

**STORAGE OF AEROSOL PRODUCTS**

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## 1.0 SCOPE

This data sheet provides protection recommendations on the storage of Level 1, 2, and 3 aerosol products stored in metal containers; aerosol cooking spray products in metal containers; and aerosol products in plastic containers up to a maximum size of 33.8 oz (1000 ml).

This data sheet does not apply to other products consisting of ignitable liquids and flammable or nonflammable gas propellants stored in larger containers. That guidance is provided in other FM Global property loss prevention data sheets, including the following:

- 7-29, *Ignitable Liquid Storage in Portable Containers*
- 7-32, *Ignitable Liquid Operations*
- 7-50, *Compressed Gases in Cylinders*
- 7-55, *Liquefied Petroleum Gas*
- 7-88, *Storage Tanks for Ignitable Liquids*

### 1.1 Changes

**February 2020. Interim revision.** A small modification was made to Section E.2.4 to include the recommended design flow of 57 gpm (220 L/min), which was incorrectly omitted from the January 2020 revision.

**January 2020. Interim revision.** Fire Protection Scheme A (Section E.2) was updated to cover both metal and plastic aerosol products.

## 2.0 LOSS PREVENTION RECOMMENDATIONS

### 2.1 Introduction

The classification of aerosol products is critical to providing adequate protection. The classification method used for aerosol products in metal containers is based on the results for full scale fire tests involving those types of products. This classification cannot be applied to aerosol products in non-metal containers. A new classification method for plastic aerosol products has been developed. It is also based on full scale fire testing results.

The biggest challenge in determining how to adequately product aerosol products is the proper classification of the products. Not all countries/codes support the classification system used in this standard however, the system presented here for aerosol products in metal and plastic containers is the only approach tied to defining adequate protection for the storage of aerosol products in warehouses. In the United States the transportation code and NFPA 30B, *Code for the Manufacture and Storage of Aerosol Products*, use the same classification system presented in this standard. Both codes require the boxes to be properly labelled including the new labelling for aerosol products in plastic containers.

#### 2.1.1 Aerosol Product Classification: Aerosol Products in Metal Containers of 33.8 oz (1000 ml) or Less

2.1.1.1 Classify aerosol products using one of the following methods:

A. Sum the chemical heat of combustion for the constituent components of the aerosol product (e.g., propellant, liquid products) multiplied by their weight fraction. This is represented in mathematical notation by the following formula:

$$\Delta H_{\text{cht}} = \sum x_i \Delta H_{\text{chi}}$$

Where  $\Delta H_{\text{cht}}$  = total chemical heat of combustion of the product, Btu/lb [kJ/g]

$x_i$  = weight fraction of component i

$\Delta H_{\text{chi}}$  = chemical heat of combustion of component i

Based on the calculated chemical heat of combustion, use Table 1 to classify the aerosol product.

Table 1. Aerosol Product Classification

| Chemical Heat of Combustion ( $\Delta H_{ch}$ )                        | Aerosol Product Level |
|--|-----------------------|
| $0 < \Delta H_{ch} \leq 8600$<br>( $0 < \Delta H_{ch} \leq 20$ )       | 1                     |
| $8600 < \Delta H_{ch} \leq 12,900$<br>( $20 < \Delta H_{ch} \leq 30$ ) | 2                     |
| $\Delta H_{ch} > 12,900$<br>( $\Delta H_{ch} > 30$ )                   | 3                     |

B. Use Figure 1 if the aerosol product's constituent materials are known and consist of saturated hydrocarbons, such as propane and isobutane, alcohols such as ethanol or methanol, and inert materials.

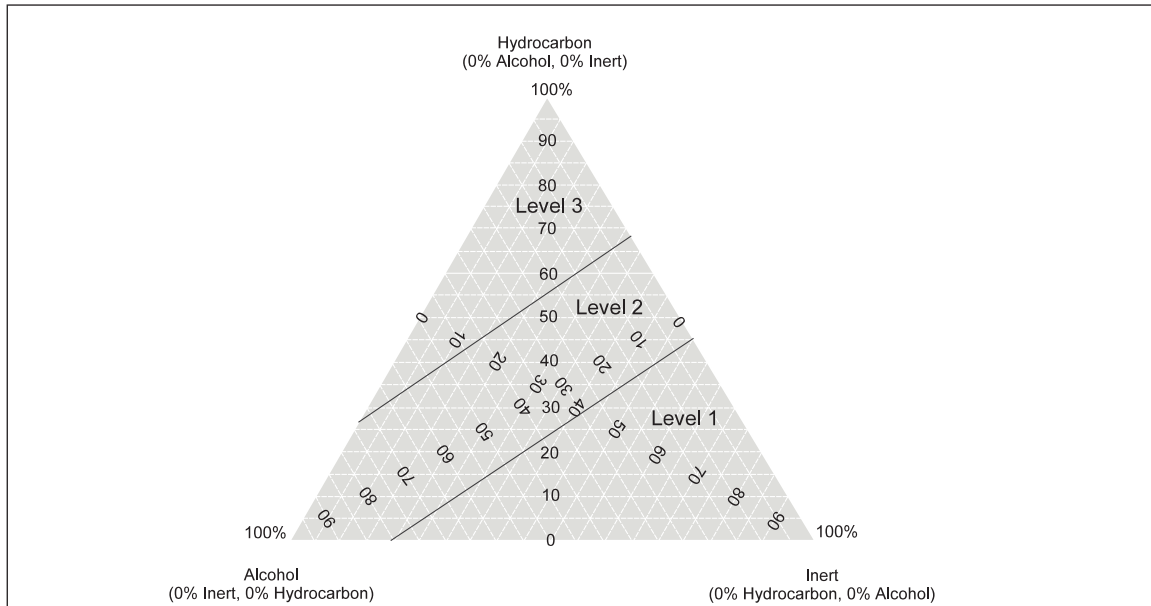


Fig. 1. Aerosol product classification

C. Classify the aerosol product as Level 3 if its composition is not known and test results are not available.

2.1.1.2 Determine the chemical heat of combustion for the component materials of an aerosol product using **one** of the following means:

- If the exact aerosol product components and their weight fraction are known, use the chemical heat of combustion data in Table 13, located in Appendix D of this document.
- If the exact aerosol product components and their weight fraction are known but the chemical heat of combustion is not available, use the total heat of combustion as determined by oxygen bomb calorimeter measurements.
- If the exact components of the aerosol product are not known but the product can be broken down by weight fraction into the generic groups of hydrocarbon (e.g., propellant, non-water-miscible ignitable liquids), alcohol (e.g., ethanol, isopropanol), and inert (e.g., solids, nonignitable liquids), use the values shown in Table 2.
- Conduct an oxygen bomb calorimeter test on the aerosol product mixture, including the propellant.

**Note:** Consider materials inert if they are nonignitable liquids (e.g., water, liquids without a fire point), solids (e.g., powders), or nonflammable gases (e.g., carbon dioxide).

Table 2. Chemical Heat of Combustion for Various Materials

| Material    | $\Delta H_{ch}$<br>(Btu/lb) | $\Delta H_{ch}$<br>(kJ/g) |
|-------------|-----------------------------|---------------------------|
| Hydrocarbon | 19,000                      | 44                        |
| Alcohol     | 11,000                      | 25                        |
| Inert       | 0                           | 0                         |

2.1.1.3 Classify aerosol products in metal containers of 5 oz (150 ml) or less in accordance with Section 2.1.1.

**2.1.2 Aerosol Product Classification: Aerosol Cooking Spray Products in Metal Containers of 33.8 oz (1000 ml) or Less**

2.1.2.1 Classify an aerosol product in a metal container as an aerosol cooking spray product if **both** of the following are:

- A. The product is designed to deliver a vegetable oil, a solid, or nonignitable liquid to reduce sticking on cooking and baking surfaces, or to be applied on food, or both.
- B. The product has a chemical heat of combustion that is higher than 20 KJ/g (8600 Btu/lb), and no more than 18% of its contents is a hydrocarbon propellant.

2.1.2.1.1 If the aerosol cooking spray product has a chemical heat of combustion that is 20 KJ/g (8600 Btu/lb) or lower, consider it a Level 1 aerosol product.

2.1.2.1.2 If the aerosol cooking spray has more than 18% hydrocarbon propellant, classify it in accordance with the product's chemical heat of combustion.

**2.1.3 Aerosol Product Classification: Aerosol Products in Plastic Containers of 33.8 oz (1000 ml) or Less**

#### 2.1.3.1 Plastic Aerosol 1 Products

Plastic aerosol 1 products are those that meet **one** of the following criteria:

- A. The base liquid product has no fire point when tested in accordance with ASTM D 92, *Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester*, and the propellant is nonflammable.
- B. The base product does not exhibit sustained combustion when tested in accordance with (1) *Method of Testing for Sustained Combustibility*, Title 49, Code of Federal Regulations, Part 173, Appendix H, or (2) the UN Recommendations on the Transport of Dangerous Goods; and the propellant is nonflammable.
- C. The base liquid product contains up to 20% by volume (15.8% by weight) of ethanol or propanol or mixtures thereof in an aqueous mix, and the propellant is nonflammable.
- D. The base liquid product contains 4% by weight or less of an emulsified flammable liquefied gas propellant within an aqueous base (i.e., the aqueous base is a nonignitable liquid), and the propellant remains emulsified for the life of the product or is nonflammable.

#### 2.1.3.2 Plastic Aerosol 3 Products

Plastic aerosol 3 products are those than meet **one** of the following criteria:

- A. The base liquid product has no fire point when tested in accordance with ASTM D 92, *Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester*, and there is not more than 10% flammable propellant.
- B. The base product does not exhibit sustained combustion when tested in accordance with (1) Method of Testing for Sustained Combustibility, Title 49, Code of Federal Regulations, Part 173, Appendix H, or (2) the UN Recommendations on the Transport of Dangerous Goods; and there is not more than 10% flammable propellant.
- C. The base liquid product contains not more than 50% by volume of flammable, water-miscible alcohol in an aqueous mix, and there is not more than 10% flammable propellant.

### 2.1.3.3 Plastic Aerosol X Products

Plastic aerosol X products are those that do not meet the criteria in Section 2.1.3.1 or 2.1.3.2.

## 2.2 Construction and Location

2.2.1 Segregate aerosol product storage in accordance with Table 3.

Table 3. Aerosol Product Storage Location Options

| Aerosol Product Type       | Storage Array      | Sprinkler Response | Storage Location Options  |
|----------------------------|--------------------|--------------------|---|
| Level 1                    | Palletized or rack | Any                | Any location is acceptable.   |
| Level 2                    | Palletized or rack | Any                | Dedicated building, cutoff room, or dedicated area defined by a chain link fence  |
| Level 3                    | Palletized         | Standard response  | Dedicated building or cutoff room   |
|                            |                    | Quick response     | Dedicated building, cutoff room, or dedicated area defined by a chain link fence  |
|                            | Rack               | Any                | Dedicated building, cutoff room, or dedicated area defined by a chain link fence  |
| Plastic aerosol 1 products | Palletized or rack | Any                | Any location is acceptable.   |
| Plastic aerosol 3 products | Rack               | Any                | Dedicated building, cutoff room, or dedicated area defined by a chain link fence. |
|                            | Palletized         | Any                | Detached building or cutoff room; refer to Section 2.2.3.                         |
| Plastic aerosol X products | Any                | Any                | Detached building or cutoff room; refer to Section 2.2.3.                         |
| Aerosol cooking sprays     | Palletized or rack | Quick response     | Any location is acceptable  |

2.2.2 Design cutoff rooms in accordance with the following recommendations:

- A. Locate the room outside the building on an exterior wall. A less-desirable alternative is to locate the room inside the building on an exterior wall with access from the outside.
- B. Provide noncombustible partitions, including gypsum wallboard, with a minimum 1-hour fire resistance as described in Data Sheet 1-21, *Fire Resistance of Building Assemblies*.
- C. Provide impact protection for fire-rated walls constructed of low-impact strength materials. If gypsum wallboard is used, provide a minimum 22 gauge (0.7 mm) metal facing on the wallboard to provide some protection against aerosol product can impact. Provide the impact protection for the full height of the walls.
- D. Protect necessary interior openings with a normally closed fire door. Locate the fire door on the storage side of the wall. Arrange doors to automatically close in the event of a fire. The use of a fusible link at ceiling level, sprinkler water flow alarm, heat detector, or a flame detector are acceptable means of releasing the door.

2.2.3 For plastic aerosol X products, there is no protection criteria proven by tests to stop the spread of fire. It is expected that all of the aerosol containers within a room will release their contents, producing a hybrid ignitable liquid and flammable gas fire. Therefore, store these aerosol products in one of the following areas:

- A. A detached, low-value building.
- B. An FM Approved prefabricated ignitable liquids storage buildings (PILSB), designed in accordance with Section 2.2.8. Locate the PILSB outside the main building.
- C. If a cutoff room is to be used, design the room in accordance with the recommendations in Data Sheet 7-29. Also design an emergency drainage system for the room in accordance with DS 7-29.

2.2.4 Design dedicated storage areas within general purpose warehouses as follows:

A. Provide a floor-to-ceiling chain link fence that completely surrounds the designated aerosol product storage area. Fencing can use the rack structure for support. Alternatively, provide noncombustible impact-resistant barriers (e.g., minimum 22 gauge [0.7 mm] sheet metal) within the racks.

B. Use fencing that is at least 9 gauge (3.8 mm) steel wire woven into a maximum 2 in. (50 mm) diamond mesh.

2.2.5 Where Scheme A is used to protect the rack storage of Level 2 and Level 3 aerosol products located within a general purpose warehouse, the fencing specified in Section 2.2.4 does not need to be included in the aisles if adjacent racks are also protected with Scheme A. Fencing is only necessary at the outermost rack bays. Where adjacent racks are not protected with Scheme A, fencing is necessary around the entire perimeter of aerosol products storage. See Figures 2a and 2b.

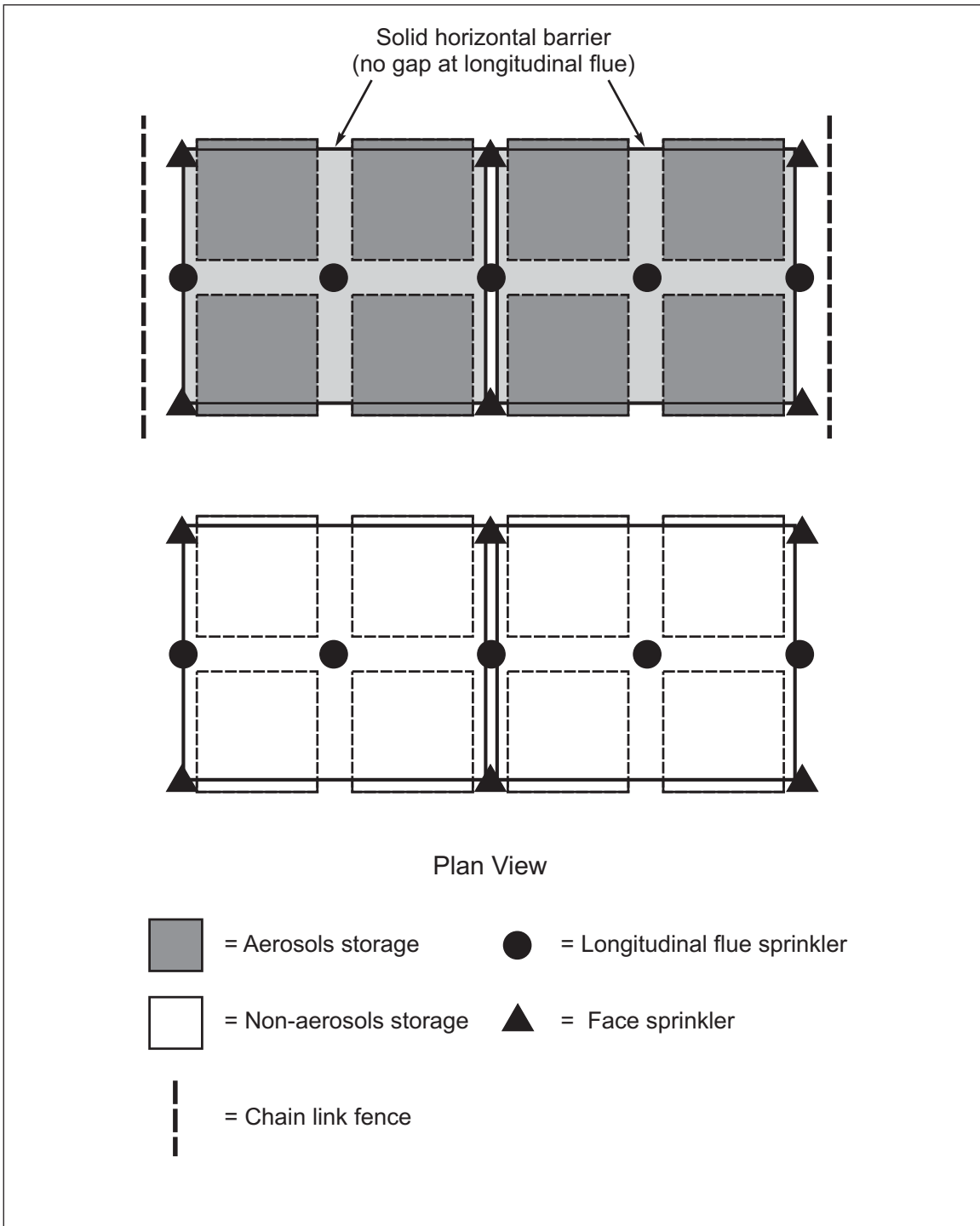


Fig. 2a. Design of fencing where adjacent storage is protected with Scheme A



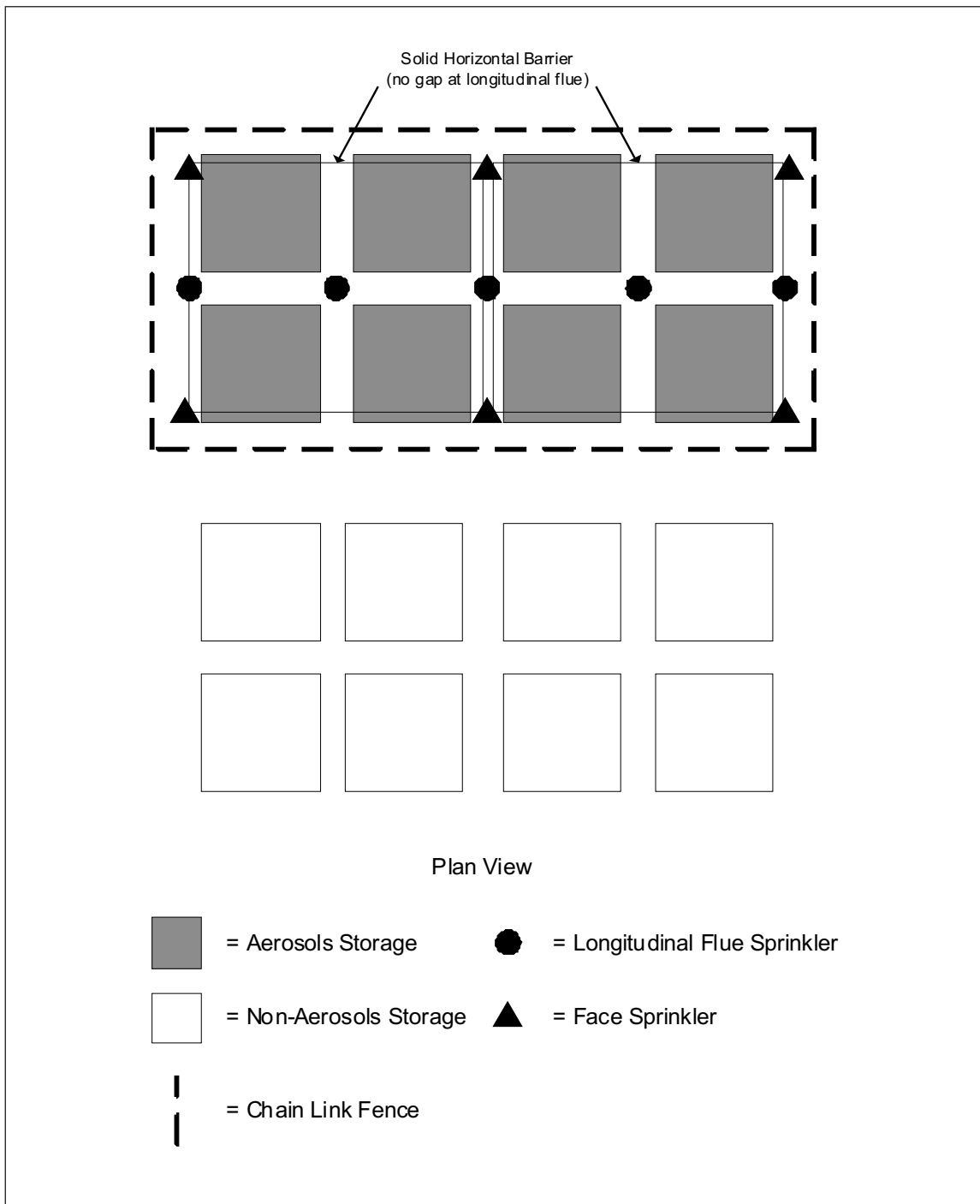


Fig. 2b. Design of fencing where adjacent storage is not protected with Scheme A

2.2.6 For cutoff rooms and dedicated areas in general purpose warehouses, protect openings with normally closed, automatically closing doors.

2.2.6.1 Arrange doors to automatically close in the event of a fire.

A. The use of a fusible link at ceiling level, sprinkler water flow alarm, heat detector, or a flame detector are acceptable means of releasing the door.

B. A less-desirable approach is to arrange a normally open door to automatically close when actuated by a fire inside or directly outside the room or area.

2.2.6.2 An alternative for openings in chain link fence-enclosed areas is to design a doorless opening (e.g., a labyrinth or tunnel approach) that does not provide a direct line of sight for a rocketing can to the area outside the enclosure (see Figure 3).

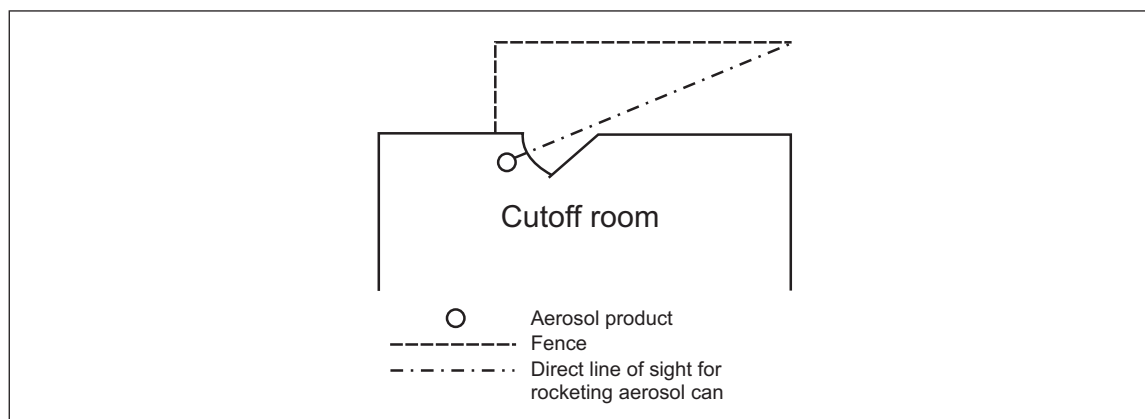


Fig. 3. Example of a labyrinth opening arrangement for a cutoff room opening.

2.2.7 In cases where aerosol storage directly expose doors in MFL walls, provide a labyrinth style barrier (See Fig. 3) at the opening in addition to the normally provided fire doors.

2.2.7.1 An acceptable alternative is to arrange the fire doors to automatically close by activation of a flame detector.

A. Arrange one flame detector to provide complete line-of-sight coverage across the front of the opening (near field).

B. Arrange a second flame detector to provide far field coverage over the top of storage.

C. Arrange doors to automatically close in the event of power loss.

2.2.8 For all detached buildings or cutoff rooms, provide an FM Approved roof covering that consists of a Class 1 internal fire resistance (see Data Sheet 1-29, *Roof Deck Securement and Above-Deck Roofing Components*) and an ASTM E108 Class A-rated external fire resistance (see Data Sheet 1-29).

2.2.8.1 For cutoff rooms that have ceilings below the main building's roof, provide a ceiling assembly that has the same fire resistance as the interior walls of the cutoff room.

2.2.8.2 For cutoff rooms that have wooden roof assemblies, isolate the wooden roof with the same fire resistance as that needed for the interior walls of the cutoff room. Provide sprinklers in any resulting combustible spaces in accordance with Data Sheet 1-12, *Ceilings and Concealed Spaces*.

2.2.9 FM Approved prefabricated ignitable liquids storage buildings (PILSB) may be used as an alternative to a permanently constructed cutoff or detached aerosol products storage room. The PILSB must provide all of the active and passive protection features recommended in this data sheet (fire rating, automatic fire protection, etc.).

2.2.10 Special storage arrangements or equipment may be used for small quantities of aerosol products, including the following:

A. Store individual cartons or cans inside FM Approved ignitable liquid cabinets. Arrange the cabinets as follows:

1. If storing plastic aerosol X products, restrict quantities as necessary so the liquid contents of all stored aerosol containers does not exceed that specified in the cabinet's FM Approval listing.
2. Cutoff is not needed from storage or nonstorage occupancies.
3. Provide a minimum of 20 ft (6 m) separation between cabinets and storage areas.
4. Do not put cabinets within rack storage arrangements.
5. Provide adequate protection for the surrounding occupancy.

B. Use portable, noncombustible bins to store pallet-load quantities. Enclose the bins on all sides, including the tops and bottoms. Construct the bins of 18 gauge (1.2 mm) steel with a continuous weld at fixed seams. Provide access to the container using a hinged door, with only a friction latch arranged in such a way that the door has to be closed so as not to obstruct the aisle. Individual designs are likely to be needed for such bins.

2.2.10.1 These storage methods are alternatives to the location recommendations in this data sheet (i.e., cutoff room or dedicated area), but they do not alter the sprinkler protection recommendations.

