Storage Hazards

Storage Hazards

What we will review:

- Sprinkler attributes
- Effect of ceiling height
- Flue spaces
- Shelving
- Obstructed construction and Obstructions
- In-rack sprinklers including alternative design
- Workshop

Basic Installation Standards

- Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*
  - "Nuts and bolts" of installing sprinklers
- Data Sheet 3-7, *Fire Protection Pumps*
- Data Sheet 3-10, *Installation/Maintenance of Fire Service Mains*
- Data Sheet 3-1, *Tanks and Reservoirs for Interconnected Fire Service and Public Mains*
- *Data Sheet 8-9, Storage of 1,2,3,4 and plastic commodities*

PROTECTING GENERAL STORAGE

Storage Standards

- 8-1 Commodity Classification
- 8-3 Rubber Tire Storage
- 8-7 Baled Fiber Storage
- 8-9 Storage of Class 1,2,3,4 and Plastic Commodities
- 8-10 Coal and Charcoal Storage
- 8-18 Storage of Hanging Garments
- 8-21 Roll Paper Storage
- 8-22 Storage of Baled Waste Paper
- 8-23 Rolled Nonwoven Fabric Storage
- 8-24 Idle Pallet Storage
- 8-27 Storage of Wood Chips
- 8-28 Pulpwood and Outdoor Log Storage
- 8-30 Storage of Carpets
- 8-33 Carousel Storage and Retrieval Systems
- 8-34 Protection for Automatic Storage and Retrieval Systems
- 7 Series Data Sheets e.g., storage of special hazards

Differences from EN12845 (Part 1)

- **Use of FM Approved Equipment**
- **No conventional sprinklers**
- **One fire pump or an 'enhanced water supply' with two pumps**
- **More detailed guidance on**

  ceiling slope

  obstructions to sprinkler discharge

  ceiling construction

  fans and airflow

  extended coverage sprinklers

- **No limit on number of sprinklers fed by one control valve**
- **No precalculated (pipe schedule) systems in FM standards since 1990s**
- **Minimum K80 sprinklers**
- **Minimum K160 sprinklers for storage**
- **Minimum 25mm pipe**
- **Velocity should remain below 9.1 m/s if using Hazen Williams calculation**
- **No requirement to calculate most favourable areas**

Similarities to EN12845 Part 2 – ESFR & CMSA

DS

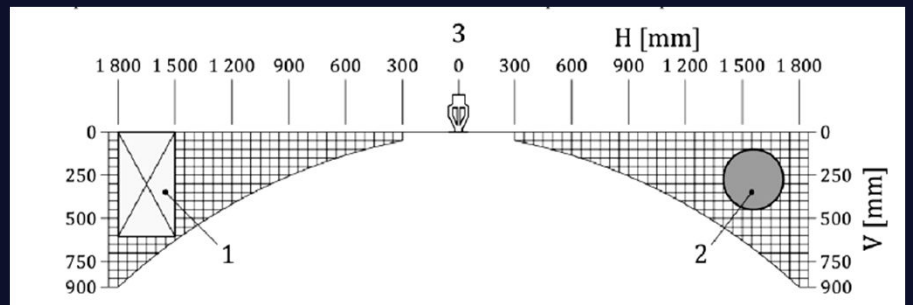
Dansk standard

DS/EN 12845-2:2024

2025-01-10

Stationære brandslukningsanlæg – Automatiske sprinkleranlæg – Del 2: Projektering og installation af ESFR- og CMSA-sprinkleranlæg

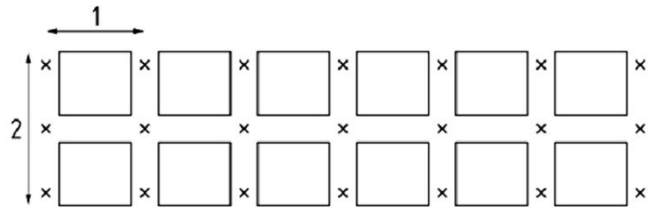
Fixed firefighting systems – Automatic sprinkler systems – Part 2: Design and installation of ESFR and CMSA sprinkler systems



Key

H	horizontal distance to edge of obstruction	2	service pipe or similar
V	vertical distance to edge of obstruction	3	centreline
1	duct, beam or similar		

Figure 29 — Plan view of modular in-rack sprinkler arrangement for double-row racks up to 2,7 m deep

