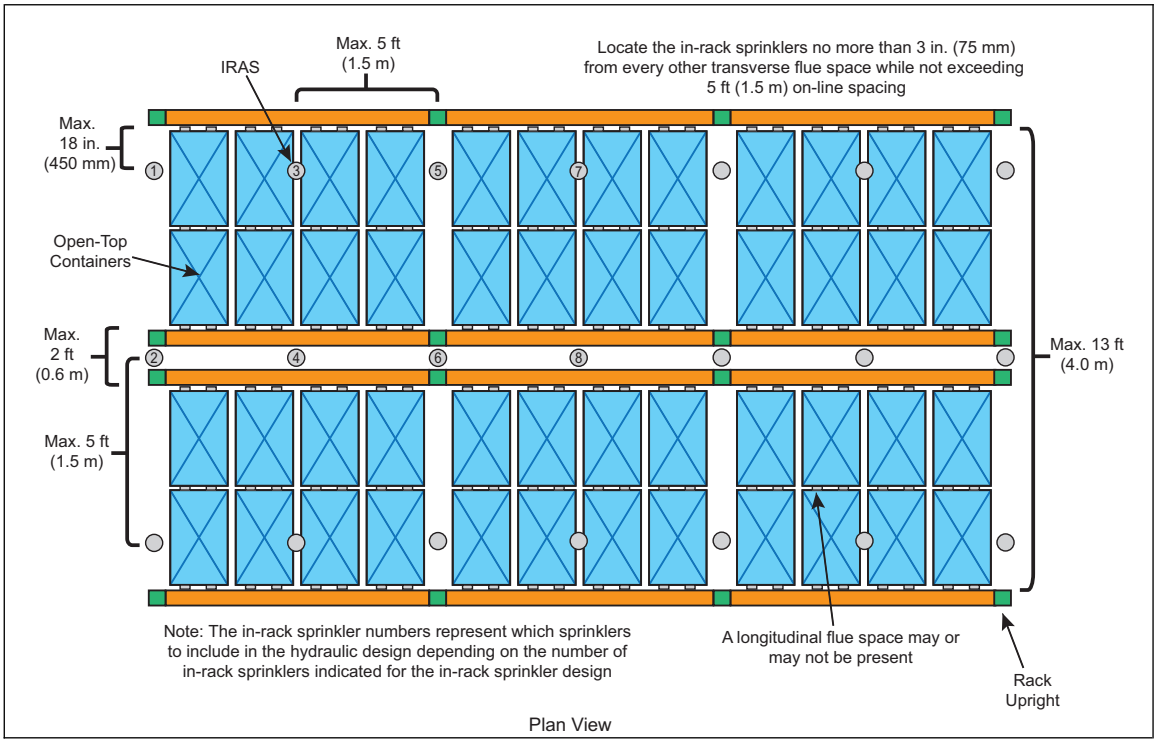

Fig. 2.2.4.2.1(d). Horizontal IRAS Arrangement on a Dry IRAS System for Open-Top Combustible Containers within a Shuttle ASRS Where the Overall Rack Depths Do Not Exceed 13 ft (4.0 m) per Table 2.2.4.2.1

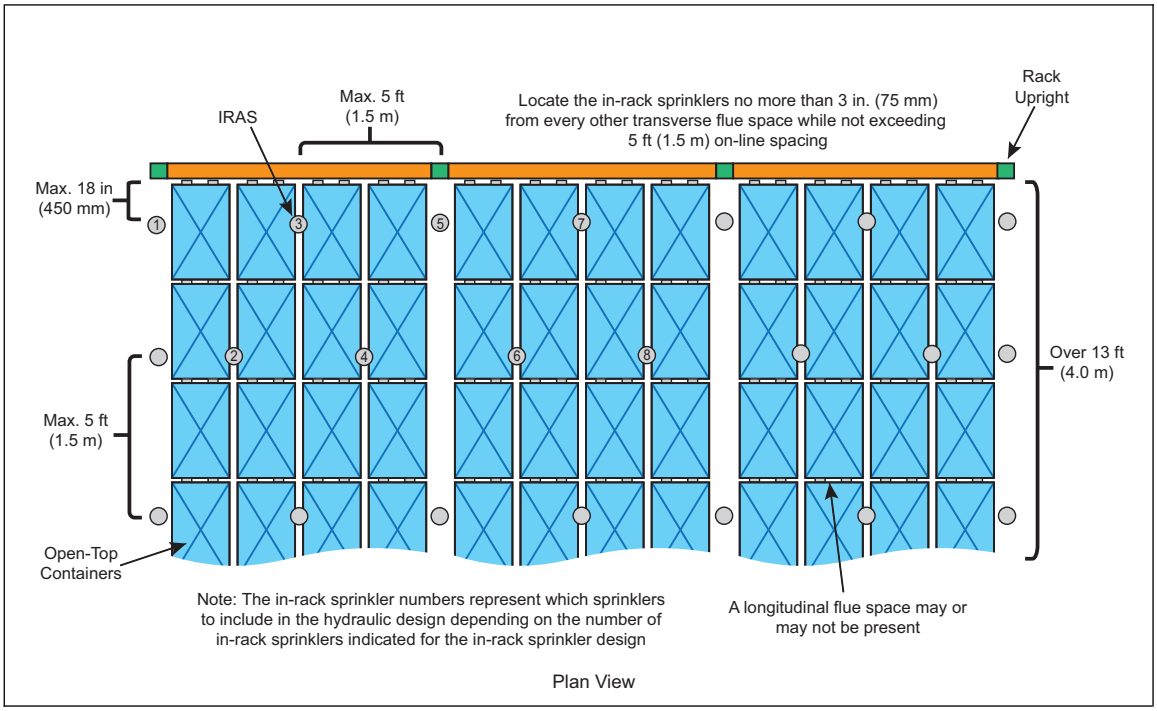

Fig. 2.2.4.2.1(e). Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Shuttle ASRS Where the Overall Rack Row Depths Exceed 13 ft (4.0 m) per Table 2.2.4.2.1

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 See the flowchart in Figure 2.2.4.2.2.1 to determine which protection table to use for obtaining the allowable in-rack sprinkler vertical locations, as well as the corresponding recommended in-rack sprinkler design.

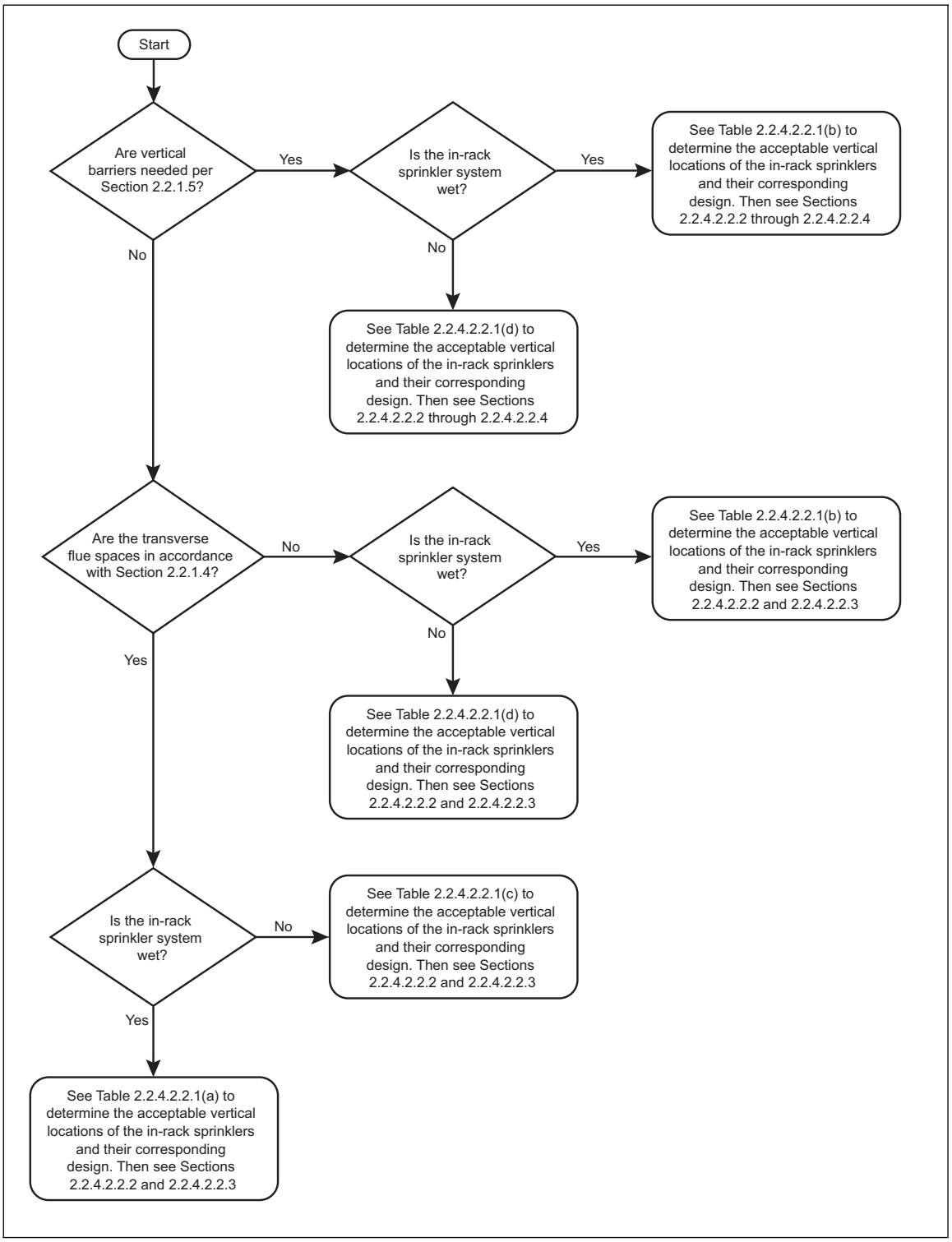

Fig. 2.2.4.2.2.1. Flowchart to determine which table to use to find the acceptable vertical locations and designs for in-rack sprinklers.

Table 2.2.4.2.2.1(a). Wet, In-Rack Sprinkler Designs for the Protection of Open-Top, Combustible Containers Stored in a Shuttle System with Flue Spaces in Accordance with Section 2.2.1.4

Recommended IRAS Arrangement per Table 2.2.4.2.1	Open-Top Container Composition	Maximum Commodity Classification	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 2.2.4.2.1(a)	Cardboard	Class 3	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
		Uncartoned Expanded Plastic	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
	Unexpanded Plastic	Any	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
Figures 2.2.4.2.1(b), 2.2.4.2.1(c), or 2.2.4.2.1(e)	Cardboard	Class 3	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
		Uncartoned Expanded Plastic	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
	Unexpanded Plastic	Any	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

* 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 2.2.4.2.2.1(b). Wet, In-Rack Sprinkler Designs for the Protection of Open-Top, Combustible Containers Stored in a Shuttle System with Flue Spaces Not in Accordance with Section 2.2.1.4

Recommended IRAS Arrangement per Table 2.2.4.2.1	Open-Top Container Composition	Maximum Commodity Classification	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 2.2.4.2.1(a)	Cardboard	Class 3	10 (3.0)	60 (230)	11.2 (160)	4 on top IRAS level	No
		Uncartoned Expanded Plastic	10 (3.0)	100 (380)	11.2 (160)	4 on top IRAS level	No
	Unexpanded Plastic	Any	10 (3.0)	100 (380)	11.2 (160)	4 on top IRAS level	No
Figures 2.2.4.2.1(b), 2.2.4.2.1(c), or 2.2.4.2.1(e)	Cardboard	Class 3	10 (3.0)	60 (230)	11.2 (160)	6 on top IRAS level	No
		Uncartoned Expanded Plastic	10 (3.0)	100 (380)	11.2 (160)	6 on top IRAS level	No
	Unexpanded Plastic	Any	10 (3.0)	100 (380)	11.2 (160)	6 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.

Table 2.2.4.2.2.1(c). Dry, In-Rack Sprinkler Designs for the Protection of Open-Top, Combustible Containers Stored in a Shuttle System with Flue Spaces in Accordance with Section 2.2.1.4

Recommended IRAS Arrangement per Table 2.2.4.2.1	*Open-Top Container Composition*	*Maximum Commodity Classification*	*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 2.2.4.2.1(a) through 2.2.4.2.1(e)	Cardboard	Class 3	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	10 (3.0)	100 (380)	11.2 (160) Upright	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
	Unexpanded Plastic	Any	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 2.2.4.2.2.1(d). Dry, In-Rack Sprinkler Designs for the Protection of Open-Top, Combustible Containers Stored in a Shuttle System with Flue Spaces Not in Accordance with Section 2.2.1.4

Recommended IRAS Arrangement per Table 2.2.4.2.1	*Open-Top Container Composition*	*Maximum Commodity Classification*	*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 2.2.4.2.1(a) through 2.2.4.2.1(e)	Cardboard	Class 3	10 (3.0)	60 (230)	11.2 (160) Upright	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
		Uncartoned Expanded Plastic	10 (3.0)	100 (380)	11.2 (160) Upright	8 if one IRAS level or 14 (7 on top 2 levels)	Yes
	Unexpanded Plastic	Any	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.

2.2.4.2.2.2 Limit the storage height above the top in-rack sprinkler level to a maximum height of 10 ft (3.0 m) when flue spaces are in accordance with Section 2.2.1.4, otherwise limit the storage height above the top in-rack sprinkler level to a maximum height of 5 ft (1.5 m).

2.2.4.2.2.3 While the in-rack sprinkler designs given in Tables 2.2.4.2.2.1(a) through 2.2.4.2.2.1(d) 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.

2.2.4.2.2.4 When Section 2.2.1.5 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 2.2.4.2.1(c), and the number of in-rack sprinklers between the vertical barriers is 11, then the design for the in-rack sprinkler system would be per Table 2.2.4.2.2.1(b) and would be based on 11 IRAS @ 100 gpm (380 L/min) instead of 6 IRA100 m (380 L/min).

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 2.2.4.2.3.1 to determine the wet ceiling-level sprinkler system designs in combination with in-rack sprinklers by using the vertical distance between the top in-rack sprinkler level and the maximum ceiling height above the ASRS protected area. 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 2.2.4.2.3.1, or
2. Install in-rack sprinklers over the top of storage and design the ceiling sprinkler system per Table 2.2.4.2.3.1.

Table 2.2.4.2.3.1. Wet System Ceiling-Level Sprinkler Protection Guidelines, in Combination with In-Rack Sprinklers, on a Wet System 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		
		K11.2 (160)	K14.0 (200)	K16.8 (240)	K22.4 (320)	K25.2 (360)	K25.2EC (360EC)	K28.0 (400)	K33.6 (480)	K11.2 (160)	K14.0 (200)	K19.6 (280)	K25.2 (360)	K11.2 (160)	K14.0 (200)	K16.8 (240)	K25.2EC (360EC)	K11.2 (160)	K16.8 (240)	K25.2 (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

2.2.4.2.3.2 Use Table 2.2.4.2.3.2 to determine the dry ceiling-level sprinkler system designs in combination with in-rack sprinklers by using the vertical distance between the top in-rack sprinkler level and the maximum ceiling height above the ASRS protected area. 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 2.2.4.2.3.2, or
2. Install in-rack sprinklers over the top of storage and design the ceiling sprinkler system per Table 2.2.4.2.3.2.

Table 2.2.4.2.3.2 . 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			
		K11.2 (160)	K16.8 (240)	K25.2 (360)	K33.6 (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)

2.2.4.2.3.3 See Section 2.1.4.5.4 to determine the ceiling sprinkler's hose demand design and water supply duration.

2.2.4.2.3.4 See Section 2.1.4.5.5 to determine the number of sprinklers per branch line for ceiling-level sprinkler calculations.

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

2.2.5.1 When noncombustible closed-top containers are used throughout the horizontal-loading ASRS storage area, install ceiling-level sprinkler protection over the horizontal-loading ASRS storage area using a design that, as a minimum, will be acceptable for the protection of the occupancies adjacent to the horizontal-loading ASRS storage area.

2.2.5.2 When the horizontal-loading ASRS storage area will not consist entirely of noncombustible closed-top containers, design and install sprinkler protection for the horizontal-loading ASRS storage area designed for the protection of the worst-case container being used.

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 supporting 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.

See the flowchart in Figure 2.2.6 for guidance on how to navigate this section.

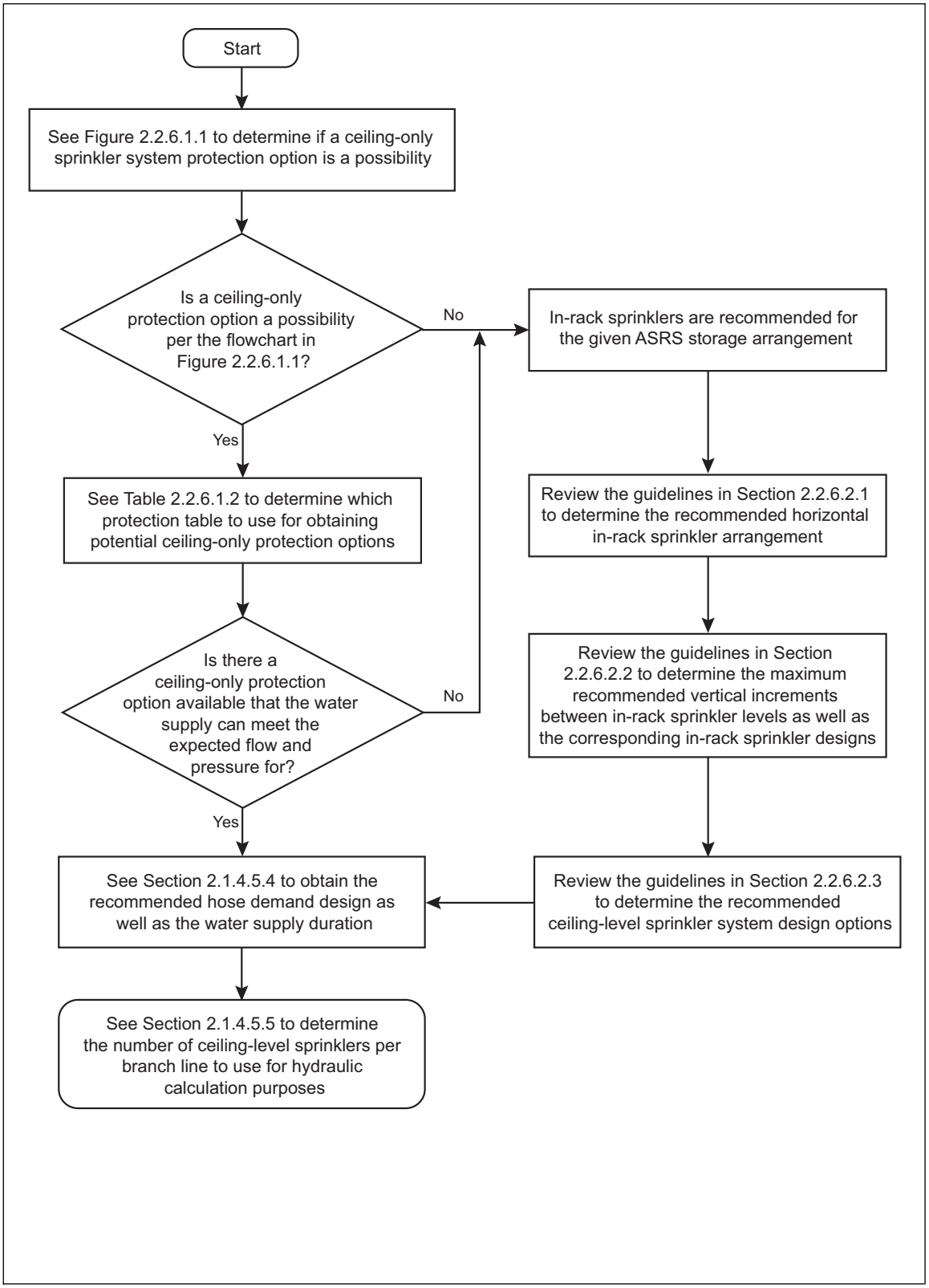

Fig. 2.2.6. Flowchart for how to navigate Section 2.2.6

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

2.2.6.1.1 See the flowchart in Figure 2.2.6.1.1 to determine if a ceiling-only sprinkler system protection scheme is a potential option.