2.2.10.2 If stored in racks, limit these containers to the first tier of the rack, with no combustibles located below except for the pallet. Provide in-rack sprinklers over such storage in accordance with Section 2.4. Determine the need for additional in-rack sprinkler protection based on the other commodities in the racks.

#### 2.2.11 Shipping/Receiving Areas

2.2.11.1 For loading docks where aerosol products are staged, provide construction and protection as recommended by this data sheet. The term "staged" in this context excludes continuous movement of containers from inside the shipping vehicle directly to the storage area.

2.2.11.2 Where small amounts of aerosol product outside of appropriately arranged storage areas cannot be avoided, such as in staging areas, provide racking in the staging area sufficient for the required amount of product protected with Scheme A protection.

2.2.11.3 Locate aerosol product storage areas next to shipping/receiving areas to prevent the creation of an aerosol product fire hazard along transportation routes that are not protected for that hazard. Provide space in the cutoff rooms for staging products before they are placed in storage or while they are waiting to be shipped.

### 2.3 Occupancy

2.3.1 Maintain only aerosol product storage in designated aerosol product storage areas or cutoff rooms/buildings.

2.3.2 Any level of aerosol product in maximum 33.8 oz (1000 ml) metal containers may be stored with ignitable liquids in metal containers up to 33.8 oz (1000 ml), if the provided fire protection scheme, isolation, and construction features are fully adequate for both storage types. Refer to Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers*. Do not mix aerosol product storage with ignitable liquid storage beyond this limit. In all other cases, maintain only aerosol product storage in designated aerosol product storage areas or cutoff rooms or buildings.

2.3.2.1 Do not mix storage of plastic aerosols with ignitable liquids.

2.3.3 Where Scheme A is used to protect the rack storage of Level 2 and Level 3 aerosol products, mixed storage within the rack is acceptable if the following criteria are met:

2.3.2 Provide minimum 8 ft (2.4 m) aisles for all rack storage of Level 2 and 3 aerosols.

A. For double-row rack tiers fully protected with Scheme A, provide a vertical chain link fence in longitudinal and transverse flue spaces to separate aerosol storage from adjacent storage of other commodities as shown in Figure 4a.

B. For double-row rack tiers protected with Scheme A over aerosol product storage only (e.g., in one side of the rack), provide a solid vertical barrier in the longitudinal and transverse flue spaces to separate aerosol product storage from adjacent storage of other commodities as shown in Figure 4b. Protect the

adjacent storage based on the commodity stored in that area.

C. If aerosol products are stored at the outermost bay, provide a solid vertical barrier or chain link fence at the end of the bay, as shown in Figures 4a and 4b.

D. A chain link fence is not necessary within the aisles if adjacent racks are also protected with Scheme A (refer to Section 2.2.5).

## 2.4 Protection

### 2.4.1 General

2.4.1.1 Protect small propane cylinders up to 17 oz (500 ml) [nominal 1 lb (450 g) cylinders] with protection criteria suitable for Level 3 aerosols with all of the following limitations:

A. Store containers with the relief vent in the vapor space.

B. For palletized storage use only quick response storage sprinkler protection criteria.

C. For rack storage use either (1) quick response storage sprinkler protection criteria at the ceiling or (2) standard response storage sprinklers at the ceiling plus in-rack protection criteria.

2.4.1.2 Use a wet, preaction, or deluge sprinkler system. For information on the design of deluge and preaction systems, refer to Sections 2.4.1.11 and 2.4.1.12, respectively.

2.4.1.3 A dry system is acceptable if the sprinkler operating area is equal to the room's footprint as defined by its walls, and water is delivered to the most remote sprinkler within 30 seconds of activation in a fire.

2.4.1.4 Install sprinklers in accordance with Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*.

2.4.1.5 Arrange sprinklers on a maximum 100 ft<sup>2</sup> (9 m<sup>2</sup>) spacing.

2.4.1.6 Arrange sprinklers with a maximum spacing of 10 ft (3.0 m). A variation of ±1 ft (0.3 m) is permitted on either dimension to avoid obstructions by structural elements.

2.4.1.7 Base the in-rack sprinkler water demand on the simultaneous operation of the most hydraulically remote sprinklers as follows:

A. Eight (8) sprinklers where only one level of in-rack sprinklers is provided.

B. Twelve (12) sprinklers (six [6] sprinklers on two [2] levels) where only two (2) levels of in-rack sprinklers are provided.

C. Eighteen (18) sprinklers (six [6] sprinklers on the top three [3] levels) where more than two (2) levels of in-rack sprinkler are provided.

2.4.1.8 In-rack design flows are provided in Tables 7 through 10. The end-sprinkler discharge pressure should be at least 15 psi (1 bar) regardless of sprinkler type.

2.4.1.9 When recommended per Tables 7 through 10, install in-rack sprinklers in accordance with Figures 5 through 10. Stagger in-rack sprinklers vertically where indicated in the figures.

2.4.1.10 Ensure the water supply is capable of providing the combined sprinkler system (ceiling protection and, if provided, in-rack sprinklers) and hose stream demands at adequate pressure for the durations listed in Table 4.

Table 4. Hose Demand and Water Supply Duration Design Guidelines

| Sprinkler Type by Spacing | No. of Sprinklers in Ceiling Design | Hose Demand, <sup>1</sup><br>gpm (L/min) | Duration, minutes |
|---------------------------|-------------------------------------|--|-------------------|
| Standard spacing          | Up to 12                            | 250 (950)                                | 60                |
|                           | 13 to 19                            | 500 (1900)                               | 90                |
|                           | 20 or more                          | 500 (1900)                               | 120               |
| Extended-coverage         | Up to 6                             | 250 (950)                                | 60                |
|                           | 7 to 9                              | 500 (1900)                               | 90                |
|                           | 10 or more                          | 500 (1900)                               | 120               |

<sup>1</sup> Provide 250 gpm (950 L/min) for buildings or rooms with a floor area of 2000 ft<sup>2</sup> (185 m<sup>2</sup>) or less, regardless of the ceiling protection.

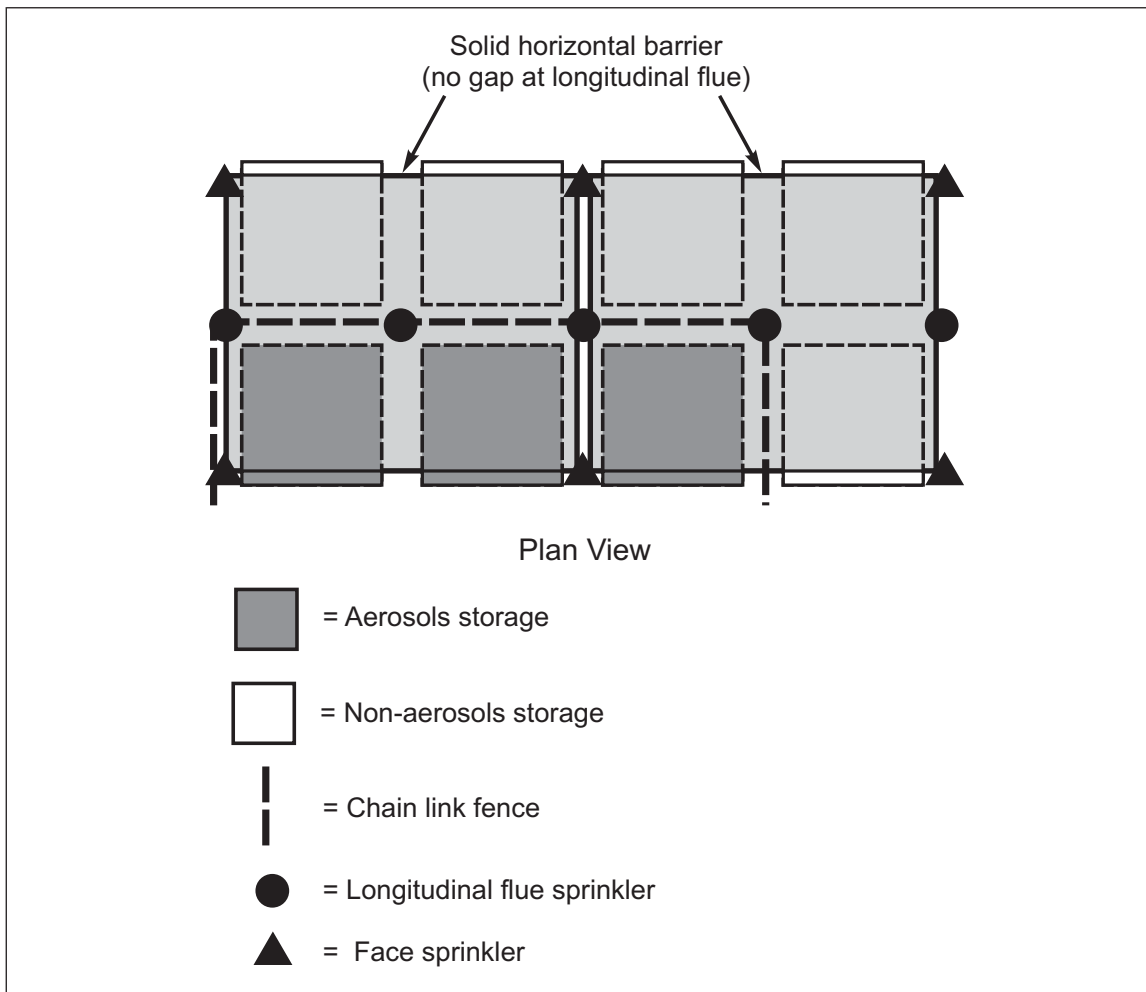


Fig. 4a. Separation of aerosol product storage from non-aerosol storage using a chain link fence

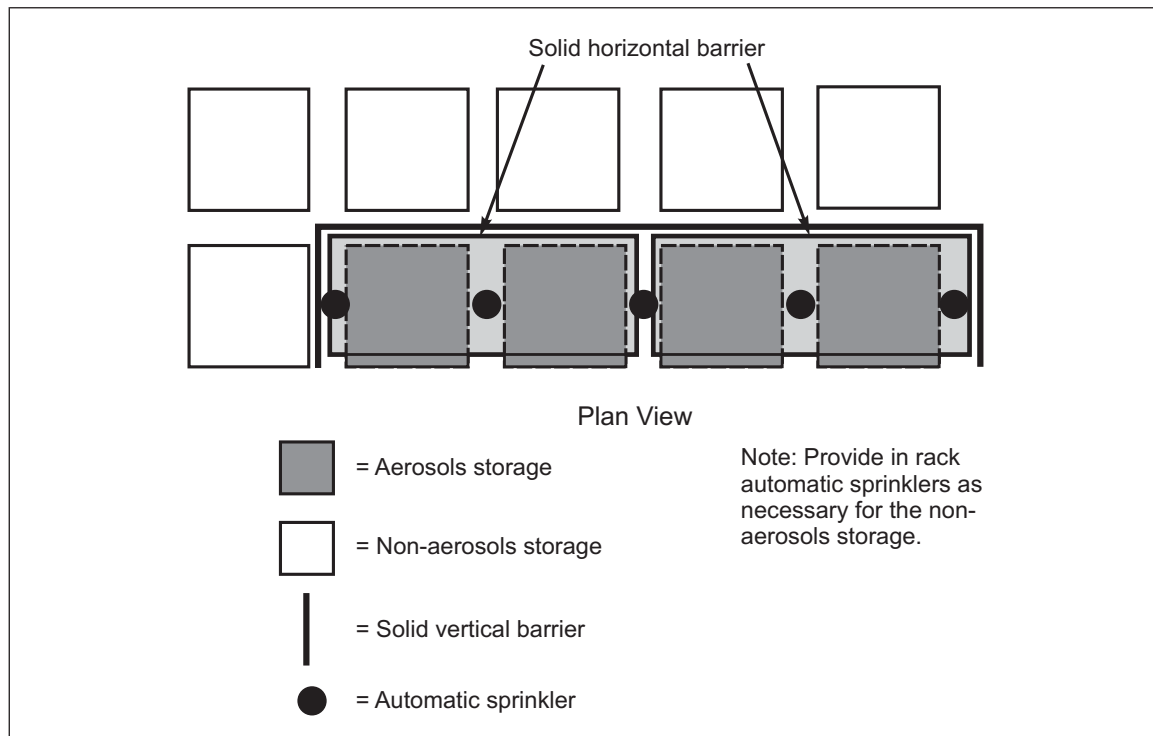


Fig. 4b. Separation of aerosol product storage from non-aerosol storage using a solid vertical barrier

2.4.1.11 Space detectors for interior deluge systems (pilot sprinkler, electric, or pneumatic) as follows:

- A. Install pilot sprinklers on the same spacing as sprinklers.
- B. Install electric or pneumatic devices under smooth ceilings in accordance with the manufacturer's specifications, the requirements listed in the *Approval Guide* for the particular model, and Data Sheet 5-48, *Automatic Fire Detection*.

2.4.1.12 Space detectors for preaction systems (pilot sprinkler, electric, or pneumatic) as follows:

- A. Install electric or pneumatic detectors at a spacing of one-half the listed linear detector spacing, or the full sprinkler spacing, whichever is greater. For design purposes, treat preaction systems with this detector spacing the same as wet systems (e.g., if a detector is FM Approved for 30 ft by 30 ft [9.1 m by 9.1 m] and allowable sprinkler spacing is 100 ft<sup>2</sup> [9 m<sup>2</sup>], then maximum allowable linear detector spacing is 15 ft by 15 ft [4.6 m by 4.6 m]).

If a preaction system has a detector spacing greater than the above spacing, consider it a deluge system for design purposes. Refer to the *Approval Guide* for the maximum allowable spacing.

- B. Install pilot sprinklers on the same spacing as the sprinklers. For design purposes, treat preaction sprinkler systems that use pilot sprinklers the same as dry systems, regardless of detector spacing.

2.4.1.13 Provide portable extinguishers in areas (interior and exterior) where aerosol products are stored. Use carbon dioxide, dry chemical, or AFFF extinguishers. Refer to Data Sheet 4-5, *Portable Extinguishers*, to determine effective sizes and locations for the extinguishers.

## 2.4.2 Warehouse Storage of Aerosol Products in Metal Containers

2.4.2.1 Protect Level 1 aerosol products in accordance with the recommendations for a Class 3 commodity in Data Sheet 8-9, *Storage of Class 1, 2, 3, 4 and Plastic Commodities*.

2.4.2.2 Protect palletized or solid-pile storage of Level 2 and Level 3 aerosol products in accordance with Tables 5 and 6.

2.4.2.3 Protect rack storage of Level 2 and Level 3 aerosol products in accordance with Tables 7 through 10 and Figures 5 through 10.

2.4.2.4 Protect rack, palletized, and solid-pile storage of cartoned aerosol cooking spray products in accordance with Table 11.

2.4.2.4.1 Protect uncartoned aerosol cooking spray products as Level 2 or Level 3 aerosols based on the product's chemical heat of combustion.

2.4.2.5 Where aerosol products are segregated by fencing in a general purpose warehouse, provide a consistent level of sprinkler protection throughout the dedicated area. Provide protection for the most hazardous classification of products present. Extend the recommended ceiling protection 20 ft (6.1 m) beyond the fence if it is more stringent than the ceiling sprinkler requirement for the adjacent occupancy.

Table 5. Palletized and Solid Pile Storage of Level 2 Aerosol Products

| Packaging Type | Maximum Ceiling Height ft (m) | Maximum Storage Height ft (m) | Ceiling Sprinkler Protection (Note 1)                           |  |   |
|----------------|-------------------------------|-------------------------------|---|--|---|
|                |                               |                               | Response, Nominal Temperature Rating, and Sprinkler Orientation | K-Factor (Note 2) gpm/psi <sup>1/2</sup> (l/min/bar <sup>1/2</sup> ) | Design, # Sprinklers @ Pressure psi (bar) |
| Cartoned       | 25 (7.6)                      | 18 (5.5)                      | SR, Ordinary, Upright   | 11.2 (161)   | 15 @ 50 (3.4)                             |
|                |                               |                               | QR, Ordinary, Pendent   | 14.0 (202)   | 12 @ 50 (3.4)                             |
|                |                               | 16.8 (235)                    |   | 12 @ 35 (2.4)  |   |
|                |                               | 22.4 (314)                    |   | 12 @ 25 (1.7)  |   |
|                |                               | 25.2 (363)                    | 12 @ 25 (1.7)   |  |   |
|                | 30 (9.1)                      | 5 (1.5)                       | SR, High, Any   | ≥11.2 (≥161)   | 25 @ 7 (0.5)                              |
|                |                               |                               | QR, Ordinary, Pendent   | 14.0 (202)   | 12 @ 50 (3.4)                             |
|                |                               | 16.8 (235)                    |   | 12 @ 35 (2.4)  |   |
|                |                               | 22.4 (314)                    |   | 12 @ 25 (1.7)  |   |
|                |                               | 25.2 (363)                    | 12 @ 25 (1.7)   |  |   |
| Uncartoned     | 25 (7.6)                      | 15 (4.6)                      | QR, Ordinary, Pendent   | 14.0 (202)   | 12 @ 50 (3.4)                             |
|                |                               |                               |   | 16.8 (235)   | 12 @ 35 (2.4)                             |
|                |                               |                               |   | 22.4 (314)   | 12 @ 25 (1.7)                             |
|                |                               |                               |   | 25.2 (363)   | 12 @ 25 (1.7)                             |
|                |                               |                               |   | 25.2 (363)   | 12 @ 25 (1.7)                             |
|                | 30 (9.1)                      | 15 (4.6)                      | QR, Ordinary, Pendent   | 14.0 (202)   | 12 @ 75 (5.2)                             |
|                |                               |                               |   | 16.8 (235)   | 12 @ 52 (3.6)                             |
|                |                               |                               |   | 22.4 (314)   | 12 @ 45 (3.1)                             |
|                |                               |                               |   | 25.2 (363)   | 12 @ 25 (1.7)                             |
|                |                               |                               |   | 25.2 (363)   | 12 @ 25 (1.7)                             |

Notes:

1. SR = Standard response; QR = quick response.
2. The FM Approved K19.6 (282) sprinkler is not acceptable for the protection of palletized and solid pile storage of Level 2 aerosol products.

Table 6. Palletized and Solid Pile Storage of Level 3 Aerosol Products

| Packaging Type | Maximum Ceiling Height<br>ft (m) | Maximum Storage Height<br>ft (m) | Ceiling Sprinkler Protection (Note 1)                           |  |  |  |
|----------------|----------------------------------|----------------------------------|---|--|--|--|
|                |                                  |                                  | Response, Nominal Temperature Rating, and Sprinkler Orientation | K-Factor (Note 2)<br>gpm/psi <sup>1/2</sup><br>(l/min/bar <sup>1/2</sup> ) | Design, # Sprinklers @ Pressurepsi (bar) |  |
| Cartoned       | 20 (6.1)                         | 5 (1.5)                          | SR, High, Any   | ≥11.2 (≥161)   | 25 @ 7 (0.5)                             |  |
|                |                                  | 10 (3)                           | SR, Ordinary, Upright   | 11.2 (161)   | 15 @ 75 (5.2)                            |  |
|                | 25 (7.6)                         | 15 (4.6)                         | QR, Ordinary, Pendent   | 14.0 (202)   | 12 @ 50 (3.4)                            |  |
|                |                                  |                                  |   | 16.8 (235)   | 12 @ 35 (2.4)                            |  |
|                |                                  |                                  |   | 22.4 (314)   | 12 @ 25 (1.7)                            |  |
|                |                                  |                                  |   | 25.2 (363)   | 12 @ 25 (1.7)                            |  |
|                | 30 (9.1)                         | 5 (1.5)                          | SR, High, Any   | 11.2 (161)   | 25 @ 29 (2.0)                            |  |
|                |                                  |                                  |   | 14.0 (202)   | 25 @ 18 (1.2)                            |  |
|                |                                  |                                  |   | 16.8 (235)   | 25 @ 13 (0.9)                            |  |
|                |                                  |                                  |   | 25.2 (363)   | 25 @ 7 (0.5)                             |  |
|                |                                  | 15 (4.6)                         | QR, Ordinary, Pendent   | 14.0 (202)   | 12 @ 75 (5.2)                            |  |
|                |                                  |                                  |   | 16.8 (235)   | 12 @ 52 (3.6)                            |  |
|                | Uncartoned                       | No Protection Criteria Available |   |  |  |  |

## Notes:

1. SR = Standard response; QR = quick response.

2. The FM Approved K19.6 (282) sprinkler is not acceptable for the protection of palletized and solid pile storage of Level 3 aerosol products.



Table 7. Rack Storage of Cartoned Level 2 Aerosol Products

|  |                                | Ceiling Sprinkler Protection (Note 1) |   |   |                                   | In-Rack Sprinkler Protection (Note 1) |                                      |   |                             |
|--|--------------------------------|---------------------------------------|---|---|-----------------------------------|---------------------------------------|--------------------------------------|---|-----------------------------|
| Maximum Ceiling Height, ft (m)   | Maximum Storage Height, ft (m) | Minimum Aisle Width, ft (m)           | Response, Nominal Temperature Rating, and Sprinkler Orientation | K-Factor (Note 2), gpm/psi <sup>1/2</sup> (L/min/bar <sup>1/2</sup> ) | # Sprinklers @ Pressure psi (bar) | Layout, See Figure                    | Response, Nominal Temperature Rating | K-Factor, gpm/psi <sup>1/2</sup> (L/min/bar <sup>1/2</sup> ) (Note 3) | Discharge Flow, gpm (L/min) |
| 25 (7.6)   | 20 (6.1)                       | 4 (1.2)                               | QR, Ordinary, Pendent   | 14.0 (202)  | 12 @ 50 (3.4)                     | NA                                    | NA                                   | NA  | NA                          |
|  |                                |                                       |   | 16.8 (235)  | 12 @ 35 (2.4)                     |                                       |                                      |   |                             |
|  |                                |                                       |   | 22.4 (314)  | 12 @ 25 (1.7)                     |                                       |                                      |   |                             |
|  |                                |                                       |   | 25.2 (363)  | 12 @ 25 (1.7)                     |                                       |                                      |   |                             |
| 30 (9.1)   | 15 (4.6)                       | 4 (1.2)                               | QR, Ordinary, Pendent   | 14.0 (202)  | 12 @ 50 (3.4)                     | NA                                    | NA                                   | NA  | NA                          |
|  |                                |                                       |   | 16.8 (235)  | 12 @ 35 (2.4)                     |                                       |                                      |   |                             |
|  |                                |                                       |   | 22.4 (314)  | 12 @ 25 (1.7)                     |                                       |                                      |   |                             |
|  |                                |                                       |   | 25.2 (363)  | 12 @ 25 (1.7)                     |                                       |                                      |   |                             |
| Unlimited  | 20 (6.1)<br>25 (7.6)           | 8 (2.4)<br>8 (2.4)                    | SR, High, Any<br>QR, Ordinary, Pendent                          | ≥ 11.2 (161)  | 25 @ 7 (0.5)                      | 5a-c<br>5a-c                          | QR, Ordinary<br>QR, Ordinary         | ≥ 8.0 (≥115)  | 30 (114)                    |
|  |                                |                                       |   | 14.0 (202)  | 12 @ 50 (3.4)                     |                                       |                                      | ≥ 8.0 (≥115)  | 30 (114)                    |
|  |                                |                                       |   | 16.8 (235)  | 12 @ 35 (2.4)                     |                                       |                                      |   |                             |
|  |                                |                                       |   | 22.4 (314)  | 12 @ 25 (1.7)                     |                                       |                                      |   |                             |
| Unlimited  | Unlimited                      | 8 (2.4)                               | SR, High, Any   | 11.2 (161)  | 25 @ 13 (0.9)                     | 5a-c                                  | SR or QR, Ordinary                   | ≥ 8.0 (≥115)  | 30 (114)                    |
|  |                                |                                       |   | 14.0 (202)  | 25 @ 8 (0.6)                      |                                       |                                      |   |                             |
|  |                                |                                       |   | ≥ 16.8 (235)  | 25 @ 7 (0.5)                      |                                       |                                      |   |                             |
|  |                                |                                       |   | Any   | See Scheme A                      |                                       |                                      |   |                             |
| For storage up to 25 ft and building heights greater than 30 ft, use the same level of protection as outlined in Table 8 for Level 3 aerosol products or Scheme A. |                                |                                       |   |   |                                   |                                       |                                      |   |                             |

Notes:

1. SR = Standard response; QR = quick response. See Appendix E for an explanation of fire protection schemes.
2. The FM Approved K19.6 (282) sprinkler is not acceptable for the protection of rack storage of cartoned Level 2 aerosol products.
3. Where IRAS with k-factors greater than those listed in the table are used, the end-sprinkler discharge pressure must be at least 15 psi (1 bar).