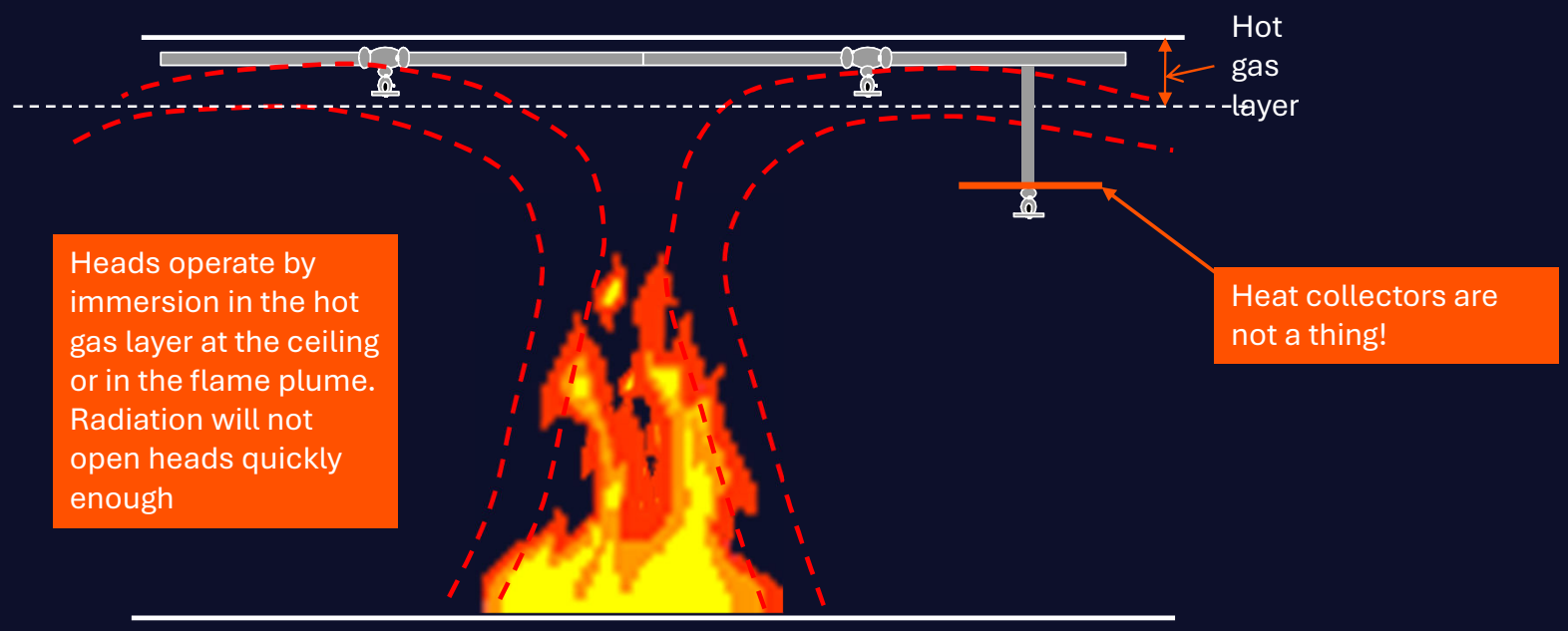


PROTECTING GENERAL STORAGE

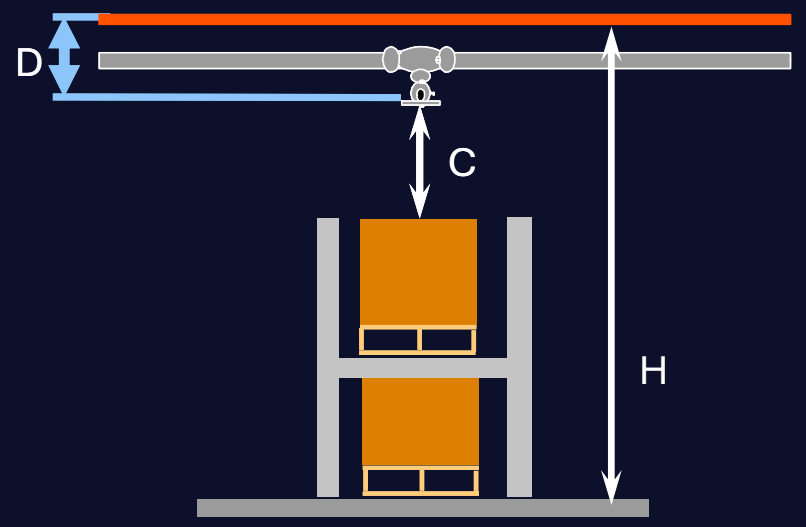
Commodity Classification

- **Class 1,2 and 3**
  - Non-combustible commodity on wood pallets
  - Wood, paper or natural fibre materials, no more than 5% plastic
- **Class 4 / Cartoned Unexpanded Plastic**
  - No more than 5% expanded plastic by weight or 40% by volume per pallet load
  - Corrugated carton
- **Cartoned Expanded Plastic**
  - Corrugated carton
- **Uncartoned Unexpanded Plastic**
- **Uncartoned Expanded Plastic**
  - Empty, non-nested, unexpanded plastic containers
- **Plastic Pallets**
  - Increase class 1,2 or 3 commodities by one class
- **Encapsulation (plastic wrapping)**
  - Already accounted for

How Ceiling Sprinklers Work



Sprinkler Position



- Typically, D ≈ 300mm
- For storage C should be at least 0.9m
- H limited to a maximum value unless in-rack sprinklers added

Key sprinkler attributes

Key Sprinkler Attributes

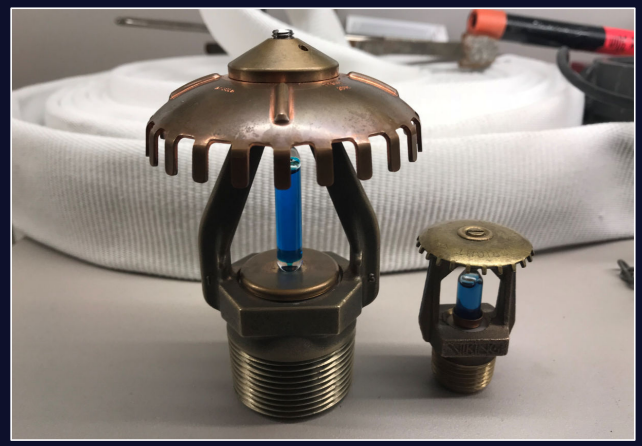
1. **Orientation**
2. **K-Factor**
3. **RTI Rating**
4. **Temperature Rating**
5. **Sprinkler Spacing**

- Which way up it is
- How big the orifice is
- How quickly it operates
- What temperature it operates at
- The area each sprinkler covers