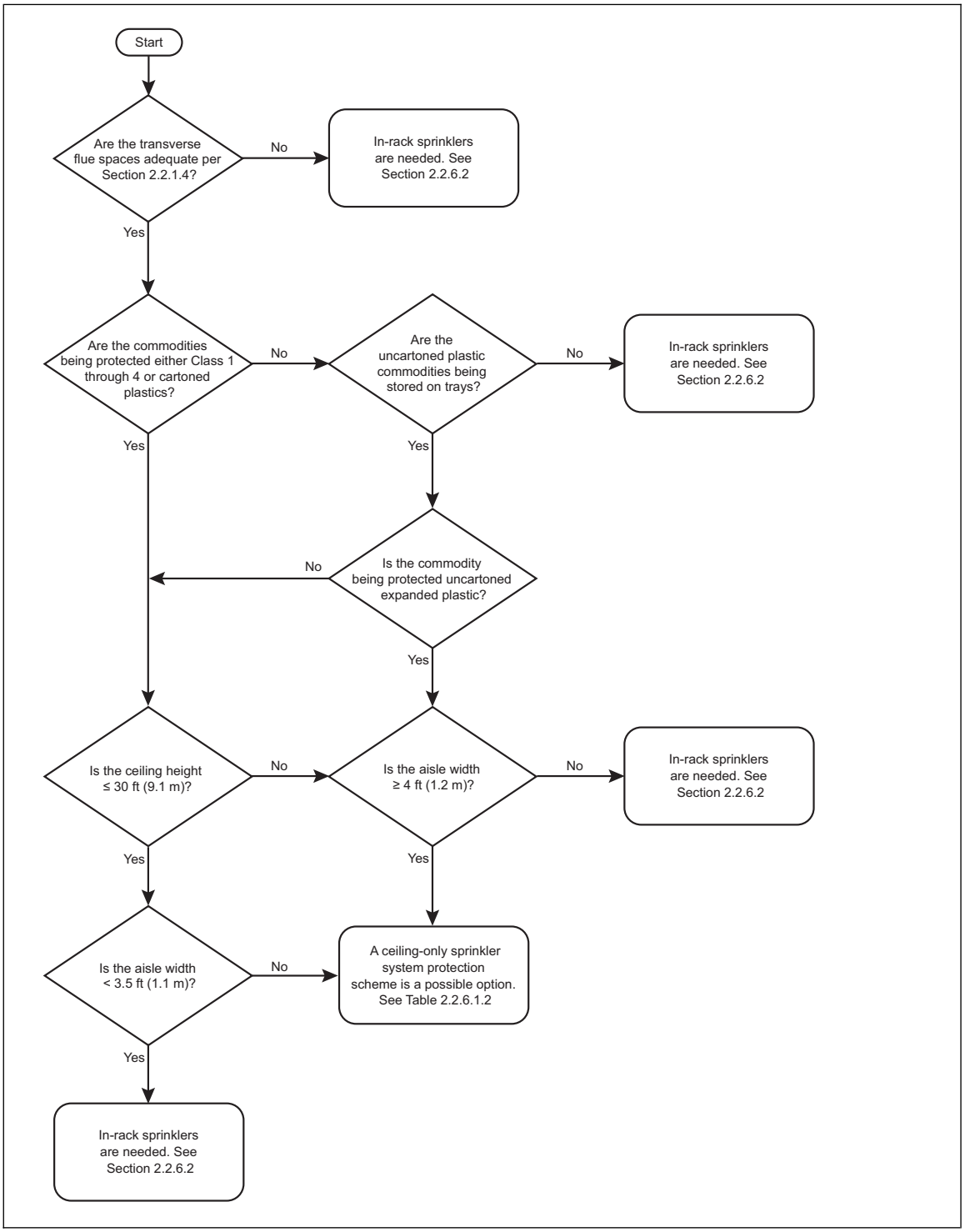

Fig. 2.2.6.1.1. Flowchart to determine if a ceiling-only sprinkler system protection scheme is a potential option

2.2.6.1.2 When a ceiling-only protection scheme is a potential option per the flowchart in Figure 2.2.6.1.1, use Table 2.2.6.1.2 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.

Table 2.2.6.1.2.. 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	2.2.6.1.2(a)
		Dry	2.2.6.1.2(c)
	Uncartoned Expanded Plastics	Wet	2.2.6.1.2(b)
		Dry	2.2.6.1.2(d)

Note 1. In Tables 2.2.6.1.2(a) and 2.2.6.1.2(b), 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 2.2.6.1.2(a). Ceiling-Level Sprinkler Protection Guidelines on a Wet System for the Protection of 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 2.2.6.1.2(b). Ceiling-Level Sprinkler Protection Guidelines on a Wet System for the Protection of 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 2.2.6.1.2(c). Ceiling-Level Sprinkler Protection Guidelines on a Dry System for the Protection of 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 2.2.6.1.2(d). Ceiling-Level Sprinkler Protection Guidelines on a Dry System for the Protection of 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)

2.2.6.1.3 See Section 2.1.4.5.4 to determine the ceiling sprinkler's hose demand design and water supply duration.

2.2.6.1.4 See Section 2.1.4.5.5 to determine the number of sprinklers per branch line for ceiling-level sprinkler calculations.

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-Load ASRS

Use Table 2.2.6.2.1 to determine the recommended horizontal in-rack sprinkler arrangements for the storage rack to be protected.

Table 2.2.6.2.1. Recommended Horizontal In-Rack Sprinkler (i.e., IRAS) Arrangements for Closed-Top Combustible Containers, or Storage on Trays in a Mini-Load ASRS

Overall Maximum Rack Depth, ft (m)	*In-Rack Sprinkler Type*	*Applicable Horizontal IRAS Arrangement Figures*
3 (0.9)	Wet or Dry	2.2.6.2.1(a)
8 (2.4)	Wet or Dry	2.2.6.2.1(b)
13 (4.0)	Wet	2.2.6.2.1(c)
	Dry	2.2.6.2.1(d)
Over 13 (4.0)	Wet or Dry	2.2.6.2.1(e)

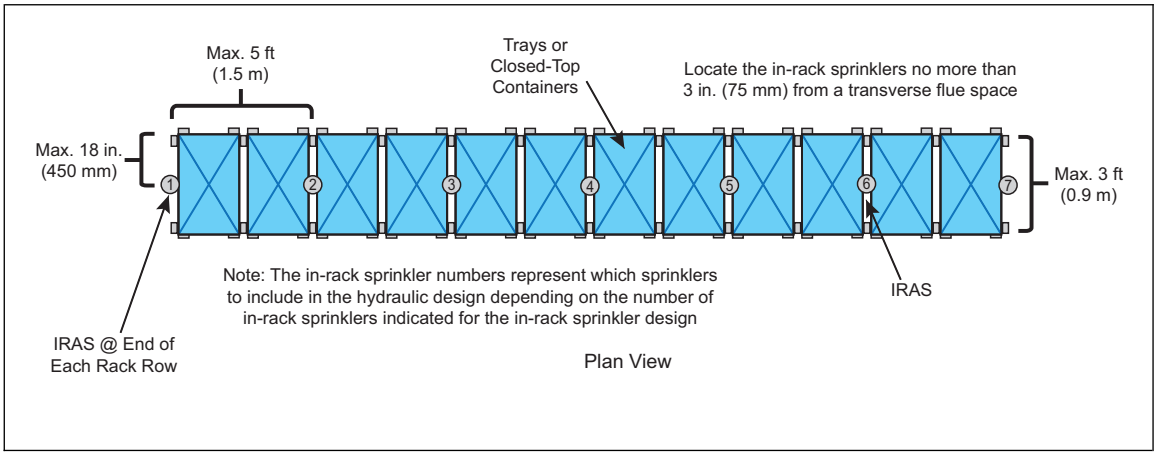

Fig. 2.2.6.2.1(a). Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Mini-Load ASRS Where Rack Row Depths Do Not Exceed 3 ft (0.9 m) per Table 2.2.6.2.1

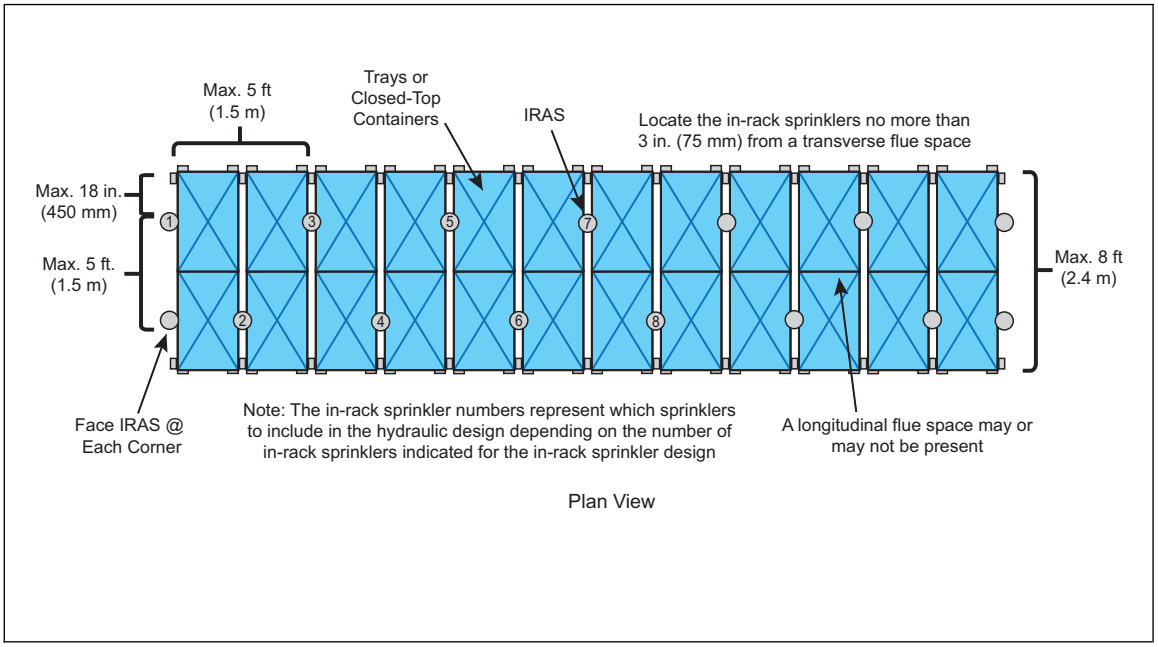

Fig. 2.2.6.2.1(b). Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Mini-Load ASRS Where the Overall Rack Depths Do Not Exceed 8 ft (2.4 m) per Table 2.2.6.2.1

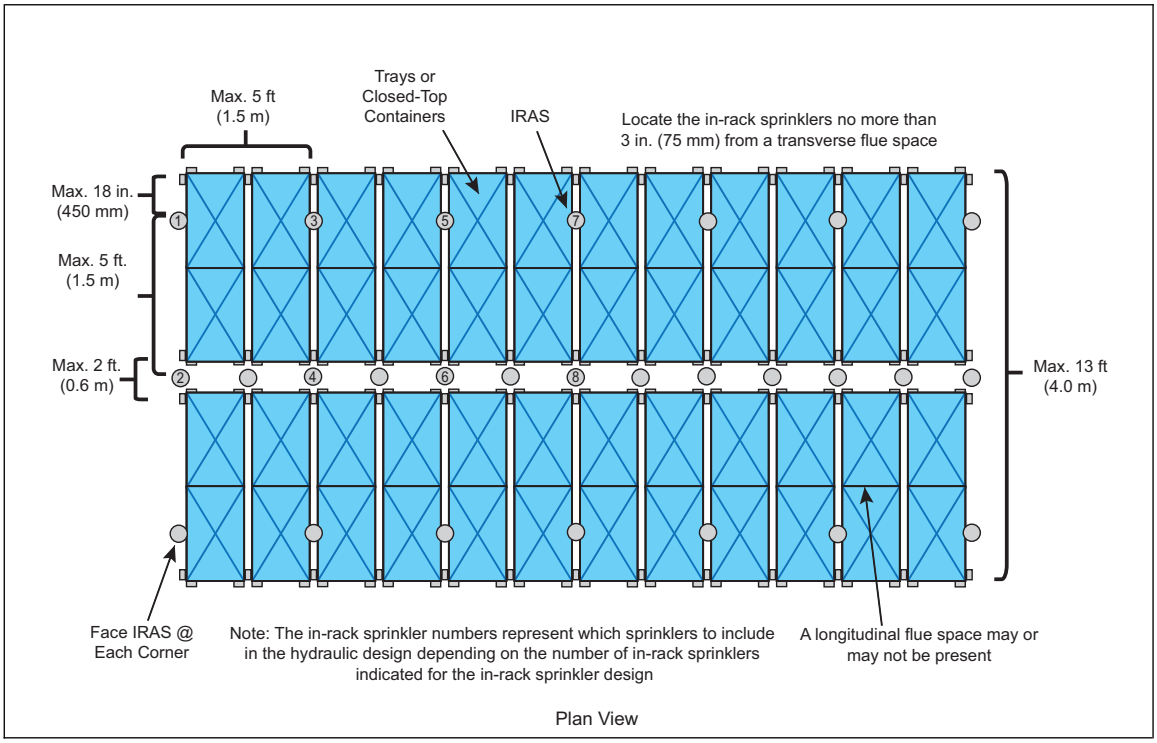

Fig. 2.2.6.2.1(c). Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Mini-Load ASRS Where the Overall Rack Depths Do Not Exceed 13 ft (4.0 m) per Table 2.2.6.2.1

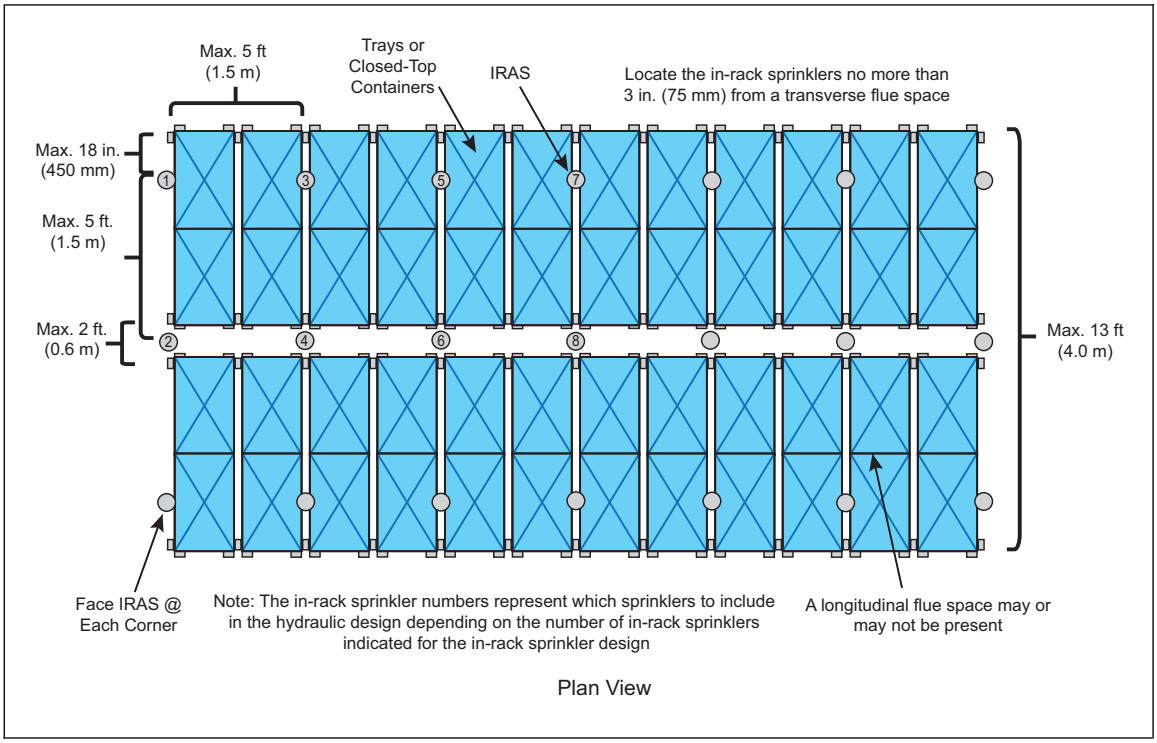

Fig. 2.2.6.2.1(d). Horizontal IRAS Arrangement on a Dry System for Closed-Top Combustible Containers, or Storage on Trays within a Mini-Load ASRS Where the Overall Rack Depths Do Not Exceed 13 ft (4.0 m) per Table 2.2.6.2.1

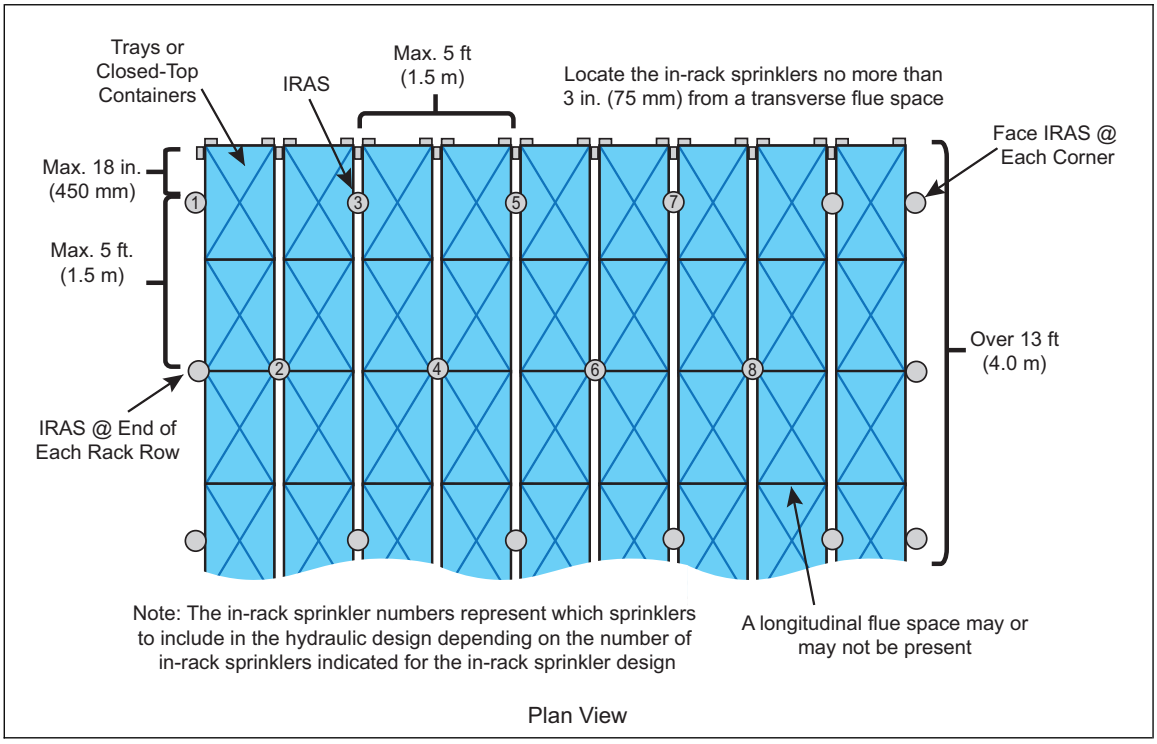

Fig. 2.2.6.2.1(e). Horizontal IRAS Arrangement for Closed-Top Combustible Containers, or Storage on Trays within a Mini-Load ASRS Where the Overall Rack Depths Exceed 13 ft (4.0 m) per Table 2.2.6.2.1

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 See the flowchart in Figure 2.2.6.2.2.1 to determine which protection table to use for obtaining the allowable in-rack sprinkler vertical locations, as well as the corresponding recommended in-rack sprinkler design.

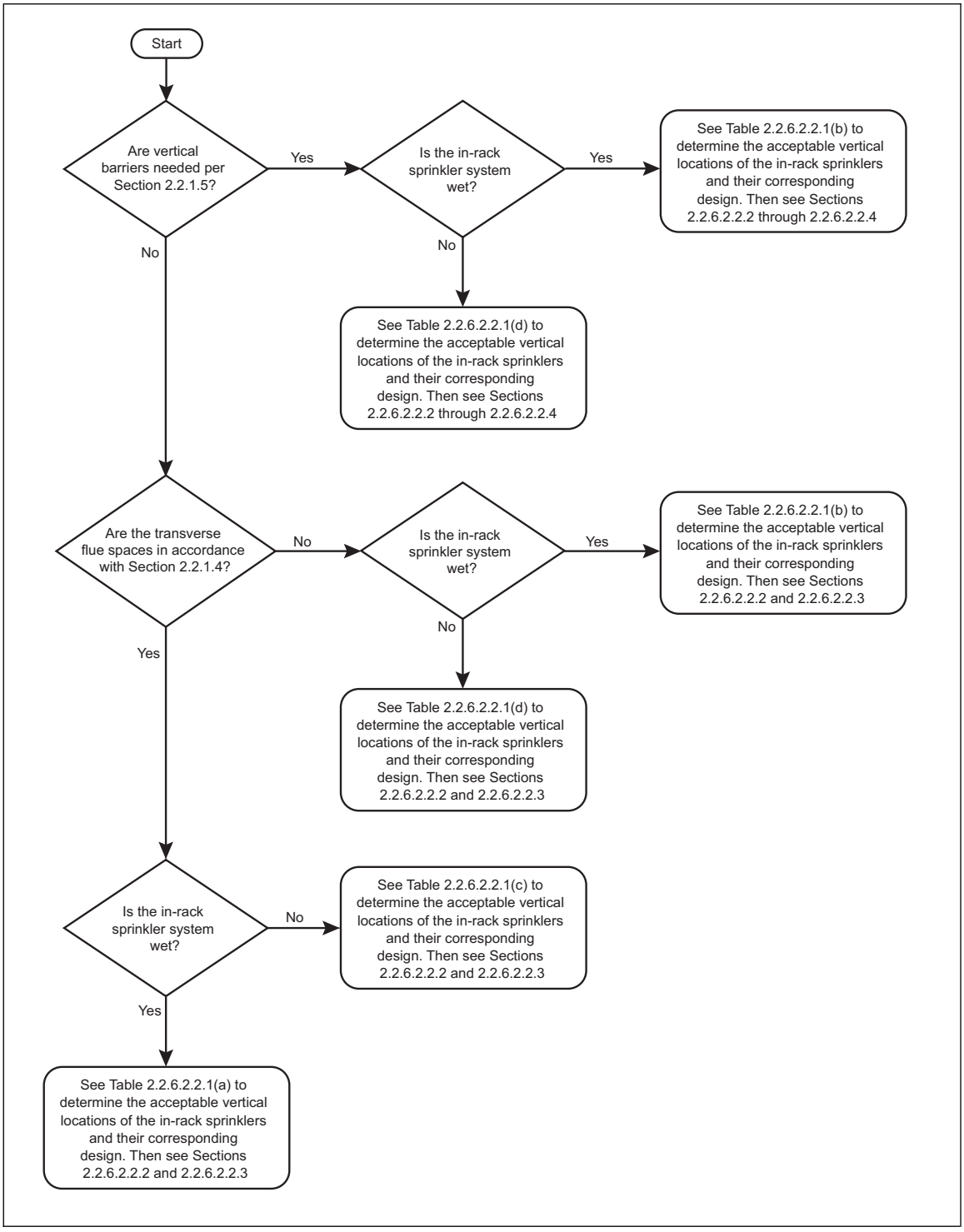

Fig. 2.2.6.2.2.1. Flowchart to determine which table to use to find the acceptable vertical locations and designs of in-rack sprinklers.