Table 8. Rack Storage of Cartoned Level 3 Aerosol Products

| Maximum Ceiling Height, ft (m) | Maximum Storage Height, ft (m) | Minimum Aisle Width, ft (m) | Ceiling Sprinkler Protection (Note 1)                           |  |   | In-Rack Sprinkler Protection (Note 1) |                                      |   |                             |          |
|--------------------------------|--------------------------------|-----------------------------|---|--|---|---------------------------------------|--------------------------------------|---|-----------------------------|----------|
|                                |                                |                             | Response, Nominal Temperature Rating, and Sprinkler Orientation | K-Factor (Note 2) gpm/psi <sup>1/2</sup> (L/min/bar <sup>1/2</sup> ) | Design, # Sprinklers @ Pressure psi (bar) | Layout, See Figure                    | Response, Nominal Temperature Rating | K-Factor (Note 3), gpm/psi <sup>1/2</sup> (L/min/bar <sup>1/2</sup> ) | Discharge Flow, gpm (L/min) |          |
| 25 (7.6)                       | 15 (4.6)                       | 4 (1.2)                     | QR, Ordinary, Pendent   | 14.0 (202)   | 12 @ 50 (3.4)                             | NA                                    | NA                                   | NA  | NA                          | NA       |
|                                |                                |                             |   | 16.8 (235)   | 12 @ 35 (2.4)                             |                                       |                                      |   |                             |          |
|                                |                                |                             |   | 22.4 (314)   | 12 @ 25 (1.7)                             |                                       |                                      |   |                             |          |
| 30 (9.1)                       | 15 (4.6)                       | 8 (2.4)                     | QR, Ordinary, Pendent   | 14.0 (202)   | 12 @ 25 (1.7)                             | NA                                    | NA                                   | NA  | NA                          | NA       |
|                                |                                |                             |   | 16.8 (235)   | 12 @ 75 (5.2)                             |                                       |                                      |   |                             |          |
|                                |                                |                             |   | 22.4 (314)   | 12 @ 52 (3.6)                             |                                       |                                      |   |                             |          |
| 40 (12.2)                      | 25 (7.6)                       | 8 (2.4)                     | QR, Ordinary, Pendent   | 14.0 (202)   | 12 @ 45 (3.1)                             | 6a-b                                  | 7a-c                                 | QR, Ordinary  | ≥8.0 (≥115)                 | 45 (170) |
|                                |                                |                             |   | 16.8 (235)   | 12 @ 25 (1.7)                             |                                       |                                      |   |                             |          |
|                                |                                |                             |   | 25.2 (363)   | 12 @ 50 (3.4)                             |                                       |                                      |   |                             |          |
| 40 (12.2)                      | 25 (7.6)                       | 8 (2.4)                     | SR, High, Any   | 16.8 (235)   | 12 @ 35 (2.4)                             | 6a-b                                  | 7a-c                                 | QR, Ordinary  | ≥8.0 (≥115)                 | 45 (170) |
|                                |                                |                             |   | 22.4 (314)   | 12 @ 25 (1.7)                             |                                       |                                      |   |                             |          |
|                                |                                |                             |   | 25.2 (363)   | 12 @ 25 (1.7)                             |                                       |                                      |   |                             |          |
| 40 (12.2)                      | 25 (7.6)                       | 8 (2.4)                     | SR, High, Any   | ≥11.2 (≥161)   | 25 @ 7 (0.5)                              | 7a-c                                  | 7a-c                                 | SR or QR, Ordinary  | ≥8.0 (≥115)                 | 30 (114) |
|                                |                                |                             |   | 11.2 (161)   | 25 @ 29 (2.0)                             |                                       |                                      |   |                             |          |
|                                |                                |                             |   | 14.0 (202)   | 25 @ 18 (1.2)                             |                                       |                                      |   |                             |          |
| 40 (12.2)                      | 25 (7.6)                       | 8 (2.4)                     | SR, High, Any   | 16.8 (235)   | 25 @ 13 (0.9)                             | 7a-c                                  | 7a-c                                 | SR or QR, Ordinary  | ≥8.0 (≥115)                 | 30 (114) |
|                                |                                |                             |   | 25.2 (363)   | 25 @ 7 (0.5)                              |                                       |                                      |   |                             |          |
|                                |                                |                             |   | 25.2 (363)   | 25 @ 7 (0.5)                              |                                       |                                      |   |                             |          |

Table 8. Rack Storage of Cartoned Level 3 Aerosol Products (continued)

| Maximum Ceiling Height, ft (m) | Maximum Storage Height, ft (m) | Minimum Aisle Width, ft (m) | Ceiling Sprinkler Protection (Note 1)                           |  | In-Rack Sprinkler Protection (Note 1)     |                    |                                      |   |                             |
|--------------------------------|--------------------------------|-----------------------------|---|--|---|--------------------|--------------------------------------|---|-----------------------------|
|                                |                                |                             | Response, Nominal Temperature Rating, and Sprinkler Orientation | K-Factor (Note 2) gpm/psi <sup>1/2</sup> (L/min/bar <sup>1/2</sup> ) | Design, # Sprinklers @ Pressure psi (bar) | Layout, See Figure | Response, Nominal Temperature Rating | K-Factor (Note 3), gpm/psi <sup>1/2</sup> (L/min/bar <sup>1/2</sup> ) | Discharge Flow, gpm (L/min) |
| >40 (>12.2) (Note 7)           | 25 (7.6)                       | 8 (2.4)                     | SR, High, Any   | ≥11.2 (≥161) (Note 4)  | 25 @ 7 (0.5)                              | 8a-c               | SR or QR, Ordinary                   | ≥8.0 (≥115)   | 30 (114)                    |
| Unlimited                      | Unlimited                      | 8 (2.4)                     | Any   | Any  | See Scheme A                              |                    | See Scheme A                         |   |                             |

Notes:

1. SR = Standard response; QR = quick response. See Appendix E for an explanation of fire protection schemes.
2. The FM Approved K19.6 (282) sprinkler is not acceptable for the protection of rack storage of cartoned Level 3 aerosol products.
3. Where IRAS with k-factors greater than listed in the table are used, the end-sprinkler discharge pressure must be at least 15 psi (1 bar).

Table 9. Rack Storage of Uncartoned Level 2 Aerosol Products

| Maximum Ceiling Height<br>ft (m) |           | Maximum Storage Height<br>ft (m) | Minimum Aisle Width<br>ft (m) | Ceiling Sprinkler Protection (Note 1)                           |  |                                      |                   | In-Rack Sprinkler Protection (Note 1) |   |                               |  |
|----------------------------------|-----------|----------------------------------|-------------------------------|---|--|--------------------------------------|-------------------|---------------------------------------|---|-------------------------------|--|
|                                  |           |                                  |                               | Response, Nominal Temperature Rating, and Sprinkler Orientation | K-Factor (Note 2)<br>gpm/psi <sup>1/2</sup><br>(l/min/bar <sup>1/2</sup> ) | # Sprinklers @ Pressure<br>psi (bar) | Layout See Figure | Response, Nominal Temperature Rating  | K-Factor<br>gpm/psi <sup>1/2</sup><br>(l/min/bar <sup>1/2</sup> )<br>(Note 3) | Discharge Flow<br>gpm (L/min) |  |
| 30 (9.1)                         | 15 (4.6)  | 4 (1.2)                          | QR, Ordinary, Pendent         | 14.0 (202)  | 12 @ 75 (5.2)  | NA                                   | NA                | NA                                    | NA  | NA                            |  |
|                                  |           |                                  |                               | 16.8 (235)  | 12 @ 52 (3.6)  |                                      |                   |                                       |   |                               |  |
|                                  |           |                                  |                               | 22.4 (314)  | 12 @ 45 (3.1)  |                                      |                   |                                       |   |                               |  |
|                                  |           |                                  |                               | 25.2 (363)  | 12 @ 25 (1.7)  |                                      |                   |                                       |   |                               |  |
|                                  | 20 (6.1)  | 4 (1.2)                          | QR, Ordinary, Pendent         | 14.0 (202)  | 12 @ 50 (3.4)  | 9a-c                                 | QR, Ordinary      | ≥8.0 (≥115)                           | 45 (170)  |                               |  |
|                                  |           |                                  |                               | 16.8 (235)  | 12 @ 35 (2.4)  |                                      |                   |                                       |   |                               |  |
|                                  |           |                                  |                               | 22.4 (314)  | 12 @ 25 (1.7)  |                                      |                   |                                       |   |                               |  |
|                                  |           |                                  |                               | 25.2 (363)  | 12 @ 25 (1.7)  |                                      |                   |                                       |   |                               |  |
|                                  |           |                                  |                               | ≥11.2 (≥161)  | 25 @ 7 (0.5)   |                                      |                   |                                       |   |                               |  |
|                                  |           |                                  |                               | 11.2 (161)  | 20 @ 29 (2.0)  |                                      |                   |                                       |   |                               |  |
| 8 (2.4)                          | 8 (2.4)   | SR, High, Any                    | 14.0 (202)                    | 20 @ 18 (1.2)   | 10a-c  | QR, Ordinary                         | ≥8.0 (≥115)       | 45 (170)                              |   |                               |  |
|                                  |           |                                  | 16.8 (235)                    | 20 @ 13 (0.9)   |  |                                      |                   |                                       |   |                               |  |
|                                  |           |                                  | 25.2 (363)                    | 20 @ 7 (0.5)  |  |                                      |                   |                                       |   |                               |  |
|                                  |           |                                  | 14.0 (202)                    | 12 @ 50 (3.4)   |  |                                      |                   |                                       |   |                               |  |
| 25 (7.6)                         | 4 (1.2)   | QR, Ordinary, Pendent            | 16.8 (235)                    | 12 @ 35 (2.4)   | 10a-c  | QR, Ordinary                         | ≥8.0 (≥115)       | 45 (170)                              |   |                               |  |
|                                  |           |                                  | 22.4 (314)                    | 12 @ 25 (1.7)   |  |                                      |                   |                                       |   |                               |  |
|                                  |           |                                  | 25.2 (363)                    | 12 @ 25 (1.7)   |  |                                      |                   |                                       |   |                               |  |
|                                  |           |                                  | ≥11.2 (≥161)                  | 25 @ 7 (0.5)  |  |                                      |                   |                                       |   |                               |  |
| Unlimited                        | Unlimited | 8 (2.4)                          | SR, High, Any                 | Any   | See Scheme A   | 10a-c                                | QR, Ordinary      | ≥8.0 (≥115)                           | 45 (170)  |                               |  |
|                                  |           |                                  |                               | Any   | See Scheme A   |                                      |                   |                                       |   |                               |  |

Notes:

1. SR = Standard response; QR = quick response. See Appendix E for an explanation of fire protection schemes.
2. The FM Approved K19.6 (282) sprinkler is not acceptable for the protection of rack storage of uncartoned Level 2 aerosol products.
3. Where IRAS with k-factors greater than listed in the table are used, the end-sprinkler discharge pressure must be at least 15 psi (1 bar).

Table 10. Rack Storage of Uncartoned Level 3 Aerosol Products

| Maximum Ceiling Height, ft (m) | Maximum Storage Height, ft (m) | Minimum Aisle Width, ft (m) | Ceiling Sprinkler Protection (Note 1)                           |   |   | In-Rack Sprinkler Protection (Note 1) |                                      |   |                             |          |       |              |             |          |
|--------------------------------|--------------------------------|-----------------------------|---|---|---|---------------------------------------|--------------------------------------|---|-----------------------------|----------|-------|--------------|-------------|----------|
|                                |                                |                             | Response, Nominal Temperature Rating, and Sprinkler Orientation | K-Factor, gpm/psi <sup>1/2</sup> (L/min/bar <sup>1/2</sup> ) (Note 2) | Design, # Sprinklers @ Pressure psi (bar) | Layout, See Figure                    | Response, Nominal Temperature Rating | K-Factor, gpm/psi <sup>1/2</sup> (L/min/bar <sup>1/2</sup> ) (Note 3) | Discharge Flow, gpm (L/min) |          |       |              |             |          |
| 30 (9.1)                       | 20 (6.1)                       | 4 (1.2)                     | QR, Ordinary, Pendent   | 14.0 (202)  | 12 @ 75 (5.2)                             | 9a-c                                  | QR, Ordinary                         | ≥8.0 (≥115)   | 45 (170)                    |          |       |              |             |          |
|                                |                                |                             |   | 16.8 (235)  | 12 @ (2.4)                                |                                       |                                      |   |                             |          |       |              |             |          |
|                                |                                |                             |   | 22.4 (314)  | 12 @ 25 (1.7)                             |                                       |                                      |   |                             |          |       |              |             |          |
|                                |                                |                             |   | 25.2 (363)  | 12 @ 25 (1.7)                             |                                       |                                      |   |                             |          |       |              |             |          |
|                                |                                |                             |   | 11.2 (161)  | 20 @ 29 (2.0)                             |                                       |                                      |   |                             |          |       |              |             |          |
|                                |                                |                             |   | 14.0 (202)  | 20 @ 18 (1.2)                             |                                       |                                      |   |                             |          |       |              |             |          |
|                                | 8 (2.4)                        | SR, High, Any               | 8 (2.4)   | SR, High, Any   | 16.8 (235)                                | 20 @ 13 (0.9)                         | 9a-c                                 | QR, Ordinary  | ≥8.0 (≥115)                 | 45 (170) |       |              |             |          |
|                                |                                |                             |   |   | 25.2 (363)                                | 20 @ 7 (0.5)                          |                                      |   |                             |          |       |              |             |          |
|                                |                                |                             |   |   | ≥11.2 (≥161)                              | 25 @ 7 (0.5)                          |                                      |   |                             |          |       |              |             |          |
|                                |                                |                             |   |   | 14.0 (202)                                | 12 @ 75 (5.2)                         |                                      |   |                             |          | 10a-c | QR, Ordinary | ≥8.0 (≥115) | 45 (170) |
|                                |                                |                             |   |   | 16.8 (235)                                | 12 @ 35 (2.4)                         |                                      |   |                             |          |       |              |             |          |
|                                |                                |                             |   |   | 22.4 (314)                                | 12 @ 25 (1.7)                         |                                      |   |                             |          |       |              |             |          |
| Unlimited                      | Unlimited                      | 8 (2.4)                     | SR, High, Any   | 25.2 (363)  | 12 @ 25 (1.7)                             | 10a-c                                 | QR, Ordinary                         | ≥8.0 (≥115)   | 45 (170)                    |          |       |              |             |          |
|                                |                                |                             |   | ≥11.2 (≥161)  | 25 @ 7 (0.5)                              |                                       |                                      |   |                             |          |       |              |             |          |
|                                |                                | 8 (2.4)                     | Any   | Any   | See Scheme A                              |                                       | See Scheme A                         |   |                             |          |       |              |             |          |

Notes:

1. SR = Standard response; QR = quick response. See Appendix E for an explanation of fire protection schemes.
2. The FM Approved K19.6 (282) sprinkler is not acceptable for the protection of rack storage of uncartoned Level 3 aerosol products.
3. Where IRAS with k-factors greater than those listed in the table are used, the end-sprinkler discharge pressure must be at least 15 psi (1 bar).

Table 11. Rack, Palletized, and Solid-Pile Storage of Cartoned Aerosol Cooking Spray Products <sup>1</sup>

| Maximum Ceiling Height, ft (m) | Maximum Storage Height, ft (m) | Minimum Aisle Width, ft (m) | Ceiling Sprinkler Protection                                    |  |   |
|--------------------------------|--------------------------------|-----------------------------|---|--|---|
|                                |                                |                             | Response, Nominal Temperature Rating, and Sprinkler Orientation | K-Factor, gpm/psi <sup>1/2</sup> (L/min/bar <sup>1/2</sup> ) | Design, Number of Sprinklers @ Pressure psi (bar) |
| 30 (9.1)                       | 25 (7.6)                       | 8 (2.4)                     | QR, Ordinary, Pendent   | 14.0 (202)   | 12 @ 75 (5.2)                                     |

<sup>1</sup> Aerosol cooking spray products can be adequately protected using the protection criteria provided for Level 2 and 3 aerosol products.

#### 2.4.2.6 Protect picking areas that contain Level 2 and Level 3 aerosol products as follows:

A. For picking in standard configuration single-row and double-row racks, locate aerosol product storage on the first and second tiers of the rack. Install fire protection Scheme A over the picking area (see Section E.2). Provide a chain link fence or similar restraint at the edges of the aerosol product storage area. For example, if the aerosol product storage is located only on one side of a double-row rack, install vertical barriers down the longitudinal flue space and at each end of the storage rack (refer to Section 2.3.3).

B. For picking in "flow-through" racks (those with shelves consisting of slanted rollers spaced less than 1 ft (0.3 m) apart so product loaded on one side rolls to the other), store and protect the aerosol products in accordance with the aerosol product flow-through rack protection scheme described and illustrated in Section E.3.

#### 2.4.2.7 Protect aerosol product storage in automated rack storage warehouses that are higher than 30 ft (9.1 m) with aisle widths of 4 ft (1.2 m) or more as follows:

A. Limit aerosol product storage to the bottom tiers of the racks.

B. Provide chain link fencing or noncombustible vertical barriers around the limits of the aerosol product storage. The rack face does not need to be enclosed (refer to Section 2.3.3).

C. Provide fire protection Scheme A over all aerosol product storage within the racks. If aerosol products are stored above the bottom two rack tiers, protect all tiers below the aerosol product storage using Scheme A as well.

### 2.4.3 Warehouse Storage of Aerosol Products in Plastic Containers of 33.8 oz (1000 ml) or Less

2.4.3.1 Protect plastic aerosol 1 products using the protection criteria provided for Class 3 commodities in Data Sheet 8-9, *Storage of Class 1, 2, 3, 4 and Plastic Commodities*.

2.4.3.2 Protect plastic aerosol 3 products in accordance with Table 12.

Table 12. Rack Storage of Plastic Aerosol 3 Products

| Maximum Ceiling Height, ft (m) | Maximum Storage Height, ft (m) | Minimum Aisle Width, ft (m) | Ceiling Sprinkler Protection                                    |  |   | In-Rack Sprinkler Protection         |  |                             |
|--------------------------------|--------------------------------|-----------------------------|---|--|---|--------------------------------------|--|-----------------------------|
|                                |                                |                             | Response, Nominal Temperature Rating, and Sprinkler Orientation | K-factor, gpm/psi <sup>1/2</sup> (L/min/bar <sup>1/2</sup> ) | Design, # Sprinklers @ Pressure psi (bar) | Response, Nominal Temperature Rating | K-Factor, gpm/psi <sup>1/2</sup> (L/min/bar <sup>1/2</sup> ) | Discharge flow, gpm (L/min) |
| Unlimited                      | Unlimited                      | 8 (2.4)                     | Any   | Any  | See Scheme A                              | See Scheme A                         |  |                             |

2.4.3.3 Currently there are no proven protection criteria available for plastic aerosol X products. Ideally, limit the quantity of these products stored in a single area and locate the area well away from important buildings.

2.4.3.3.1 Protect plastic aerosol X products located in a cutoff room with a wet, dry, or deluge sprinkler systems designed to provide 75 psi (5.2 bar) discharge pressure for all of the sprinklers in the cutoff room.

#### 2.4.4 Mercantile Locations

2.4.4.1 In locations that display and sell aerosol products in areas of less than 8 ft (2.4 m), such as supermarkets and department stores, remove the aerosol products from their combustible packaging. Typically, this involves the removal of at least the tops and parts of the faces and sides of the combustible cartons. Provide protection based on the surrounding occupancy.

2.4.4.2 Many retail occupancies, such as superstores or “big box” stores, display aerosol products in picking shelves or racks. Additional bulk storage of aerosol products is often located in racks above the display areas. Provide the following protection for these arrangements:

- A. Limit the bottom 8 ft (2.4 m) to the display of aerosol products that have been removed from their combustible packaging per Section 2.4.4.1.
- B. Maintain storage of aerosol products located in upper tiers within cartons. Do not exceed a storage height of 18 ft (5.5 m).
- C. Store and protect the aerosol products in accordance with Appendix E.4.
- D. Limit uncartoned plastic aerosol X product on display shelves to a single case. Do not store aerosol 3 products in bulk storage area above display shelves.

2.4.4.3 Consider aerosol products that are not on display as described in Sections 2.4.4.1 or 2.4.4.2 (i.e., back-stock storage areas) as warehouse storage of aerosol products. Provide segregation and protection in accordance with this data sheet. Alternatively, relocate these aerosol products to one of the areas recommended in Sections 2.2.8 and 2.2.9.

2.4.4.3.1 Do not store plastic aerosol X products in back-stock areas. Provide segregation and protection in accordance with Sections 2.2.8. and 2.2.9.

#### 2.5 Training

2.5.1 Train facility personnel in accordance with Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers*. Instruct and train operating employees and members of the Emergency Response Team in the hazards of aerosol products and butane and propane containers, and in the emergency procedures to follow in the event of an accident. Alert the public fire service to the hazards and to the fire protection provided.

#### 2.6 Human Factor

2.6.1 Establish an emergency response plan in accordance with Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers*.

#### 2.7 Ignition Source Control

2.7.1 Control ignition sources in accordance with Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers*.

### 3.0 SUPPORT FOR RECOMMENDATIONS

#### 3.1 General

The typical aerosol container is a small, welded-joint, high-strength container (design pressures are as high as 240 to 400 psi [16.5 to 27.5 bar]) used to package a wide variety of consumer, industrial, and pharmaceutical products. A partial list of products includes air fresheners, starches, cleaners, shaving creams, furniture polishes, hair sprays, deodorants, spot removers, insecticides, lubricants, engine degreasers, and paints. Aerosol cans have capacities up to one (1) qt. (1 L), containing up to 16 oz (475 ml) of liquid.

Propellants include propane and butane, which are highly flammable, and other gases such as nitrogen, carbon dioxide, and nitrous oxide. Although nitrous oxide is a stable nonflammable gas, it is an oxidizer.

Nonflammable chlorofluorocarbons have been eliminated in the United States for almost all uses in compliance with federal regulations, and have been replaced with mixtures of propane and butane. Propellants in aerosol containers are 0.5% to more than 90% of the weight of the contents.

Aerosol products stored in metal containers have been grouped into Levels 1, 2, and 3. Level 1 aerosol products represent the lowest fire hazard. Level 3 represents the highest fire hazard.

Level 1 aerosol products include shaving cream, spray starch, window cleaner, alkaline oven cleaner, rug shampoo, some air fresheners, and some insecticides. The storage hazard of Level 1 aerosol products is about the same as ordinary combustible goods in cartons. Storage should be arranged and protected accordingly.

When a Level 1 aerosol product can fails, the nonflammable product has a quenching effect on the flammable contents. Some products have very small quantities of flammable product. These products will have an overall chemical heat of combustion that is low.

Level 2 aerosol products include many personal care products such as deodorant (except for oil-based antiperspirants), hair spray, antiseptic, and anesthetic. Other products include some furniture polishes and windshield deicers.

Level 3 aerosol products include many automotive products (engine and carburetor cleaner, undercoat), home products (some wood polishes), paint and lacquer, lubricants, some insecticides, and oil-based antiperspirants.

A separate aerosol classification has been created for cooking sprays stored in metal containers. Historically, cooking sprays were classified as Level 1 aerosols due to the use of high flash point vegetable oils in the products. However, based on full-scale fire testing, aerosol cooking spray products have been shown to represent a fire hazard somewhere between a Level 1 aerosol product and a Level 2 aerosol product.

The use of plastic containers as a packaging method is a recent development in the aerosol industry. While the level of protection necessary for aerosols in metal containers has been established for over 30 years, protection methods do not currently exist for aerosols in plastic containers. Recent testing has indicated that the fire hazard increases when the aerosols are stored in plastic containers. As such, aerosols in plastic containers cannot follow the same classification scheme (i.e., Levels 1, 2, and 3) as aerosols in metal containers. Research and testing is ongoing in an effort to develop a classification scheme and corresponding fire protection criteria for aerosols in plastic containers.

### 3.2 Aerosol Products in Metal Containers: Classification by Chemical Heat of Combustion

Test data indicates the overall fire hazard of an aerosol product in a metal container is a function of the chemical heat of combustion. The chemical heat of combustion is the product of the theoretical heat of combustion and a combustion efficiency. Typical chemical heats of combustion are provided in Table 13 in Appendix D. A typical combustion efficiency is 95%. Research conducted at FM Global correlated the chemical heat of combustion with results of various 12-pallet tests to provide a classification methodology based exclusively on chemical heat of combustion. Figure 1 in this data sheet is based on this methodology.

Some aerosol cans are labeled "Flammable" or "Extremely Flammable" in accordance with the Federal Hazardous Substances Act, but these designations have no relation to the classification of the aerosol product. The test for determining the label involves spraying an aerosol product can toward an ignition source and measuring the flame extension. This test will not predict the classification of the aerosol product.

Solids (e.g., powders), nonflammable gases (e.g., carbon dioxide), and nonignitable liquids (e.g., water, liquids without a fire point) are considered inert.

### 3.3 Fire Hazard

The initial aerosol product storage fire is driven by the packaging. However, once the aerosol products become involved, the fire severity increases significantly. As an aerosol can is heated, the interior pressure increases until the can ruptures. The rocketing can allows the fire to spread and impedes firefighting efforts. Alternatively, the aerosol product may fail at the valve, allowing the contents to leak and creating an equally challenging pool fire scenario. It is not possible to differentiate between aerosol products that vent and those that rupture. For this reason, this standard accounts for both failure modes, and the proper segregation and sprinkler protection of aerosol product storage is critical.



Plastic aerosol product storage fire hazards is also driven by the packaging. In this case, the plastic bottle will fail quickly when exposed to fire and release the liquid content plus the propellant. Unpressurized, the plastic bottle and ignitable liquid content produces a known severe fire hazard. The addition of a flammable propellant to the liquid-bottle combination produces a fire hazard that has not been fully quantified but will at least be as severe as the ignitable liquid-plastic bottle combination and likely more severe.

### 3.3.1 Fire Protection

#### 3.3.1.1 Level 1 Aerosol Products

Fire testing on Level 1 aerosol products indicated they could be adequately protected in accordance with the criteria in Data Sheet 8-9, *Storage of Class 1, 2, 3, 4 and Plastic Commodities*.

#### 3.3.1.2 Rack Storage vs. Palletized or Solid Pile Storage

Initial fire testing revealed that palletized storage of Level 2 and 3 aerosol products in excess of one pallet high could not be protected using standard-response sprinklers, even with a 0.6 gpm/ft<sup>2</sup> (24 mm/min) density. Palletized storage of aerosol products protected in this manner should therefore be located in a cutoff room. The use of a chain link fence is not appropriate, as the level of fire control is marginal, resulting in an exposure to commodities stored beyond the chain link fence.

Subsequent testing demonstrated that palletized storage of aerosol products exceeding one pallet high could be protected using a K11.2 (K161), standard-response, ordinary temperature-rated, upright sprinkler. Similarly, adequate protection can be achieved for this storage configuration using quick-response sprinklers. These protection options are provided in Tables 5 and 6 of this data sheet.

These early fire test programs revealed that the key to providing adequate protection for aerosol products is to provide prompt cooling for aerosol products exposed to fire. Therefore, even though adequate fire protection was established for palletized and solid pile storage, the storage of aerosol products in racks is preferable, as in-rack sprinklers can provide water to quickly cool the aerosol products. Further, fire tests demonstrated that the used of face and flue in-rack sprinklers provided better protection than tests using in-rack sprinklers in the longitudinal flue space only. Fire protection options for the rack storage of Level 2 and 3 aerosol products are provided in Tables 7 through 10 of this data sheet.

#### 3.3.1.3 Cartoned vs. Uncartoned Storage

Cartoned storage of aerosol products includes cans that are packaged in at least a single layer of corrugated cardboard, where the cardboard covers at least the bottom, top, and two complete sides of the unit. The remaining two sides are at least 80% covered with corrugated cardboard. Uncartoned storage of aerosol products is any arrangement that does not meet the definition of cartoned storage, such as aerosol product arranged on slip sheets or trays, or stacked on a pallet and shrink wrapped.