Key Sprinkler Attributes

Orientation

K-Factor



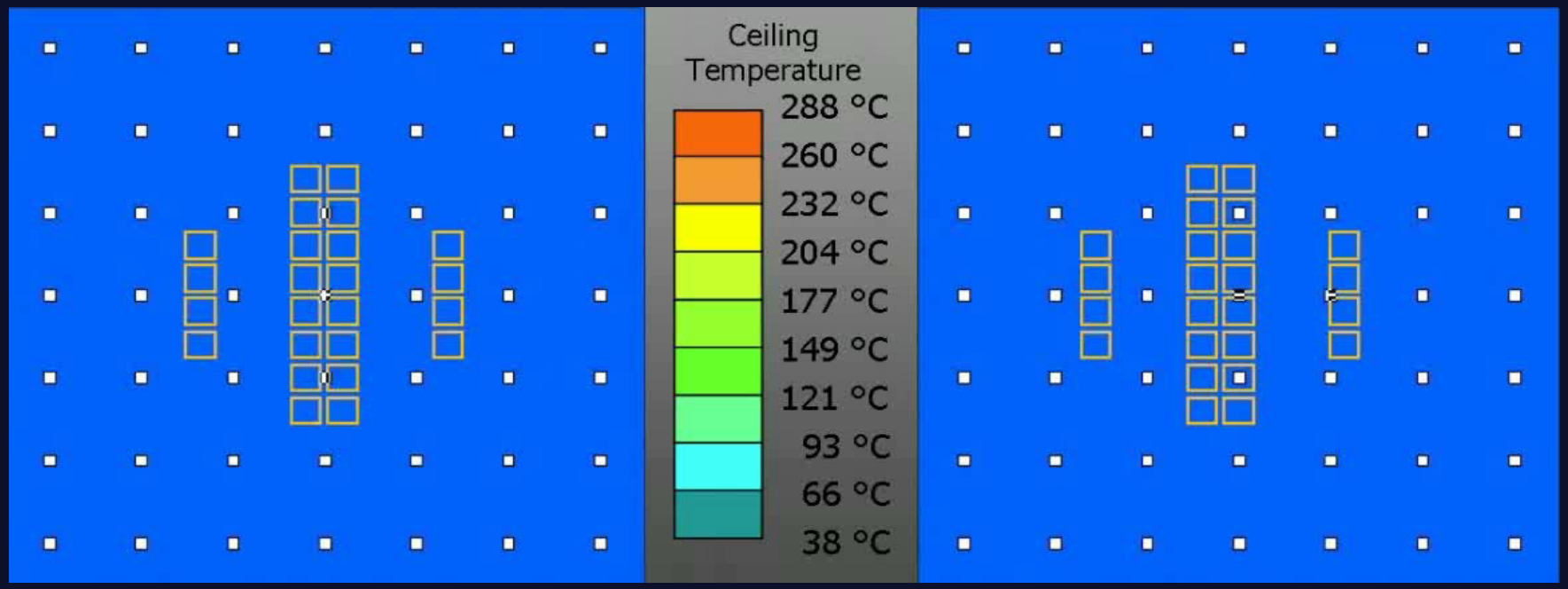
RTI Rating

Temp. Rating

Orientation

K160 Pendent Sprinkler @ 230l/min

K160 Upright Sprinkler @ 380l/min



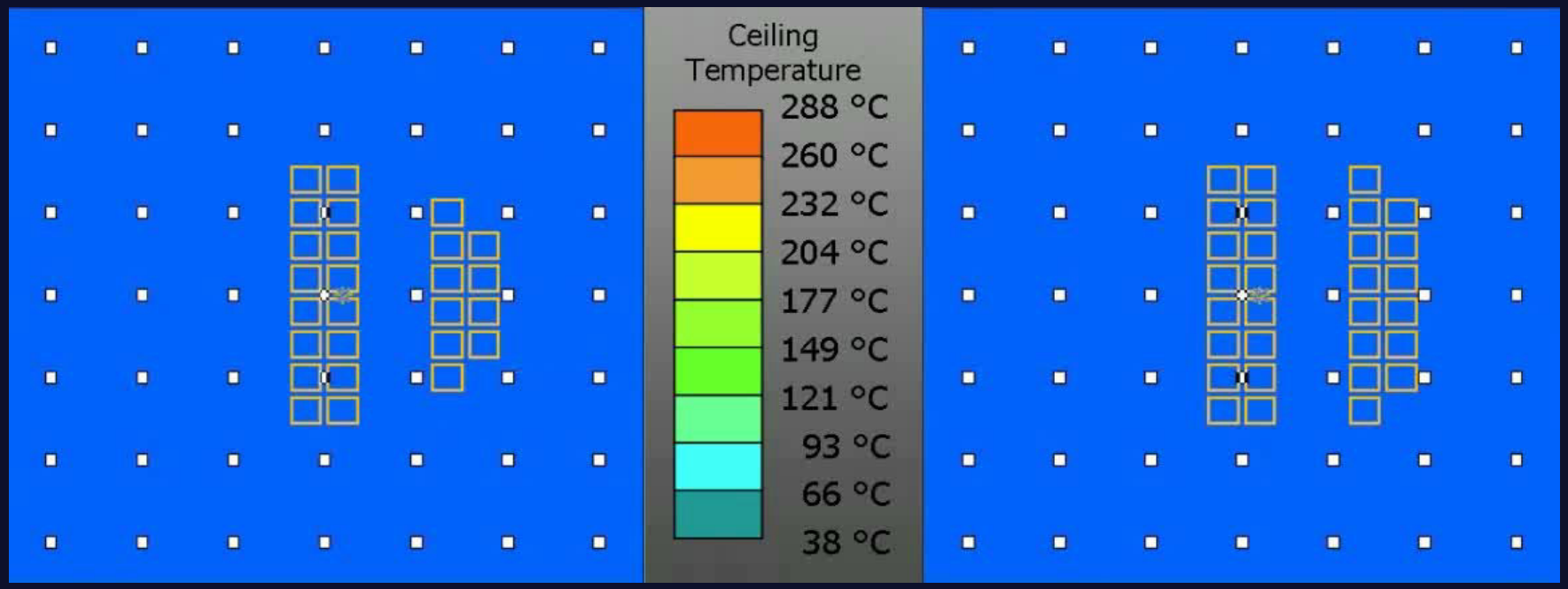
10 Sprinklers Operated

32 Sprinklers Operated

K-Factor

K240 Upright Sprinkler @ 300l/min