Table 2.2.6.2.2.1(a). Wet, In-Rack Sprinkler Designs for the Protection of Closed-Top, Combustible Containers Stored in a Mini-Load Type ASRS with Flue Spaces in Accordance with Section 2.2.1.4

Recommended IRAS Arrangement per Table 2.2.6.2.1	*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 2.2.6.2.1(a)	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
	Uncartoned Unexpanded 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)	6 on top IRAS level	No
Figures 2.2.6.2.1(b), 2.2.6.2.1(c), or 2.2.6.2.1(e)	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
	Uncartoned Unexpanded 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 2.2.6.2.2.1(b). Wet, In-Rack Sprinkler Designs for the Protection of Closed-Top, Combustible Containers Stored in a Mini-Load Type ASRS with Flue Spaces Not in Accordance with Section 2.2.1.4

Recommended IRAS Arrangement per Table 2.2.6.2.1	*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 2.2.6.2.1(a)	Cartoned Unexpanded Plastics	Directly on Rails or On Trays	10 (3.0)	60 (230)	11.2 (160)	4 on top IRAS level	No
	Uncartoned Unexpanded 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
	Uncartoned Expanded Plastics	On Trays	10 (3.0)	60 (230)	11.2 (160)	6 on top IRAS level	No
Figures 2.2.6.2.1(b), 2.2.6.2.1(c), or 2.2.6.2.1(e)	Cartoned Unexpanded Plastics	Directly on Rails or On Trays	10 (3.0)	60 (230)	11.2 (160)	6 on top IRAS level	No
	Uncartoned Unexpanded 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
	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 5 ft (1.5 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 2.2.6.2.2.1(c). Dry, In-Rack Sprinkler Designs for the Protection of Closed-Top, Combustible Containers Stored in a Mini-Load Type ASRS with Flue Spaces in Accordance with Section 2.2.1.4

Recommended IRAS Arrangement per Table 2.2.6.2.1	*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 2.2.6.2.1(a)	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
	Uncartoned Unexpanded 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 2.2.6.2.1(b), 2.2.6.2.1(c), 2.2.6.2.1(d), or 2.2.6.2.1(e)	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
	Uncartoned Unexpanded 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.

Table 2.2.6.2.2.1(d). Dry, In-Rack Sprinkler Designs for the Protection of Closed-Top, Combustible Containers Stored in a Mini-Load Type ASRS with Flue Spaces Not in Accordance with Section 2.2.1.4

Recommended IRAS Arrangement per Table 2.2.6.2.1	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 2.2.6.2.1(a)	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
	Uncartoned Unexpanded 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
	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 2.2.6.2.1(b), 2.2.6.2.1(c), 2.2.6.2.1(d), or 2.2.6.2.1(e)	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
	Uncartoned Unexpanded 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
	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 5 ft (1.5 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.

2.2.6.2.2.2 Limit the storage height above the top in-rack sprinkler level to a maximum height of 10 ft (3.0 m) when flue spaces are in accordance with Section 2.2.1.4, otherwise limit the storage height above the top in-rack sprinkler level to a maximum height of 5 ft (1.5 m).

2.2.6.2.2.3 While the in-rack sprinkler designs given in Tables 2.2.4.2.2.1(a) through 2.2.4.2.2.1(d) 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.

2.2.6.2.2.4 When Section 2.2.1.5 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 2.2.6.2.1(c), and the number of in-rack sprinklers between the vertical barriers is 11, then the design for the in-rack sprinkler system would be per Table 2.2.6.2.2.1(a) and would be designed for 11 IRAS \@ 60 gpm (230 L/min) as opposed to 6 IRAS \@ 60 gpm (230 L/min).

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 2.2.6.2.3.1 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 2.2.6.2.3.1, or

2. Install in-rack sprinklers over the top of storage and design the ceiling sprinkler system per Table 2.2.6.2.3.1.

Table 2.2.6.2.3.1. 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 UseTable 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	2.2.6.1.2(a)	10 (3.0)
		5 (1.5)	5 (1.5)	2.2.6.1.2(a)	10 (3.0)
			10 (3.0)	2.2.6.1.2(a)	15 (4.6)
			20 (6.1)	2.2.6.1.2(a)	20 (6.1)
			> 20 (6.1)	2.2.6.1.2(a)	Vertical distance between top IRAS level and ceiling
		10 (3.0)	Any	2.2.6.1.2(a)	Vertical distance between top IRAS level and ceiling
Cartoned Expanded Plastics	Directly on Supporting Rails	0 (0)	Any	2.2.6.1.2(b)	10 (3.0)
		5 (1.5)	5 (1.5)	2.2.6.1.2(b)	10 (3.0)
			10 (3.0)	2.2.6.1.2(b)	15 (4.6)
			20 (6.1)	2.2.6.1.2(b)	25 (7.6)
			> 20 (6.1)	2.2.6.1.2(b)	Vertical distance between top IRAS level and ceiling
		0 (3.0)	Any	2.2.6.1.2(b)	Vertical distance between top IRAS level and ceiling
	On Trays	0 (0)	Any	2.2.6.1.2(a)	10 (3.0)
		5 (1.5)	5 (1.5)	2.2.6.1.2(a)	10 (3.0)
			10 (3.0)	2.2.6.1.2(a)	15 (4.6)
			20 (6.1)	2.2.6.1.2(a)	20 (6.1)
			> 20 (6.1)	2.2.6.1.2(a)	Vertical distance between top IRAS level and ceiling
		10 (3.0)	Any	2.2.6.1.2(a)	Vertical distance between top IRAS level and ceiling
Uncartoned Unexpanded Plastics	Directly on Supporting Rails	0 (0)	Any	2.2.6.1.2(a)	10 (3.0)
	On Trays	0 (0)	Any	2.2.6.1.2(a)	10 (3.0)
		5 (1.5)	5 (1.5)	2.2.6.1.2(a)	10 (3.0)
			10 (3.0)	2.2.6.1.2(a)	15 (4.6)
			20 (6.1)	2.2.6.1.2(a)	20 (6.1)
			> 20 (6.1)	2.2.6.1.2(a)	Vertical distance between top IRAS level and ceiling
		10 (3.0)	Any	2.2.6.1.2(a)	Vertical distance between top IRAS level and ceiling
Uncartoned Expanded Plastics	Directly on Supporting Rails	0 (0)	Any	2.2.6.1.2(b)	10 (3.0)
	On Trays	0 (0)	Any	2.2.6.1.2(b)	10 (3.0)
		5 (1.5)	5 (1.5)	2.2.6.1.2(b)	10 (3.0)
			10 (3.0)	2.2.6.1.2(b)	15 (4.6)
			20 (6.1)	2.2.6.1.2(b)	25 (7.6)
			> 20 (6.1)	2.2.6.1.2(b)	Vertical distance between top IRAS level and ceiling
		10 (3.0)	Any	2.2.6.1.2(b)	Vertical distance between top IRAS level and ceiling

2.2.6.2.3.2 Use Table 2.2.6.2.3.2 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 2.2.6.2.3.2, or
2. Install in-rack sprinklers over the top of storage and design the ceiling sprinkler system per Table 2.2.6.2.3.2.

Table 2.2.6.2.3.2. 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	2.2.6.1.2(c)	10 (3.0)
		5 (1.5)	5 (1.5)	2.2.6.1.2(c)	10 (3.0)
			10 (3.0)	2.2.6.1.2(c)	15 (4.6)
		10 (3.0)	5 (1.5)	2.2.6.1.2(c)	15 (4.6)
Cartoned Expanded Plastics	Directly on Supporting Rails	0 (0)	Any	2.2.6.1.2(d)	10 (3.0)
		5 (1.5)	5 (1.5)	2.2.6.1.2(d)	10 (3.0)
			10 (3.0)	2.2.6.1.2(d)	15 (4.6)
		10 (3.0)	5 (1.5)	2.2.6.1.2(d)	15 (4.6)
	On Trays	0 (0)	Any	2.2.6.1.2(c)	10 (3.0)
		5 (1.5)	5 (1.5)	2.2.6.1.2(c)	10 (3.0)
			10 (3.0)	2.2.6.1.2(c)	15 (4.6)
		10 (3.0)	5 (1.5)	2.2.6.1.2(c)	15 (4.6)
Uncartoned Unexpanded Plastics	Directly on Supporting Rails	0 (0)	Any	2.2.6.1.2(c)	10 (3.0)
	On Trays	0 (0)	Any	2.2.6.1.2(c)	10 (3.0)
		5 (1.5)	5 (1.5)	2.2.6.1.2(c)	10 (3.0)
			10 (3.0)	2.2.6.1.2(c)	15 (4.6)
		10 (3.0)	5 (1.5)	2.2.6.1.2(c)	15 (4.6)
Uncartoned Expanded Plastics	Directly on Supporting Rails	0 (0)	Any	2.2.6.1.2(d)	10 (3.0)
	On Trays	0 (0)	Any	2.2.6.1.2(d)	10 (3.0)
		5 (1.5)	5 (1.5)	2.2.6.1.2(d)	10 (3.0)
			10 (3.0)	2.2.6.1.2(d)	15 (4.6)
		10 (3.0)	5 (1.5)	2.2.6.1.2(d)	15 (4.6)

2.2.6.2.3.3 See Section 2.1.4.5.4 to determine the ceiling sprinkler's hose demand design and water supply duration.

2.2.6.2.3.4 See Section 2.1.4.5.5 to determine the number of sprinklers per branch line for ceiling-level sprinkler calculations.

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

See the flowchart in Figure 2.2.7 for guidance on how to navigate this section. Note that the protection of expanded plastic containers is outside the scope of this data sheet.

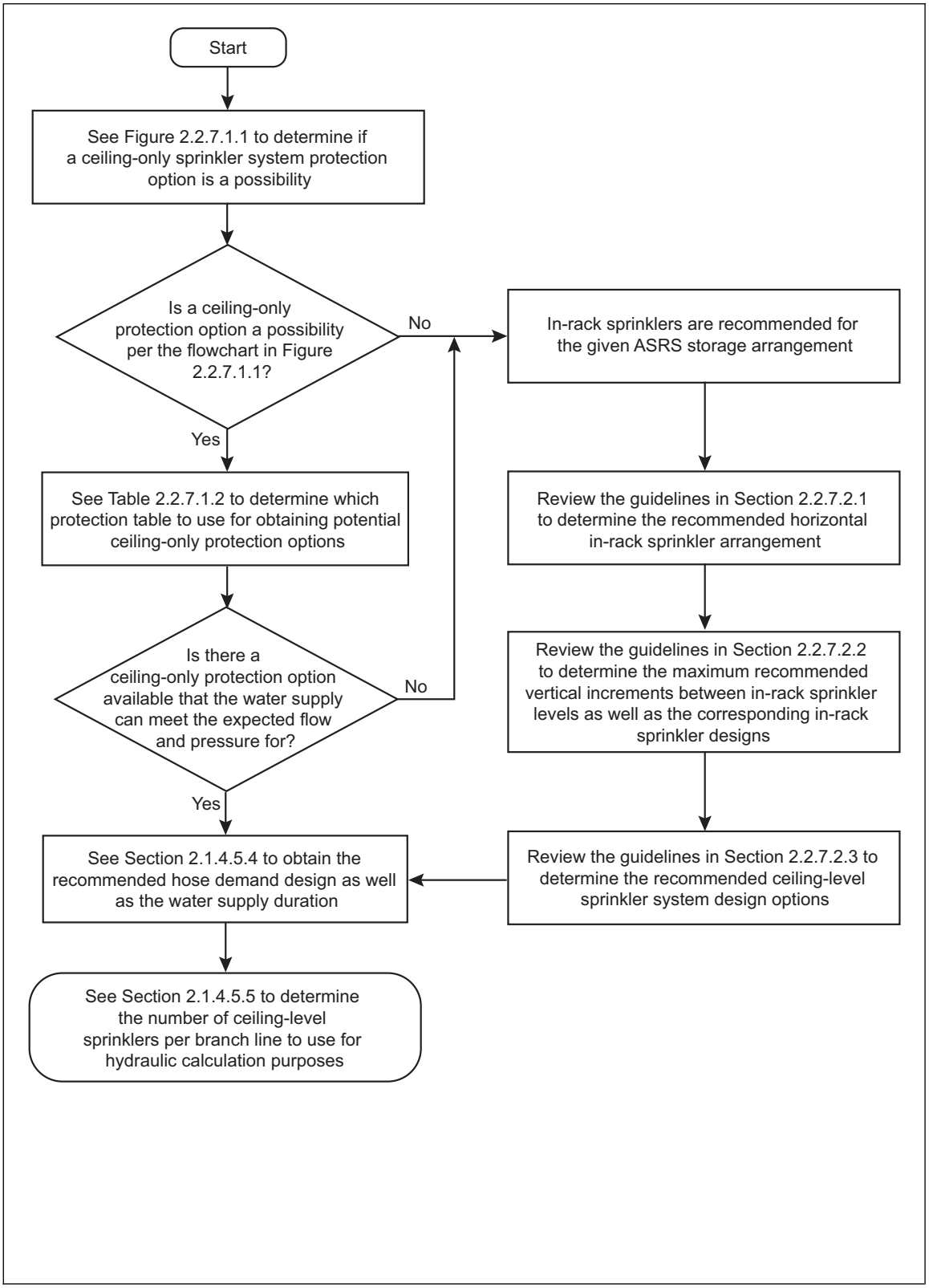

Fig. 2.2.7. Flowchart for how to navigate Section 2.2.7

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 See the flowchart in Figure 2.2.7.1.1 to determine if a ceiling-only sprinkler system protection scheme is a potential option.

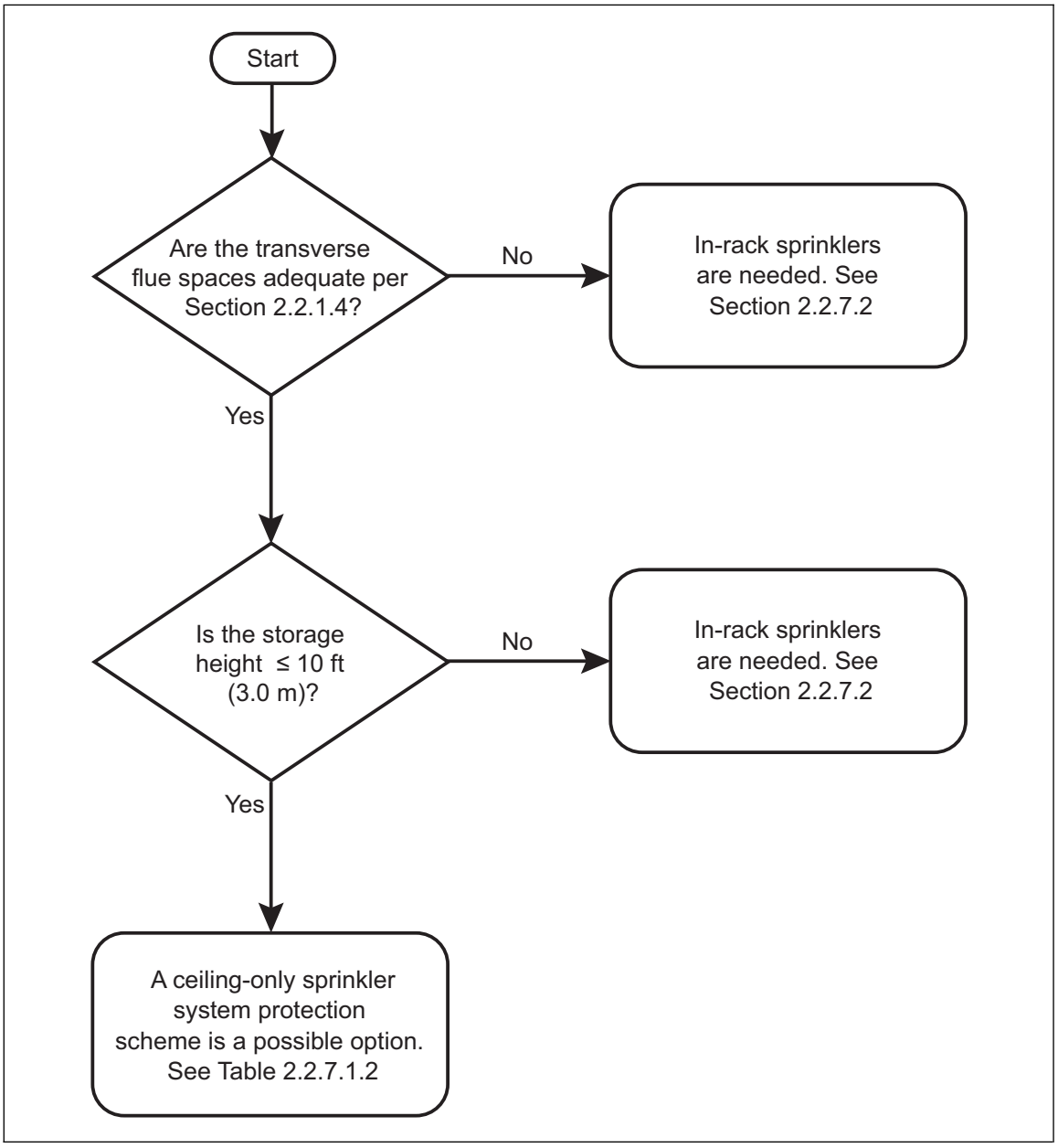

Fig. 2.2.7.1.1. Flowchart to determine if a ceiling-only sprinkler system protection scheme is a potential option

2.2.7.1.2 When a ceiling-only protection scheme is acceptable per the flowchart in Figure 2.2.7.1.1, use Table 2.2.7.1.1 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 2.2.7.1.2. 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	2.2.7.1.2(a)
	Dry	2.2.7.1.2(b)

Note: In Table 2.2.7.1.2(a), 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 2.2.7.1.2(a). Ceiling-Level Sprinkler Protection Guidelines on a Wet System for the Protection of 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 2.2.7.1.2(b). Ceiling-Level Sprinkler Protection Guidelines on a Dry System for the Protection of 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 2.1.4.5.4 to determine the ceiling sprinkler's hose demand design and water supply duration.

2.2.7.1.4 See Section 2.1.4.5.5 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 2.2.7.2.1 to determine the recommended horizontal in-rack sprinkler arrangement for the storage rack to be protected.