Cartoned aerosol products promotes initial fire growth and sprinkler operation, providing sprinklers an opportunity to control a fire prior to involvement of the aerosol containers. The corrugated cardboard segregates the aerosol cans, and provides good insulation against heat when wet. Conversely, uncartoned aerosol products have slow fire growth, allowing the aerosol cans to be heated and become involved in the fire before sprinkler operation. Uncartoned storage provides no segregation or insulation of cans.

For these reasons, when properly protected, cartoned aerosol products represent a less severe fire hazard than uncartoned aerosol products. It is important to note that completely removing aerosol products from their combustible packaging and displaying them in mercantile locations is different than uncartoned storage. Mercantile locations have a large variety of aerosol products in storage and on display. Products on display in selling areas do not present an unusual fire hazard in sprinklered buildings if they are removed from their combustible packaging.

#### 3.3.1.4 Mixed Commodities

It is not recommended that aerosol products be mixed with other commodities, such as ignitable liquid storage or unexpanded plastics, in the same storage array. Previous experience with mixed commodities has shown that test results are worse than for each commodity by itself. In the early stages of a fire, before can ruptures begin to increase in frequency, the exposure fire of the bottom tier to the tiers above is intermittent and is essentially a cardboard fire. Replacing the bottom tier or tiers with plastics is expected to create a more intense and prolonged fire exposure to the tiers of aerosol products above, with unknown results.

Section 2.3 of this data sheet outlines specific instances of where the storage of mixed commodities is tolerable.

### 3.3.1.5 Aerosol Products in Plastic Containers

The use of plastic containers as a packaging method will increase the fire hazard associated with the aerosol product. The aerosol industry in the US is working with FM Global to determine what types of aerosol products in plastic containers can be protected. The first step was confirming that aerosol products with non-flammable propellants and non-ignitable liquid content did not create an unexpected fire hazard. Testing has shown that these products can be protected with protection criteria for Class 3 commodities and have been labeled "plastic aerosol 1 products."

Plastic aerosol products that consist of ignitable liquids or flammable propellants do not have proven protection schemes available. These products are labeled "plastic aerosol X products." The aerosol industry continues to work with FM Global to define content-propellant combinations that can be protected in plastic bottles.

Guidance exists in this document for plastic aerosol 1, plastic aerosol 3, and plastic aerosol X products. The aerosol industry has not yet defined the extent of formulations that plastic aerosol products might comprise. As such, a decision was made in the development of the 2019 edition of NFPA 30b to leave the plastic aerosol 2 designation open for potential future products that represent a higher fire hazard than plastic aerosol 1 products, but not to the level represented by plastic aerosol 3 products. Currently there are no plastic aerosol 2 products being produced and a definition of, and protection for, plastic aerosol 2 products will be developed as part of future work as and when required.

### 3.3.2 Segregation

Even a single pallet load of a Level 3 aerosol product in a general purpose warehouse (as they are usually protected) constitutes a potential serious loss. The rocketing cans, regardless of contents, could severely hamper manual firefighting efforts, and thick, black smoke will quickly obscure visibility.

This data sheet recommends storing Level 2 and 3 aerosol products in cutoff rooms having one-hour fire resistance, which is in accordance with FM Global basic philosophies of confinement for low flash point ignitable liquids. In lieu of a cutoff room, FM Global has concluded the provision of a chain link fence enclosure can be accepted under certain conditions, provided the rack storage is protected with longitudinal flue and face sprinklers, and ceiling protection is provided.

As described in Section 3.3.1.2, the use of a chain link fence enclosure is not acceptable for palletized or solid pile Level 3 aerosol products unless quick-response sprinklers are provided at the ceiling. With standard-response sprinklers, the degree of control is not as pronounced as it is with quick-response ceiling sprinklers or with in-rack sprinklers. If a chain link fence was used with standard-response ceiling sprinklers, there would be a greater exposure to the commodities stored beyond the chain link fence. Furthermore, the heat release from an aerosol product storage fire is significant. If a chain link fence was used with standard-response ceiling sprinklers, additional sprinklers would be expected to operate and potentially deplete the water supply. Fire testing demonstrated that an area protected with standard-response sprinklers produced enough heat to operate sprinklers installed in an area of the test building 50 ft (15 m) away.

## 4.0 REFERENCES

### 4.1 FM Global

Data Sheet 1-21, *Fire Resistance of Building Assemblies*

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

Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers*

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

### 4.2 Others

Green, Don W. and Robert H. Perry, eds. *Perry's Chemical Engineering Handbook*. McGraw-Hill. 2008.

National Fire Protection Association (NFPA). *Code for Manufacture and Storage of Aerosol Products*. NFPA 30B.

Society of Fire Protection Engineers (SFPE). *SFPE Handbook of Fire Protection Engineering*. 4th edition. National Fire Protection Association (NFPA). 2008.

## APPENDIX A GLOSSARY OF TERMS

**Aerosol product:** A combination of a container, a propellant, and a material that is dispensed.

**Aerosol container:** A metal can or plastic container up to a maximum size of 33.8 oz (1000 ml).

**Aerosol propellant:** The liquefied or compressed gas that expels the content from an aerosol container with the valve is actuated. The propellant may be flammable or non-flammable gas.

**Aerosol product packaging - cartoned:** Aerosol cans packaged in at least a single layer of corrugated cardboard. The cardboard must cover at least the bottom, top, and two complete sides of the unit. The other two sides must be at least 80% covered.

**Aerosol product packaging - uncartoned:** Aerosol cans arranged on slip sheets or trays that are stacked on a pallet and shrink wrapped, and packaging that does not meet the definition of cartoned.

**Base product (concentrate):** The contents of an aerosol container, excluding the propellant.

**Aerosol cooking spray product:** An aerosol product designed to deliver a vegetable oil, solid, or nonignitable liquid to reduce sticking on cooking and baking surfaces, or to be applied to food, or both. These products have a chemical heat of combustion greater than 8600 Btu/lb (20 kJ/g) and contain not more than 18% by weight of flammable propellant.

**Emulsion:** An emulsion is a stable mixture of two or more immiscible liquids held in suspension by small percentages of substances called emulsifiers.

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

**Ignitable liquid:** Any liquid or liquid mixture that is capable of fueling a fire, including flammable liquids, combustible liquids, inflammable liquids, or any other term for a liquid that will burn. An ignitable liquid is one that has a fire point.

**Prefabricated ignitable liquid storage building (PILSB):** A structure designed to provide a safe, secure storage area with secondary containment for chemicals and hazardous waste materials. They are designed for the indoor and outdoor storage of hazards such as aerosols and ignitable liquids. FM Approved buildings are normally of noncombustible construction, and some are of fire-rated construction. Additional details are provided in the *Approval Guide*.

**Water-miscible liquid:** A liquid that mixes in all proportions with water. When water-miscible ignitable liquids are mixed with water, a homogeneous solution is formed. The flash point, fire point, heat of combustion, and heat release rate of the solution will be different from the pure ignitable liquid. The flash point and fire point of the solution will increase as the water concentration increases. At a certain water concentration (which varies for different ignitable liquids), the fire point will no longer exist and the solution will no longer present a fire hazard (e.g., 15% ethyl alcohol in water, 15% acetone in water).

## APPENDIX B DOCUMENT REVISION HISTORY

**February 2020. Interim revision.** A small modification was made to Section E.2.4 to include the recommended design flow of 57 gpm (220 L/min), which was incorrectly omitted from the January 2020 revision.

**January 2020. Interim revision.** Fire Protection Scheme A (Section E.2) was updated to cover both metal and plastic aerosol products.

**January 2019. Interim revision.** Incorporated guidance for plastic aerosol 3 products. The following changes were made:

- A. Added a definition of plastic aerosol 3 products.
- B. Added guidance on construction and location for plastic aerosol 3 products (Table 3).
- C. Created a new table with protection guidance for plastic aerosol 3 products (Table 12).

D. Added guidance on mercantile storage of plastic aerosol 3 products.

**April 2016.** Interim revision. Editorial changes were made.

**January 2016.** The following major changes have been made:

- A. Replaced references to “flammable” and “combustible” liquids with “ignitable” liquids throughout the document.
- B. Reorganized the document to provide a consistent format with other data sheets.
- C. Removed guidance on the storage of small liquefied petroleum gas (LPG) containers, such as butane cigarette lighters (0.2 oz [6 ml]).
- D. Provided guidance for protecting propane cylinders up to 17 oz (500 ml) [nominal 1 lb (450 g) cylinders].
- E. Deleted a recommendation to consider liquids with flash points higher than 500°F (260°C), such as some vegetable cooking oils, as inert materials when classifying aerosol products. New guidance has been provided for aerosol cooking spray products.
- F. Added information on the storage and fire protection of aerosol products in plastic containers.
- G. Updated Table 3, Aerosol Product Storage Location Options, to include new sprinkler terminology, aerosol cooking spray products and aerosol products in plastic containers.
- H. Provided additional details on the proper storage of aerosol products protected using Scheme A.
- I. Provided additional details on the appropriate design of cutoff rooms, including roof construction.
- J. Added a figure to demonstrate the appropriate design of a “labyrinth” or “tunnel” approach to protect openings in fenced aerosol product areas.
- K. Provided recommendations on the storage of small quantities of aerosol products in FM Approved ignitable liquid storage cabinets and buildings.
- L. Clarified the recommendations related to shipping and receiving areas.
- M. Added guidance on the mixing of aerosol products and ignitable liquid storage.
- N. Provided additional general information on the design of sprinkler systems, including guidance on spacing and sprinkler system types.
- O. Changed all ceiling sprinkler recommendations to provide a K11.2 (K161) or larger sprinkler in accordance with the requirements of NFPA 13, *Standard for the Installation of Sprinkler Systems*.
- P. Renumbered, edited, and reformatted all fire protection recommendations to improve consistency, clarity, and alignment with the pressure/number of sprinklers approach used in Data Sheet 8-9, *Storage of Class 1, 2, 3, 4, and Plastic Commodities*.
- Q. Clarified fire protection recommendations for mercantile locations.
- R. Reorganized Section 3, Support for Recommendations, for improved clarity.
- S. The section on fire test data has been consolidated.

**January 2012.** Terminology related to ignitable liquids has been revised to provide increased clarity and consistency with regard to FM Global’s loss prevention recommendations for ignitable liquid hazards.

**May 2003.** Minor editorial changes were made for this revision.

**January 2003.** The following changes were made for this revision:

1. Added new protection criteria for uncartoned aerosol storage.
2. Added new protection criteria for Suppression Mode sprinklers.
3. Revised all of the protection tables into a consistent format and provided figures for determining in-rack sprinkler layout.
4. Revised the text to be consistent with the new tables.

5. Eliminated allowance for unrestrained Level 2 aerosol storage to ensure a consistent application of aerosol protection.
6. Revised protection criteria for aerosol picking racks.
7. Revised protection criteria for aerosol storage in automated storage and retrieval warehouses.

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

**January 1998.** Minor technical revision (uncartoned aerosol information added).

**May 1983.** Full technical revision.

## APPENDIX C NFPA STANDARD

The fire protection recommendations in this data sheet are nearly identical to those provided in NFPA 30B, *Code for the Manufacture and Storage of Aerosol Products*, 2011 Edition. The main differences are as follows:

- A. NFPA 30B allows unlimited roof heights for the rack storage of cartoned Level 2 and 3 aerosol products without the use of barriers (i.e., without the use of Scheme A protection).
- B. NFPA 30B allows limited quantities of aerosol products to be stored in various locations without protecting them based on their classification as aerosol products. For example, up to 1000 lb (454 kg), 500 lb (227 kg), and 100 lb (45 kg) of Level 2, Level 3, and plastic aerosol X products, respectively, are permitted in occupancies other than warehouses or mercantile locations without any special fire protection. Also, up to 2500 lb (1135 kg), 1000 lb (454 kg), and 250 lb (115 kg) of Level 2, Level 3, and plastic aerosol X products, respectively, are permitted in general purpose warehouses regardless of protection level provided.
- C. Subject to the approval of the AHJ NFPA 30B allows up to 12,000 lb (5450 kg) of solid pile or palletized storage of Level 2 and/or Level 3 aerosols in a general purpose warehouse without any separation such as a chain link fence. Similarly, NFPA 30B allows up to 24,000 lb (10,900 kg) of rack storage of Level 2 and/or Level 3 aerosols in a general purpose warehouse without any separation.
- D. Where aerosol storage is segregated from other commodities by fire walls or a chain link fence, NFPA 30B limits the floor area of the segregated aerosol storage to a percentage of the total floor area of the warehouse. Data Sheet 7-31 does not limit the floor area of aerosols in this manner.
- E. NFPA 30B limits the density of aerosol storage in mercantile occupancies (i.e., product weight per unit area). Data Sheet 7-31 does not include this limitation.
- F. NFPA 30B allows the storage of aerosols in plastic containers up to 4 oz (118 ml), regardless of the container contents. Data Sheet 7-31 allows the storage of aerosols in plastic containers up to 33.8 oz (1000 ml), provided the contents are considered nonignitable in accordance with Section 2.1.3.1.

## APPENDIX D AEROSOL PRODUCTS CLASSIFICATION

### D.1 Chemical Heat of Combustion Data

The following table was generated by FM Global at the request of aerosol product manufacturers. It is not considered an all-inclusive table, but does contain many commonly used materials. The table will be updated as additional materials are tested. The table footnotes may be used as an additional source of information.

Table 13. Chemical Heat of Combustion Data

| CAS#       | Material Name                             | Theoretical Heat of combustion<br>(Note 1)<br>$\Delta H_c$<br>(kJ/g) | Combustion Efficiency<br>(Note 2)<br>$\chi_{ch}^2$ | Chemical Heat of Combustion<br>$\Delta H_{ch}$<br>(kJ/g) |
|------------|---|--|--|--|
| 75-37-6    | 1,1-Difluoroethane (HFC 152a)             | 18.1   | 0.35 (Note 3)                                      | 6.3  |
| 95-63-6    | 1,1,1-Trimethylbenzene (Pseudocumene)     | 41.0   | 0.67 (Note 3)                                      | 27.5   |
| 1717-00-6  | 1,1-Dichloro-1-Fluoroethane               | 8.4  | 0.35 (Note 3)                                      | 2.9  |
| 110-71-4   | 1,2-Dimethoxyethane                       | 26.7 (Note 2)  | 0.97   | 25.9   |
| 75-68-3    | 1-Chloro-1,1-Difluoroethane (HCFC 142b)   | 9.3  | 0.35 (Note 3)                                      | 3.3  |
| 108-65-6   | 1-Methoxy-2-Propanol Acetate              | 32.2 (Note 2)  | 0.96   | 30.9   |
| 111-76-2   | 2-Butoxyethanol                           | 30.8 (Note 2)  | 0.96   | 29.6   |
| 110-80-5   | 2-Ethoxyethanol                           | 26.7 (Note 2)  | 0.97   | 25.9   |
| 111-15-9   | 2-Ethoxyethyl Acetate                     | 32.2 (Note 2)  | 0.96   | 30.9   |
| 75-28-5    | 2-Methylpropane (Isobutane)               | 45.5   | 0.94   | 42.8   |
| 67-64-1    | Acetone                                   | 28.6   | 0.97 (Note 3)                                      | 27.7   |
| 8052-42-4  | Asphalt                                   | 30.2 (Note 4)  | 0.75   | 22.7   |
| 7727-43-7  | Barium Sulfate                            | 0.0  |  | 0.0  |
| 106-97-8   | Butane                                    | 45.6   | 0.95 (Note 3)                                      | 43.3   |
| 85-68-7    | Butyl Benzl Phthalate                     | 37.1 (Note 2)  | 0.85   | 3.15   |
| 1317-65-3  | Calcium Carbonate                         | 0.0  |  | 0.0  |
| 124-38-9   | Carbon Dioxide                            | 0.0  |  | 0.0  |
| 1308-14-1  | Chromium Hydroxide                        | 0.0  |  | 0.0  |
| 8001-30-7  | Corn Oil                                  | 36.8 (Note 4)  | 0.96   | 35.3   |
| 5989-27-5  | d-Limonene                                | 45.2   | 0.88   | 39.8   |
| 123-42-2   | Diacetone Alcohol                         | 37.3 (Note 2)  | 0.94   | 35.1   |
| 112-34-5   | Diethylene Glycol Methyl Ether            | 34.4 (Note 2)  | 0.96   | 33.0   |
| 115-10-6   | Dimethyl Ether                            | 28.8   | 0.92   | 26.5   |
| 34590-94-8 | Dipropylene Glycol Methyl Ether           | 33.5 (Note 2)  | 0.96   | 32.2   |
| 64-17-15   | Ethanol (95.6 Azeotrope)                  | 25.6   | 0.92   | 23.6   |
| 64-17-15   | Ethanol                                   | 26.8   | 0.92   | 24.7   |
| 763-69-9   | Ethyl 3-Ethoxypropionate                  | 33.3 (Note 2)  | 0.96   | 32.0   |
| 100-41-4   | Ethylbenzene                              | 40.9   | 0.71   | 29.0   |
| 107-21-1   | Ethylene Glycol                           | 16.9   | 0.97   | 16.4   |
| 111-55-7   | Ethylene Glycol Diacetate                 | 33.3 (Note 2)  | 0.96   | 32.0   |
| 107-41-5   | Hexylene Glycol                           | 29.7   | 0.96   | 28.5   |
| 1309-37-1  | Iron Oxide                                | 0.0  |  | 0.0  |
| 78-83-1    | Isobutyl Alcohol                          | 32.7   | 0.91   | 29.8   |
| 108-21-4   | Isopropyl Acetate                         | 26.0   | 0.98   | 25.5   |
| 67-63-0    | Isopropyl Alcohol                         | 30.1   | 0.91   | 27.4   |
| 142-91-6   | Isopropyl Palmitate                       | 38.8 (Note 2)  | 0.96   | 37.2   |
| 110-27-0   | Isopropyl Myristate                       | 38.2 (Note 2)  | 0.95   | 36.2   |
| 1332-58-7  | Kaolin Clay (Aluminum Silicate Hydroxide) | 0.0  |  | 0.0  |

Table 13. Chemical Heat of Combustion Data (continued)

| CAS#       | Material Name                          | Theoretical Heat of combustion<br>(Note 1)<br>$\Delta H_c$<br>(kJ/g) | Combustion Efficiency<br>(Note 2)<br>$\chi_{ch}^2$ | Chemical Heat of Combustion<br>$\Delta H_{ch}$<br>(kJ/g) |
|------------|--|--|--|--|
| 8008-20-6  | Kerosene (Kerosine)                    | 46.0 (Note 4)  | 0.90 (Note 5)                                      | 41.4   |
|            | Liquids, Non-Contributory              |  |  | 0.0  |
|            | Liquids, Nonignitable                  |  |  | 0.0  |
| 14807-96-6 | Magnesium Silicate (Talc)              | 0.0  |  | 0.0  |
| 67-56-1    | Methanol                               | 20.0   | 0.95 (Note 3)                                      | 19.0   |
| 78-93-3    | Methyl Ethyl Ketone                    | 31.5   | 0.97 (Note 3)                                      | 30.6   |
| 563-80-4   | Methyl Isopropyl Ketone                | 33.1   | 0.94   | 31.1   |
| 110-43-0   | Methyl n-Amyl Ketone                   | 37.2 (Note 2)  | 0.94   | 35.0   |
| 75-09-2    | Methylene Chloride                     | 6.0  | 0.35 (Note 3)                                      | 2.1  |
| 12001-26-2 | Mica (Mica Silicate)                   | 0.0  |  | 0.0  |
| 64742-47-8 | Mineral Spirits (Petroleum Distillate) | 44.8   | 0.92   | 41.2   |
| 8012-95-1  | Mineral Oil                            | 41.5 (Note 4)  | 0.76 (Note 5)                                      | 31.5   |
| 64742-88-7 | Mineral Spirits (Petroleum Distillate) | 44.8   | 0.92   | 41.2   |
| 134-62-3   | N,N-Diethyl-m-Toluamide (Deet)         | 38.1 (Note 2)  | 0.74   | 28.2   |
| 123-86-4   | n-Butyl Acetate                        | 28.2   | 0.98   | 27.6   |
| 142-82-5   | n-Heptane                              | 44.6   | 0.92 (Note 3)                                      | 41.0   |
| 110-54-3   | n-Hexane                               | 44.7   | 0.92 (Note 3)                                      | 41.1   |
| 113-48-4   | n-Octyl Bicycloheptane Dicarboximide   | 38.0 (Note 2)  | 0.79   | 30.0   |
| 64742-48-9 | Naphtha, VM&P (Petroleum Distillate)   | 44.8   | 0.92   | 41.2   |
| 8030-30-6  | Naphtha (Petroleum Distillate)         | 44.8   | 0.92   | 41.2   |
| 8052-41-3  | Naphtha (High Flash Point)             | 44.8   | 0.92   | 41.2   |
| 64742-95-6 | Naphtha, VM&P (Petroleum Distillate)   | 44.8   | 0.92   | 41.2   |
| 64742-94-5 | Naphtha, VM&P (Petroleum Distillate)   | 44.8   | 0.92   | 41.2   |
| 7727-37-9  | Nitrogen                               | 0.0  |  | 0.0  |
| 109-66-0   | Pentane                                | 45.0   | 0.93 (Note 2)                                      | 41.9   |
| 64741-65-7 | Petroleum Distillate                   | 44.8   | 0.92   | 41.2   |
| 51-03-6    | Piperonyl Butoxide                     | 37.2 (Note 2)  | 0.86   | 32.0   |
| 74-68-6    | Propane                                | 46.3   | 0.95 (Note 3)                                      | 44.0   |
| 57-55-6    | Propylene Glycol                       | 21.4   | 0.96   | 20.5   |
| 78-92-2    | sec-Butyl Alcohol                      | 32.9   | 0.91   | 39.9   |
|            | Silica (Crystalline)                   | 0.0  |  | 0.0  |
| 7631-86-9  | Silica, Amorphous Hydrated             | 0.0  |  | 0.0  |
|            | Solids, Non-Contributory               |  |  | 0.0  |
|            | Solids, Noncombustible                 | 0.0  |  | 0.0  |
| 1338-39-2  | Sorbitan Monolaurate                   | 39.5 (Note 2)  | 0.96   | 37.9   |
| 26266-57-9 | Sorbitan Monopalmitate                 | 39.5 (Note 2)  | 0.96   | 37.9   |
| 16252-10-5 | Tin Oxide                              | 0.0  |  | 0.0  |

Table 13. Chemical Heat of Combustion Data (continued)

| CAS#       | Material Name    | Theoretical Heat of combustion<br>(Note 1)<br>$\Delta H_c$<br>(kJ/g) | Combustion Efficiency<br>(Note 2)<br>$\chi_{ch}^2$ | Chemical Heat of Combustion<br>$\Delta H_{ch}$<br>(kJ/g) |
|------------|------------------|--|--|--|
| 13463-67-7 | Titanium Dioxide | 0.0  |  | 0.0  |
| 108-88-3   | Toluene          | 40.5   | 0.70   | 28.4   |
| 102-76-1   | Triacetin        | 36.9   | 0.96   | 35.4   |
| 7732-18-5  | Water            | 0.0  |  | 0.0  |
| 1330-20-7  | Xylene           | 40.9   | 0.67 (Note 3)                                      | 27.4   |
| 1314-13-2  | Zinc Oxide       | 0.0  |  | 0.0  |

Note 1. Except as noted, theoretical heat of complete combustion (net) was determined from heat of formation or heat of combustion data assuming all products in the vapor phase per the *CRC Handbook of Chemistry and Physics*, 73th ed., David R. Lide, ed., CRC Press, Boca Raton, Florida, 1992.

Note 2. Except as noted, chemical combustion efficiency was determined by correlations based on chemical structure as given in *Smoke Point Height and Fire Properties of Materials*, Tewarson, A., NTIS P889-141089, May 1988.

Note 3. Chemical combustion efficiency reported in "Generation of Heat and Chemical Compounds in Fires," Tewarson, A, Chapter 1-13 in *SFPE Handbook of Fire Protection Engineering*, P. J. DiNenno, ed., 1st ed., National Fire Protection Association, Quincy, Massachusetts, 1988.

Note 4. Heat of complete combustion (net) as measured by oxygen bomb calorimetry described in *Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter*, ASTM D240-92.

Note 5. Chemical combustion efficiency measured under simulated fire conditions using the method described in "Generation of Heat and Chemical Compounds in Fires," Tewarson, A, Chapter 1-13 in *SFPE Handbook of Fire Protection Engineering*, P. J. DiNenno, ed., 1st ed., National Fire Protection Association, Quincy, Massachusetts, 1988.

## APPENDIX E IN-RACK SPRINKLER LAYOUTS AND FIRE PROTECTION SCHEMES

### E.1 In-Rack Sprinkler Layouts

Figures 5 through 10 show in-rack sprinkler layouts.