K160 Upright Sprinkler @ 300l/min



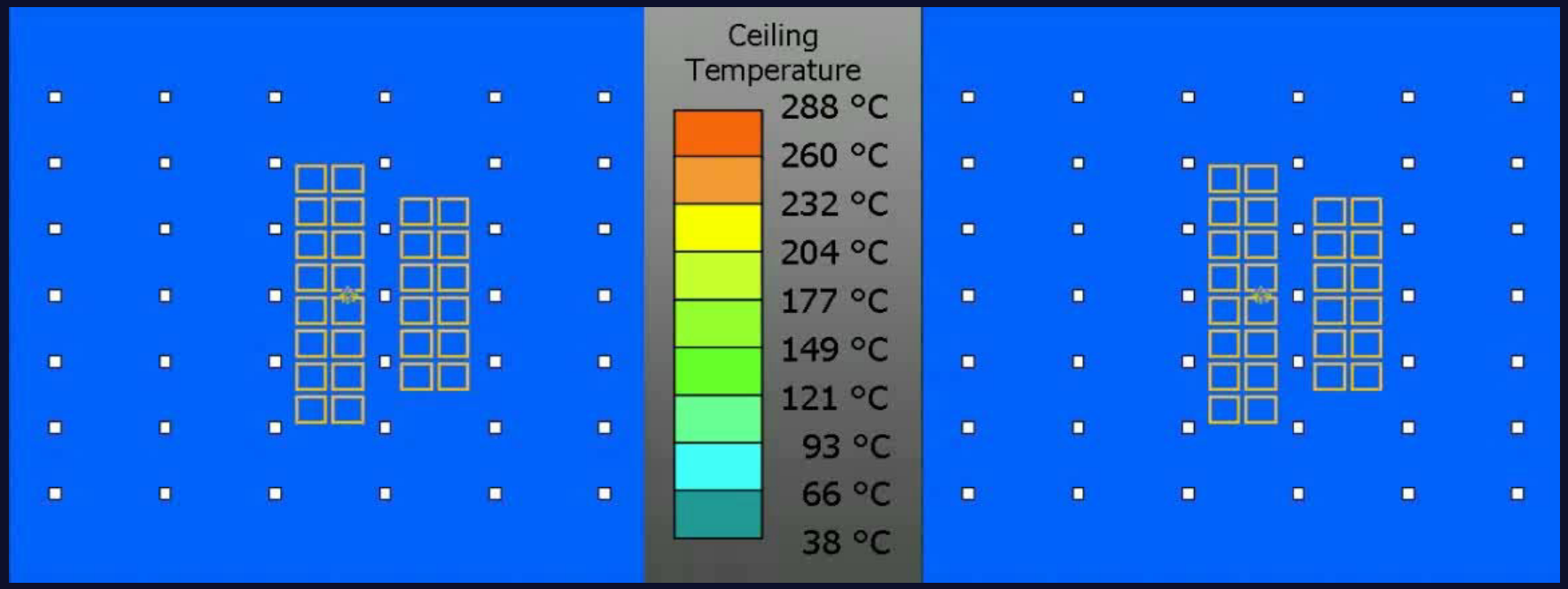
15 Sprinklers Operated

29 Sprinklers Operated

Response Time Index Rating

K200 QR Pendent Sprinkler @ 380l/min

K200 SR Pendent Sprinkler @ 450l/min



11 Sprinklers Operated

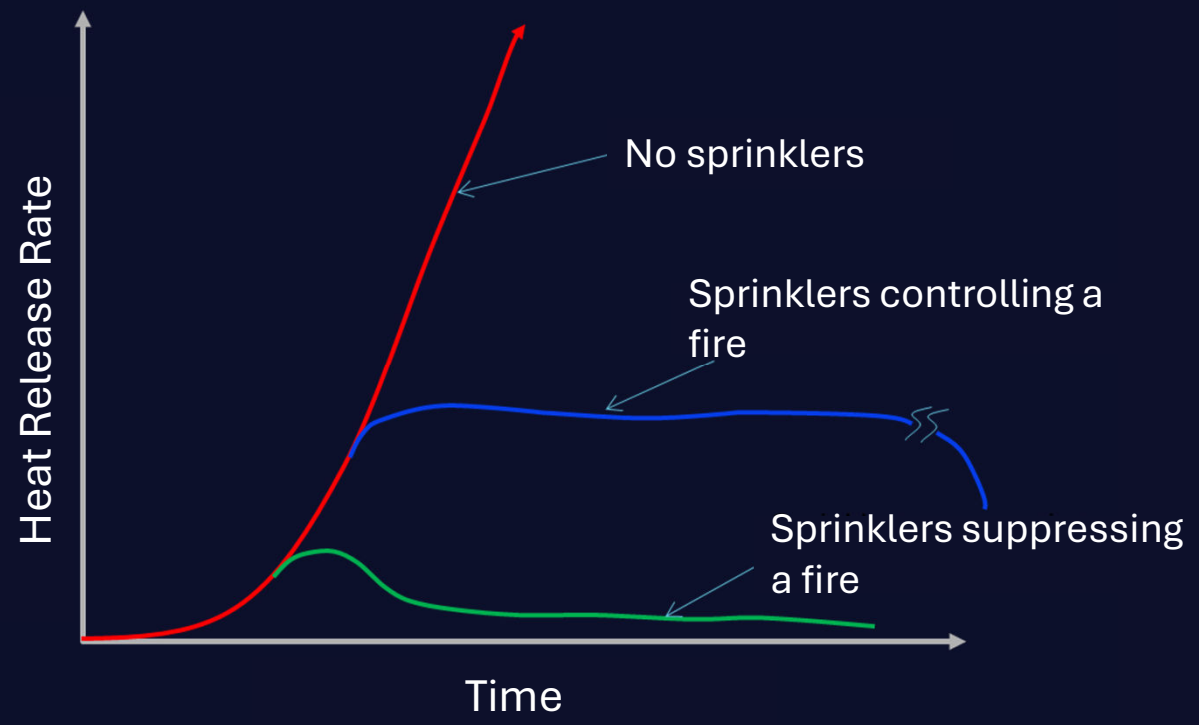
17 Sprinklers Operated

(Uncontrolled Fire - Test Terminated)