Table 2.2.7.2.1. Recommended Horizontal In-Rack Sprinkler Arrangements for the Protection of Open-Top, Combustible Containers in a Mini-Load ASRS

Overall Maximum Rack Depth, ft (m)	*In-Rack Sprinkler Type*	*Applicable Horizontal IRAS Arrangement Figures*
3 (0.9)	Wet or Dry	2.2.7.2.1(a)
8 (2.4)	Wet or Dry	2.2.7.2.1(b)
13 (4.0)	Wet	2.2.7.2.1(c)
	Dry	2.2.7.2.1(d)
Over 13 (4.0)	Wet or Dry	2.2.7.2.1(e)

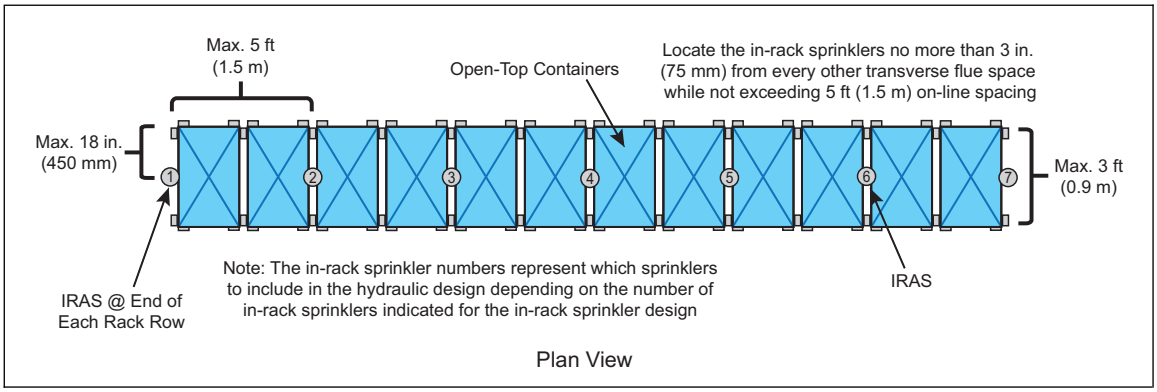

Fig. 2.2.7.2.1(a). Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Mini-Load ASRS Where Rack Row Depths Do Not Exceed 3 ft (0.9 m) per Table 2.2.7.2.1

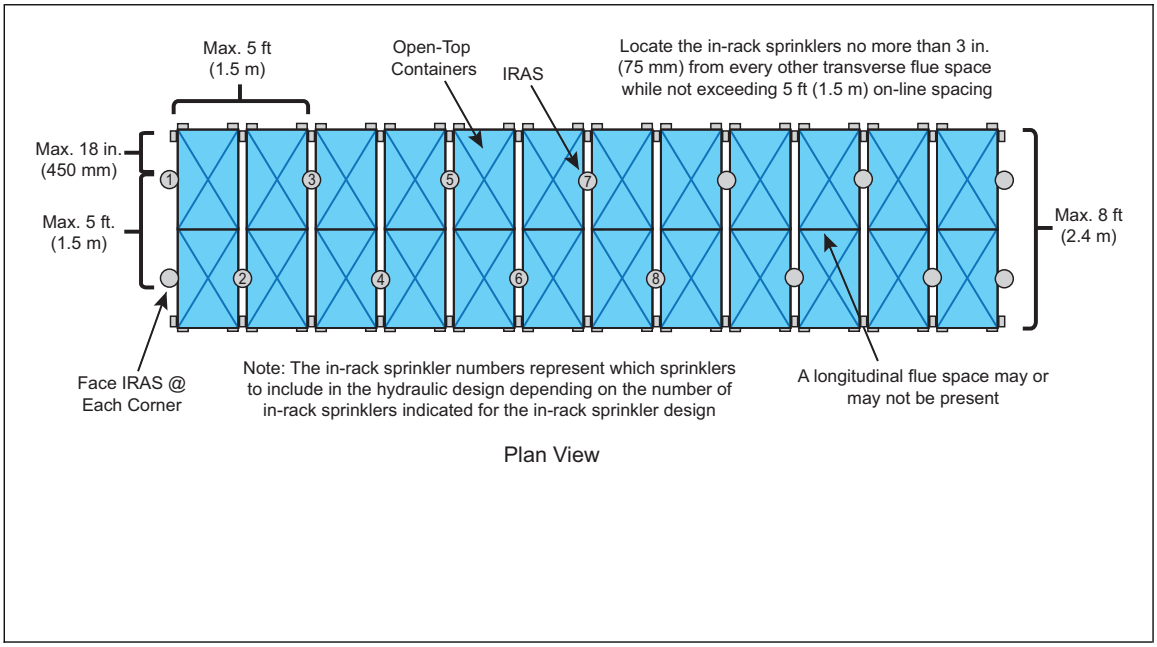

Fig. 2.2.7.2.1(b). Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Mini-Load ASRS Where the Overall Rack Depths Do Not Exceed 8 ft (2.4 m) per Table 2.2.7.2.1

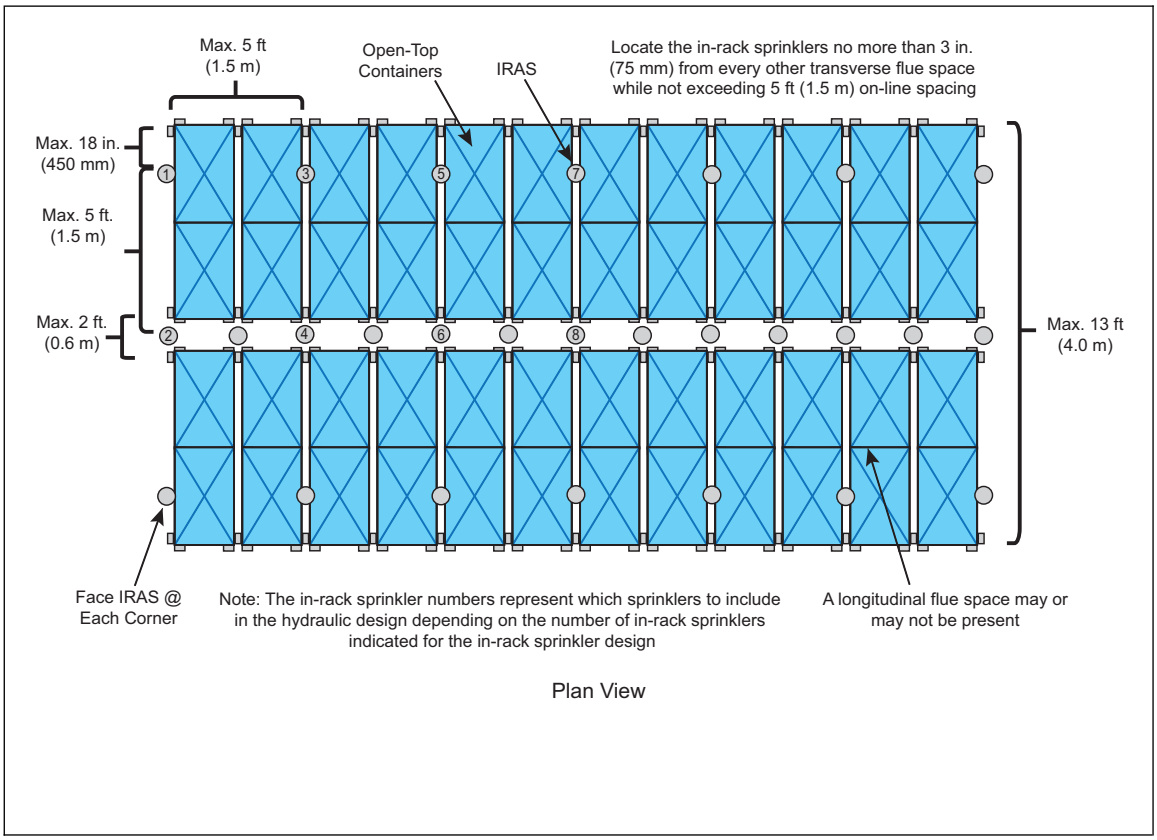

Fig. 2.2.7.2.1(c). Horizontal IRAS for Open-Top Combustible Containers within a Mini-Load ASRS Where the Overall Rack Depths Do Not Exceed 13 ft (4.0 m) per Table 2.2.7.2.1

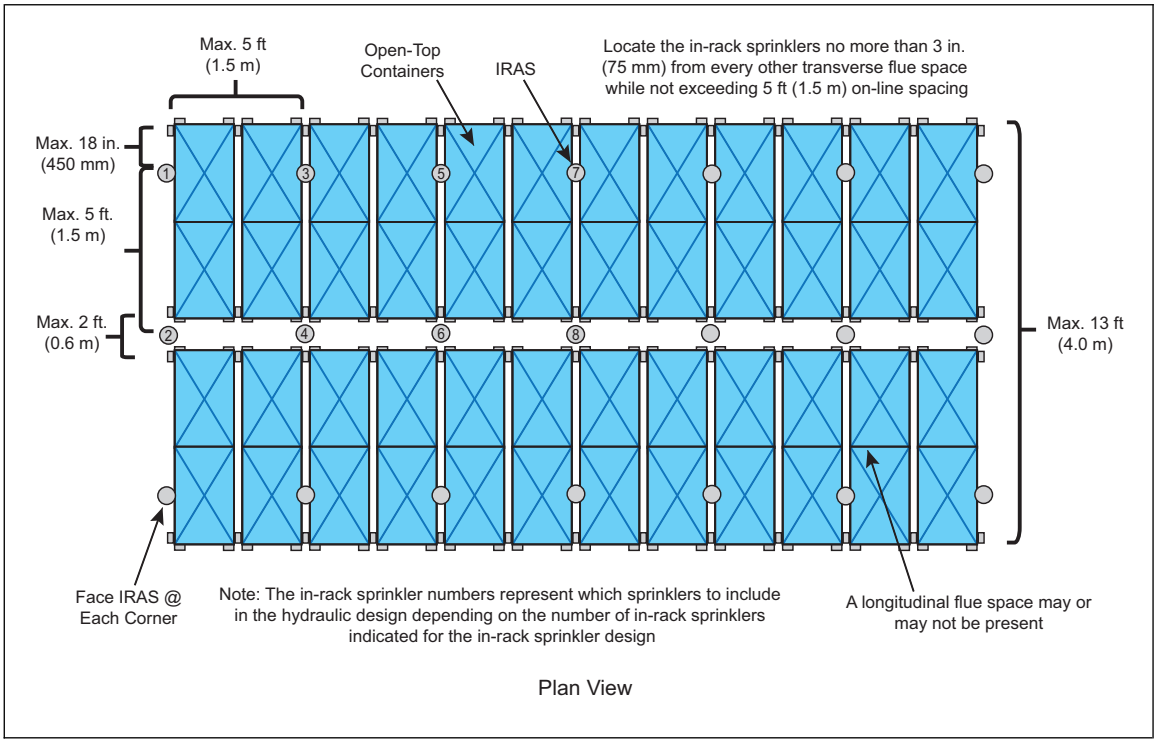

Fig. 2.2.7.2.1(d). Horizontal IRAS on a Dry System for Open-Top Combustible Containers within a Mini-Load ASRS Where the Overall Rack Depths Do Not Exceed 13 ft (4.0 m) per Table 2.2.7.2.1

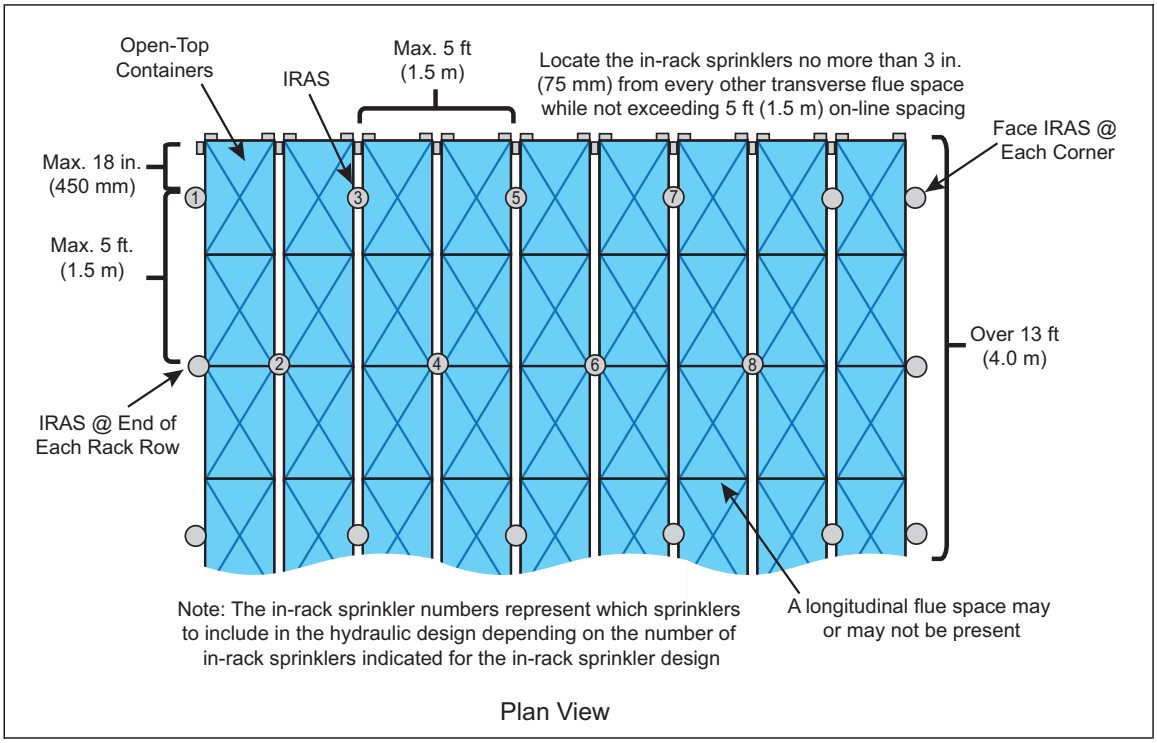

Fig. 2.2.7.2.1(e). Horizontal IRAS Arrangement for Open-Top Combustible Containers within a Mini-Load ASRS Where the Overall Rack Depths Exceed 13 ft (4.0 m) per Table 2.2.7.2.1

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 See the flowchart in Figure 2.2.7.2.2.1 to determine which protection table to use for obtaining the allowable in-rack sprinkler vertical locations, as well as the corresponding recommended in-rack sprinkler design.

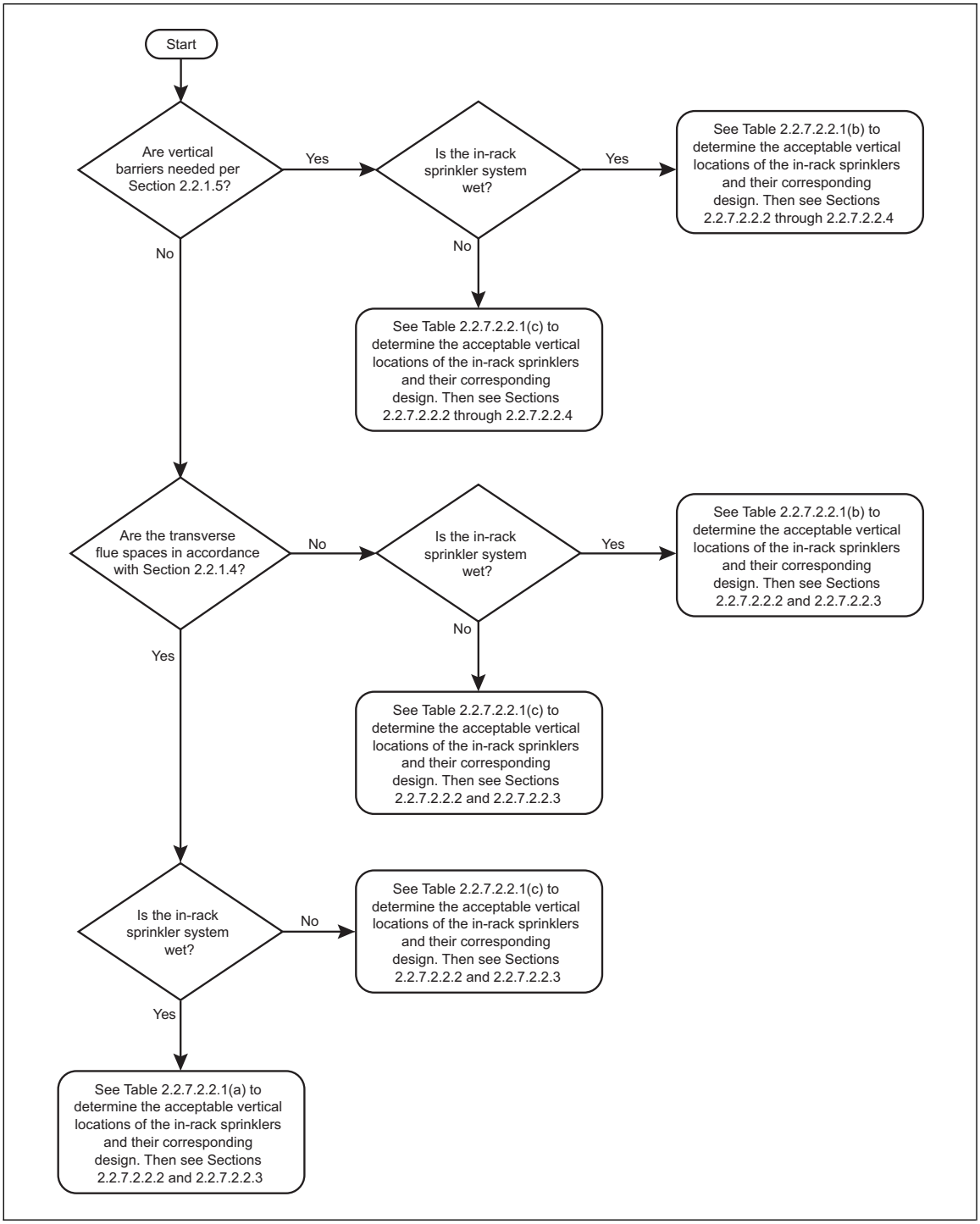

Fig. 2.2.7.2.2.1. Flowchart to determine which table to use to find the acceptable vertical locations and designs for in-rack sprinklers

Table 2.2.7.2.2.1(a). Wet, 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 with Flue Spaces in Accordance with Section 2.2.1.4

Recommended IRAS Arrangement per Table 2.2.7.2.1	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 2.2.7.2.1(a)	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
Figures 2.2.7.2.1(b), 2.2.7.2.1(c), or 2.2.7.2.1(e)	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

* 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 2.2.7.2.2.1(b). Wet, 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 with Flue Spaces Not in Accordance with Section 2.2.1.4

Recommended IRAS Arrangement per Table 2.2.7.2.1	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 2.2.7.2.1(a)	10 (3.0)	100 (380)	11.2 (160)	4 on top IRAS level	No
Figures 2.2.7.2.1(b), 2.2.7.2.1(c), or 2.2.7.2.1(e)	10 (3.0)	100 (380)	11.2 (160)	6 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.

Table 2.2.7.2.2.1(c). Dry, 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 2.2.7.2.1	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 2.2.7.2.1(a) through 2.2.7.2.1(e)	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.

2.2.7.2.2.2 Limit the storage height above the top in-rack sprinkler level to a maximum height of 10 ft (3.0 m) when flue spaces are in accordance with Section 2.2.1.4, otherwise limit the storage height above the top in-rack sprinkler level to a maximum of 5 ft (1.5 m).

2.2.7.2.2.3. While the in-rack sprinkler designs given in Tables 2.2.7.2.2.1(a) through 2.2.7.2.2.1(c) 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.

2.2.7.2.2.4 When Section 2.2.1.5 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 2.2.7.2.1(c), and the number of in-rack sprinklers between the vertical barriers is 11 then the design for the in-rack sprinkler system would be per Table 2.2.7.2.2.1(b) and would be based on 11 IRAS @ 100 gpm (380 L/min) instead of 6 IRAS @ 100 gpm (380 L/min).

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 2.2.7.2.3.1 to determine the wet ceiling-level sprinkler system designs in combination with in-rack sprinklers by using the vertical distance between the top in-rack sprinkler level and the maximum ceiling height above the ASRS protected area. 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 2.2.7.2.3.1, or
2. Install in-rack sprinklers over the top of storage and design the ceiling sprinkler system per Table 2.2.7.2.3.1.

Table 2.2.7.2.3.1. Ceiling-Level Sprinkler Protection Guidelines, in Combination with In-Rack Sprinklers, on a Wet System 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		
		K11.2 (160)	K14.0 (200)	K16.8 (240)	K22.4 (320)	K25.2 (360)	K25.2EC (360EC)	K28.0 (400)K	33.6 (480)	K11.2 (160)	K14.0 (200)	K19.6 (280)	K25.2 (360)	K11.2 (160)	K14.0 (200)	K16.8 (240)	K25.2EC (360EC)	K11.2 (160)	K16.8 (240)	K25.2 (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.

2.2.7.2.3.2 Use Table 2.2.7.2.3.2 to determine the dry ceiling-level sprinkler system designs in combination with in-rack sprinklers by using the vertical distance between the top in-rack sprinkler level and the maximum ceiling height above the ASRS protected area. 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 2.2.7.2.3.2, or
2. Install in-rack sprinklers over the top of storage and design the ceiling sprinkler system per Table 2.2.7.2.3.2.

Table 2.2.7.2.3.2. Ceiling-Level Sprinkler Protection Guidelines, in Combination with In-Rack Sprinklers, on a Dry System 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			
		K11.2 (160)	K16.8 (240)	K25.2 (360)	K33.6 (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)

2.2.7.2.3.3 See Section 2.1.4.5.4 to determine the ceiling sprinkler's hose demand design and water supply duration.

2.2.7.2.3.4 See Section 2.1.4.5.5 to determine the number of sprinklers per branch line for ceiling-level sprinkler calculations.

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

Use the flowchart in Figure 2.3 to help navigate Section 2.3 depending on the type of containers being used within the top-loading ASRS storage arrangement.