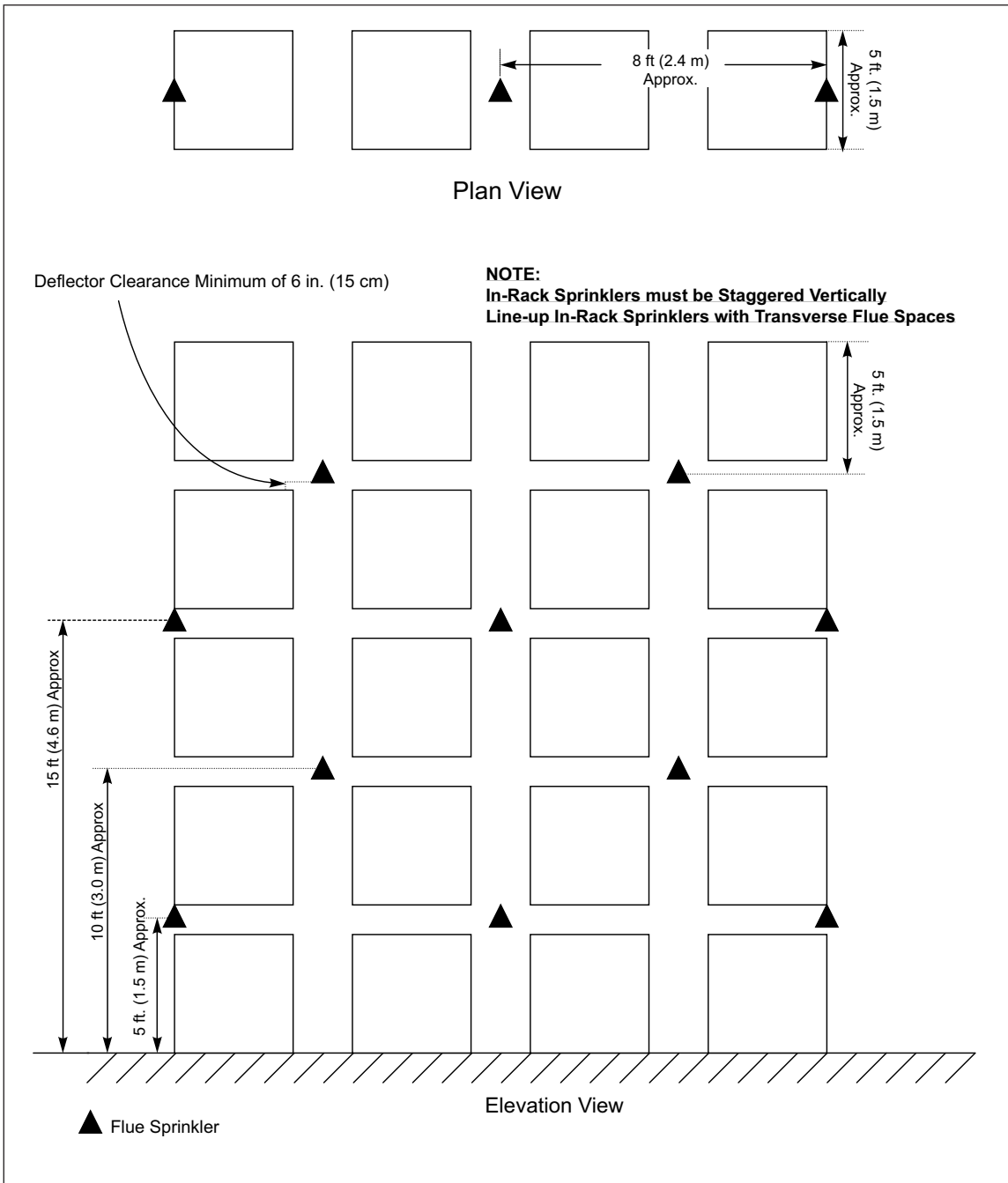


Fig. 5a. Cartoned Level 2 and 3 aerosol products — single row racks

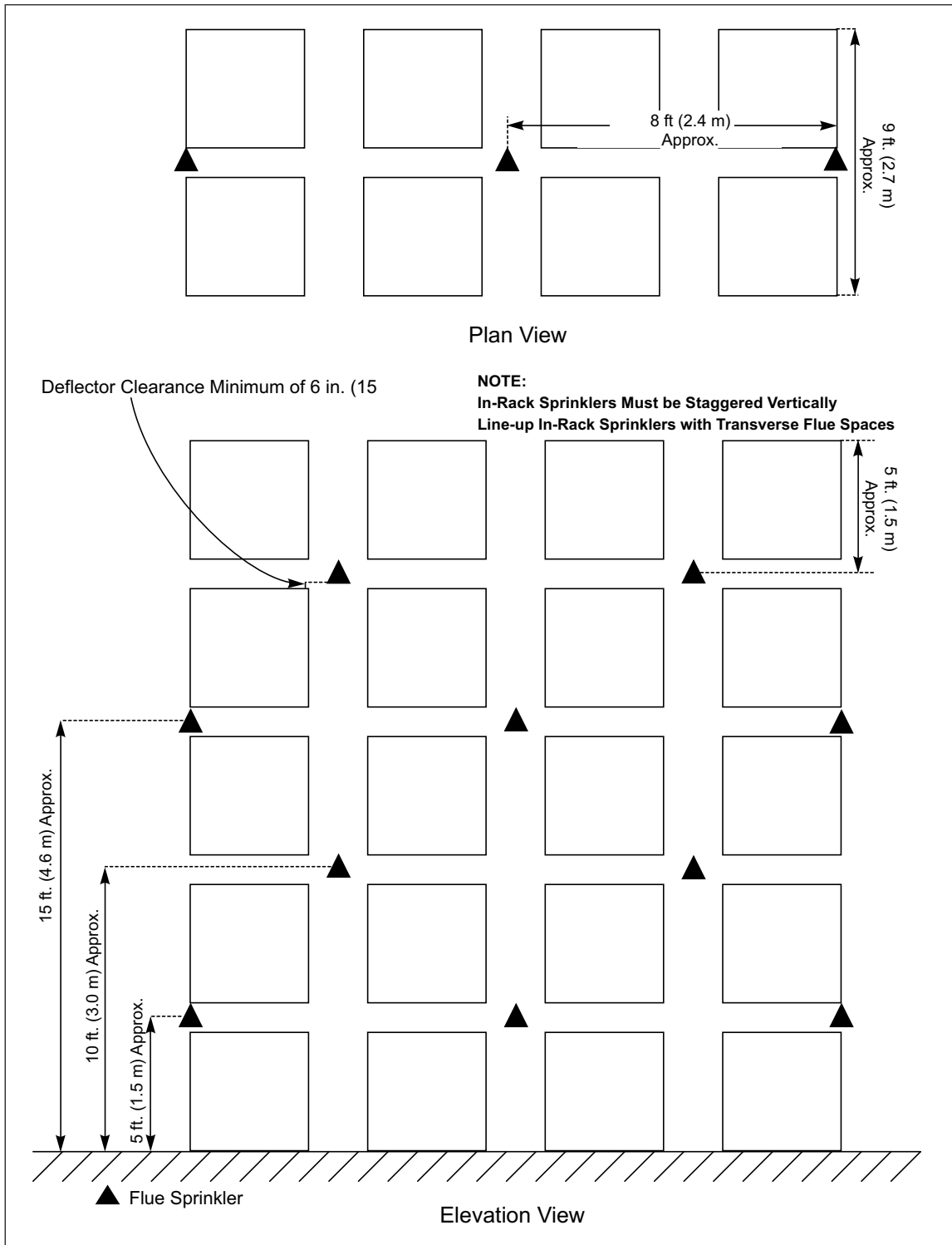


Fig. 5b. Cartoned Level 2 and 3 aerosol products — double row racks

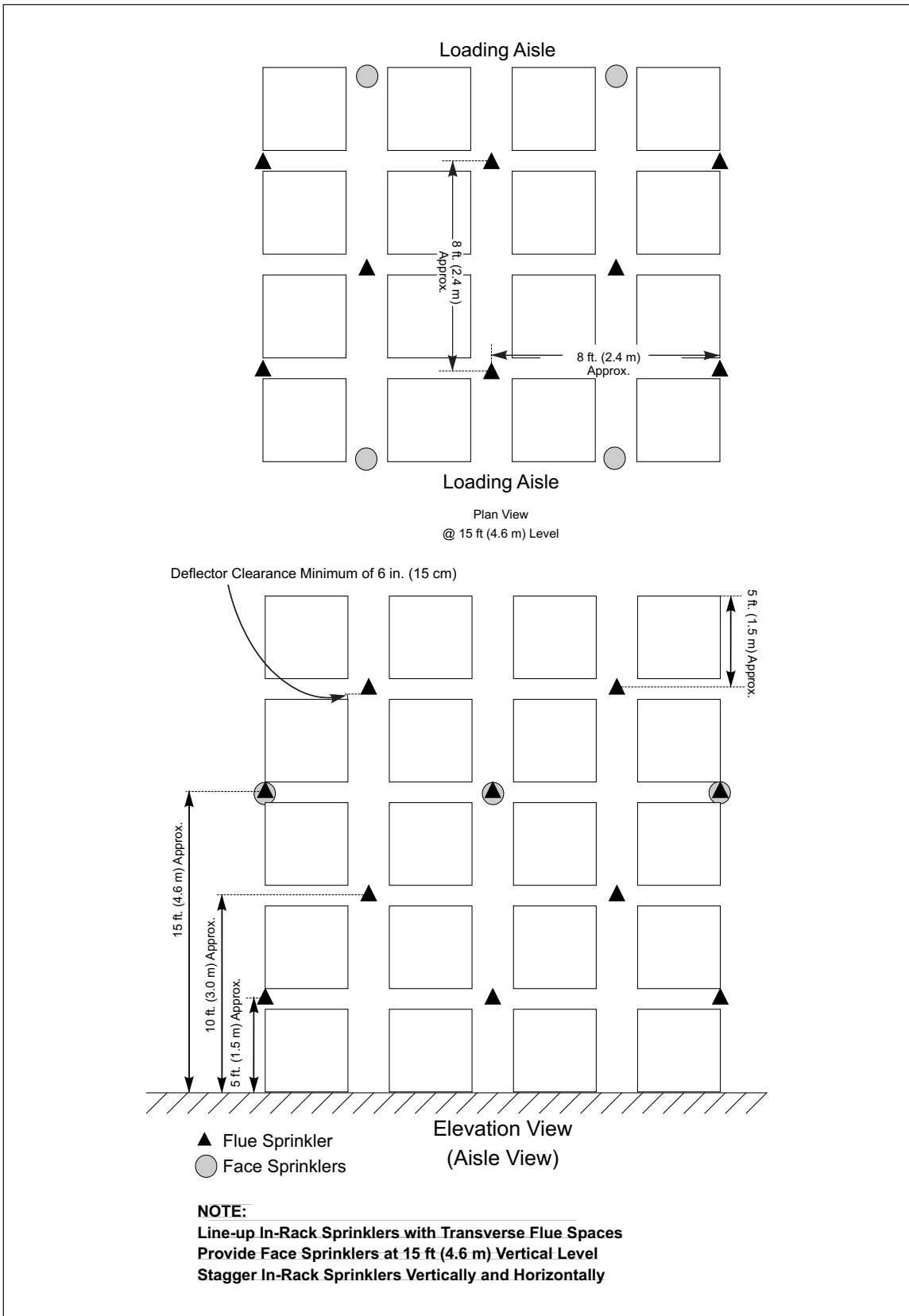


Fig. 5c. Cartoned Level 2 and 3 aerosol products — multiple row racks

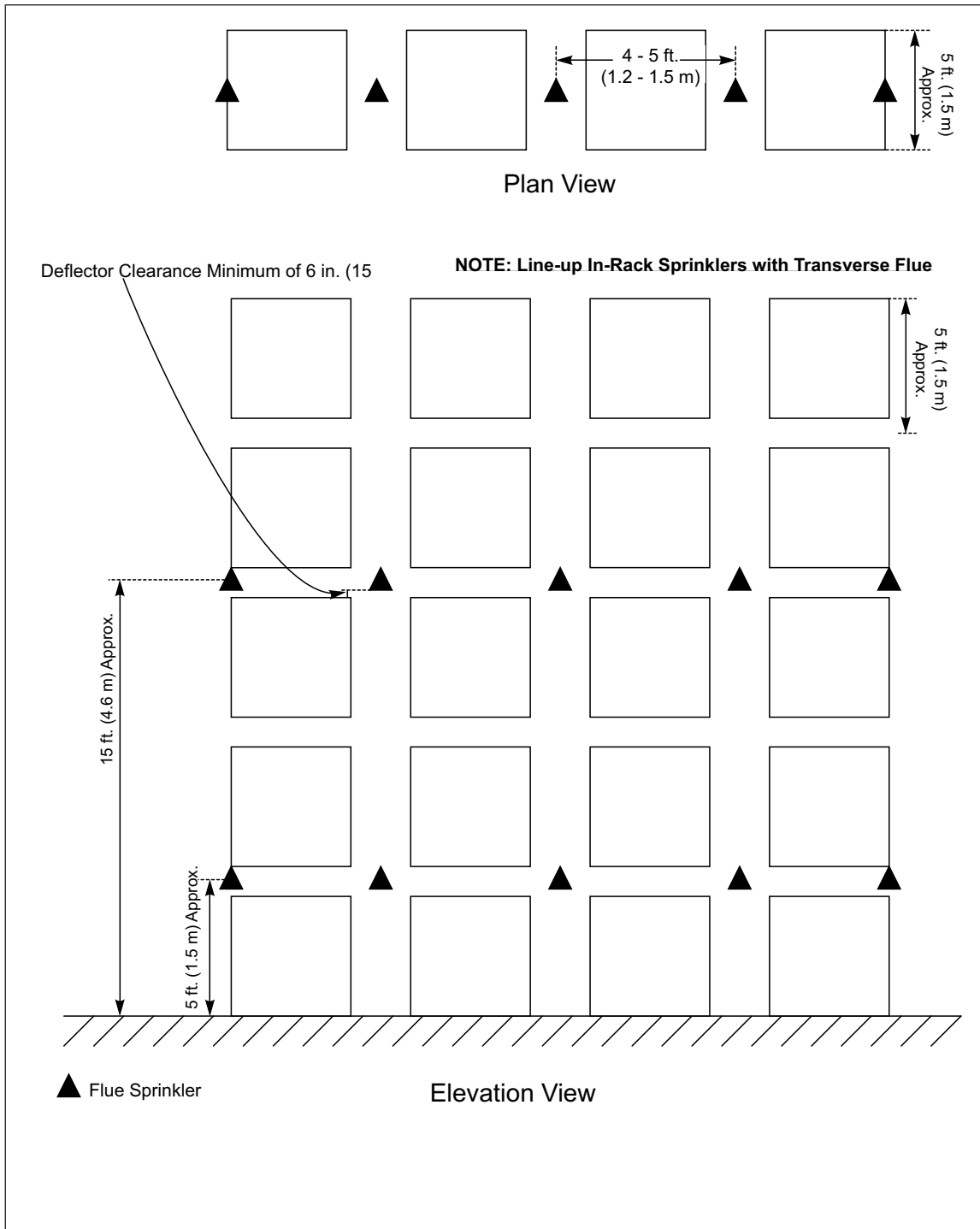


Fig. 6a. Cartoned Level 3 aerosol products — single row racks up to 25 ft (7.6 m) high storage in quick-response sprinkler protected building

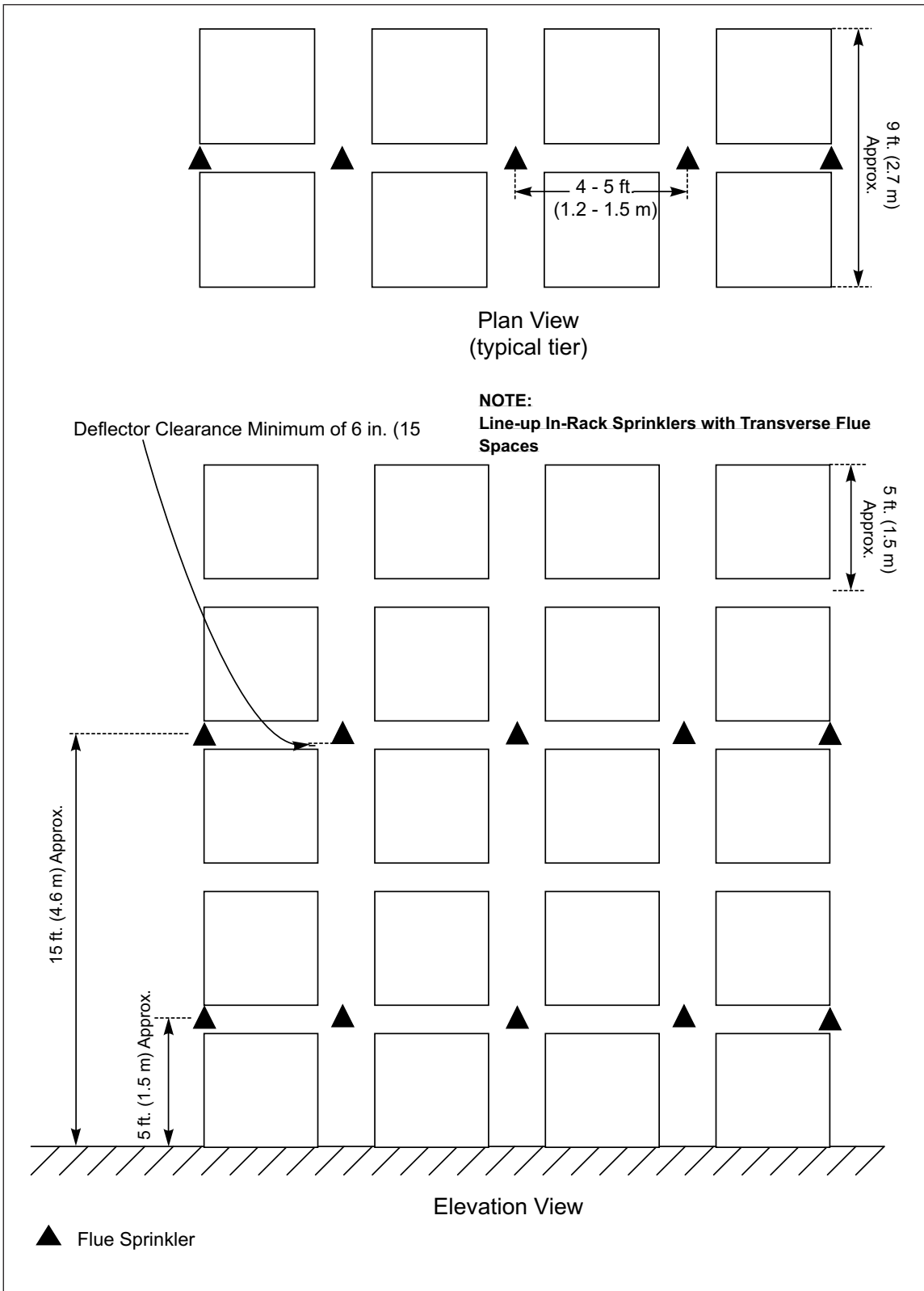


Fig. 6b. Cartoned Level 3 aerosol products — double row racks up to 25 ft (7.6 m) high storage in quick-response sprinkler protected building