Suppression versus control

PROTECTING GENERAL STORAGE

Suppression Vs Control

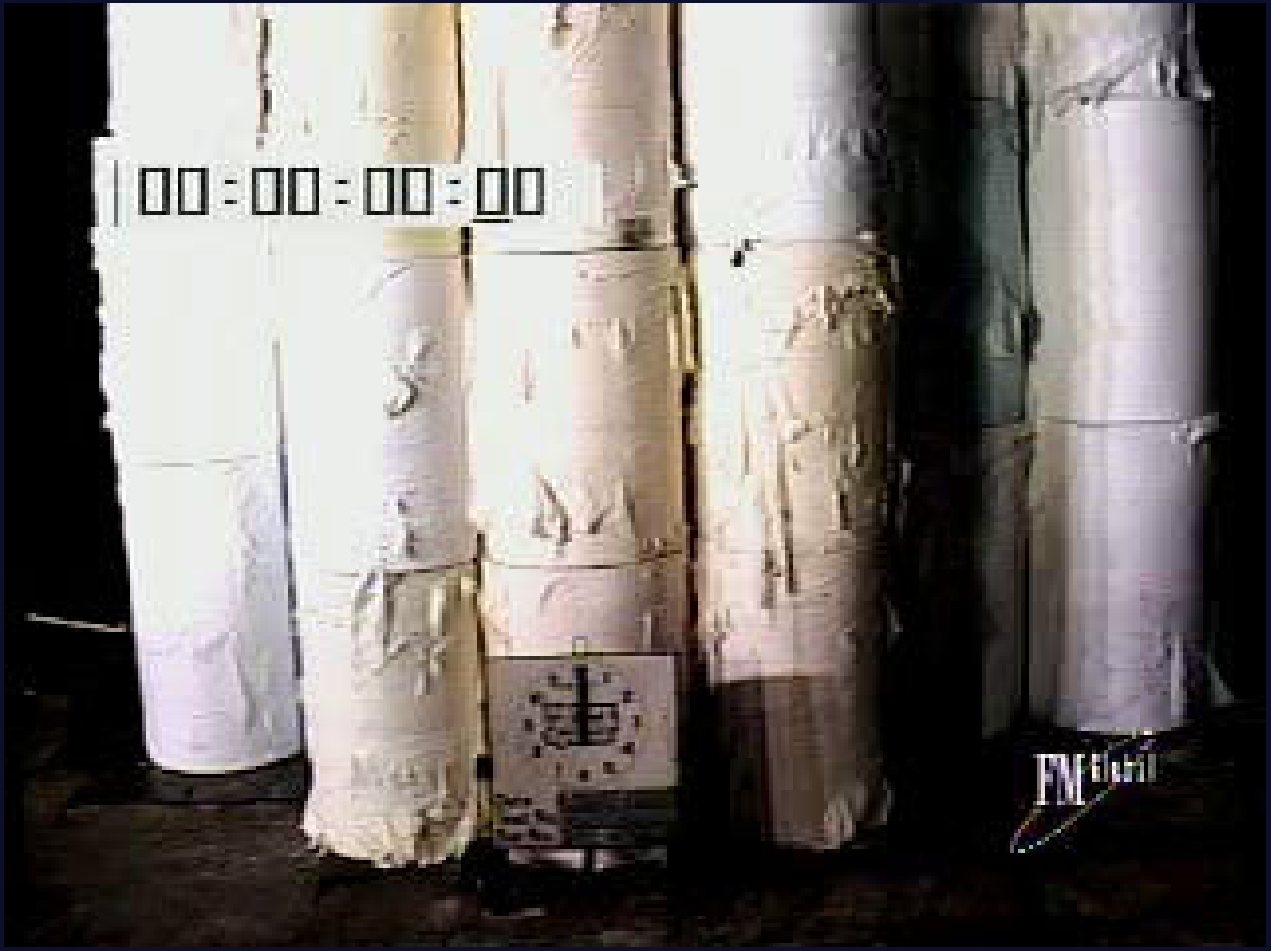


PROTECTING GENERAL STORAGE

Suppression Vs Control

PROTECTING GENERAL STORAGE

Suppression Vs Control



Ceiling Sprinkler Design

Some designs use fewer than 12 sprinklers

Minimum K160 sprinklers

Green highlighting indicates preferred options

Table 5. Ceiling-Level Protection Guidelines for Uncartoned Unexpanded Plastic Commodities in a Solid-Piled, Palletized, Shelf, or Bin-Box Storage Arrangement

Protection of Uncartoned Unexpanded Plastic Commodities in Solid-Piled, Palletized, Shelf, and Bin-Box Arrangements; No. of AS @ psi (bar)																				
Max. Ceiling Height, ft (m)	Wet System, 160°F (70°C) Nominally Rated, Pendent Sprinklers										Wet System, 160°F (70°C) Nominally Rated, Upright Sprinklers							Dry System, 280°F (140°C) Nominally Rated, Upright Sprinklers		
	Quick Response						Standard Response				Quick Response				Standard Response			Standard Response		
	K11.2 (K160)	K14.0 (K200)	K16.8 (K240)	K22.4 (K320)	K25.2 (K360)	K25.2EC (K360EC)	K11.2 (K160)	K14.0 (K200)	K19.6 (K280)	K25.2 (K360)	K11.2 (K160)	K14.0 (K200)	K16.8 (K240)	K25.2EC (K360EC)	K11.2 (K160)	K16.8 (K240)	K25.2 (K360)	K11.2 (K160)	K16.8 (K240)	K25.2 (K360)
10 (3.0)	12 @ 10 (0.7)	12 @ 7 (0.5)	12 @ 7 (0.5)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 20 (1.4)	12 @ 10 (0.7)	12 @ 7 (0.5)	12 @ 16 (1.1)	12 @ 7 (0.5)	12 @ 10 (0.7)	12 @ 7 (0.5)	12 @ 7 (0.5)	6 @ 20 (1.4)	12 @ 10 (0.7)	12 @ 7 (0.5)	12 @ 7 (0.5)	16 @ 10 (0.7)	16 @ 7 (0.5)	16 @ 7 (0.5)
20 (6.0)	12 @ 40 (2.8)	12 @ 26 (1.8)	12 @ 18 (1.2)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 30 (2.1)	12 @ 40 (2.8)	12 @ 26 (1.8)	12 @ 16 (1.1)	12 @ 8 (0.6)	12 @ 40 (2.8)	12 @ 26 (1.8)	12 @ 18 (1.2)	6 @ 30 (2.1)	12 @ 40 (2.8)	12 @ 18 (1.2)	12 @ 8 (0.6)	16 @ 40 (2.8)	16 @ 18 (1.2)	16 @ 8 (0.6)
25 (7.5)	12 @ 50 (3.5)	9 @ 50 (3.5)	9 @ 35 (2.4)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 38 (2.6)	12 @ 50 (3.5)	12 @ 32 (2.2)	12 @ 16 (1.1)	12 @ 10 (0.7)	12 @ 50 (3.5)	12 @ 32 (2.2)	12 @ 22 (1.5)	6 @ 38 (2.6)	12 @ 50 (3.5)	12 @ 22 (1.5)	12 @ 10 (0.7)	20 @ 50 (3.5)	20 @ 22 (1.5)	20 @ 10 (0.7)
30 (9.0)	25 @ 50 (3.5)	9 @ 100 (6.9)	9 @ 70 (4.8)	9 @ 50 (3.5)	9 @ 40 (2.8)	12 @ 38 (2.6)	25 @ 50 (3.5)	25 @ 32 (2.2)	25 @ 16 (1.1)	25 @ 10 (0.7)	25 @ 50 (3.5)	25 @ 32 (2.2)	25 @ 22 (1.5)	12 @ 38 (2.6)	25 @ 50 (3.5)	25 @ 22 (1.5)	25 @ 10 (0.7)	30 @ 50 (3.5)	30 @ 22 (1.5)	30 @ 10 (0.7)
35 (10.5)				12 @ 63 (4.3)	12 @ 50 (3.5)															
40 (12.0)				12 @ 75 (5.2)	12 @ 60 (4.1)															