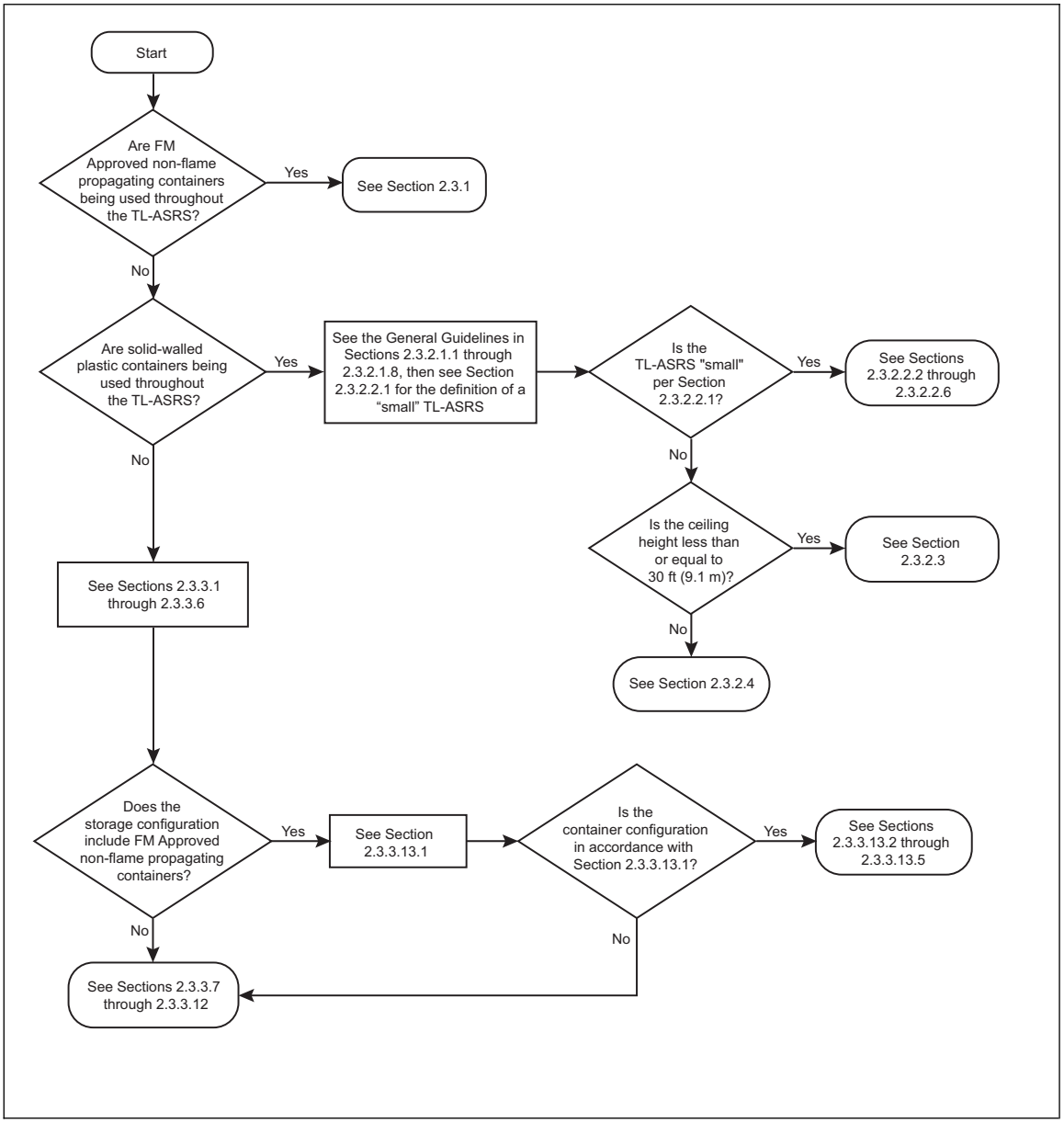

Fig. 2.3. Flowchart for navigating Section 2.3

2.3.1 Top-Loading ASRS Storage Arrangements Using FM Approved Non-Flame Propagating Containers

2.3.1.1 When FM Approved non-flame propagating containers are used throughout the top-loading ASRS storage area, install ceiling-level sprinkler protection over the top-loading ASRS storage area using a design that, as a minimum, is acceptable for the protection of the occupancies located adjacent to the top-loading ASRS storage area.

2.3.1.2 When the top-loading ASRS storage area will consist of containers other than FM Approved non-flame propagating containers, install ceiling-level protection over the top-loading ASRS storage area designed for the protection of the worst-case container being used.

2.3.2 Top-Loading ASRS Storage Arrangements Using Solid-Walled Containers

2.3.2.1 General Guidelines for TL-ASRS Storage Arrangements Using Solid-Walled Containers

2.3.2.1.1 Pre-Incident Planning for TL-ASRS Storage Arrangements Using Solid-Walled Containers

2.3.2.1.1.1 Establish a pre-incident plan with the local fire service that takes into consideration how they will gain access to any point of the ASRS storage grid for extinguishment purposes. Items to consider, at a minimum, include:

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

B. A plan on how to remove the storage containers from the storage grid, as well as a place to put them, and

C. An understanding of where the Robot Holding Areas are so they can be avoided when trying to reach the point of fire origin, and

D. Allowing the ceiling sprinkler system to operate continuously for a minimum of two hours, or until the fire has been confirmed to be extinguished by the local fire services once they have accessed the seat of the fire area.

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

2.3.2.1.2 Robots for TL-ASRS Storage Arrangements Using Solid-Walled Containers

2.3.2.1.2.1 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.

2.3.2.1.3 Robot Holding Areas for TL-ASRS Storage Arrangements Using Solid-Walled Containers

2.3.2.1.3.1 Establish “Robot Holding Areas” within the storage grid where robots can move to upon the activation of the fire detection system. See Figure 2.3.2.1.3.1 for an example of this arrangement.

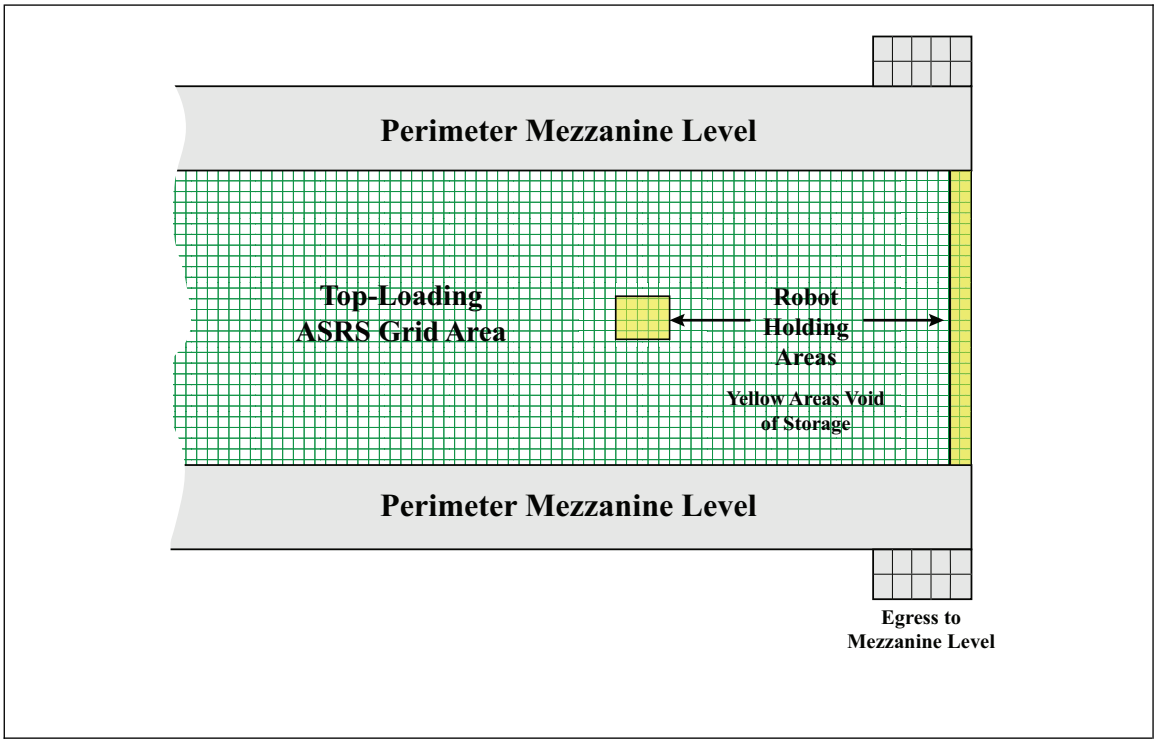

Fig. 2.3.2.1.3.1. Examples of Potential Robot Holding Areas

2.3.2.1.3.2 Avoid designating a Robot Holding Area where a local fire service access point into the storage grid has been established.

2.3.2.1.3.3 Maintain the storage columns of a Robot Holding Area free of combustibles.

2.3.2.1.4 Fire Detection for TL-ASRS Storage Arrangements Using Solid-Walled Containers

2.3.2.1.4.1 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*.

2.3.2.1.4.2 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.

2.3.2.1.4.3 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.

2.3.2.1.4.4 Arrange the fire detection system upon activation to:

A. Send an alarm to a constantly attended location, and
B. Automatically send the robots to the Robot Holding Area, and
C. Deactivate the robot charging stations

2.3.2.1.5 Containment and Drainage for TL-ASRS Storage Arrangements Using Solid-Walled Containers

2.3.2.1.5.1 If the expected water application duration during a fire event could result in excessive water damage to surrounding building and contents, consider the installation of a minimum 4 in. (100 mm) high curbing along the perimeter of the storage array in combination with properly designed floor drainage that takes into account both the ceiling sprinkler discharge and the expected hose stream application.

2.3.2.1.6 Ceiling-Level Sprinkler System Types for TL-ASRS Storage Arrangements Using Solid-Walled Containers

2.3.2.1.6.1 Depending on the ambient temperature of the ASRS area being protected, unless indicated otherwise in the applicable protection section ceiling-level sprinkler systems can be:

A. Wet-pipe sprinkler systems

B. Single-interlocked preaction sprinkler systems

C. Antifreeze solution sprinkler systems consisting of either an FM Approved antifreeze solution, or a 20% to 30% propylene glycol concentration in water

2.3.2.1.6.2 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.

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

2.3.2.1.6.4 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.

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

2.3.2.1.7 Ceiling-Level Sprinklers for TL-ASRS Storage Arrangements Using Solid-Walled Containers

2.3.2.1.7.1 Install FM Approved Storage ceiling-level sprinklers in accordance with the designs indicated in the applicable ceiling-level protection table.

2.3.2.1.7.2 When elevated mezzanines are provided over the storage grid, provide sprinkler protection under them on maximum 10 ft (3.0 m) linear spacing using the same sprinkler and branch line pipe size that is installed at ceiling level.

2.3.2.2 Small Top-Loading ASRS Storage Arrangements Using Solid-Walled Containers

2.3.2.2.1 General Guidelines for Small TL-ASRS Storage Arrangements Using Solid-Walled Containers

2.3.2.2.1.1 A top-loading ASRS storage arrangement can be considered small for design purposes when:

A. The storage height of the containers does not exceed 8 ft (2.4 m), and the size of the storage area is limited to a maximum of 10,000 ft^2 (930 m^2), or

B. The storage height of the containers does not exceed 20 ft (6.1 m), and the size of the storage area is limited to a maximum of 2,000 ft^2 (185 m^2)

2.3.2.2.1.2 The size of the small top-loading ASRS storage arrangement is defined by aisleways on all sides of the ASRS that are:

A. Located on the inside of the building (i.e., a side of the ASRS up against an exterior building wall would not be considered accessible), and

B. A minimum 8 ft (2.4 m) wide, or deemed wide enough by the authority having jurisdiction such that the local fire services can gain access within the ASRS.

2.3.2.2.2 Pre-Incident Planning for Small TL-ASRS Storage Arrangements Using Solid-Walled Containers

2.3.2.2.2.1 As a minimum, establish a pre-incident plan in cooperation with the local fire services using FM Data Sheet 10-1, *Pre-Incident Planning*, as a reference.

2.3.2.2.2.2 Establish a means by which the local fire service can monitor the status of the fire from a position above the top of the storage grid. This could include a perimeter mezzanine, an observation platform, a video camera, or other such means deemed acceptable to the local fire services.

2.3.2.2.2.3 While the recommendations in Section 2.3.2.1.1 help establish an ideal pre-incident plan, they are optional for a small top-loading ASRS storage arrangement.

2.3.2.2.3 Robot Holding Areas for Small TL-ASRS Storage Arrangements Using Solid-Walled Containers

2.3.2.2.3.1 Robot Holding Areas are optional for a small top-loading ASRS storage arrangement when:

A. The storage height does not exceed 5 ft (1.5 m), or

B. The size of the storage area does not exceed 500 ft^2 (46 m^2).

2.3.2.2.3.2 If a Robot Holding Area is provided, the columns within the Robot Holding Areas should be kept free of storage.

2.3.2.2.4 Fire Detection for Small TL-ASRS Storage Arrangements Using Solid-Walled Containers

2.3.2.2.4.1 Provide a constantly monitored fire detection system (smoke or heat) for a small top-loading ASRS storage arrangement.

2.3.2.2.5 Containment and Drainage for Small TL-ASRS Storage Arrangements Using Solid-Walled Containers

2.3.2.2.5.1 Containment and drainage are optional for a small top-loading ASRS storage arrangement.

2.3.2.2.6 Ceiling-Level Sprinkler System Design Criteria for Small TL-ASRS Storage Arrangements Using Solid-Walled Containers

2.3.2.2.6.1 Where the storage height of the containers does not exceed 5 ft (1.5 m), design the ceiling sprinkler system in accordance with a HC-3 occupancy hazard classification as outlined in FM Property Loss Prevention Data Sheet 3-26, *Fire Protection for Nonstorage Occupancies* (i.e., Data Sheet 3-26).

2.3.2.2.6.2 Where the storage height of the containers exceeds 5 ft (1.5 m) but does not exceed 8 ft (2.4 m), design the ceiling sprinkler system in accordance with Low-Piled Storage as outlined in Data Sheet 3-26. Note that the parameters indicated in the definition of low-piled storage do not apply to the small top-loading ASRS arrangement.

2.3.2.2.6.3 Where the storage height of the containers exceeds 8 ft (2.4 m), design the ceiling sprinkler system in accordance with Section 2.3.2.3 or 2.3.2.4, depending on the ceiling height.

2.3.2.3 Top-Loading ASRS Storage Arrangements Using Solid-Walled Containers; Ceiling Heights Not Exceeding 30 ft (9.1 m)

2.3.2.3.1 Access to the TL-ASRS Storage Grid

2.3.2.3.1.1 Establish readily accessible, clearly marked designated locations along the side walls of the top-loading 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.

2.3.2.3.1.2 Consider limiting the horizontal distance between one end of the storage array and the opposite end to a maximum of 100 ft (30 m).

2.3.2.3.1.3 Install mezzanine(s) and/or platform(s), at a minimum, along the longer walls of the top-loading ASRS unit at a height equal to or above the storage grid so representatives of the local fire service have visual access to the top of the storage grid. See Figure 2.3.2.3.1.3 for examples of mezzanines and/or platforms. Determine from the local fire service representatives the number of mezzanine(s) and/or platform(s) they would need, the minimum width and depth of the mezzanine(s) and/or platform(s) they would require, and the minimum number of access points for each mezzanine and/or platform area.

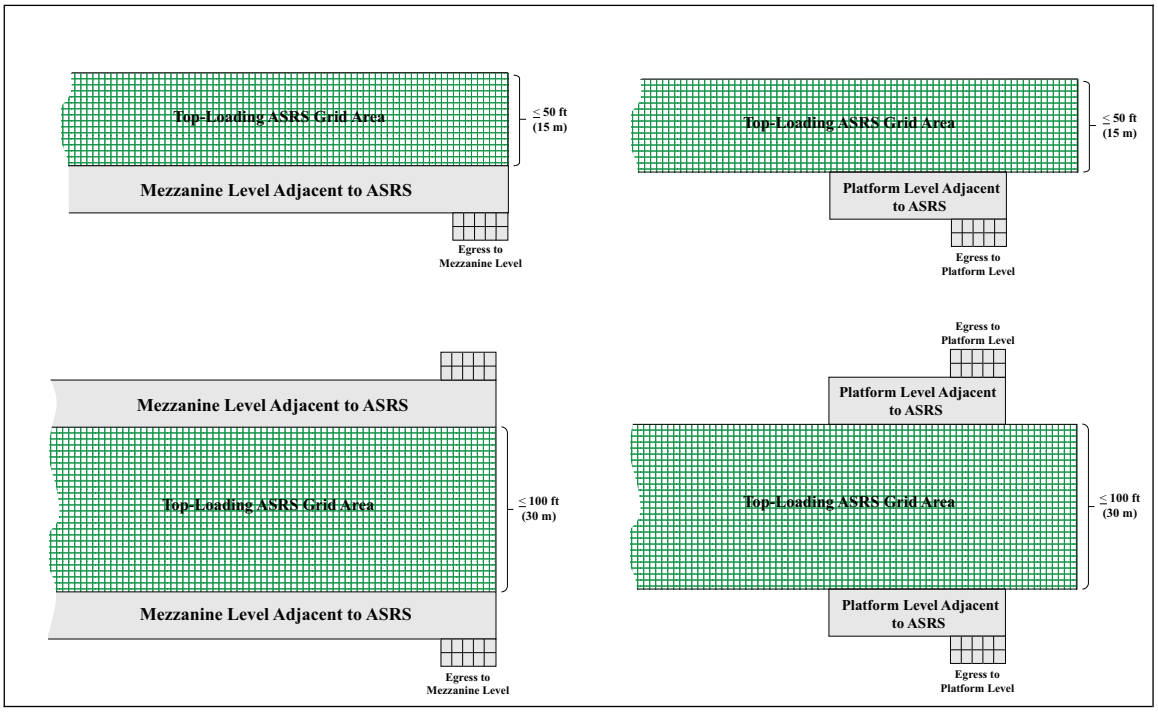

Fig. 2.3.2.3.1.3. Examples of mezzanine(s) and/or platform(s) for a TL-ASRS arrangement

2.3.2.3.2 Ceiling-Level Sprinkler System Types for TL-ASRS Storage Arrangements Using Solid-Walled Containers; Ceiling Heights Not Exceeding 30 ft (9.1 m)

2.3.2.3.2.1 Install a wet sprinkler system for the protection of the top-loading ASRS. Anti-freeze solution and single-interlocked preaction sprinkler systems are not recommended for the protection options offered in Section 2.3.2.3.

2.3.2.3.2.2 If the ambient temperature of the storage area requires the installation of a ceiling sprinkler system other than wet, design the ceiling-level sprinkler system protecting the top-loading ASRS in accordance with Section 2.3.2.4.

2.3.2.3.3 Ceiling-Level Sprinkler System Protection Guidelines for TL-ASRS Using Solid-Walled Containers; Ceiling Heights Not Exceeding 30 ft (9.1 m)

2.3.2.3.3.1 See Table 2.3.2.3.3.1 to determine the available ceiling-level sprinkler designs for the protection of solid-walled containers stored to a maximum height of 20 ft (6.1 m) in a top-loading ASRS storage arrangement.

Table 2.3.2.3.3.1. Ceiling-Level Sprinkler Protection Guidelines that Reduce Some of the Final Extinguishment Recommendations when Protecting Solid-Walled Containers Stored to a Maximum Height of 20 ft (6.1 m) in a Top-Loading ASRS Storage Arrangement; Maximum Ceiling Height of 30 ft (9.1 m)

Max. Ceiling Height, ft (m)	*Maximum Vertical Distance of Sprinkler Thermal Element Below Ceiling, in. (mm)*	*Ceiling-Level Sprinkler Protection Options for Solid-Walled Containers to Maximum 20 ft (6.1 m) in a Top-Loading ASRS Storage Arrangement; 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)	6 @ 50 (3.5)	6 @ 39 (2.7)	6 @ 32 (2.2)	6 @ 22 (1.5)
28 (8.5)	13 (325)			6 @ 85 (5.9)	6 @ 65 (4.5)	6 @ 53 (3.7)	6 @ 36 (2.5)
30 (9.1)	13 (325)				6 @ 120 (8.3)	6 @ 95 (6.6)	6 @ 65 (4.5)

*This ceiling height is recommended only for locations where the grid that supports the robots is at least 8 ft (2.4 m) below the underside of the ceiling.

2.3.2.3.3.2 For hydraulic calculation purposes, the arrangement of the design areas obtained from Table 2.3.2.3.3.1 can be based on the following:

A. For sprinkler designs with 6 sprinklers, arrange the demand area based on three branch lines with 2 sprinklers.

B. For sprinkler designs with 9 sprinklers, arrange the demand area based on three branch lines with 3 sprinklers.

2.3.2.3.4 Hose Demand Design Guidelines for TL-ASRS Storage Arrangements Using Solid-Walled Containers; Ceiling Heights Not Exceeding 30 ft (9.1 m)

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

2.3.2.3.5 Water Supply Duration Design Guidelines for TL-ASRS Storage Arrangements Using Solid-Walled Containers; Ceiling Heights Not Exceeding 30 ft (9.1 m)

2.3.2.3.5.1 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.