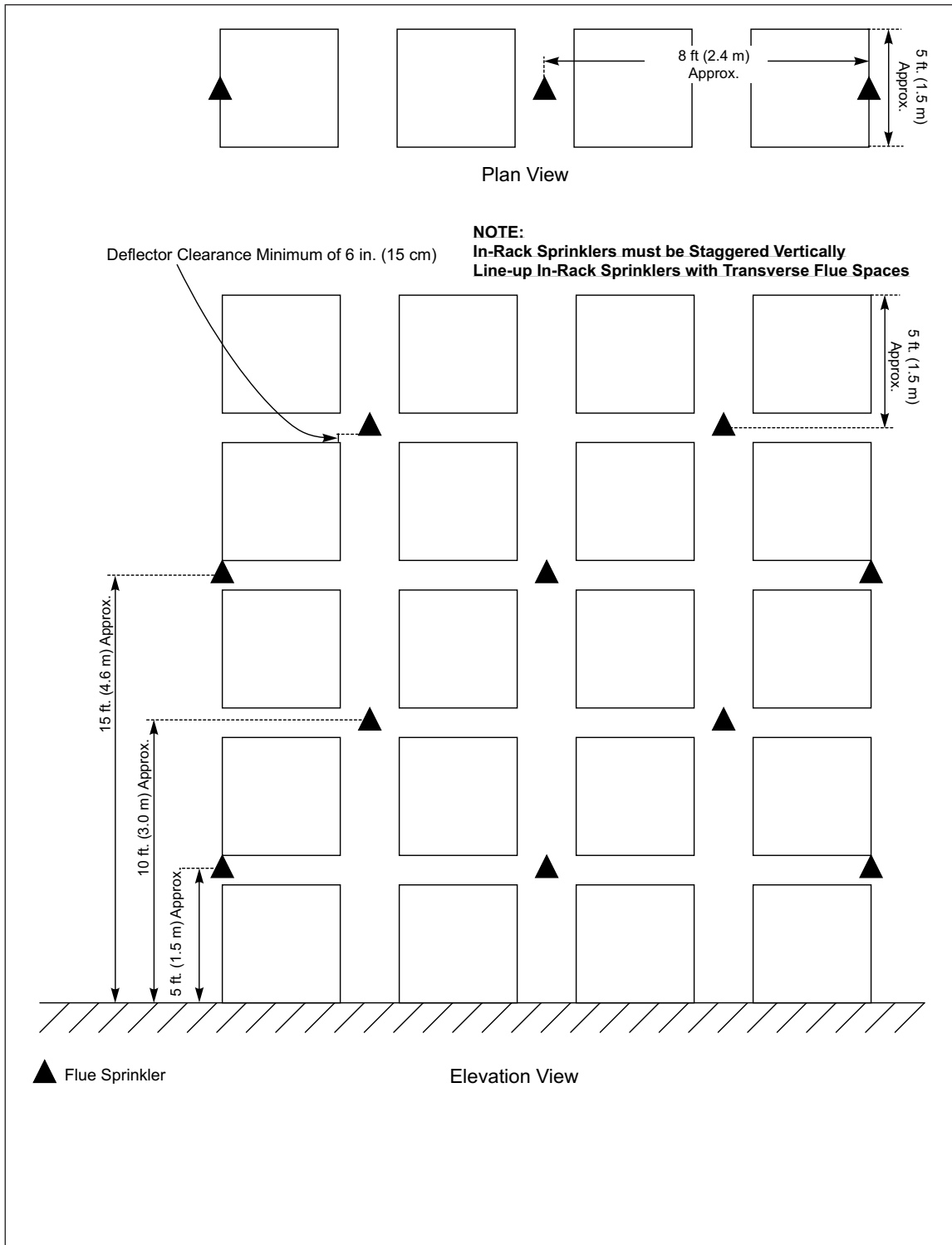


Fig. 7a. Cartoned Level 3 aerosol products — single row racks

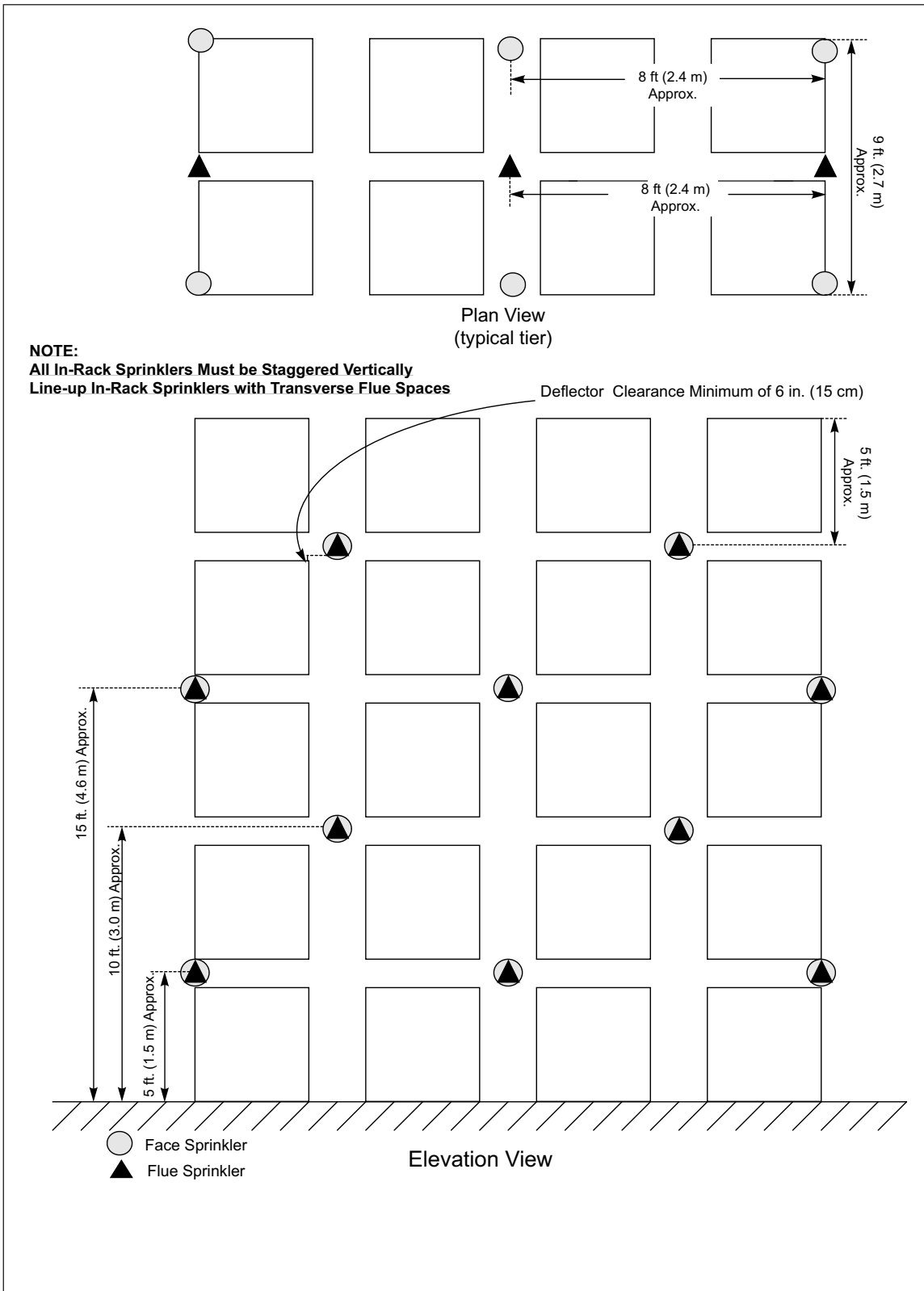


Fig. 7b. Cartoned Level 3 aerosol products — double row racks

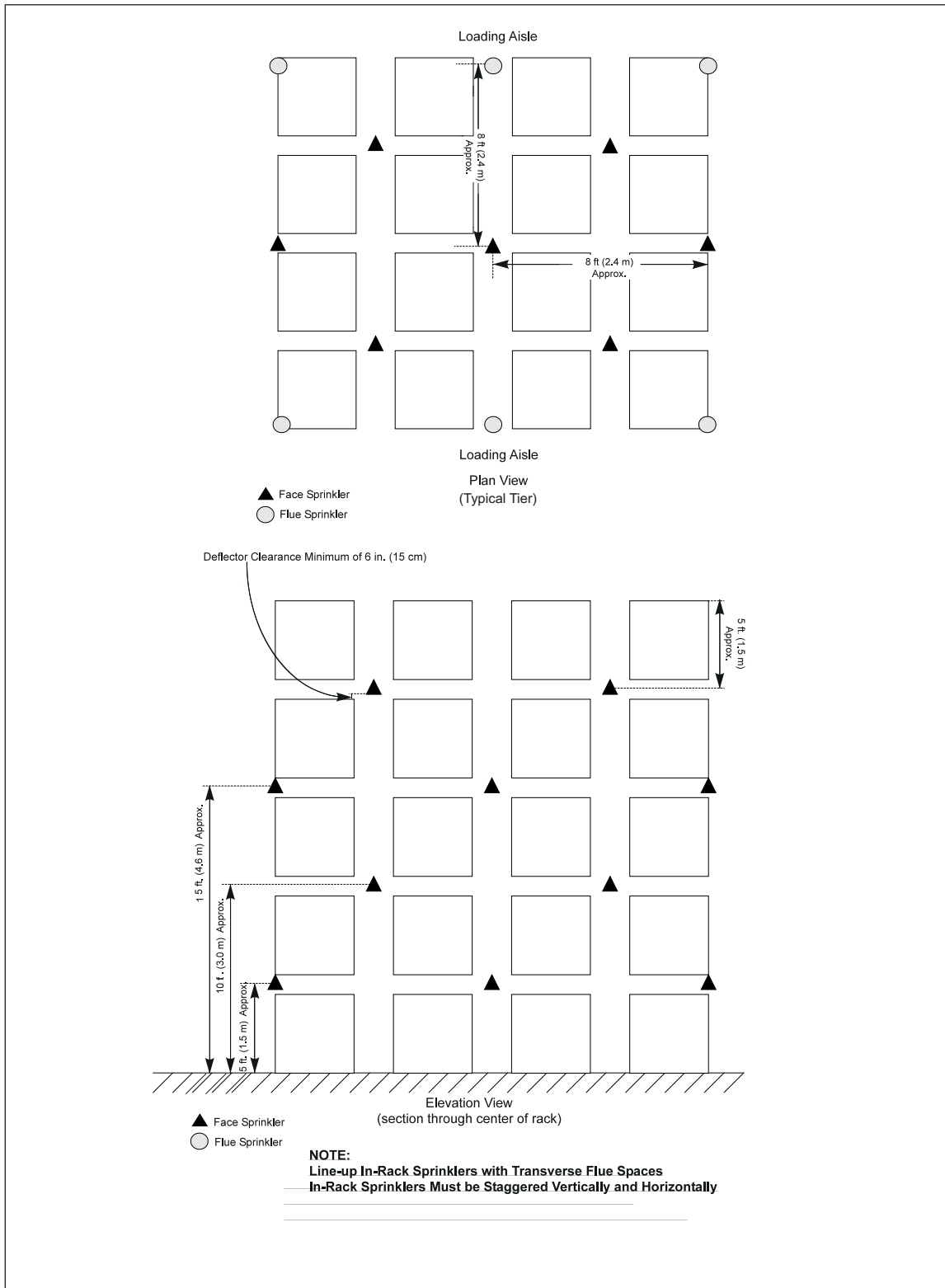


Fig. 7c. Cartoned Level 3 aerosol products — multiple row racks



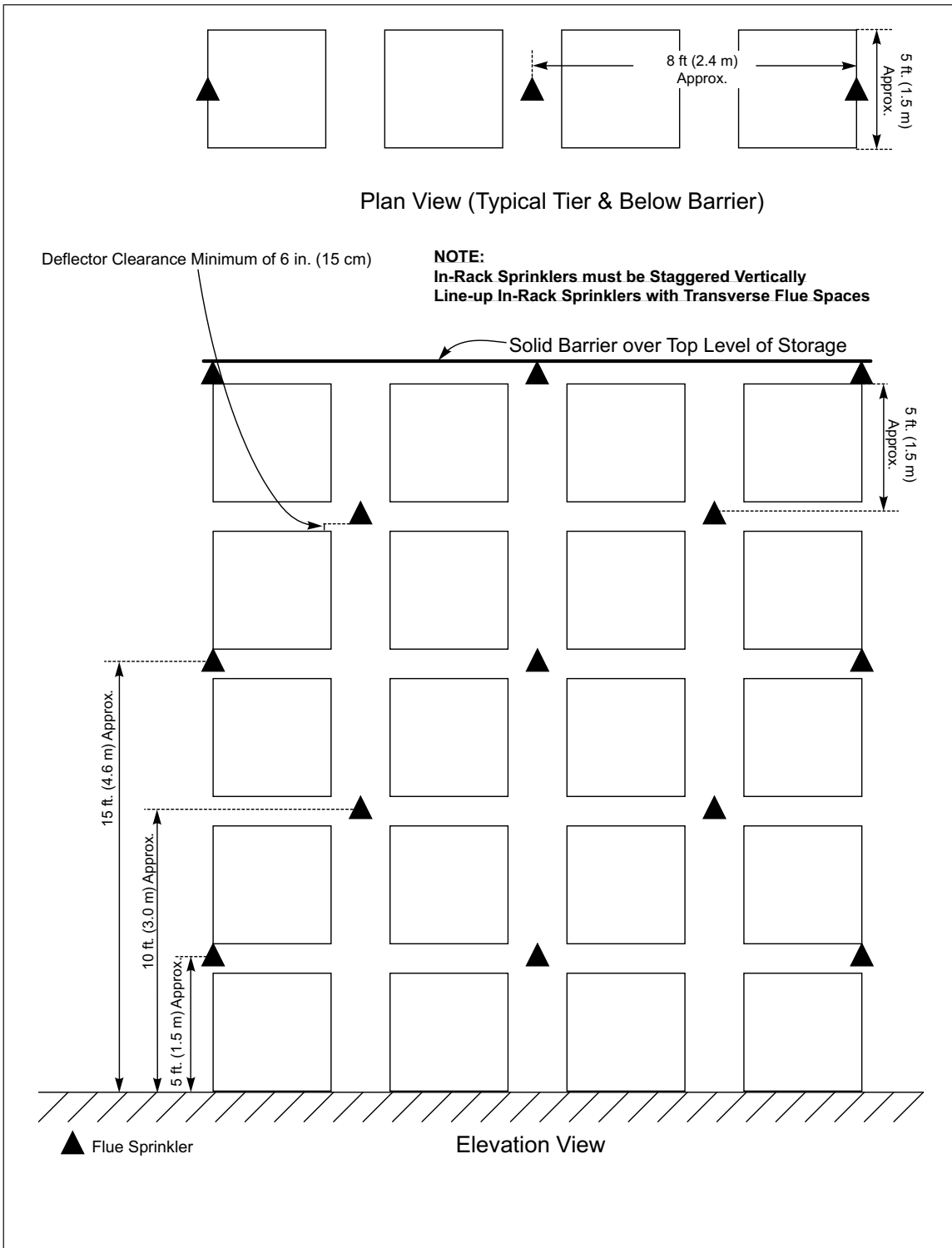


Fig. 8a. Cartoned Level 2 and 3 aerosol products, clearance more than 15 ft (4.6 m) — single row racks

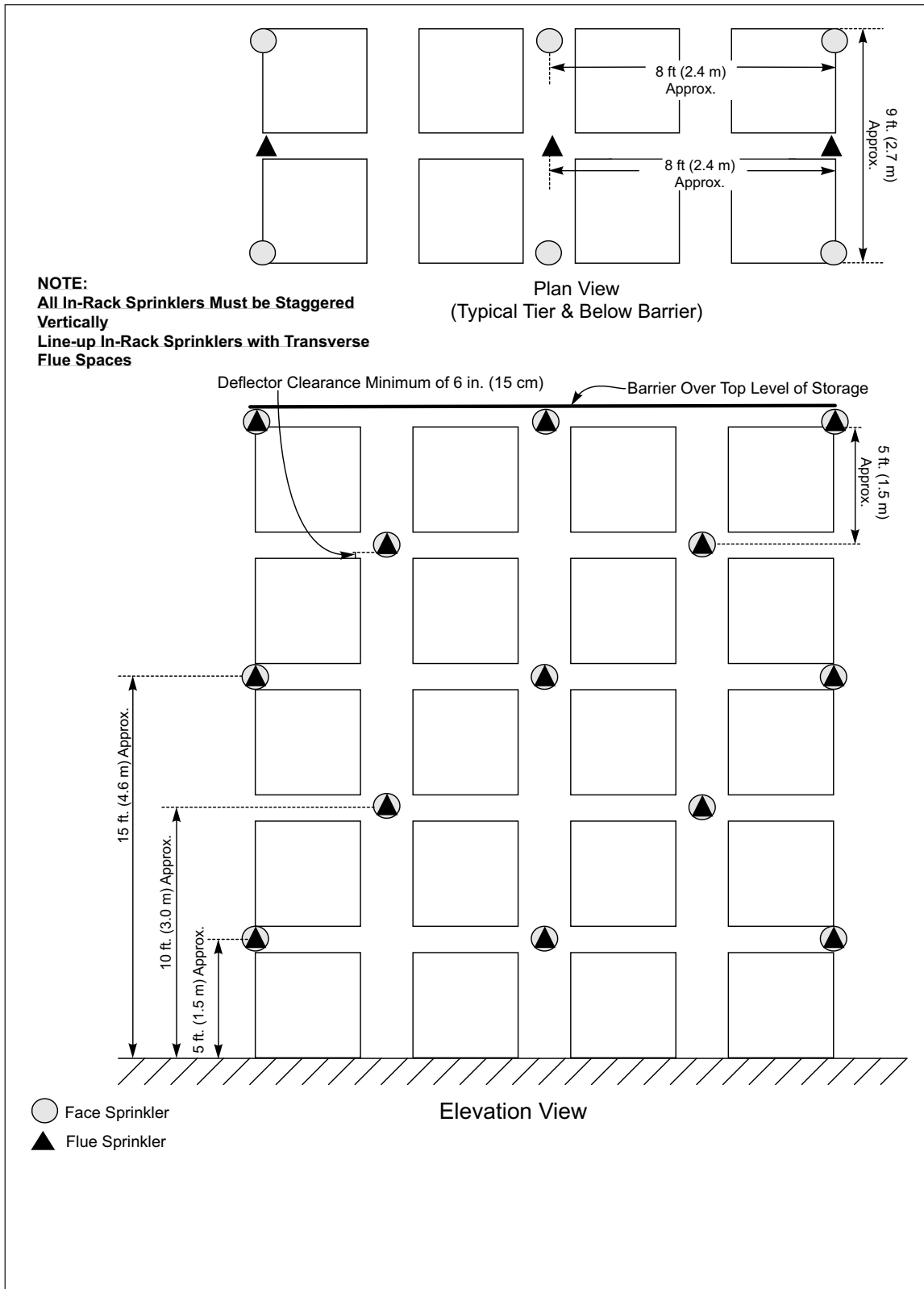


Fig. 8b. Cartoned Level 2 and 3 aerosol products, clearance more than 15 ft (4.6 m) — double row racks

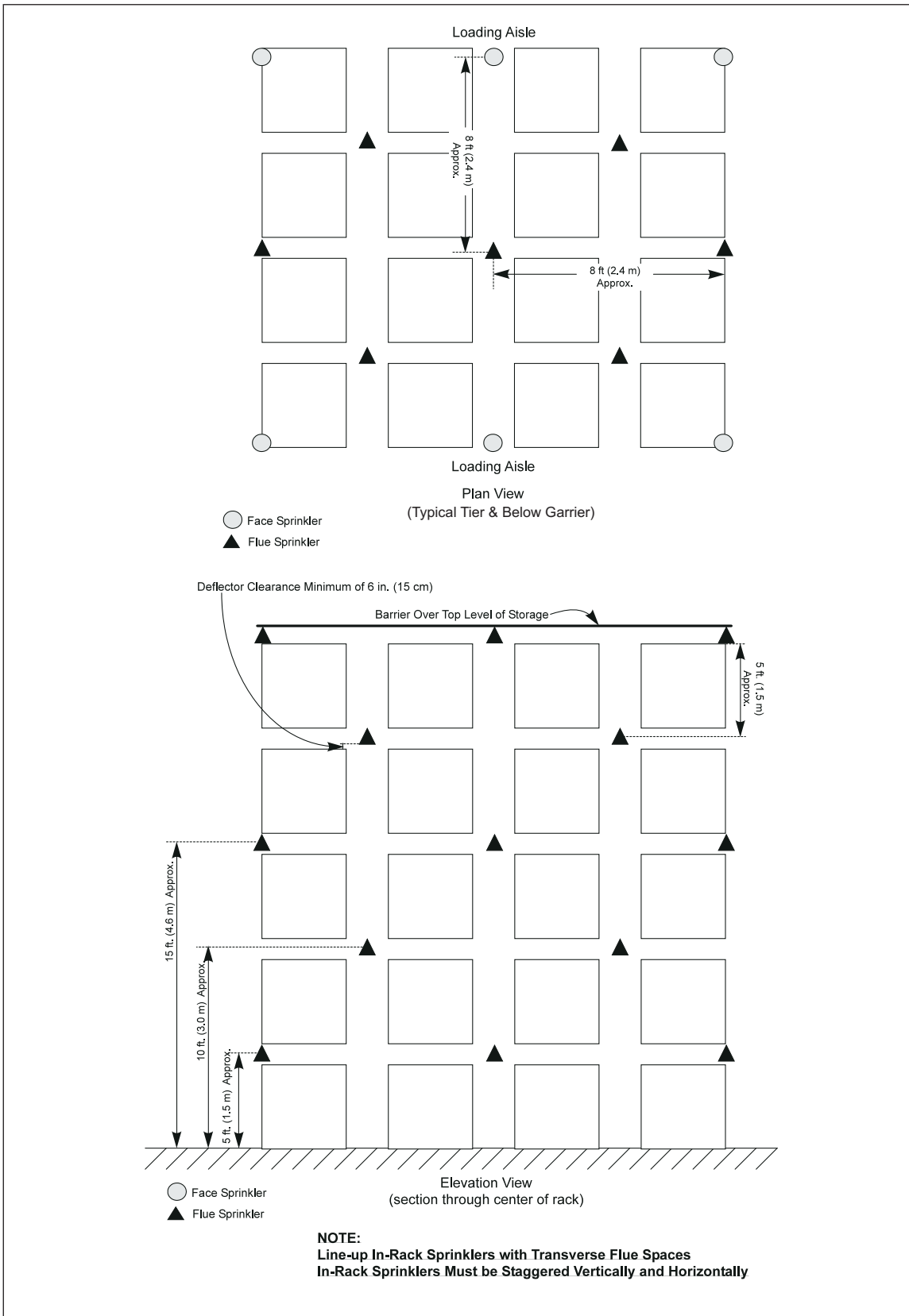


Fig. 8c. Cartoned Level 2 and 3 aerosol products, clearance more than 15 ft (4.6 m) — multiple row racks

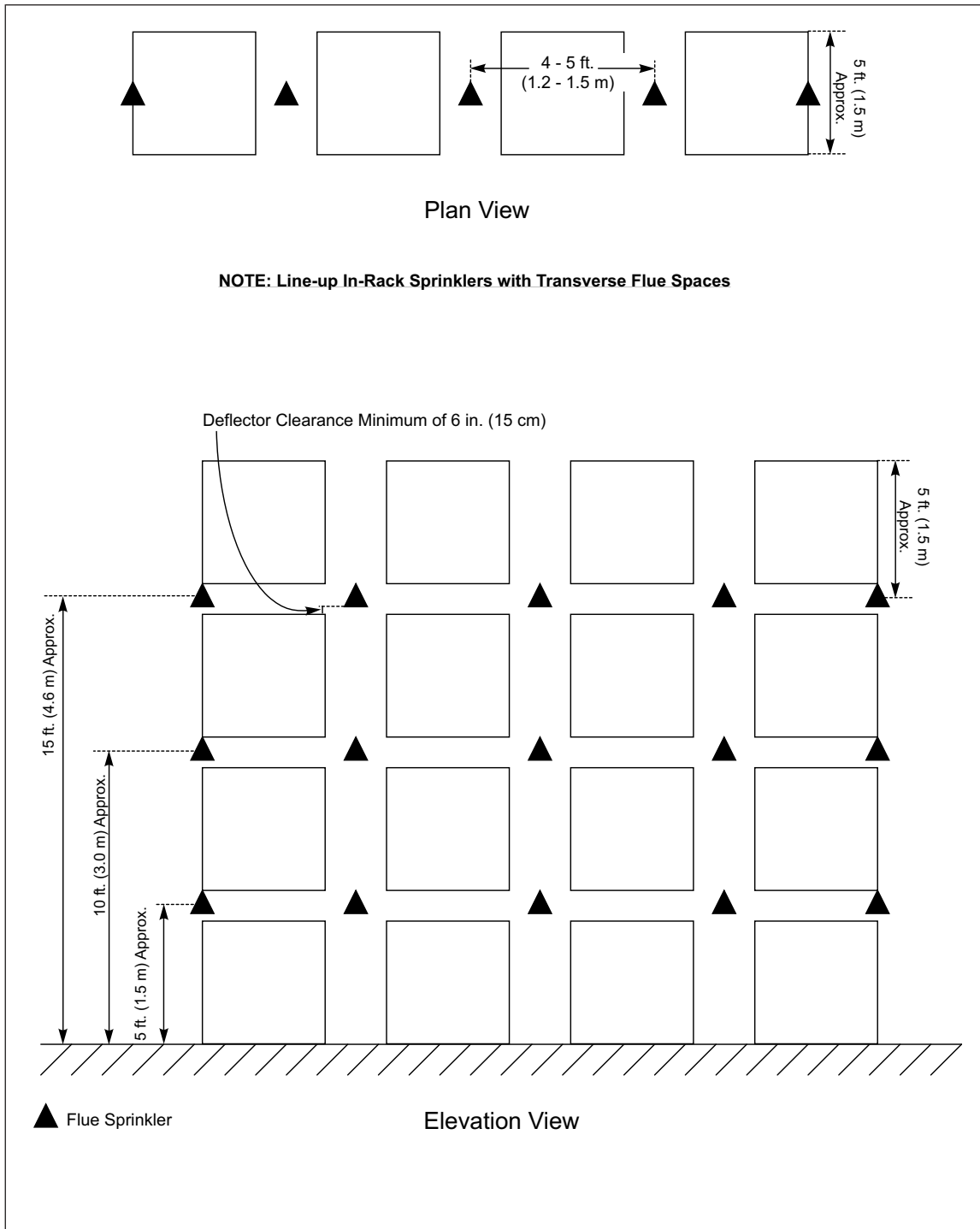


Fig. 9a. Uncartoned Level 2 and 3 aerosol products — single row racks up to 20 ft (6.1 m) high storage

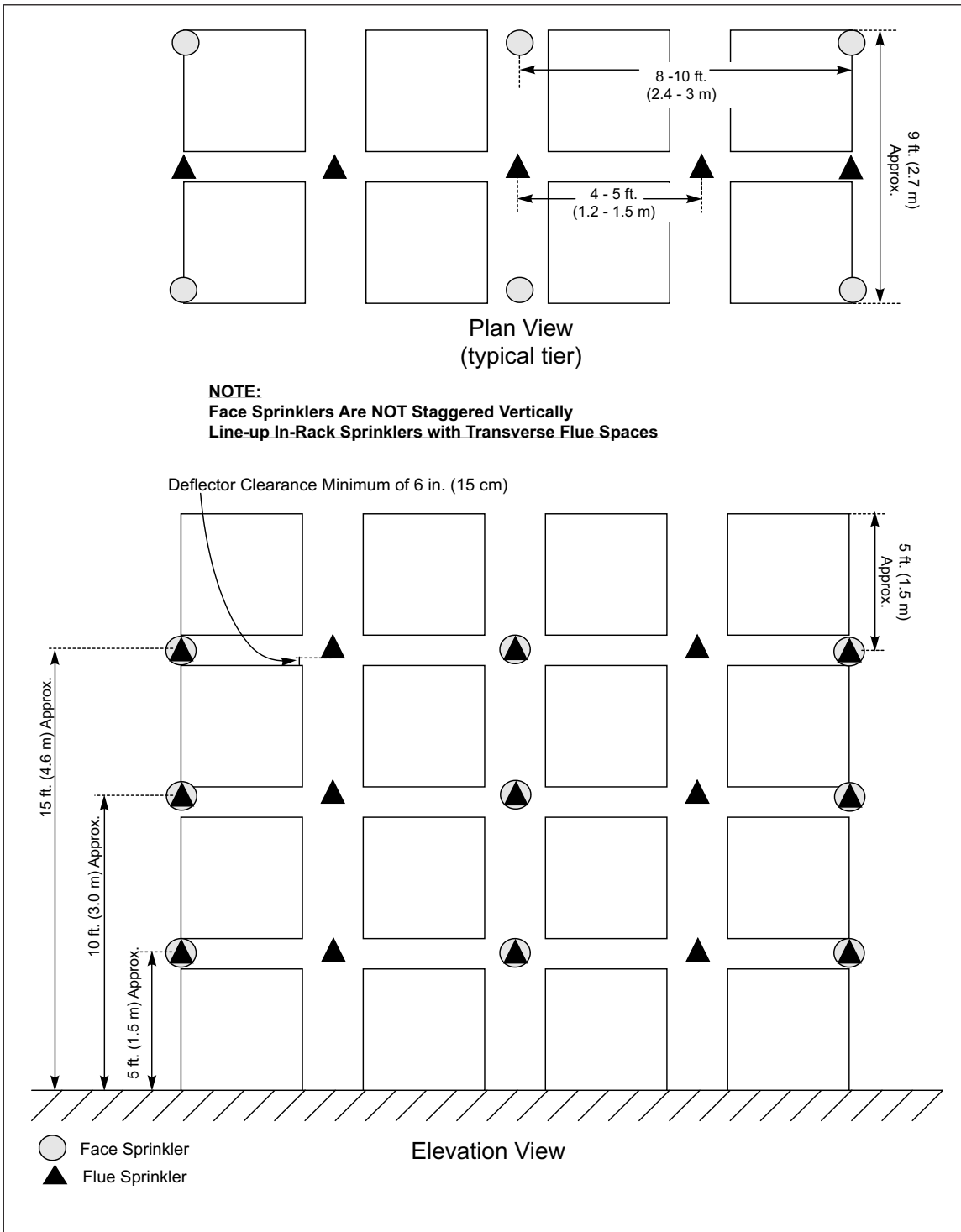


Fig. 9b. Uncartoned Level 2 and 3 aerosol products — double row racks up to 20 ft (6.1 m) high storage

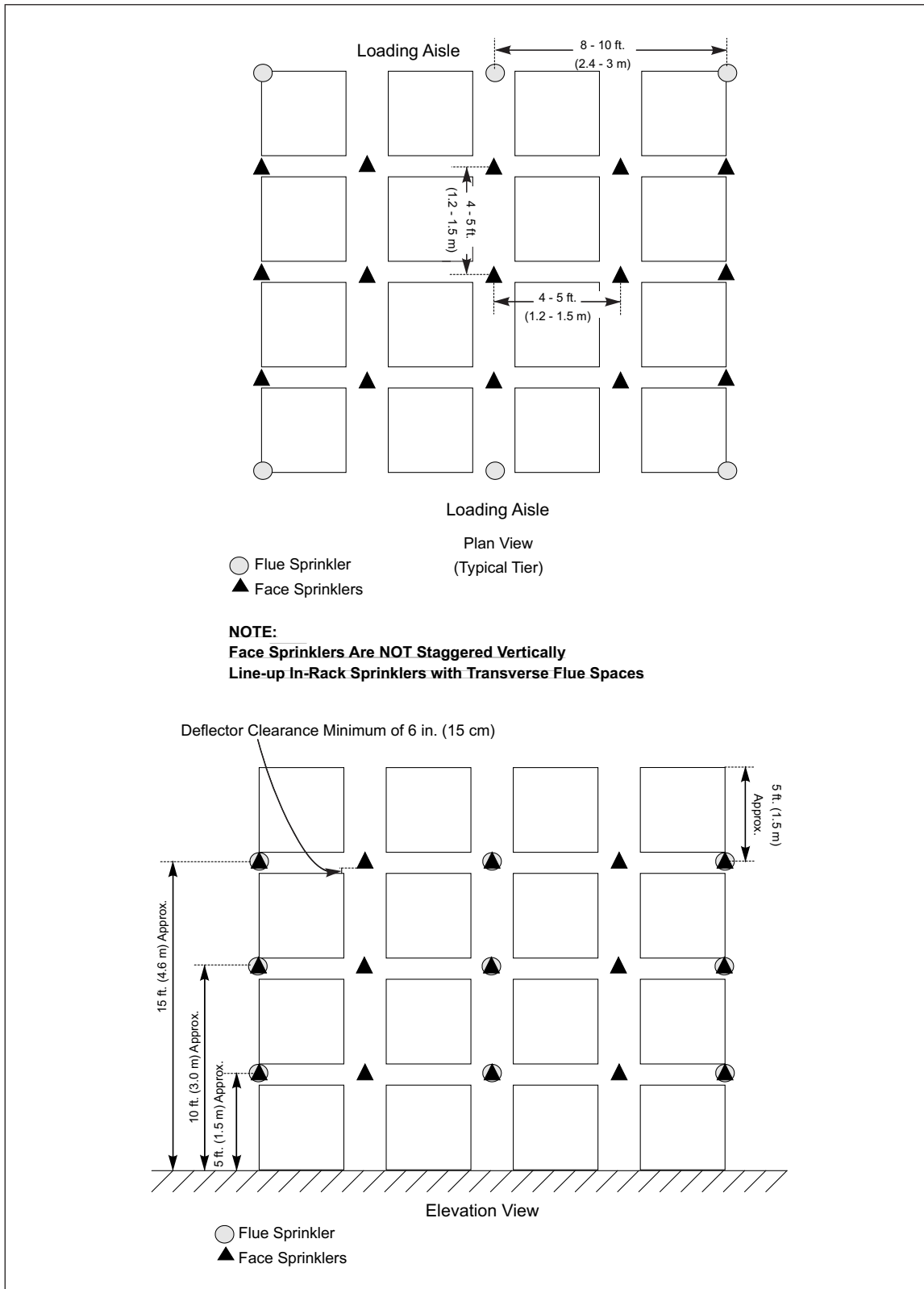


Fig. 9c. Uncartoned Level 2 and 3 aerosol products — multiple row racks up to 20 ft (6.1 m) high storage