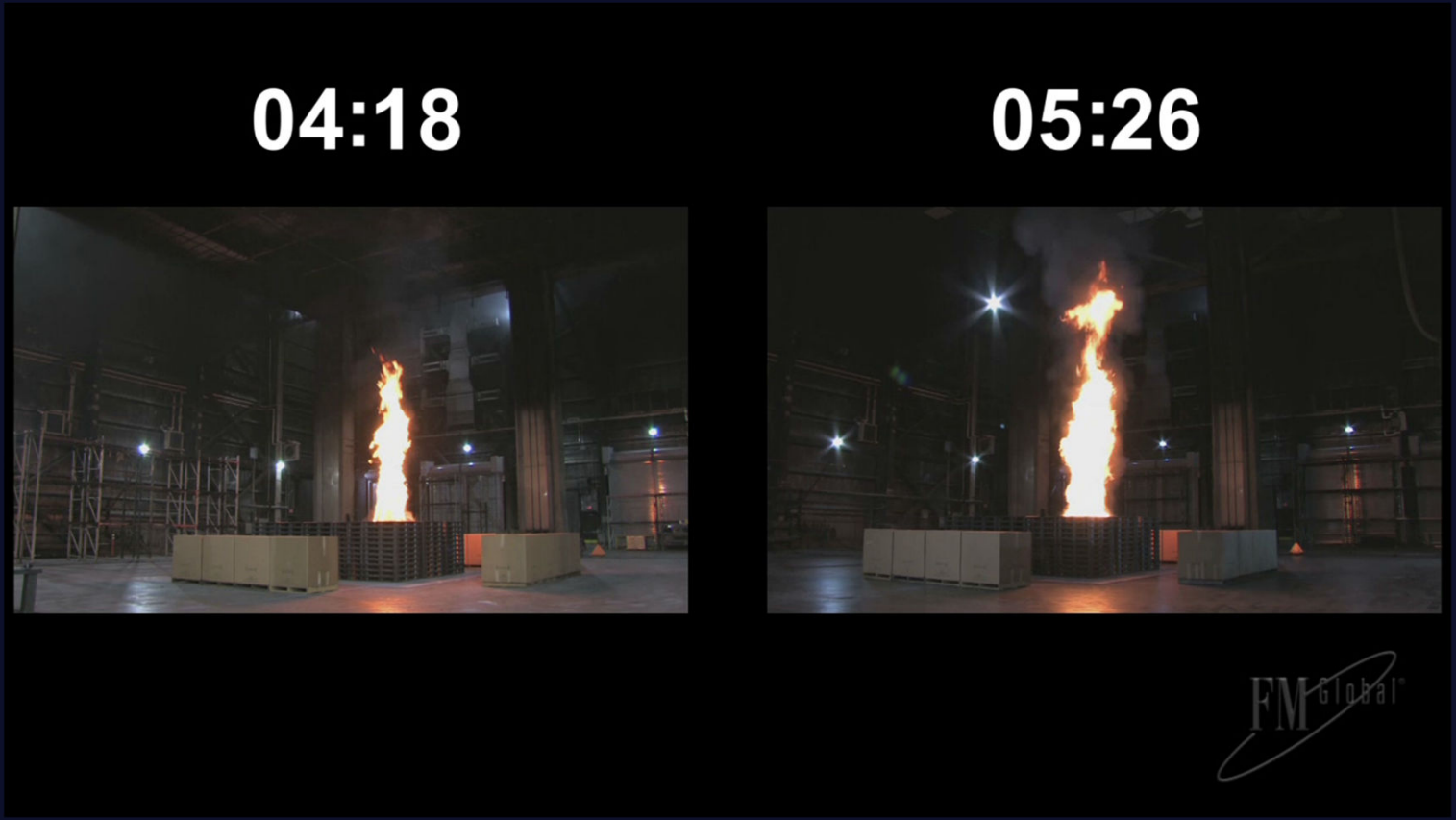
≈ 32 mm/min over 232m^2 , EN12845 – 27.5/300

Only ceiling height, not storage height affects design for a given sprinkler

PROTECTING GENERAL STORAGE

Effect of Ceiling Height

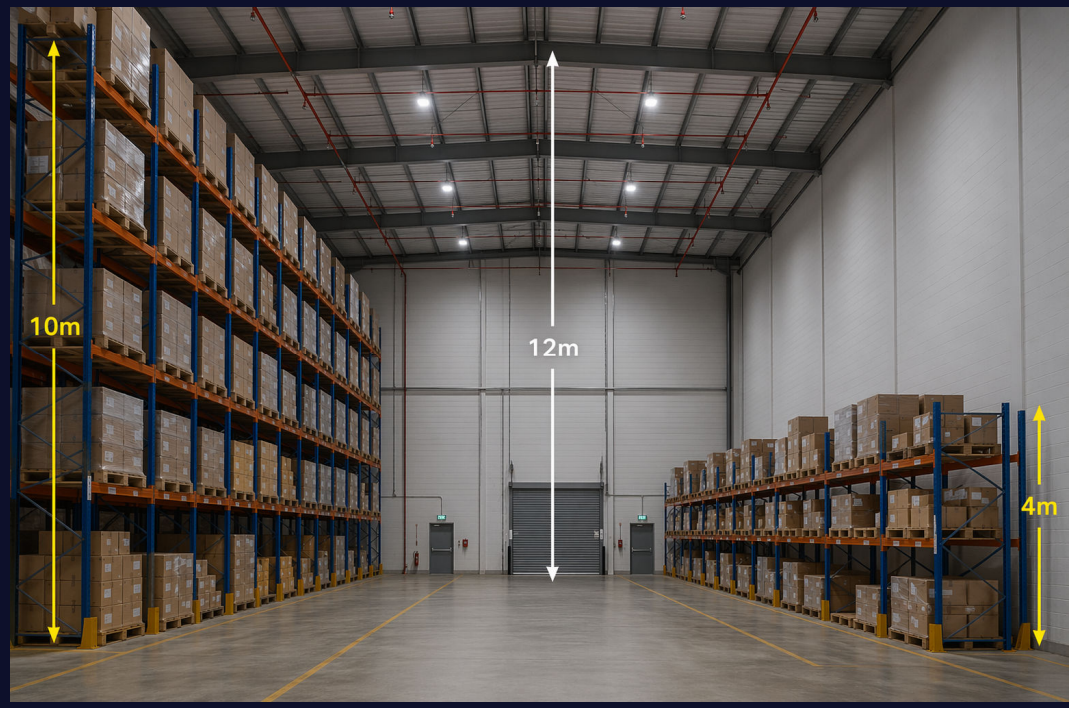
- 1.5m high storage of idle plastic pallets
- 13.7m high ceiling on the left
- 18m high ceiling on the right
- K360 Sprinklers



PROTECTING GENERAL STORAGE

Ceiling Height vs Storage Height

- Ceiling height has a greater impact than storage height on the design needed to control or suppress a fire
- Lower storage is usually beneficial but not always and not enough to warrant including in tables
- In some tests lower storage has opened more sprinklers than higher storage under the same ceiling height



Flue spaces

Rack Storage - Flues

- **Flues provide a path for heat to quickly get to ceiling sprinklers**
- **They provide a path for sprinkler water down to the fire**
- **Blocked, irregular or flues that are too small may mean treating racks as if they have solid shelves**
  - In-racks at every tier