2.3.2.4 Top-Loading ASRS Storage Arrangements Using Solid-Walled Containers; Ceiling Heights Over 30 ft (9.1 m)

2.3.2.4.1 Pre-Incident Planning for TL-ASRS Storage Arrangements Using Solid-Walled Containers with Ceiling Heights Over 30 ft (9.1 m)

2.3.2.4.1.1 In addition to the items listed in Sections 2.1.5 and 2.3.2.1.1, enhance the documented Pre-Incident Plan when ceiling heights are over 30 ft (9.1 m) to include the following:

1. A list of key personnel by name or role and contact details, including those from the local fire service, and

2. Details regarding the fire protection equipment that have been installed for extinguishment purposes, and

3. Clear step-by-step actions during a fire event, and the expected timeframe associated with each, as well as who will be conducting them (i.e., building evacuation, sprinkler valve and pump attendance, incident assessment, search and rescue, water application by monitor nozzles, water application from hoses, dismantling and entering the storage array, removal of tote boxes to a safe location, etc.), and

4. Instructions and details of the equipment required to access and disassembly the storage array, and

5. Resources needed for post-fire cleanup and restoration

2.3.2.4.1.2 Locate equipment required to disassemble the storage array in a clearly marked area or cabinet which is safely accessible in a fire.

2.3.2.4.1.3 On an annual basis review and update, as needed, the pre-incident plan. Include dates associated with the last review of the plan, when training was provided to key personnel, and the latest training drill.

2.3.2.4.1.4 Provide education and training for key personnel. See the FM Fire Service Learning Network, or other similar sources, for videos that are relevant to this topic.

2.3.2.4.1.5 Conduct on-site training drills with the site fire team and local fire service representatives at least every three years.

2.3.2.4.2 Mezzanine(s)/Platform(s) and Configuration of TL-ASRS Storage Arrangements Using Solid-Walled Containers; Ceiling Heights Over 30 ft (9.1 m)

2.3.2.4.2.1 Install mezzanine(s) and/or platform(s), at a minimum, along the longer walls of the top-loading ASRS unit at a height equal to or above the storage grid so representatives of the local fire service have visual access to the top of the storage grid. See Figure 2.3.2.4.2.1 for examples of mezzanines and/or platforms. Determine from the local fire service representatives the number of mezzanine(s) and/or platform(s) they would need, the minimum width and depth of the mezzanine(s) and/or platform(s) they would require, and the minimum number of access points for each mezzanine and/or platform area.

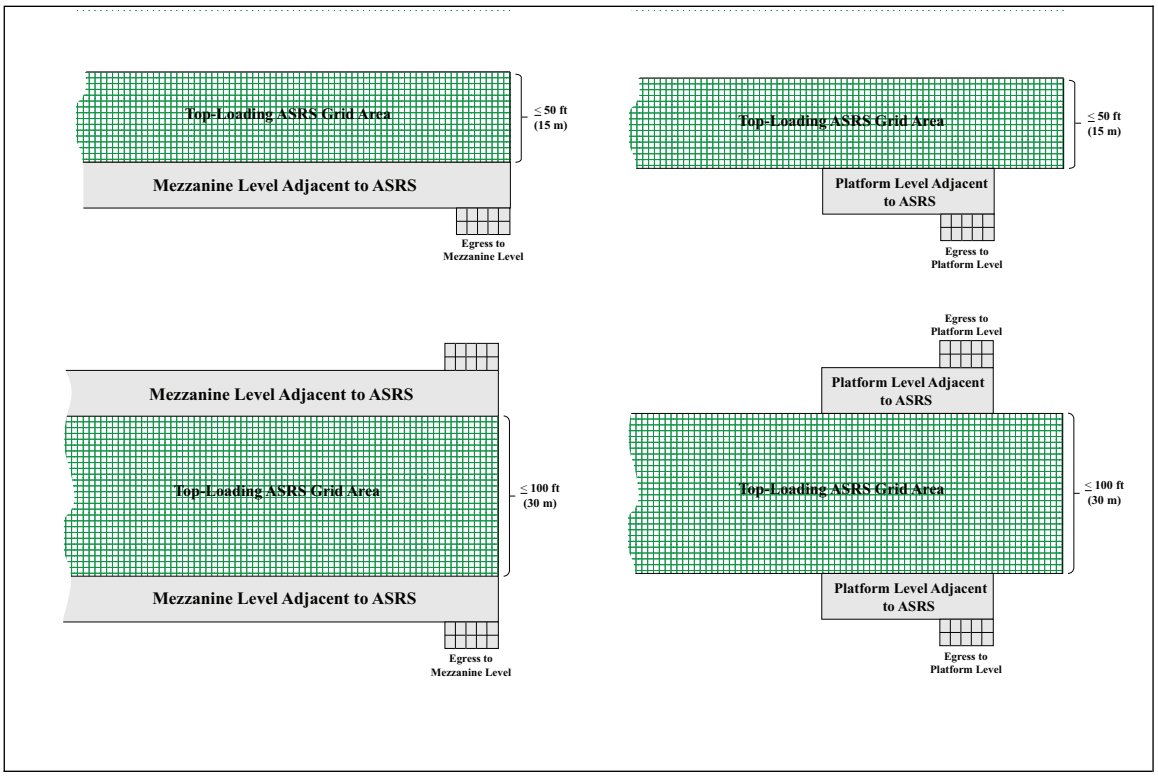

Fig. 2.3.2.4.2.1. Examples of mezzanine(s) and/or platform(s) for a TL-ASRS arrangement

2.3.2.4.2.2 Consider limiting the horizontal distance between one end of the storage array and the opposite end to a maximum of 100 ft (30 m).

2.3.2.4.2.3 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 at maximum horizontal distances of 100 ft (30 m) as demonstrated in Figure 2.3.2.4.2.3.

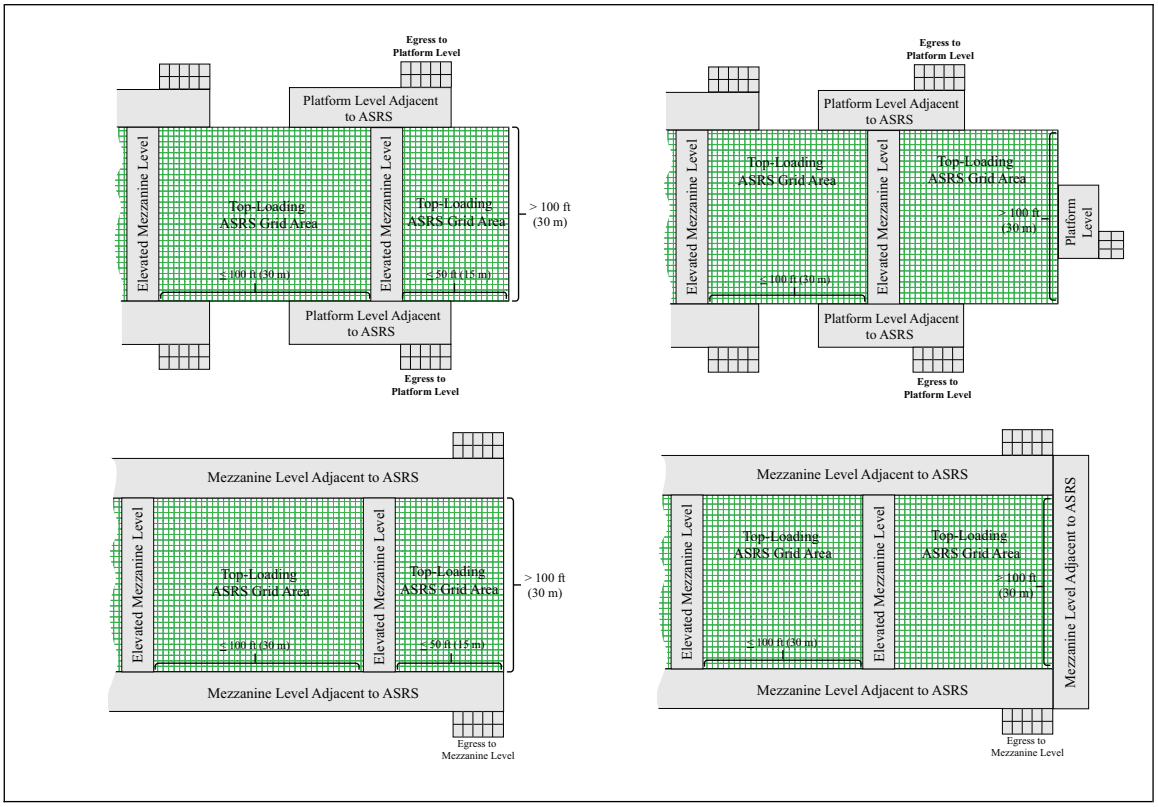

Fig. 2.3.2.4.2.3. Example of solid-floored elevated mezzanine levels when span of TL-ASRS exceeds 100 ft (30 m) in each direction

2.3.2.4.2.4 The installation of elevated mezzanines can be avoided when 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 2.3.2.4.3 and 2.3.2.4.4..

2.3.2.4.2.5 Establish readily accessible, clearly marked designated locations along the side walls of the top-loading 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.

2.3.2.4.3 Fixed-In-Place Monitor Nozzle Protection for TL-ASRS Storage Arrangements Using Solid-Walled Containers; Ceiling Heights Over 30 ft (9.1 m)

2.3.2.4.3.1 In addition to installing ceiling sprinkler protection for the TL-ASRS, install fixed-in-place monitor nozzles throughout the TL-ASRS storage area.

2.3.2.4.3.2 Attach the monitor nozzles to the mezzanine(s)/platform(s) and/or to the overhead ceiling structure as follows:

A. When the monitor nozzles are fixed-in-place on the mezzanine(s)/platform(s) structure(s), 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.

2.3.2.4.3.3 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 2.3.2.4.3.3(A) and 2.3.2.4.3.3(B) for examples of this arrangement.

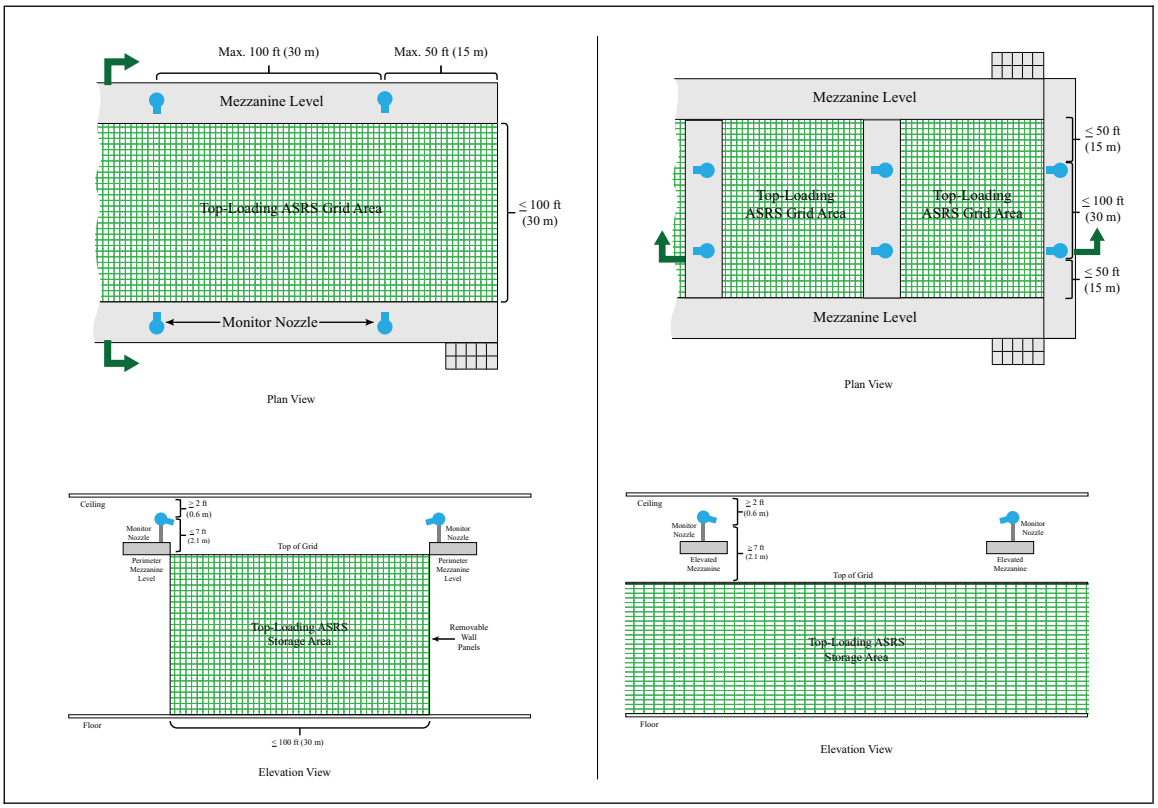

Fig. 2.3.2.4.3.3(A). Examples of TL-ASRS arrangements protected by fixed-in-place monitor nozzles installed on mezzanines and/or platforms

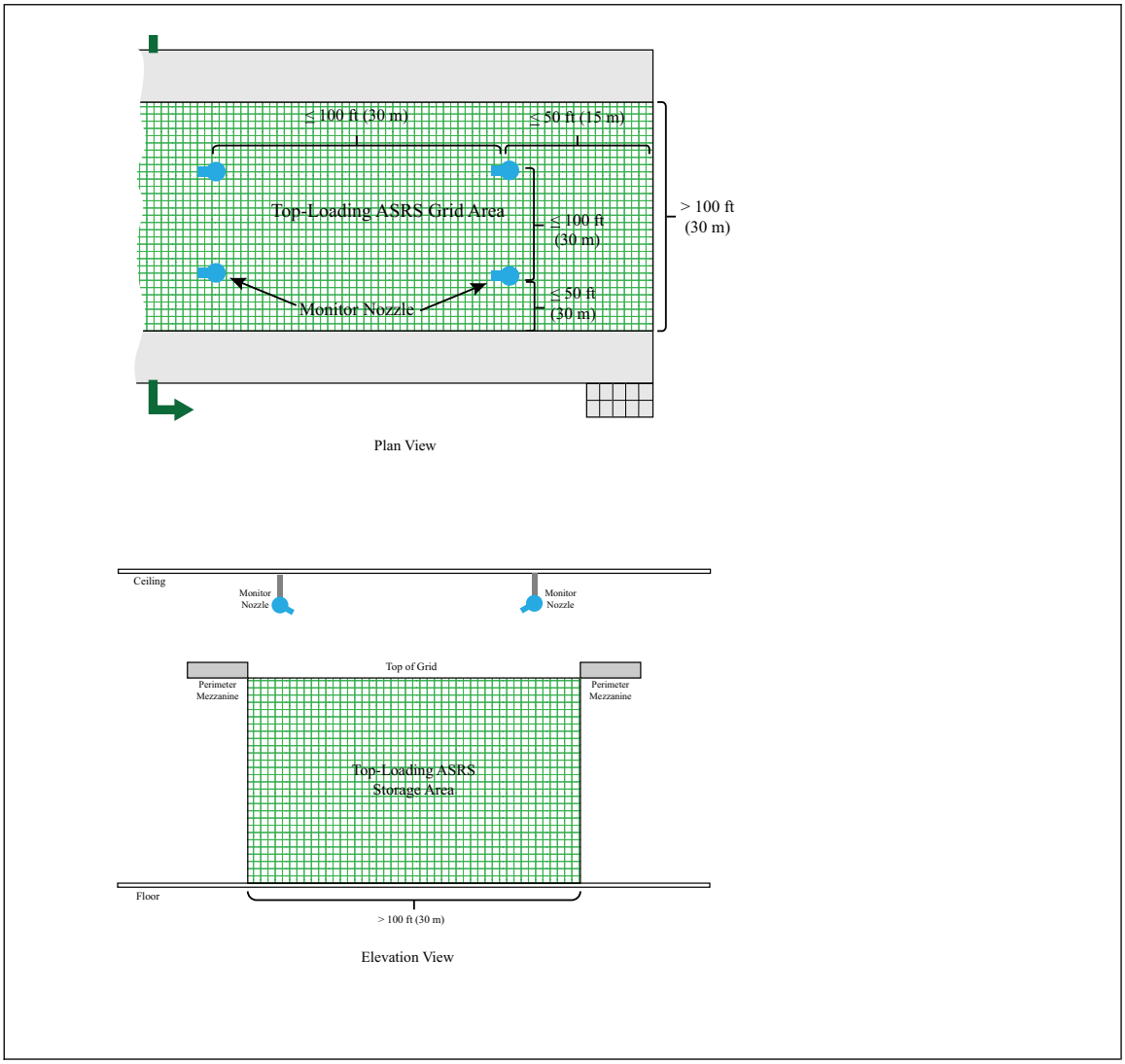

Fig. 2.3.2.4.3.3(B). Example of TL-ASRS arrangement protected by fixed-in-place monitor nozzles installed at ceiling level

2.3.2.4.3.4 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

2.3.2.4.3.5 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).

2.3.2.4.3.6 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 not protecting the ASRS storage area

2.3.2.4.4 Visible or Infrared Camera Installation for Fixed-In-Place Monitor Nozzle Operation Protecting TL-ASRS Storage Arrangements Using Solid-Walled Containers; Ceiling Heights Over 30 ft (9.1 m)

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

2.3.2.4.4.2 Arrange the IR cameras as follows:

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.

2.3.2.4.4.3 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 is (1) unconfined so that smoke can readily escape the ASRS storage area, and (2) the ceiling-level sprinklers are 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 is (1) confined so that smoke cannot readily escape the ASRS storage area, and (2) manually-operated ceiling-level ventilation is provided that can be turned on upon fire service arrival to clear the storage grid area of visible smoke.

2.3.2.4.4.4 When permitted by Section 2.3.2.4.4.3, 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.

2.3.2.4.5 Small Hose Connection Stations for TL-ASRS Storage Arrangements Using Solid-Walled Containers; Ceiling Heights Over 30 ft (9.1 m)

2.3.2.4.5.1 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/platform 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

2.3.2.4.5.2 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).

2.3.2.4.5.3 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 not protecting the TL-ASRS storage area

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

2.3.2.4.6 Ceiling-Level Sprinkler System Design Criteria for TL-ASRS Storage Arrangements Using Solid-Walled Containers; Ceiling Heights Over 30 ft (9.1 m)

2.3.2.4.6.1 Use Table 2.3.2.4.6.1 to determine the ceiling-level sprinkler system designs for TL-ASRS storage arrangements using solid-walled containers having a maximum storage height of 20 ft (6.1 m).

2.3.2.4.6.2 Use Table 2.3.2.4.6.2 to determine the ceiling-level sprinkler system designs for TL-ASRS storage arrangements using solid-walled containers having a storage height that exceeds 20 ft (6.1 m) but does not exceed 25 ft (7.6 m).

2.3.2.4.6.3 For ceiling heights over 45 ft (13.7 m), install a flat, continuous noncombustible false ceiling over the TL-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.

Table 2.3.2.4.6.1. Ceiling-Level Sprinkler Protection Guidelines for the Protection of TL-ASRS Storage Arrangements Using Solid-Walled Containers; Ceiling Heights Over 30 ft (9.1 m) and Storage Heights Not Exceeding 20 ft (6.1 m)

Max. Ceiling Height, ft (m)	*Ceiling-Level Sprinkler Protection Options for Top-Loading ASRS Storage Arrangements Not Exceeding 20 ft (6.1 m); 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)
35 (10.7)		9 @ 75 (5.2)	9 @ 52 (3.6)	9 @ 29 (2.0)	9 @ 23 (1.6)		9 @ 20 (1.4)	9 @ 20 (1.4)											
40 (12.2)		9 @ 75 (5.2)	9 @ 52 (3.6)	9 @ 29 (2.0)	9 @ 23 (1.6)		9 @ 200 (2.8)	9 @ 20 (3.8)											
45 (13.7)				9 @ 75 (5.2)	9 @ 60 (4.1)		9 @ 50 (3.5)	9 @ 34 (2.3)											

Table 2.3.2.4.6.2. Ceiling-Level Sprinkler Protection Guidelines for the Protection of TL-ASRS Storage Arrangements Using Solid-Walled Containers; Ceiling Heights Over 30 ft (9.1 m) and Storage Heights Not Exceeding 25 ft (7.6 m)

Max. Ceiling Height, ft (m)	*Ceiling-Level Sprinkler Protection Options for Top-Loading ASRS Storage Arrangements Not Exceeding 20 ft (6.1 m); 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)
35 (10.7)				12 @ 29 (2.0)	12 @ 23 (1.6)		12 @ 20 (1.4)	12 @ 20 (1.4)											
40 (12.2)				12 @ 29 (2.0)	12 @ 23 (1.6)		12 @ 20 (1.4)	12 @ 20 (1.4)											
45 (13.7)				12 @ 75 (5.2)	12 @ 60 (4.1)		12 @ 50 (3.5)	12 @ 34 (2.3)											

2.3.2.4.7 Hose Demand Design Guidelines for TL-ASRS Storage Arrangements Using Solid-Walled Containers; Ceiling Heights Over 30 ft (9.1 m)

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

2.3.2.4.7.2 When fixed-in-place monitor nozzles are provided in accordance with Section 2.3.2.4.3 and small hose connection stations are provided in accordance with Section 2.3.2.4.5, account for the 500 gpm (1,900 L/min) hose demand design as follows:

A. 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

B. Include a flow of 50 gpm (190 L/min) from each of the two most remote small hose connection stations

2.3.2.4.7.3 When only fixed-in-place monitor nozzles are provided in accordance with Section 2.3.2.4.3, 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.