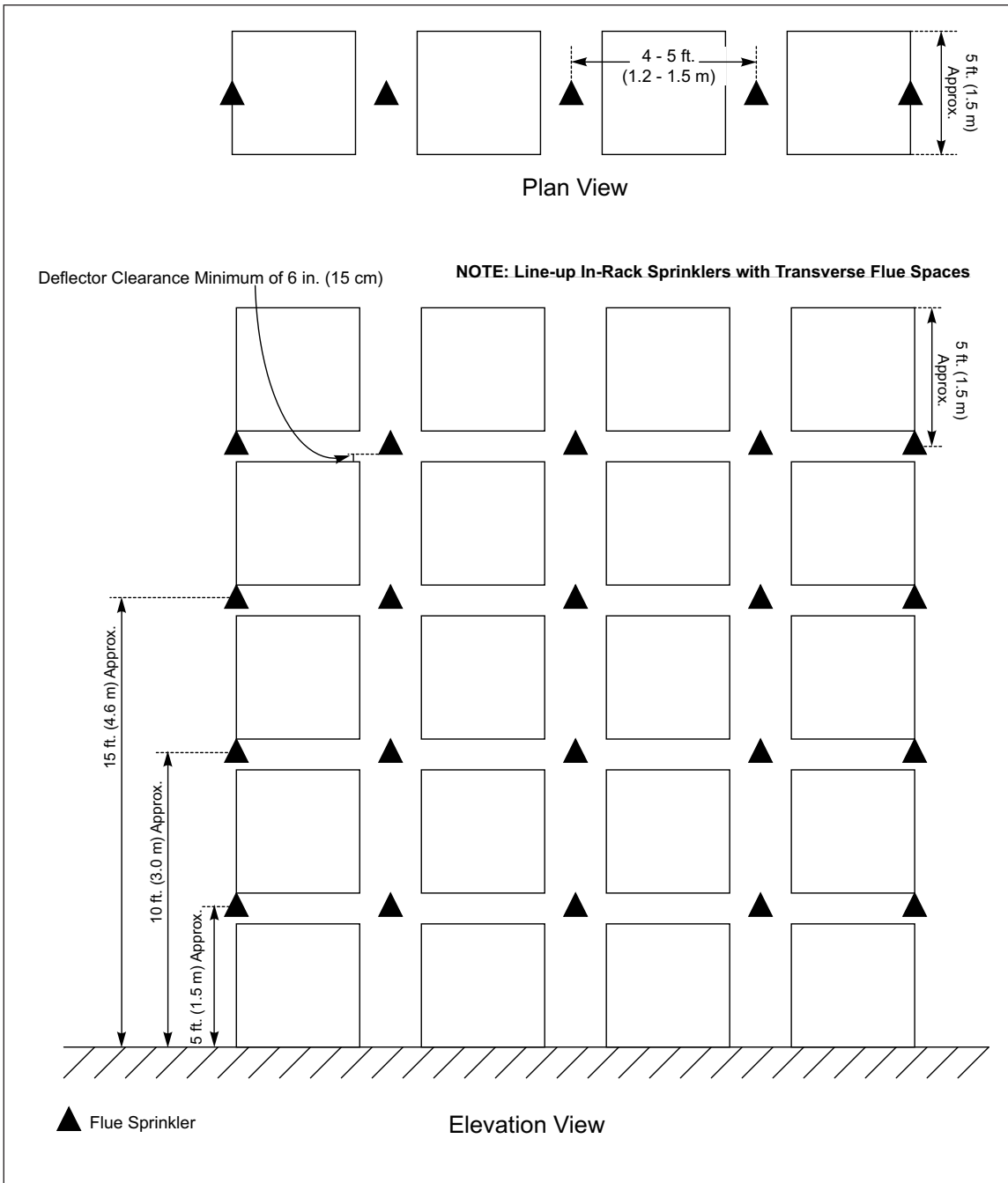


Fig. 10a. Uncartoned Level 2 and 3 aerosol products — single row racks up to 25 ft (7.6 m) high storage

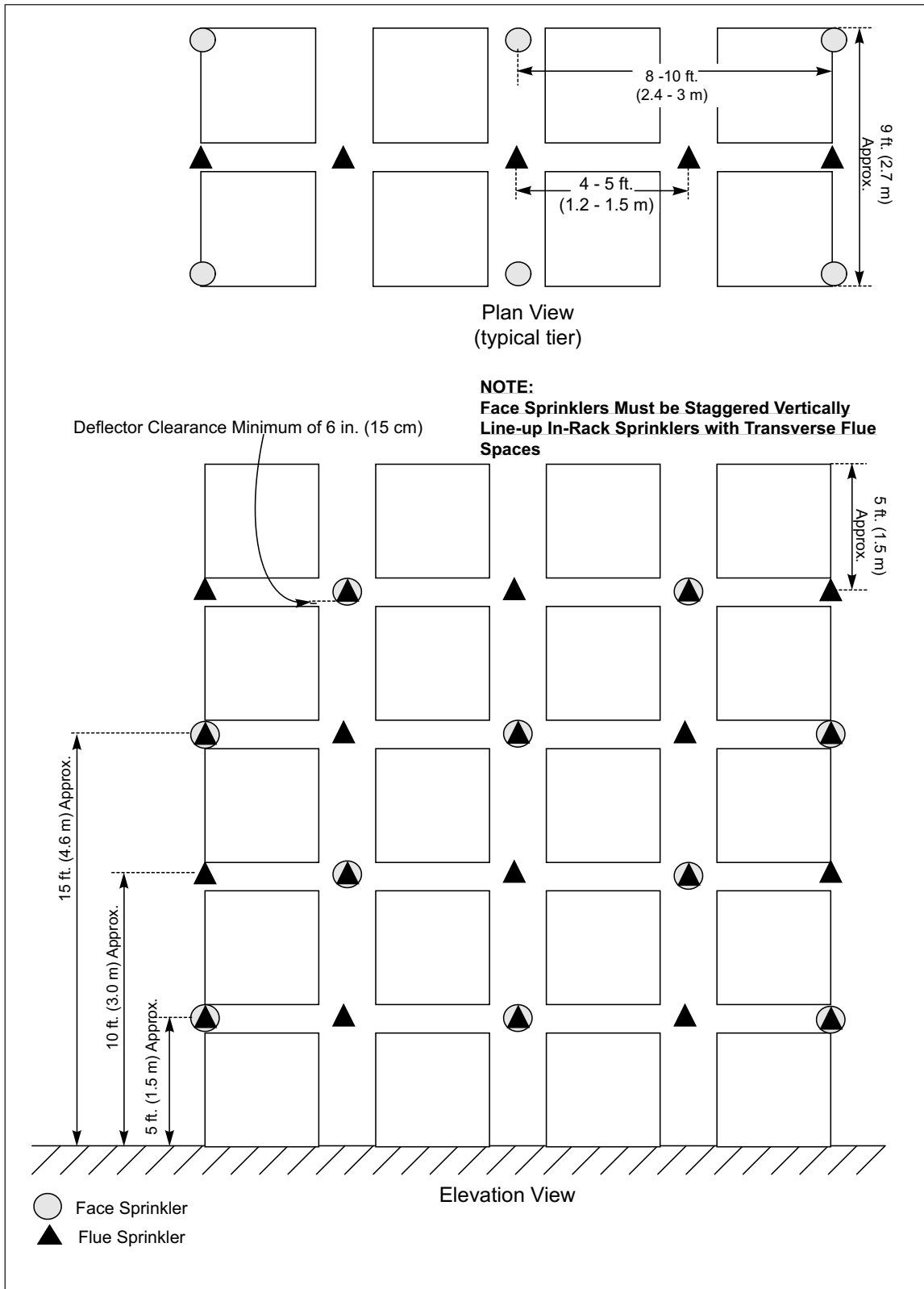


Fig. 10b. Uncartoned Level 2 and 3 aerosol products — double row racks up to 25 ft (7.6 m) high storage



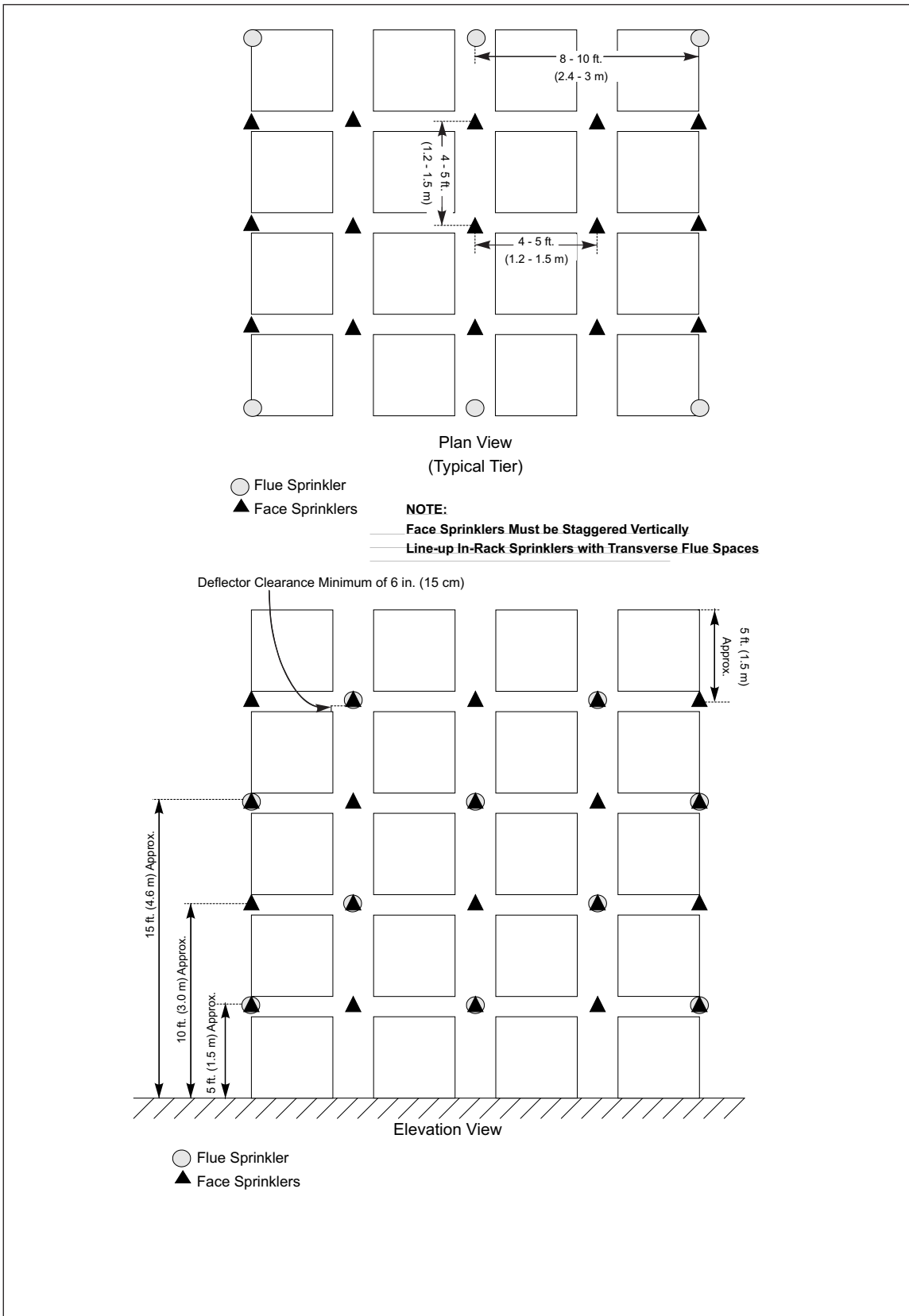


Fig. 10c. Uncartoned Level 2 and 3 aerosol product — multiple row racks up to 25 ft (7.6 m) high storage

## E.2 Fire Protection Scheme A

E.2.1 Provide plywood (minimum 3/8 in. [1 cm]) or sheet metal (minimum 22 gauge [0.7 mm]) barriers and in-rack sprinklers installed in accordance with Figures 11a, 11b, 11c, and 11d. Use a maximum vertical spacing of 12 ft (3.7 m) between barriers.

E.2.2 Do not store aerosol products above the top barrier level.

E.2.3 Install FM Approved K8.0 (K115) or K11.2 (K161), 165°F (74°C) rated, quick-response in-rack sprinklers below each barrier level.

E.2.4 Provide in-rack sprinklers with a design flow of 57 gpm (220 L/min), with a minimum operating pressure of not less than 10 psi (0.69 Bar).

E.2.5 Provide an in-rack sprinkler demand based on the aerosol container material of construction, as follows:

A. For aerosol products in metal containers, base the hydraulic demand on the hydraulically most remote six (6) sprinklers (three on two lines) if one barrier level, or the most remote eight (8) sprinklers (four on two lines) if two or more barrier levels are provided.

B. For plastic Aerosol 3 products, base the hydraulic demand on the hydraulically most remote seven (7) sprinklers on one rack and the hydraulically most remote seven (7) sprinklers on the adjacent rack (14 total in-rack sprinklers). Position face sprinklers no more than 6 in. (150 mm) in from the face of the rack.

E.2.6 If there are adjacent bays of rack arrays not dedicated to aerosol product storage, provide one of the following:

A. Provide a noncombustible, solid vertical barrier (e.g., 22 gauge [0.7 mm] sheet metal) in each longitudinal and transverse flue space to separate the aerosol product storage from adjacent bays (see Figure 4b).

1. For double-row racks with aerosol product storage on only one side of the rack, treat the side devoted to the storage of aerosol products as a single-row rack, with fire protection provided in accordance with Figure 11a. Protect the adjacent side based on the commodity stored in that area.

B. Extend Scheme A protection at least 8 ft (2.4 m) beyond the aerosol storage.

C. A vertical chain link fence may be used in lieu of a solid vertical barrier if the entire rack is protected with Scheme A (see Figure 4a).

E.2.7 For aerosol products in metal containers, provide Scheme A protection for any adjacent rack separated by an aisle of 8 ft (2.4 m) or less.

E.2.7.1 For Plastic Aerosol 3 products, provide Scheme A protection for any adjacent rack separated by an aisle of 10 ft (3 m) or less.

E.2.8 Ceiling sprinkler demand does not need to be included in the hydraulic calculations for in-rack sprinklers. Calculate the water demand at the point of supply separately for in-rack and ceiling sprinklers. Provide a 500 gpm (1900 L/min) hose stream allowance in the hydraulic calculations for the in-rack sprinkler protection. Provide the combined fire protection water demand for a 1-hour duration.

E.2.9 Design ceiling sprinklers to protect the surrounding occupancy, but not less than 7 psi (0.5 bar) using K8.0 (K115) sprinklers. If the aerosol product storage does not extend to the full height of the rack, protect the other commodities stored above the barrier (in accordance with the relevant data sheets) as if the entire rack height was filled with that commodity. If in-rack sprinklers are required for the other commodities, each level of barrier and in-rack sprinklers can be given credit as a level of in-rack sprinklers.