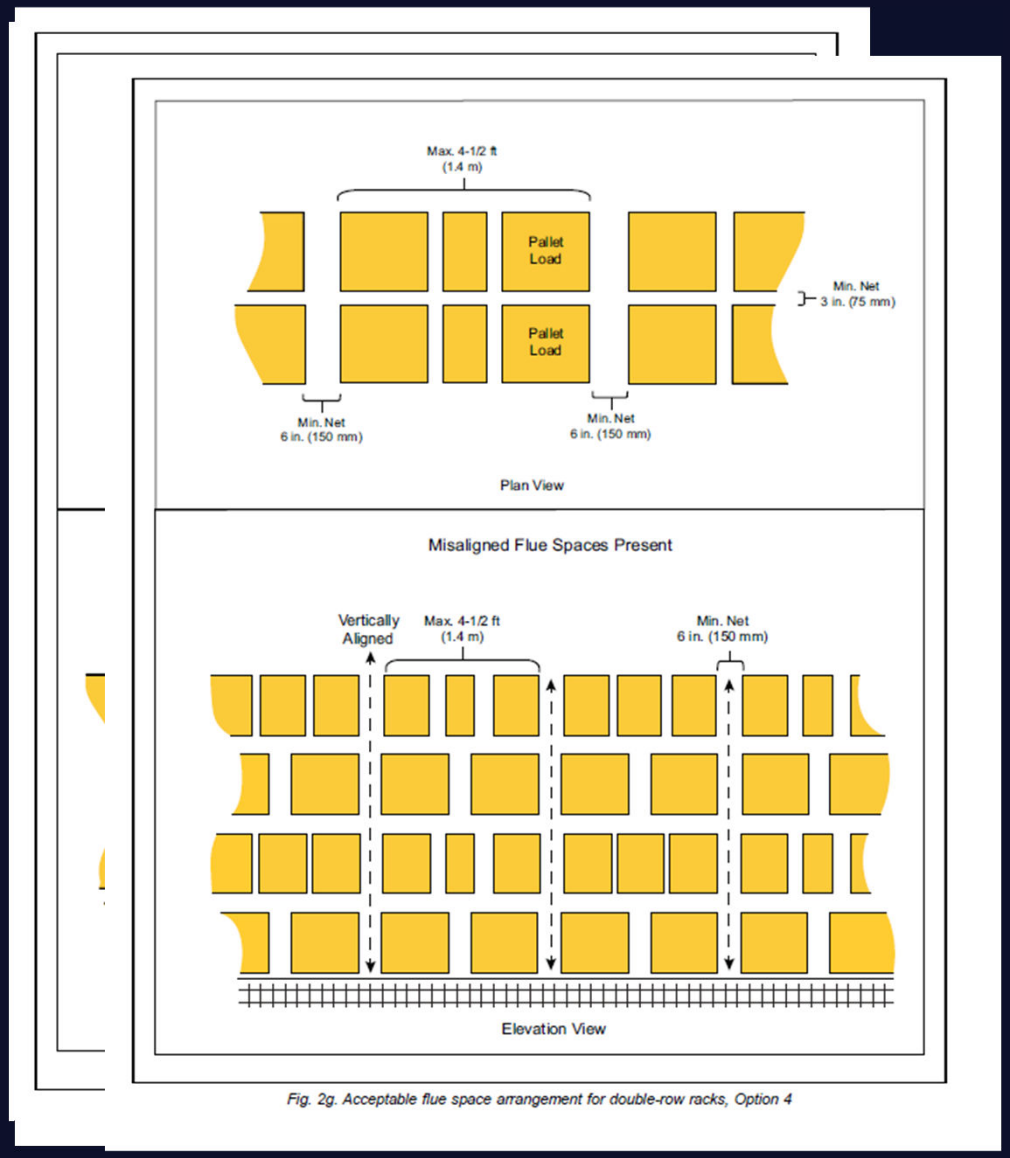


Fig. 2g. Acceptable flue space arrangement for double-row racks, Option 4

Multi-Row Rack Flues

- **Need 150mm flues in each direction**
  - Not usually possible with push through or roll through rack
- **Or limit depth of rack to 6m with 2.4m aisles**
- **Otherwise treat as racks with solid shelves**
- **Recent testing has confirmed the exposure**
- **EN12845 does not really cover MRR**
  - Requirement for additional lines of in-racks every 3.2m of width
  - Likely to leave every other flue completely unprotected