2.3.2.4.8 Water Supply Duration Guidelines for TL-ASRS Storage Arrangements Using Solid-Walled Containers; Ceiling Heights Over 30 ft (9.1 m)

2.3.2.4.8.1 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 a minimum of 4 hours.

2.3.3 Top-Loading ASRS Storage Arrangements Using Non-Solid-Walled Containers

2.3.3.1 Pre-Incident Planning for TL-ASRS Storage Arrangements Using Non-Solid Walled Containers

2.3.3.1.1 Establish a pre-incident plan with the local fire service that takes into consideration how they will gain access to any point of the ASRS storage grid for extinguishment purposes. Items to consider, at a minimum, include:

A. Access to the storage grid itself (i.e., removal of any separating walls or fences), along with instructions and details of the equipment required to access and disassembly the storage array, and

B. A plan on how to remove the storage containers from the storage grid, as well as a place to put them, and

C. An understanding of where the Robot Holding Areas are so they can be avoided when trying to reach the point of fire origin, and

D. Allowing the ceiling sprinkler system to operate continuously for a minimum of four hours, or until the fire has been confirmed to be extinguished by the local fire services once they have accessed the seat of the fire area, and

E. A list of key personnel by name or role and contact details, including those from the local fire service, and

F. Resources needed for post-fire cleanup and restoration

2.3.3.1.2 Locate equipment required to disassemble the storage array in a clearly marked area or cabinet which is safely accessible during a fire.

2.3.3.1.3 On an annual basis review and update, as needed, the pre-incident plan. Include dates associated with the last review of the plan, when training was provided to key personnel, and the latest training drill.

2.3.3.1.4 Provide education and training for key personnel. See the FM Fire Service Learning Network, or other similar sources, for possible documents and videos that are relevant to this topic.

2.3.3.1.5 Conduct on-site training drills with the site fire team and local fire service representatives at least every three years.

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

2.3.3.2 Robots for TL-ASRS Storage Arrangements Using Non-Solid Walled Containers

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

2.3.3.3 Robot Holding Areas for TL-ASRS Storage Arrangements Using Non-Solid Walled Containers

2.3.3.3.1 Establish “Robot Holding Areas” within the storage grid where robots can move to upon the activation of the fire detection system. See Figure 2.3.3.3.1 for an example of this arrangement.

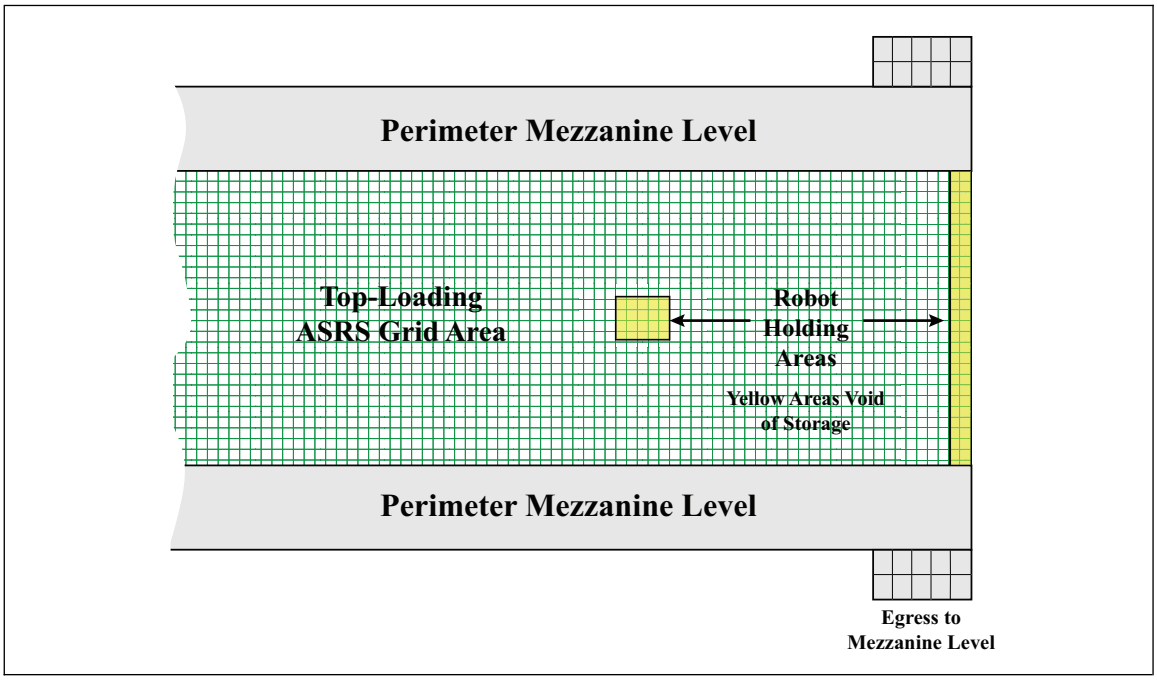

Fig. 2.3.3.3.1. Examples of potential robot holding areas

2.3.3.3.2 Avoid designating a Robot Holding Area where a local fire service access point into the storage grid has been established.

2.3.3.3.3 Maintain the storage columns of a Robot Holding Area free of combustibles.

2.3.3.4 Fire Detection for TL-ASRS Storage Arrangements Using Non-Solid Walled Containers

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

2.3.3.4.2 When the ceiling construction over the storage array is considered unobstructed per FM Property Loss Prevention Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers* (i.e., Data Sheet 2-0), 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.

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

2.3.3.4.4 Arrange the fire detection system upon activation to:

A. Send an alarm to a constantly attended location, and

B. Automatically send the robots to the Robot Holding Area, and

C. Deactivate the robot charging stations

2.3.3.5 Containment and Drainage for TL-ASRS Storage Arrangements Using Non-Solid Walled Containers

2.3.3.5.1 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).

2.3.3.6 Mezzanine(s)/Platform(s) and Configuration of TL-ASRS Storage Arrangements Using Non-Solid Walled Containers

2.3.3.6.1 Install mezzanine(s) and/or platform(s), at a minimum, along the longer walls of the top-loading ASRS unit at a height equal to or above the storage grid so representatives of the local fire service have visual access to the top of the storage grid. See Figure 2.3.3.6.1 for examples of mezzanines and/or platforms. Determine from the local fire service representatives the number of mezzanine(s) and/or platform(s) they would need, the minimum width and depth of the mezzanine(s) and/or platform(s) they would require, and the minimum number of access points for each mezzanine and/or platform area.

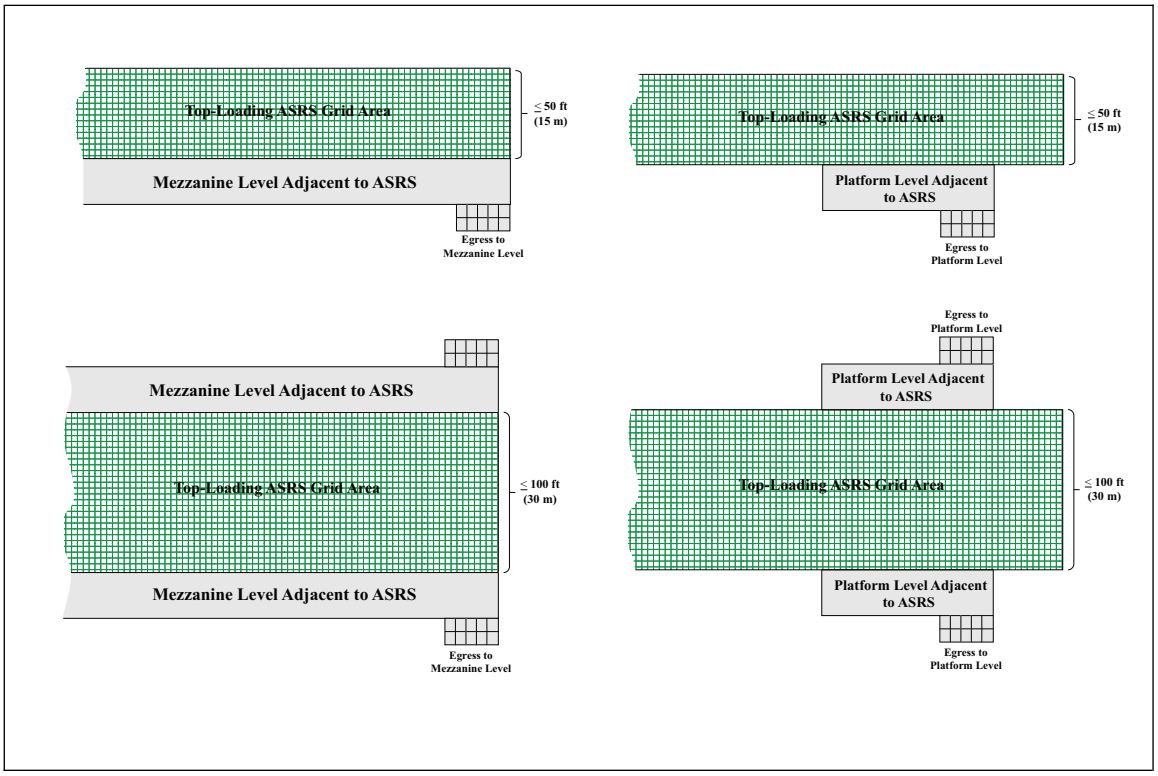

Fig. 2.3.3.6.1. Examples of mezzanine(s) and/or platform(s) for a TL-ASRS arrangement

2.3.3.6.2 Consider limiting the horizontal distance between one end of the storage array and the opposite end to a maximum of 100 ft (30 m).

2.3.3.6.3 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 at maximum horizontal distances of 100 ft (30 m) as demonstrated in Figure 2.3.3.6.3.

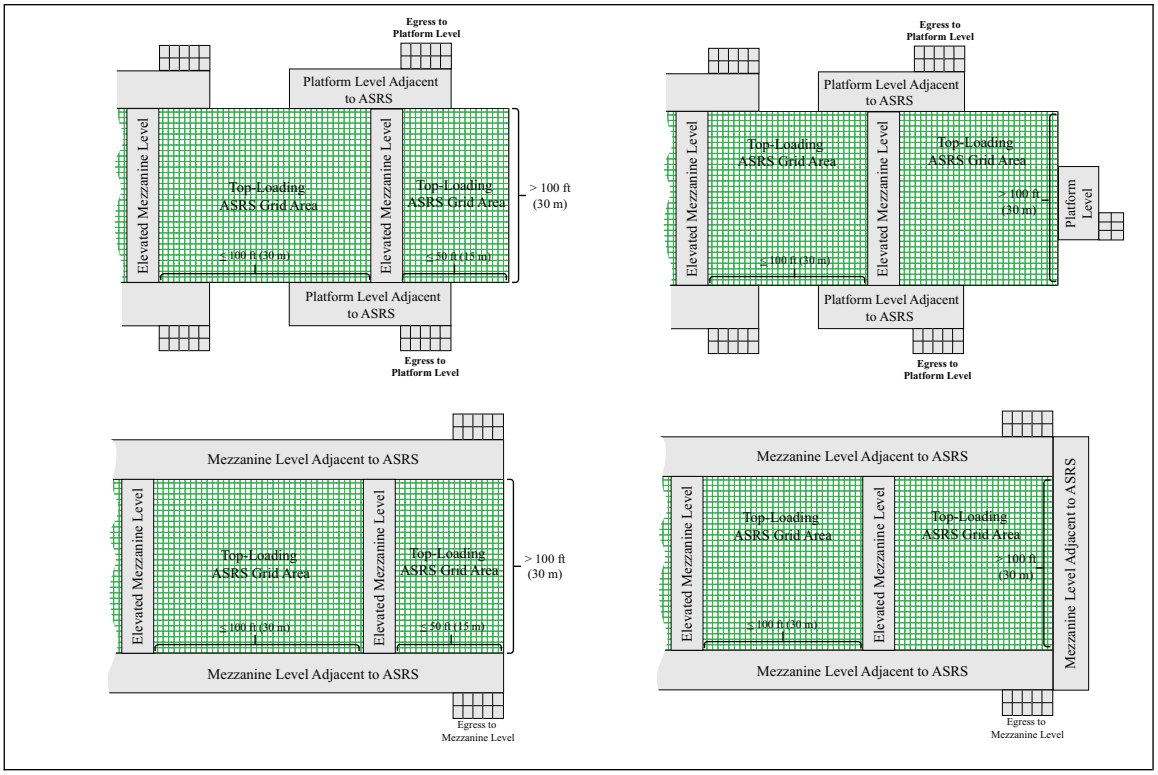

Fig. 2.3.3.6.3. Example of solid-floored elevated mezzanine levels when span of TL-ASRS exceeds 100 ft (30 m) in each direction

2.3.3.6.4 Establish readily accessible, clearly marked designated locations along the side walls of the top-loading 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.

2.3.3.6.5 See Section 2.3.3.13 when the ASRS storage consists of a combination of both non-solid walled containers and FM Approved non-flame propagating containers.

2.3.3.6.6 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 2.3.3.6.6 for a visual representation of these arrangements.

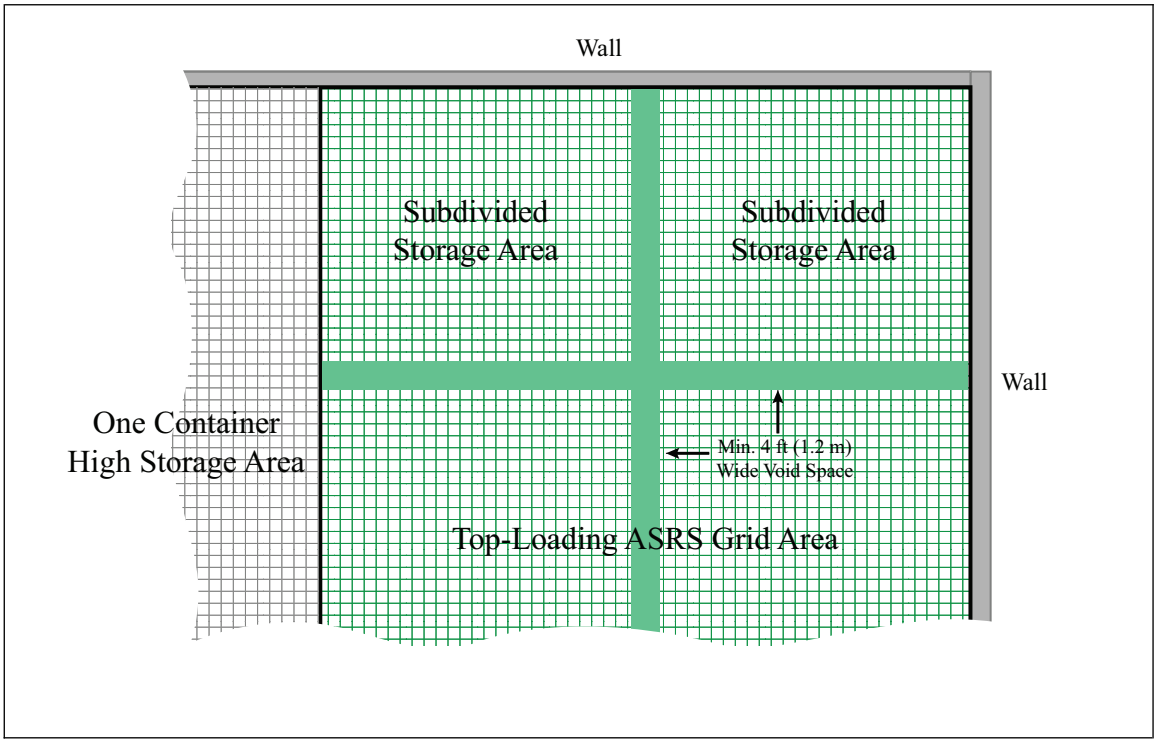

Fig. 2.3.3.6.6. Example of storage subdivisions within a TL-ASRS storage arrangement using non-solid walled containers

2.3.3.6.7 Determine the size of the storage subdivisions based on the number of operating sprinklers the water supply can support. See Section 2.3.3.10 for more information on the sprinkler system design.

2.3.3.6.8 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 2.3.3.6.8.

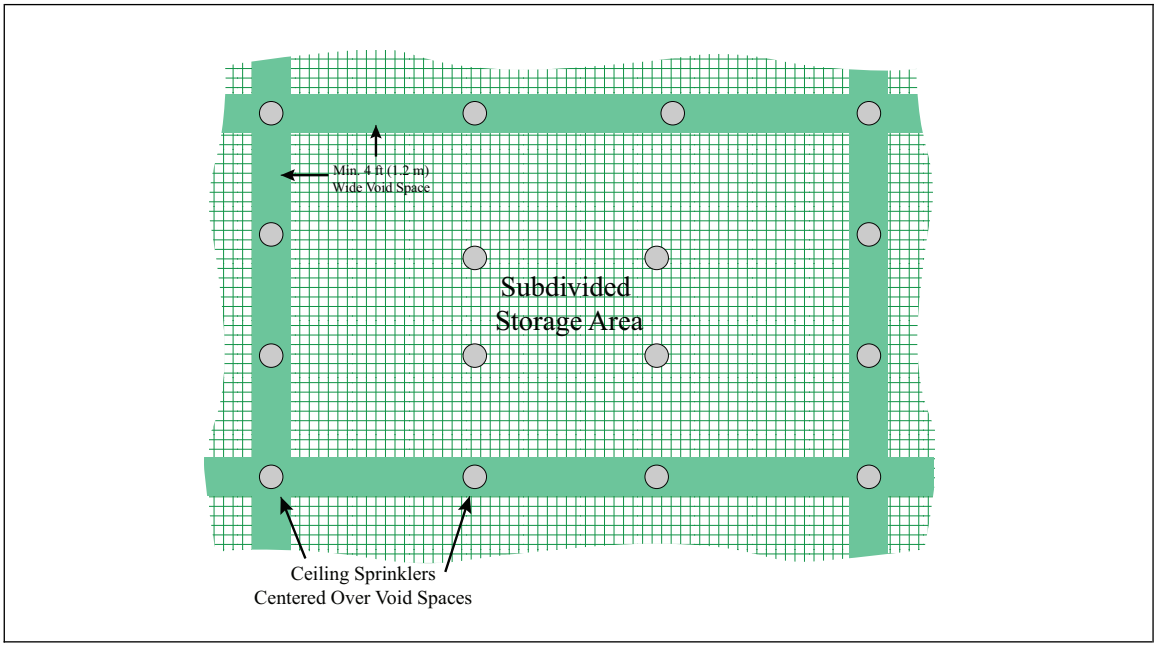

Fig. 2.3.3.6.8. Positioning of void spaces within a TL-ASRS storage arrangement using non-solid walled containers under ceiling sprinklers

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

2.3.3.7 Small Hose Connection Stations for TL-ASRS Storage Arrangements Using Non-Solid Walled Containers

2.3.3.7.1 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/platform 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

2.3.3.7.2 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).

2.3.3.7.3 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 not protecting the TL-ASRS storage area

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

2.3.3.8 Ceiling-Level Sprinkler System Types for TL-ASRS Storage Arrangements Using Non-Solid Walled Containers

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

A. Wet-pipe sprinkler system

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

2.3.3.8.2 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).

2.3.3.8.3 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.

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

2.3.3.9 Ceiling-Level Sprinklers for TL-ASRS Storage Arrangements Using Non-Solid Walled Containers

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

2.3.3.9.2 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.

2.3.3.10 Ceiling-Level Sprinkler System Design Criteria for TL-ASRS Storage Arrangements Using Non-Solid Walled Containers

2.3.3.10.1 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.

2.3.3.10.2 For ceiling heights up to and including 45 ft (13.7 m), the ceiling sprinkler system's design flow is based on a minimum flow of 120 gpm (455 L/min) from the most hydraulically remote operating sprinkler over the storage subdivision.

2.3.3.10.3 The ceiling sprinkler system's demand area is determined 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.

2.3.3.10.4 When determining the ceiling sprinkler demand area in accordance with Section 2.3.3.10.3, 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 system's design.

2.3.3.10.5 When elevated mezzanines are provided over the storage grid, provide sprinkler protection under them on maximum 10 ft (3.0 m) linear spacing using the same sprinkler and branch line pipe size that is installed at ceiling level.

2.3.3.11 Hose Demand Design Guidelines for TL-ASRS Storage Arrangements Using Non-Solid Walled Containers

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

2.3.3.11.2 When small hose connection stations are provided in accordance with Section 2.3.7.7, 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.

2.3.3.12 Water Supply Duration Guidelines for TL-ASRS Storage Arrangements Using Non-Solid Walled Containers

2.3.3.12.1 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.