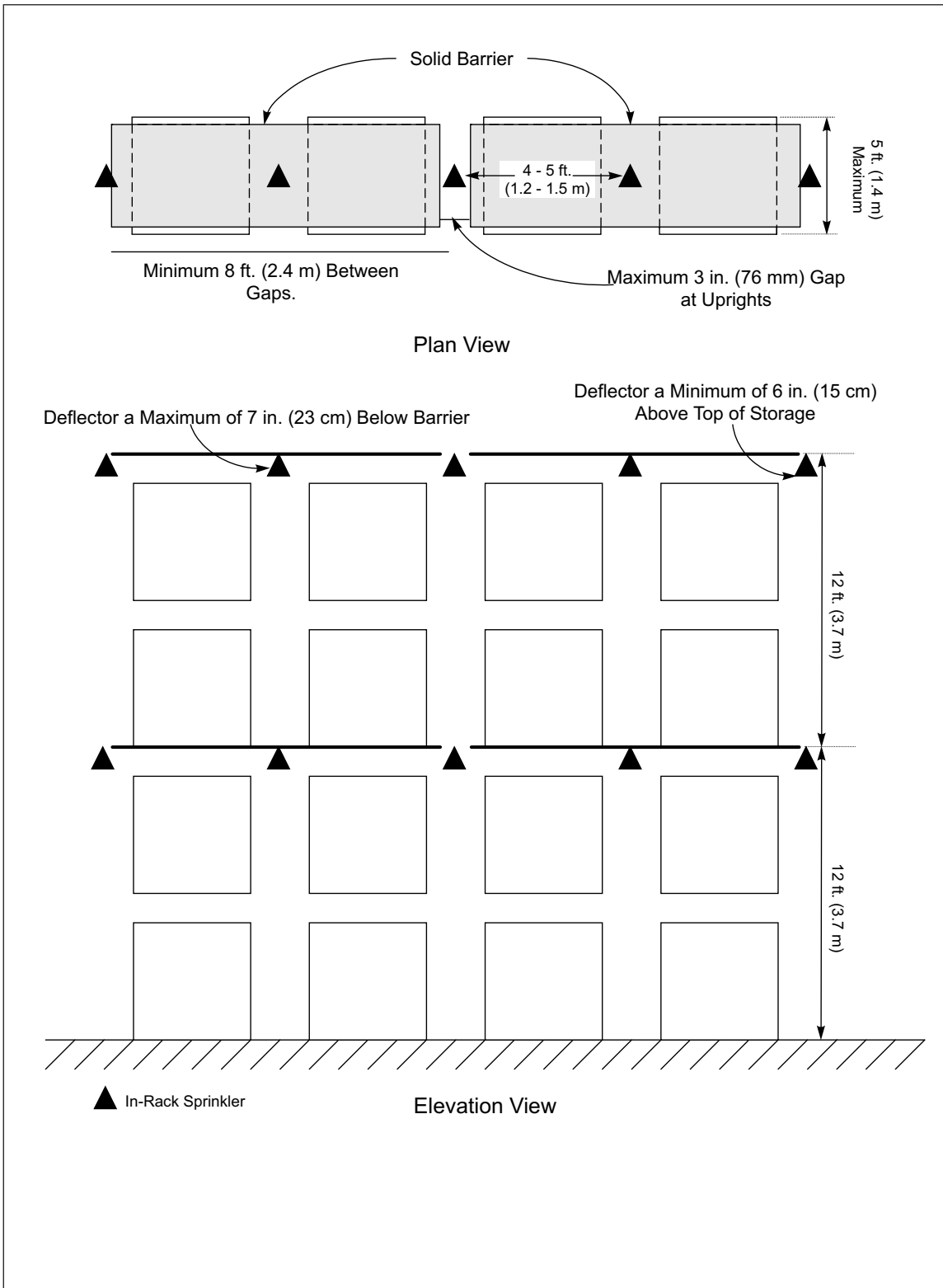


Fig. 11a. Single row rack in-rack sprinkler layout — Fire Protection Scheme A

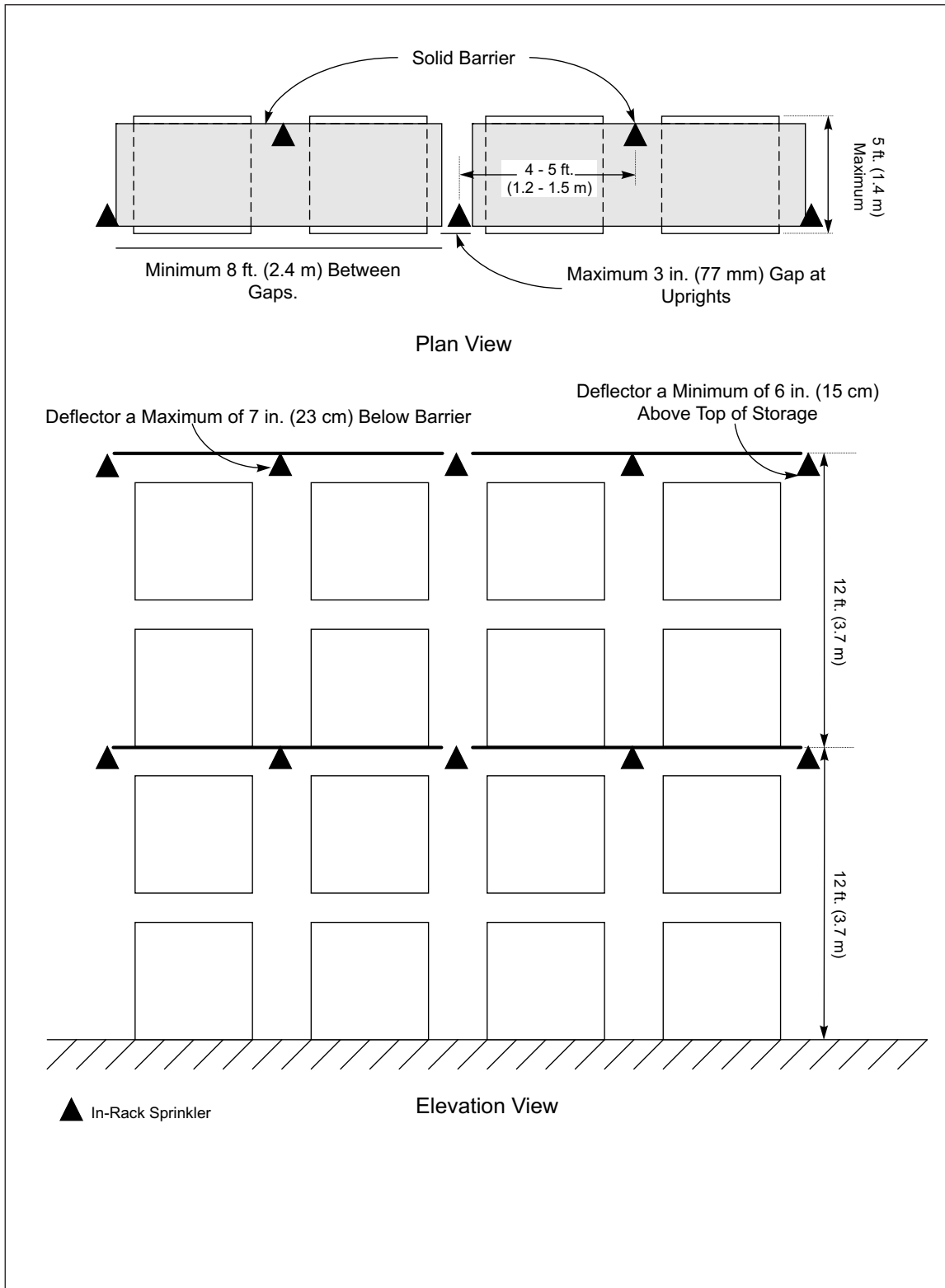


Fig. 11b. Single row rack in-rack sprinkler layout — Fire Protection Scheme A

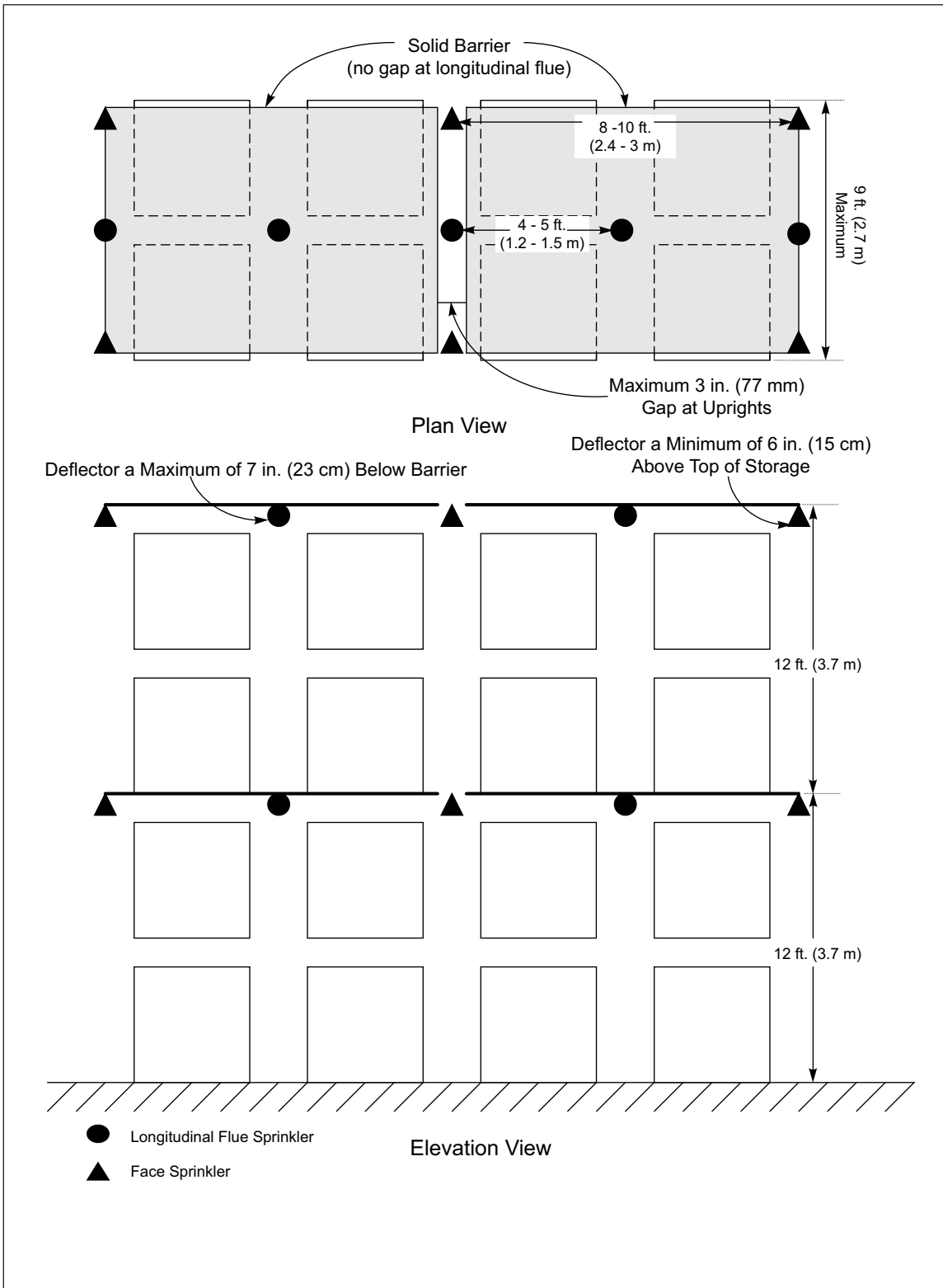


Fig. 11c. Double row rack in-rack sprinkler layout — Fire Protection Scheme A

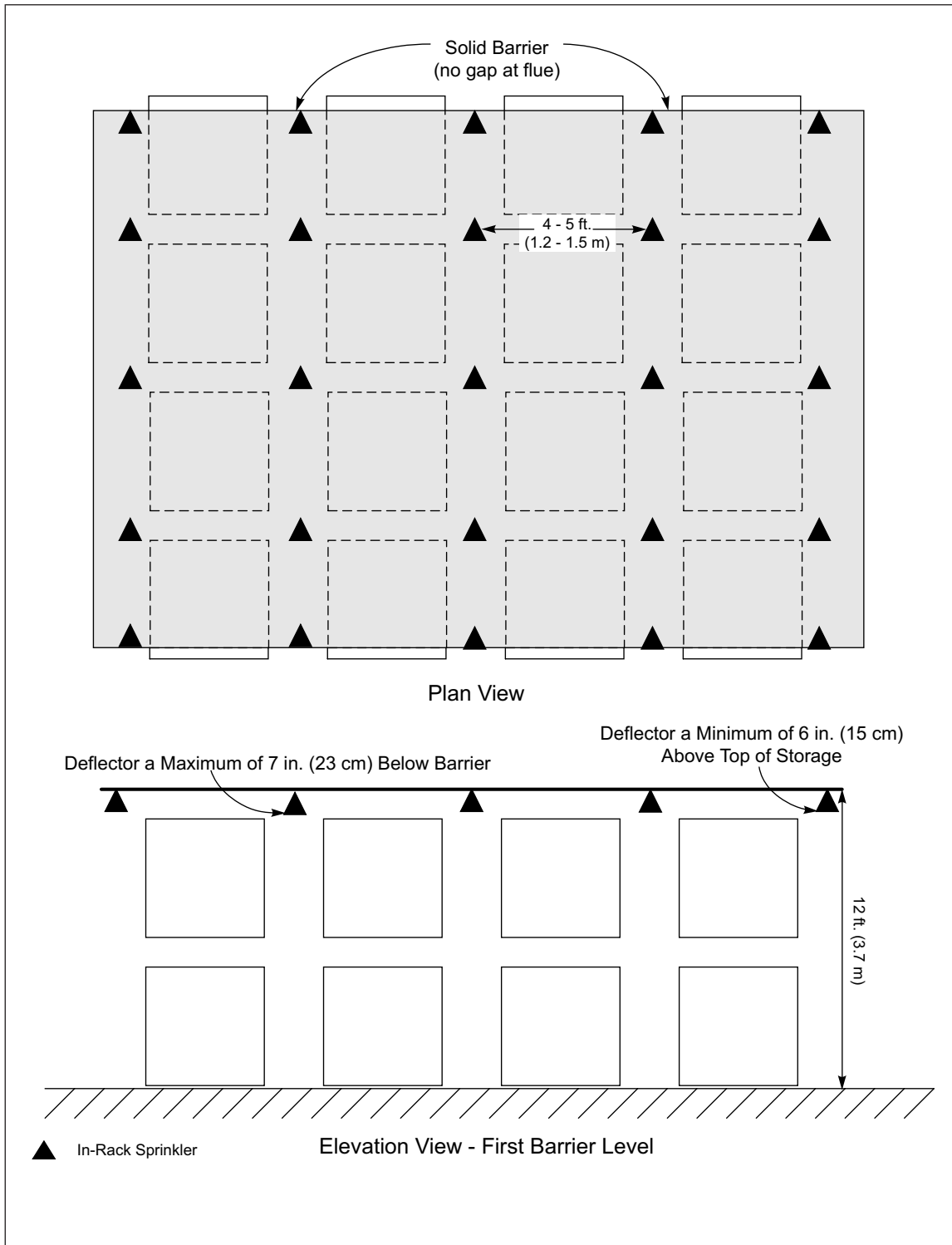


Fig. 11d. Multiple row rack in-rack sprinkler layout — Fire Protection Scheme A

**E.3 Aerosol Product Flow-Through Rack Protection Scheme**

A. Install solid 3/8 in. (10 cm) plywood or 22 gauge (0.7 mm) sheet metal barrier at the 12 ft (3.7 m) level. The barrier must completely cover the longitudinal flue space. A 3 in. (76 mm) gap is permitted over the transverse flue spaces at the rack uprights. (See Figures 12a and 12b.)

B. To prevent potential horizontal fire spread within the roller racks, provide one the following:

1. Maintain a nominal 3 in. (76 mm) gap between rows of cartons. This would create at least 2 in. (51 mm) of free space between cartons (i.e., 3 in. [76 mm] space between cartons - 1 in. [25 mm] carton guide angle = 2 in. [51 mm] open space). It is recognized that the gaps between cartons will be inconsistent and not vertically aligned. However, limiting the number of carton spaces between rack uprights creating the potential for a nominal 3 in. (76 mm) gap will ensure adequate openings for in-rack sprinkler discharge to penetrate through the roller racks and prevent excessive horizontal spread of fire within the picking racks.

2. If the 3 in. (76 mm) gap between rows of cartons cannot be provided, install vertical barriers every 24 ft (7.3 m) horizontally. Ensure the barrier spans from the floor to the bottom of the horizontal barrier. The barrier may be constructed of either 3/8 in. (1 cm) plywood or 22 gauge (0.7 mm) sheet metal. Since the barrier will be located next to in-rack sprinklers, install additional in-rack sprinklers on both sides of the barrier.

C. Install in-rack sprinklers in accordance with Figures 12a and 12b. Use FM Approved,  $K \geq 8.0$  (115), 165°F (74°C) rated, quick-response in-rack sprinklers. The number of lines of in-rack sprinklers is dependent on the rack width.

D. Locate face sprinklers a maximum of 6 in. (15 cm) from the rack face.

E. Design the in-rack sprinklers to provide a minimum discharge pressure of 50 psi (3.5 bar) out of the hydraulically most remote of the following:

1. Twelve (12) sprinklers (i.e., four (4) sprinklers operating on each of three (3) lines) for three or more lines of in-racks, or
2. Eight (8) sprinklers if only two lines of in-racks are provided (i.e., four (4) sprinklers operating on two (2) lines), or
3. Six (6) sprinklers if only one line of in-rack sprinklers is provided

F. Ceiling sprinkler demand does not need to be included in the hydraulic calculations for in-rack sprinklers. Calculate the water demand at the point of supply separately for in-rack and ceiling sprinklers. Provide a 500 gpm (1900 L/min) hose stream allowance in the hydraulic calculations for the in-rack sprinkler protection. Provide the combined fire protection water demand for a 2-hour duration.

G. Design ceiling sprinklers to protect the surrounding occupancy, but not less than 7 psi (0.5 bar) using twenty (20) K8.0 (K115) sprinklers.

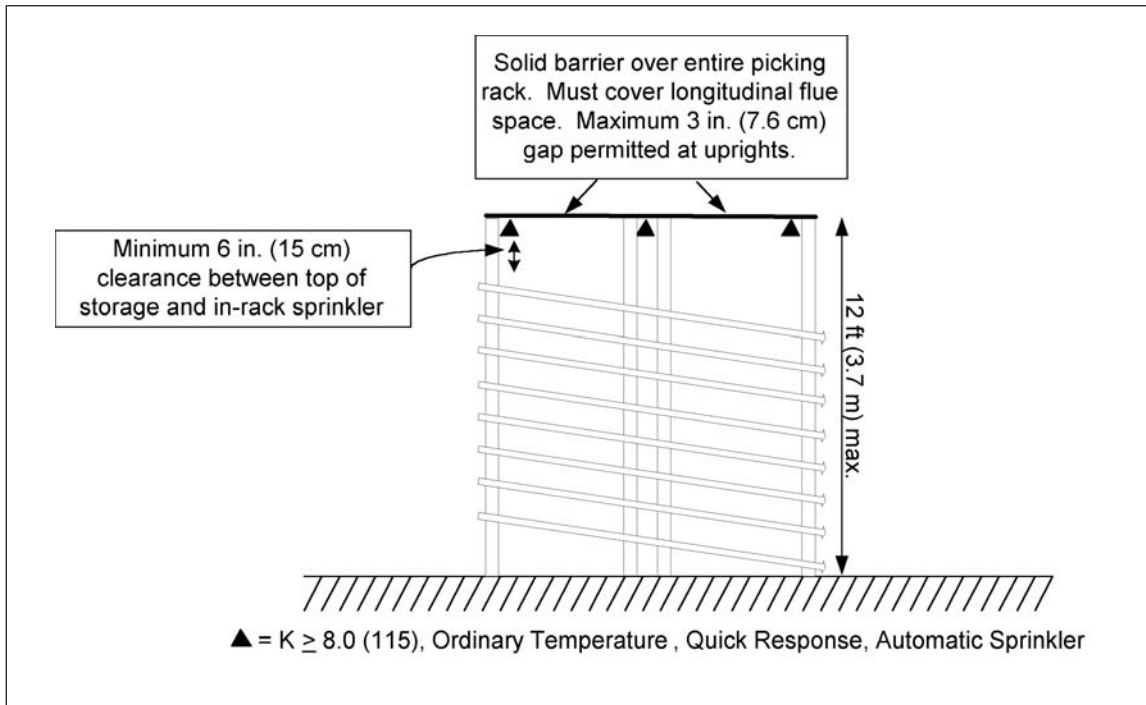


Fig. 12a. Aerosol product picking area elevation view

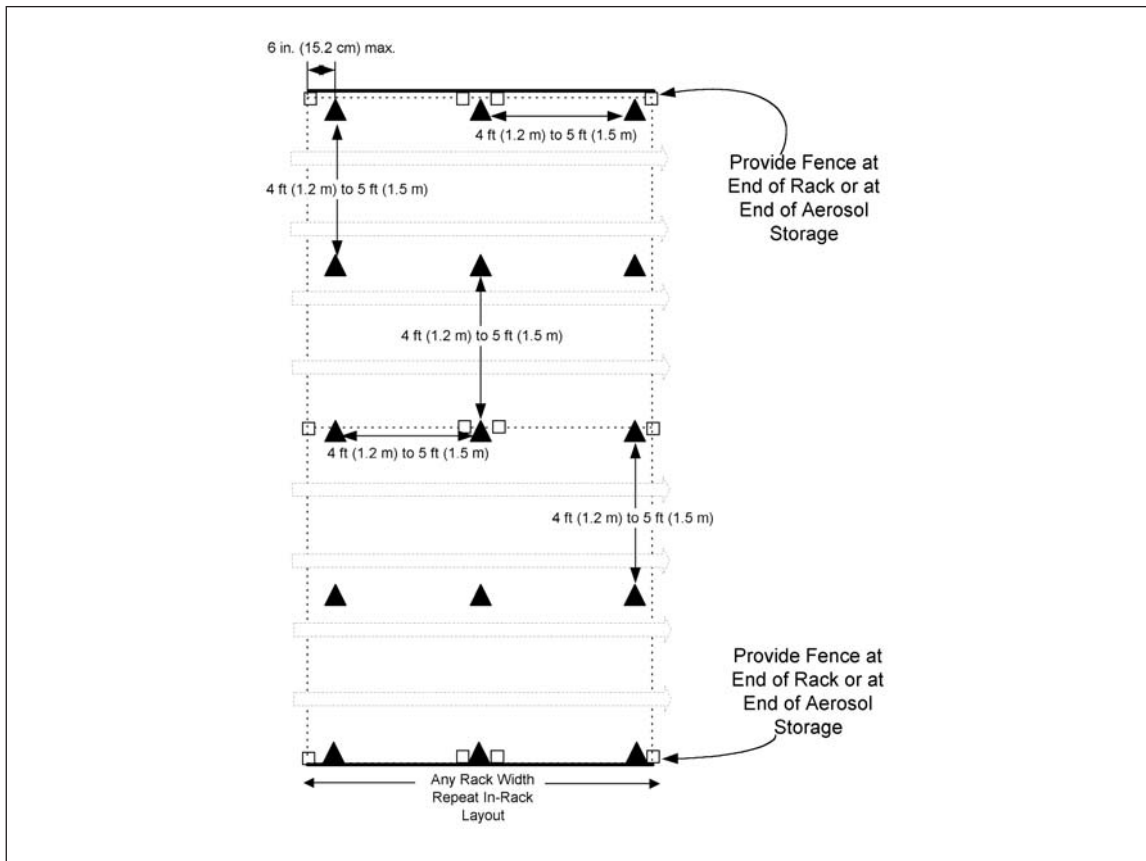


Fig. 12b. Aerosol product picking area plan view



## E.4 Mercantile Fire Protection Schemes

- A. Provide a plywood (minimum 3/8 in. [1 cm]) or sheet metal (minimum 22 gauge [0.7 mm]) barrier at the top of the picking area, at a maximum height of 8 ft (2.4 m).
- B. Install in-rack sprinklers in accordance with Figures 13a, 13b, or 13c. Use FM Approved K8.0 (K115) or K11.2 (K161), 165°F (74°C) rated, quick-response in-rack sprinklers below the barrier level. Design the in-rack sprinklers to provide a minimum flow of 57 gpm (216 L/min) out of the hydraulically most remote six (6) sprinklers (three on two lines) if one barrier level, or the most remote eight (8) sprinklers (four on two lines) if two or more barrier levels are provided.
- C. Where indicated (Figure 13c), provide a noncombustible, solid vertical barrier (e.g., 22 gauge (0.7 mm) sheet metal) in the longitudinal and transverse flue spaces to separate the aerosol product storage from adjacent areas.
- D. Where aerosol products are stored above the display area, maintain storage in upper tiers within cartons and limit the total storage height to a maximum of 18 ft (5.5 m).
- E. Provide Scheme A fire protection for the cartoned storage located within the upper tiers.
- F. Design ceiling sprinklers to protect the surrounding occupancy, but not less than 7 psi (0.5 bar) using twenty (20) K8.0 (K115) sprinklers. If the aerosol product storage does not extend to the full height of the rack, protect the other commodities stored above the barrier in accordance with appropriate data sheets as if the entire rack height was filled with that commodity. If in-rack sprinklers are required for the other commodities, each level of barrier and in-rack sprinklers can be given credit as a level of in-rack sprinklers.
- G. Ceiling sprinkler demand does not need to be included in the hydraulic calculations for in-rack sprinklers. Calculate the water demand at the point of supply separately for in-rack and ceiling sprinklers. Provide a 500 gpm (1900 L/min) hose stream allowance in the hydraulic calculations for the in-rack sprinkler protection. Provide the combined fire protection water demand for a 1-hour duration.

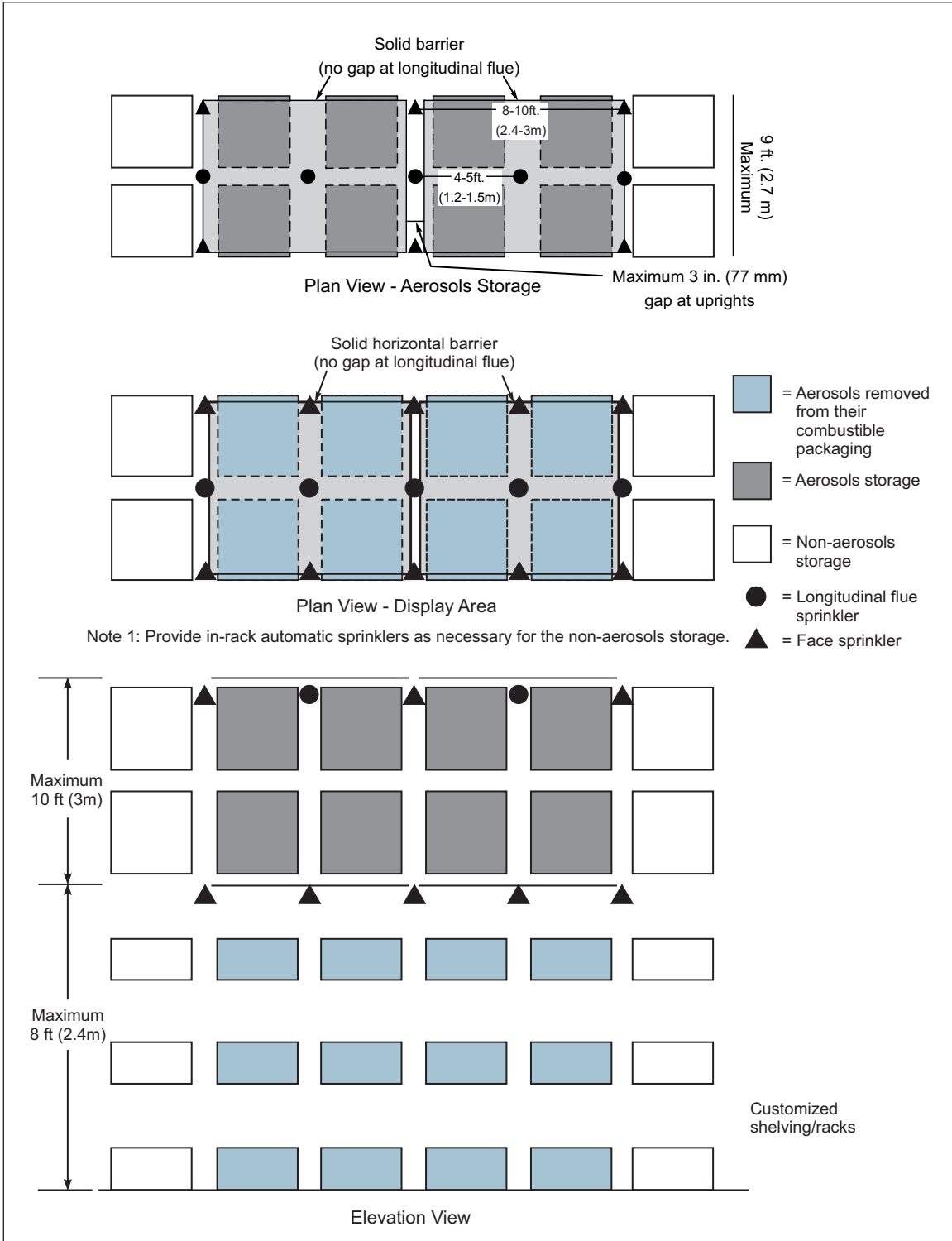


Fig. 13a. Mercantile storage, Option 1

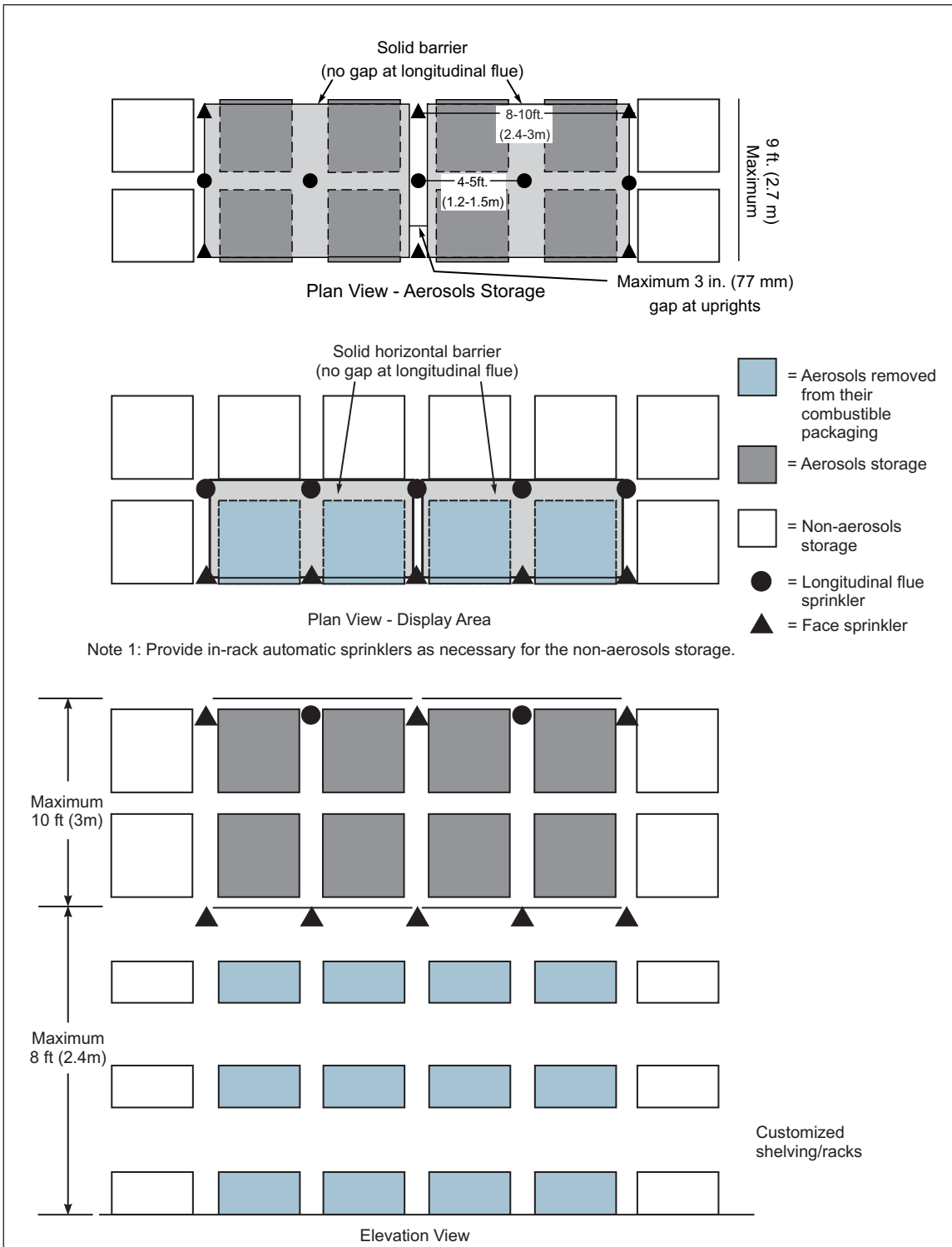


Fig. 13b. Mercantile storage, Option 2

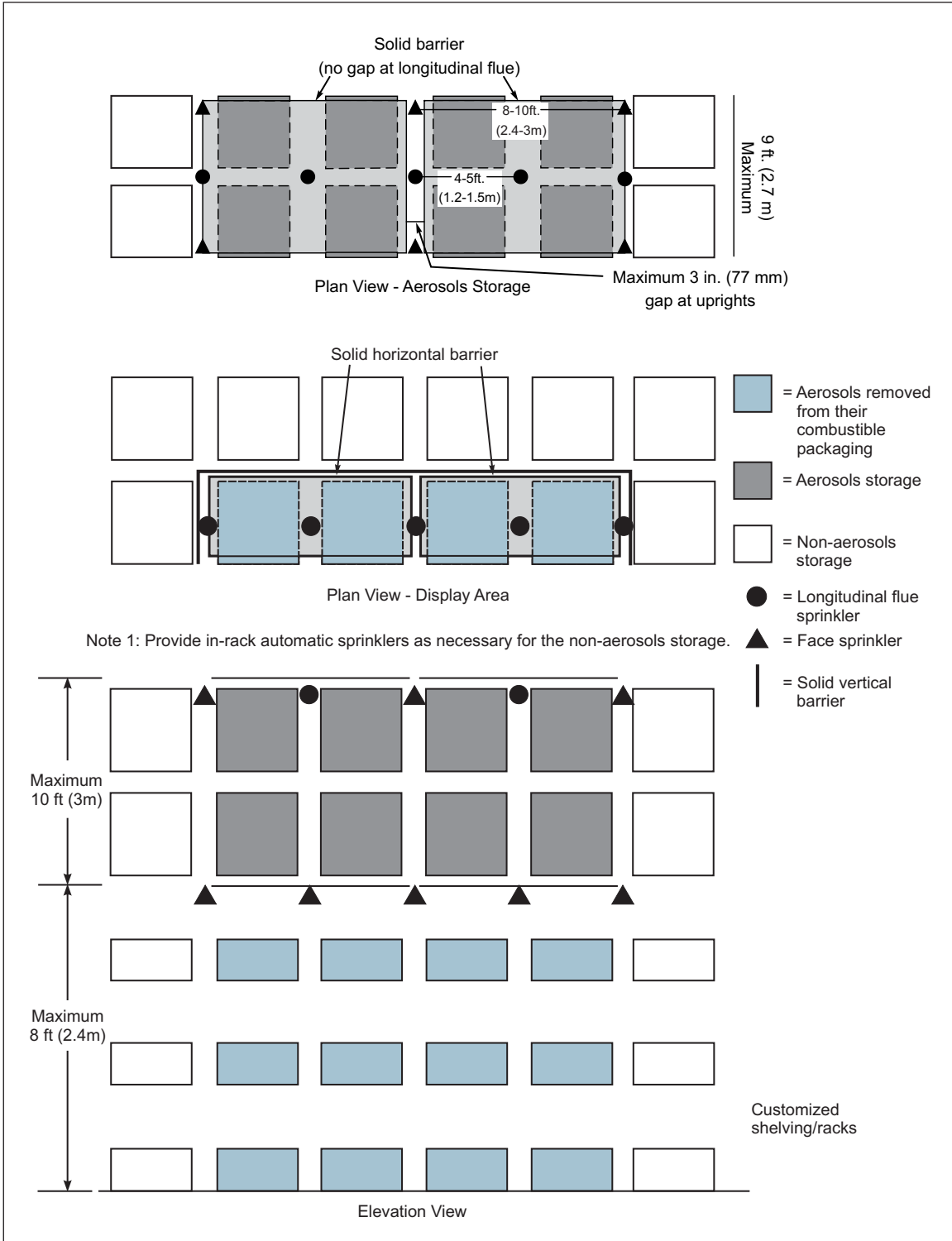


Fig. 13c. Mercantile storage, Option 3