2.3.3.13 Top-Loading ASRS Storage Arrangements Using a Combination of Non-Solid Walled Containers and FM Approved Non-Flame Propagating Containers

2.3.3.13.1 Configuration of Non-Solid Walled Containers in Combination with FM Approved Non-Flame Propagating Containers

2.3.3.13.1.1 Storage subdivisions can be avoided when the storage grid is arranged in a checkerboard pattern consisting of alternating columns of non-solid walled containers and FM Approved non-flame propagating containers as demonstrated in Figure 2.3.3.13.1.1. Arrange the columns filled with non-flame propagating containers to be maintained at full height except when containers are being retrieved from it. Note that the storage columns designated for use with plastic containers can consist of non-solid walled containers, solid-walled containers, or a combination of both.

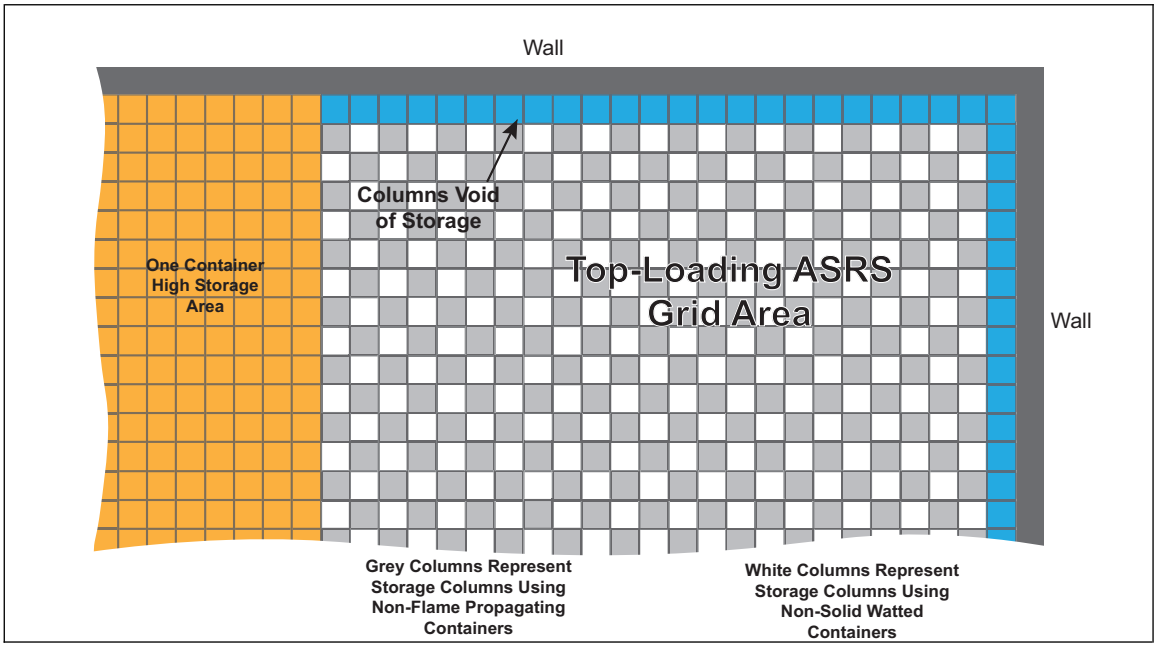

Fig. 2.3.3.13.1.1. Checkerboard storage arrangement pattern consisting of alternating columns of non-solid walled containers and FM Approved non-flame propagating containers

2.3.3.13.1.2 If a false bottom tote is provided at the bottom of a storage column, isolate the false bottom tote, or a group of connected false bottom totes, from any adjacent plastic containers by surrounding it with non-flame propagating containers.

2.3.3.13.1.3 When the storage combination of non-solid walled (or solid-walled) containers and non-flame propagating containers does not meet the intent outlined in Sections 2.3.3.13.1.1 and 2.3.3.13.1.2, treat the storage arrangement as being void of non-flame propagating containers.

2.3.3.13.2 Ceiling-Level Sprinklers for TL-ASRS Storage Arrangements Using a Combination of Non-Solid Walled Containers and FM Approved Non-Flame Propagating Containers

2.3.3.13.2.1 For ceiling heights up to 40 ft (12.2 m), when the ceiling sprinkler system is wet, install FM Approved, quick-response, minimum K14.0 (K200) pendent Storage ceiling-level sprinklers. However, if the ceiling sprinkler system is dry, install FM Approved, standard-response minimum K16.8 (K240) upright Storage ceiling-level sprinklers.

2.3.3.13.2.2 For ceiling heights over 40 ft (12.2 m) and up to 45 ft (13.7 m), when the ceiling sprinkler system is wet, install FM Approved, quick-response, minimum K16.8 (K240) pendent Storage ceiling-level sprinklers. However, if the ceiling sprinkler system is dry, install FM Approved, standard-response minimum K16.8 (K240) upright Storage ceiling-level sprinklers.

2.3.3.13.3 Ceiling-Level Sprinkler System Design Criteria for TL-ASRS Storage Arrangements Using a Combination of Non-Solid Walled Containers and FM Approved Non-Flame Propagating Containers

2.3.3.13.3.1 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 this section.

2.3.3.13.3.2 For ceiling heights up to and including 45 ft (13.7 m), the wet ceiling sprinkler system's design is based on a minimum flow of 120 gpm (455 L/min) from the most remote 6 sprinklers (2 sprinklers on 3 branch lines).

2.3.3.13.3.3 When the ceiling sprinkler system is dry, the ceiling sprinkler system's design flow is based on 80 gpm (300 L/min). For ceiling heights up to and including 30 ft (9.1 m), the number of sprinklers in the

ceiling sprinkler's design is 15 using a maximum 30 second water delivery time. For ceiling heights over 30 ft (9.1 m) and up to 45 ft (13.7 m), the number of sprinklers in the ceiling sprinkler's design is 25 using a maximum 30 second water delivery time.

2.3.3.13.3.4 When elevated mezzanines are provided over the storage grid, provide sprinkler protection under them on maximum 10 ft (3.0 m) linear spacing using the same sprinkler and branch line pipe size that is installed at ceiling level.

2.3.3.13.4 Hose Demand Design Guidelines for TL-ASRS Storage Arrangements Using a Combination of Non-Solid Walled Containers and FM Approved Non-Flame Propagating Containers

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

2.3.3.13.4.2 When small hose connection stations are provided in accordance with Section 2.3.3.7, 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 150 gpm (570 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.

2.3.3.13.5 Water Supply Duration Guidelines for TL-ASRS Storage Arrangements Using a Combination of Non-Solid Walled Containers and FM Approved Non-Flame Propagating Containers

2.3.3.13.5.1 Size the water supply feeding the ceiling sprinkler system for a minimum duration of three 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.

2.4 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 2.4.1.1 for an example of this type of storage arrangement.

Fig. 2.4.1.1. Example of a vertically enclosed ASRS storage unit

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.

2.4.1.3 Take into consideration the amount of stored product that could be exposed to damage when arranging the vertically enclosed ASRS. Ideally limit the footprint size of individual units, or continuous units installed side-by-side, to 200 ft² (185 m²).

2.4.1.4 To help prevent ignition of combustibles located outside of the vertically enclosed ASRS, avoid any storage being located up against the ASRS unit.

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, and limit the vertical distance between the top of the tray and the underside of the next higher shelf level to 2 in. (50 mm) or less.

2.4.2.2 To aid in water penetration throughout the vertical height of the vertically enclosed ASRS unit, use noncombustible trays with either gridded bottoms (when stored on solid shelving), non-watertight gaps along the bottom edge line of the tray, or minimum 10% venting area provided 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, implement one of the following options:

(1) install 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, or

(2) subdivide high-valued inventory into smaller vertically enclosed ASRS storage units to reduce the amount of product that can be exposed to damage.

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 If water damage to inventory within the vertically enclosed ASRS is a concern, install a single-interlock preaction sprinkler system where the activating detection system is installed on the same spacing as the sprinklers within the ASRS unit.

2.4.3.2.3 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.

2.4.3.2.4 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 General

2.4.3.3.1.1 Provide sprinkler protection at the top of a closed-top ASRS unit on maximum 8 ft (2.4 m) linear spacing and maximum 64 ft² (6.0 m²) area spacing.

2.4.3.3.1.2 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 ft² (1.5 m²) area spacing.

2.4.3.3.1.3 In addition to the spacing outlined in Sections 2.4.3.3.1.1 and 2.4.3.3.1.2, install sprinklers so that each wall of the ASRS unit has a sprinkler no more than 2 ft (0.6 m) horizontally from it.

2.4.3.3.1.4 Provide a minimum clearance of 18 in. (450 mm) between the sprinklers and the top of the storage trays.

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

Design the sprinkler system protecting the vertically enclosed ASRS to account for all sprinklers within the ASRS storage unit, or units if they are not separated by solid walls or vertical barriers, using minimum K11.2 (K160) Storage sprinklers operating at a minimum flow of 30 gpm (115 L/min) from the most remote sprinkler.

2.4.3.3.3 Vertically Enclosed ASRS Storage Units Over 25 ft (7.6 m) and up to 55 ft (16.8 m) Tall

2.4.3.3.3.1 Protection with Sprinklers at the Top of the ASRS Unit Only

A. Vertically enclosed ASRS units over 25 ft (7.6 m) and up to a maximum height of 55 ft (16.8 m) tall can be protected by sprinklers only at the top of the ASRS unit when the sprinkler system protecting the ASRS unit is designed in accordance with Table 2.4.3.3.3.1.

B. Account for all sprinklers within the ASRS storage unit, or units if they are not separated by solid walls or vertical barriers, for the number of sprinklers in the sprinkler system design.

Table 2.4.3.3.3.1. 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)

2.4.3.3.3.2 Protection with Ceiling- and Intermediate-Level Sprinklers

A. Vertically enclosed ASRS units over 25 ft (7.6 m) and up to a maximum height of 55 ft (16.8 m) tall can be protected by both ceiling- and intermediate-level sprinklers as follows:

1. Install sprinklers at the top of the ASRS unit using minimum K11.2 (K160) Storage sprinklers, and
2. 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, and
3. Design the sprinkler system to account for all sprinklers (ceiling and intermediate) within the vertically enclosed ASRS storage unit, or units if they are not separated by solid walls or vertical barriers, operating at a minimum flow of 30 gpm (115 L/min) from the most remote sprinkler.

2.4.3.3.4 Vertically Enclosed ASRS Storage Units Over 55 ft (16.8 m) Tall

Protect vertically enclosed ASRS units over 55 ft (16.8 m) tall using both ceiling- and intermediate-level sprinklers as follows:

1. Install sprinklers at the top of the ASRS unit using minimum K11.2 (K160) Storage sprinklers, and
2. 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, and

3. Design the sprinkler system to account for all sprinklers (ceiling and intermediate) within the vertically enclosed ASRS storage unit, or units if they are not separated by solid walls or vertical barriers, operating at a minimum flow of 30 gpm (115 L/min) from the most remote sprinkler.

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 Horizontal-Loading ASRS Storage Arrangements

For this data sheet, horizontal-loading ASRS is subdivided into two specific types of ASRS storage: (1) a shuttle ASRS, and (2) a mini-load ASRS.

Shuttle type ASRS consist of multiple levels of trays or containers that slide into a rack structure that typically uses metal slats or wire mesh shelving for material handling support [see Figure 3.1.1(a)]. The rack structure generally consists of rack uprights, comparable to traditional pallet-load type racking, that are spaced 7 to 10 ft (2.1 to 3.0 m) apart such that more than one container is stored between the rack uprights. What generally differentiates a shuttle-type ASRS from a traditional pallet-load storage rack are the tier heights. The tier heights will vary but are usually from 9 in. (225 mm) to 24 in. (600 mm) in height.

Mini-load type ASRS consist of multiple levels of trays or containers that slide into a rack structure that use angle irons or similar alignment guides for material handling support [see Figure 3.1.1(b)]. 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, compared to traditional pallet-load rack uprights, and tend to be 18 in. (450 mm) to 30 in. (750 mm) horizontally apart such that there is only one container stored between the rack uprights. 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 3.1.1(c)] and thus can be very tall.

Fig. 3.1.1(a). Example of a shuttle type horizontal-loading ASRS

Fig. 3.1.1(b). Example of a mini-load type horizontal-loading ASRS

Fig. 3.1.1(c). Example of a rack-supported ASRS storage arrangement

Fig. 3.1.1(d). Example of a crane robot that moves within the storage aisle on a rail located at ground level

In both shuttle and mini-load ASRS, trays or containers used for product handling are removed from the rack by an automated picking robot [see an example of one robot type in Figure 3.1.1(d)]. 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 computer-operated picking 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. Aisles are usually a minimum of about 2-1/2 ft (0.8 m) wide.

This data sheet differentiates shuttle ASRS storage arrangements from mini-load ASRS storage arrangements based on whether the material handling supports for the trays or containers have alignment guides that rise vertically and can prevent water from entering the adjacent transverse flue spaces.

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.

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.

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, is not required, eliminating the need for aisles between storage arrays.

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 3-26, *Fire Protection for Nonstorage Occupancies*
Data Sheet 4-13, *Oxygen Reduction 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 overall rack row depth: The horizontal length of storage within a horizontal-loading ASRS storage arrangement, measured perpendicular to the loading aisle, between (1) the face of the rack, and (2) a horizontal opening that is more than 2 ft (0.6 m) wide. See Figure A-1 for a visual representation of this term.

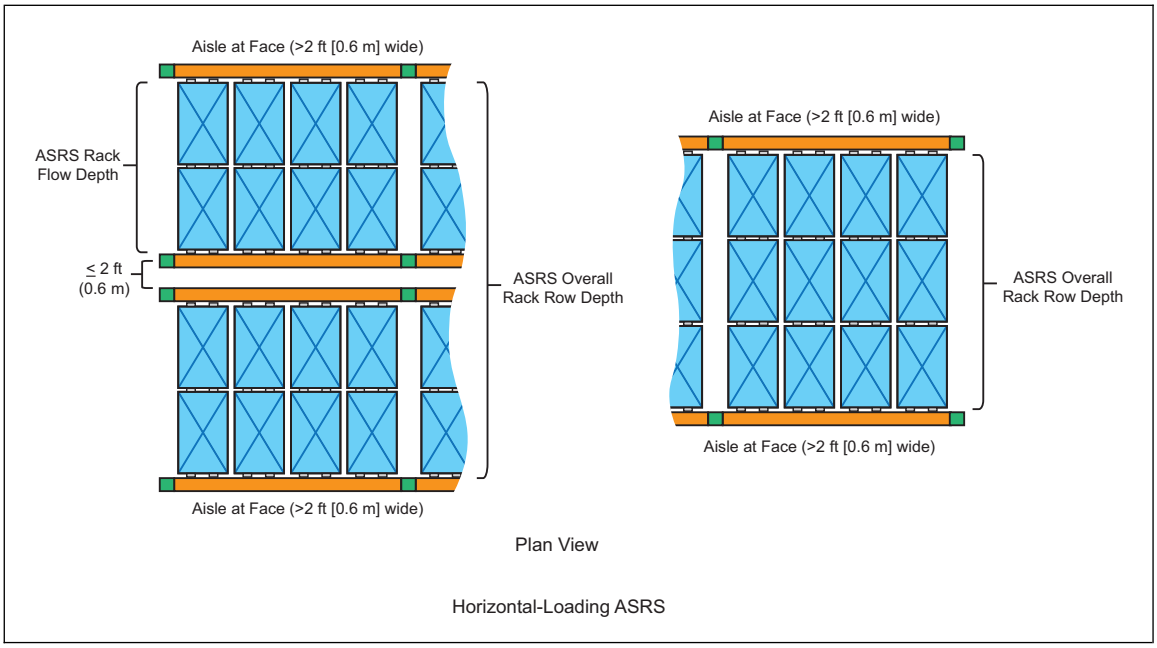

Fig. A-1.Example of ASRS overall rack row depth

ASRS rack row depth: The horizontal length of storage within a horizontal-loading ASRS storage arrangement, measured perpendicular to the loading aisle, between (1) the face of the rack, and (2) a horizontal opening that is a minimum of 6 in. (150 mm) wide (usually either a longitudinal flue space or an aisle). Note that the rack row depth could also equal the overall rack row depth. See Figure A-2 for a visual representation of this term.

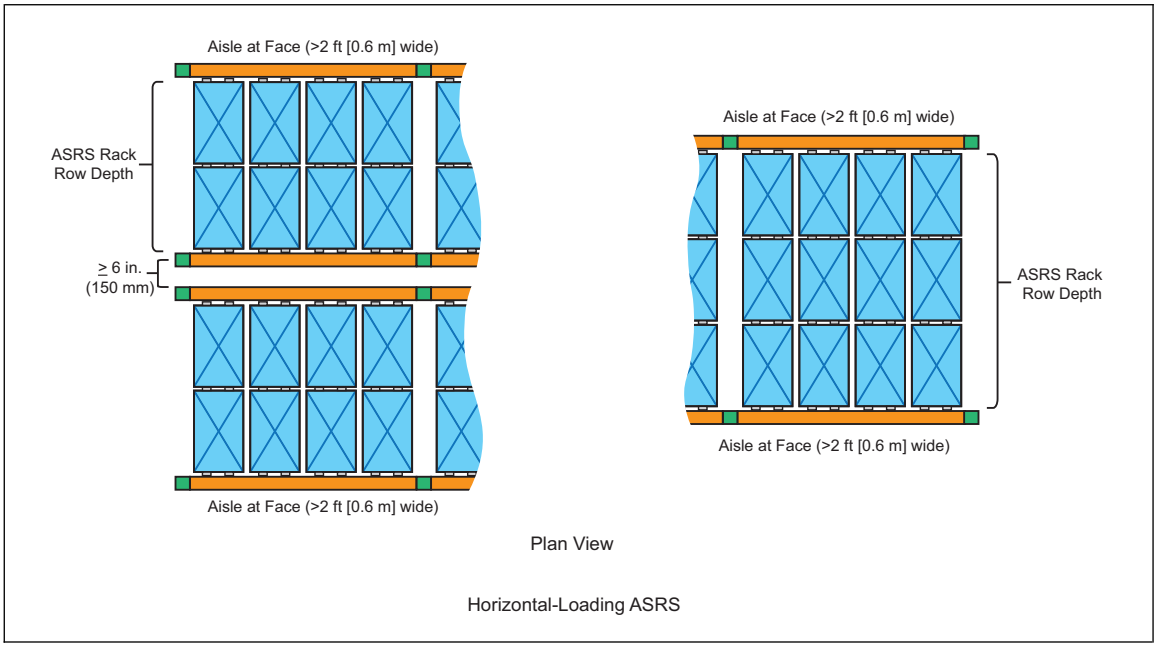

Fig. A-2. Example of ASRS rack row depth

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.

Flue Space: The horizontal space between two adjacent loads or containers of storage. See the definitions of Gross Flue Space Width and Net Flue Space Width to determine how they differ from each other as well as how they are calculated.

Gross Flue Space Width: The measured horizontal space between two adjacent loads or containers of storage. See the definition of Net Flue Space Width to determine how it differs from the gross flue space width.

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.

Net Flue Space Width: For storage racks, the net flue space width is the measured horizontal opening between two adjacent loads or containers of storage continuous to the tier level located below the loads or containers. Where there are any objects less than 70% open located within this space that are pitched at an angle less than 30 degrees, their width is subtracted from the measured horizontal opening between tier levels to obtain the net flue space width. See Figure 2.2.1.4.1.1 for a demonstration of this definition.

Non-Flame Propagating Container: A container that prevents horizontal flame spread to adjacent containers when a fire originates within it.

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 when measured from the inside surface of the tray.

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

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).

April 2026. Interim revision. Significant changes for this version of the data sheet include the following:

A. Section 2.2.1.4 has been updated to provide better clarification on how to measure the gross and net width of transverse flue spaces as well as what are the recommended net widths of the transverse flue spaces.

B. A new Section 2.2.1.5 has been created to indicate when vertical barriers are recommended for horizontal-loading ASRS arrangements.

C. The horizontal in-rack sprinkler arrangements in Sections 2.2.3.2.1, 2.2.4.2.1, 2.2.6.2.1, and 2.2.7.2.1 have been modified to provide for a more streamlined method of in-rack sprinkler installations.

D. Section 2.3 has been modified to (1) incorporate the guidelines specific to FM Approved Non-Flame Propagating Containers, (2) differentiate the guidelines for solid-walled containers when the ceiling height is either greater than 30 ft (9.1 m), or 30 ft (9.1 m) or less, (3) add a new ceiling-level sprinkler design based on a 28 ft (8.5 m) high ceiling, (4) address systems of limited size, and (5) address systems consisting of both plastic containers and FM Approved non-flame propagating containers.

E. The protection guidelines for vertically enclosed ASRS arrangements in Section 2.4 have been enhanced to address storage heights over 55 ft (16.8 m).

F. The format of Table 2.1.4.5.4 was updated to be consistent with the same table in Data Sheet 8-9.

G. Several editorial modifications were incorporated into this version of the data sheet including renumbering of the figures and the tables based on their section number.

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.