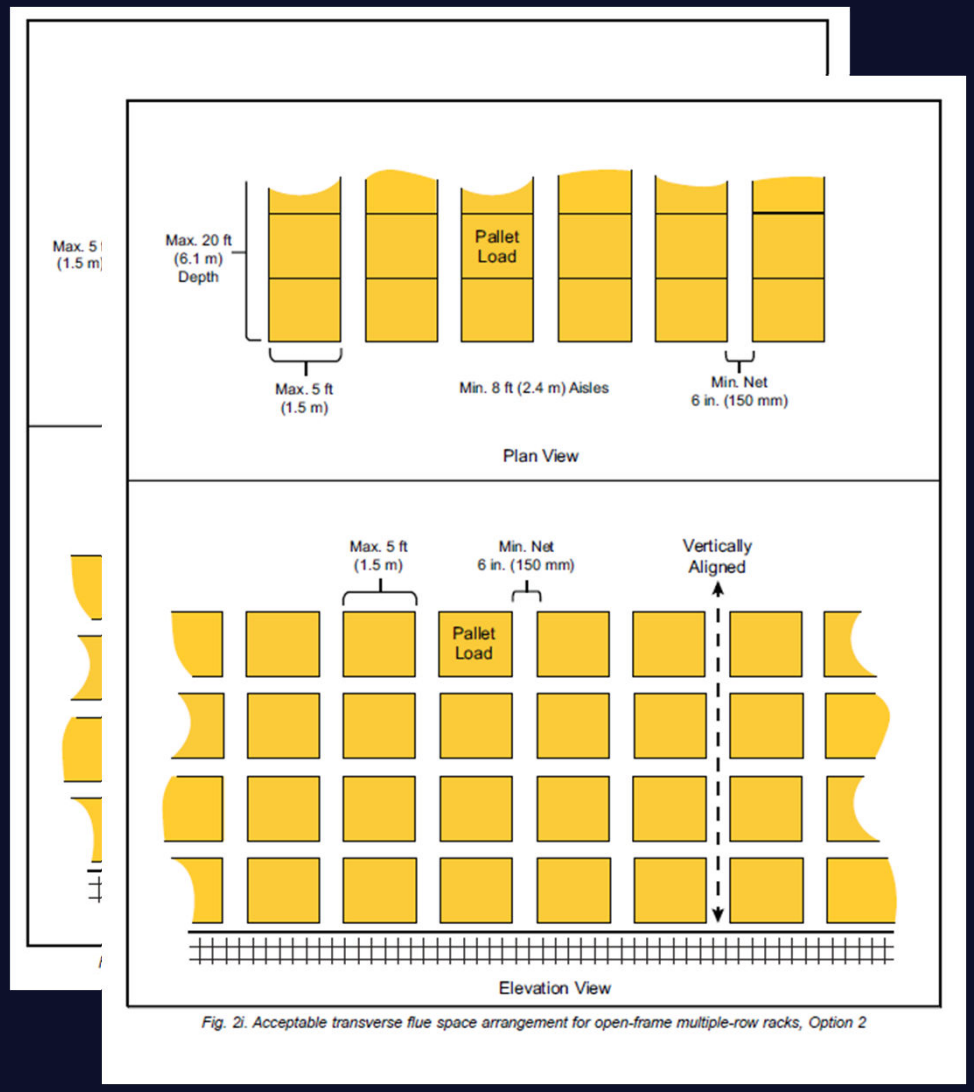
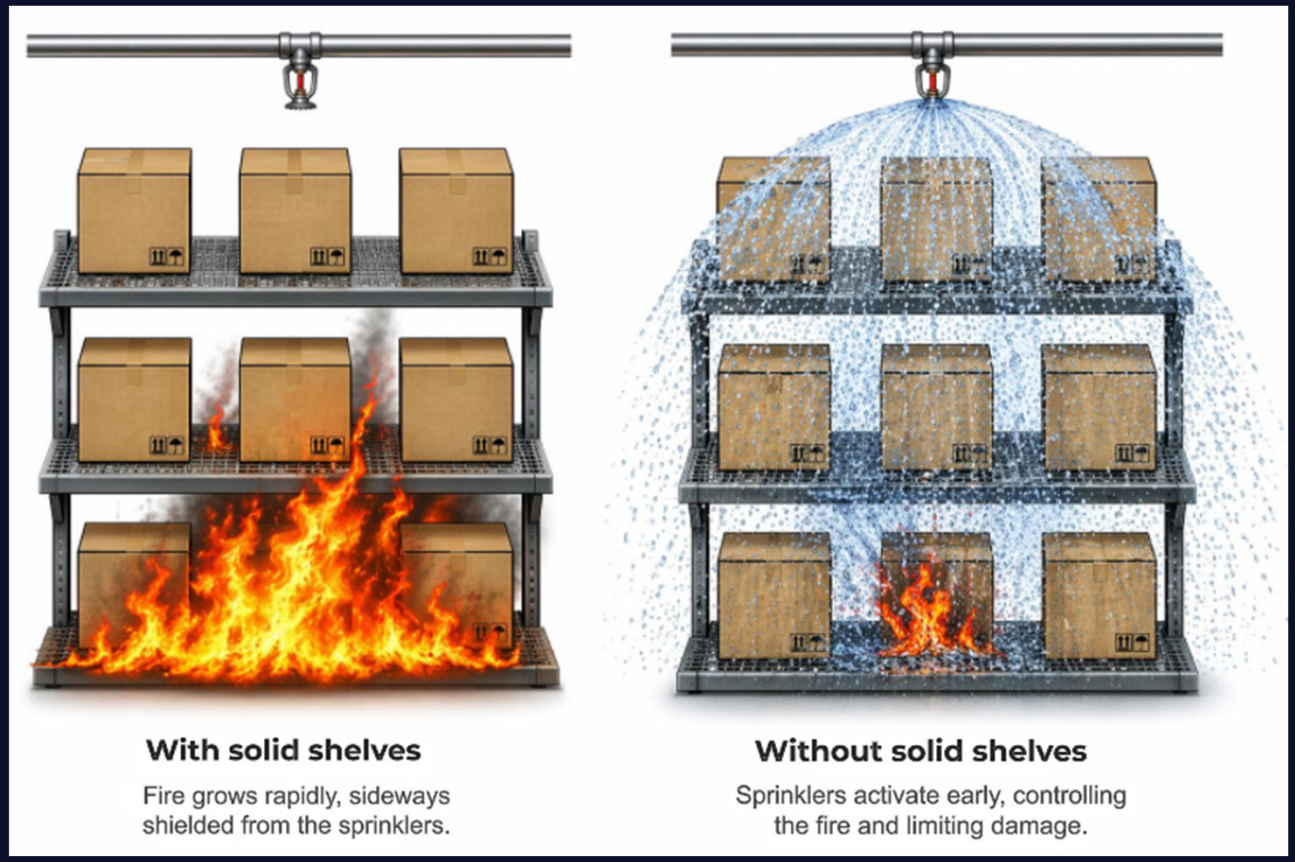


Fig. 2i. Acceptable transverse flue space arrangement for open-frame multiple-row racks, Option 2

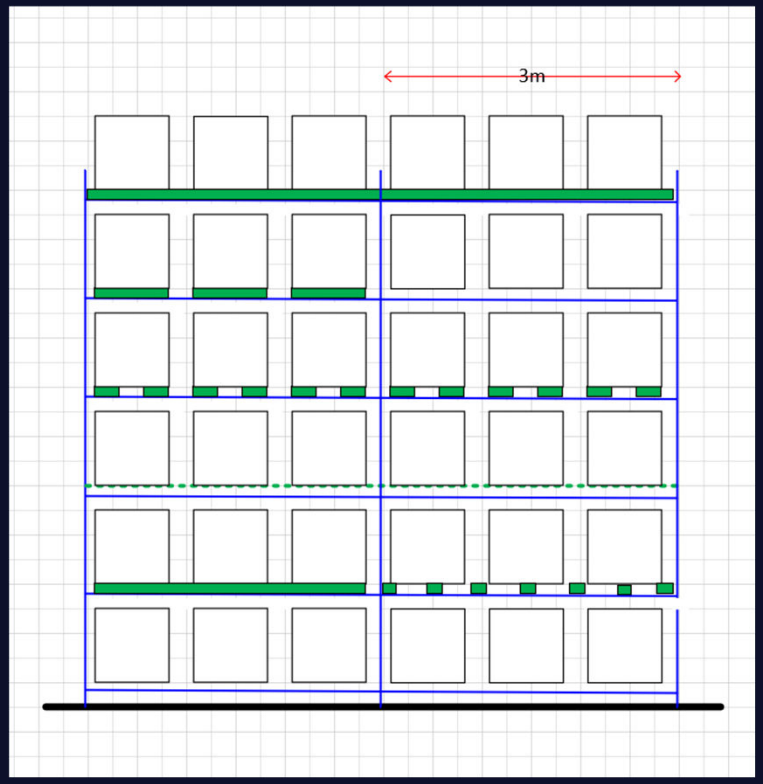
Shelving in racks

Shelving withing Racking



Shelves within Racking

- **Racks with continuous solid shelves likely to need in-rack sprinklers at every tier**
- **Solid shelves up to 6m² likely to need some in-rack sprinklers**
- **Solid shelves up to 2m² acceptable without additional in-racks provided flues are acceptable**
- **70% open mesh can span flues without compromising them**
- **Slatted shelves where the slats block flues likely to be treated as solid shelves**

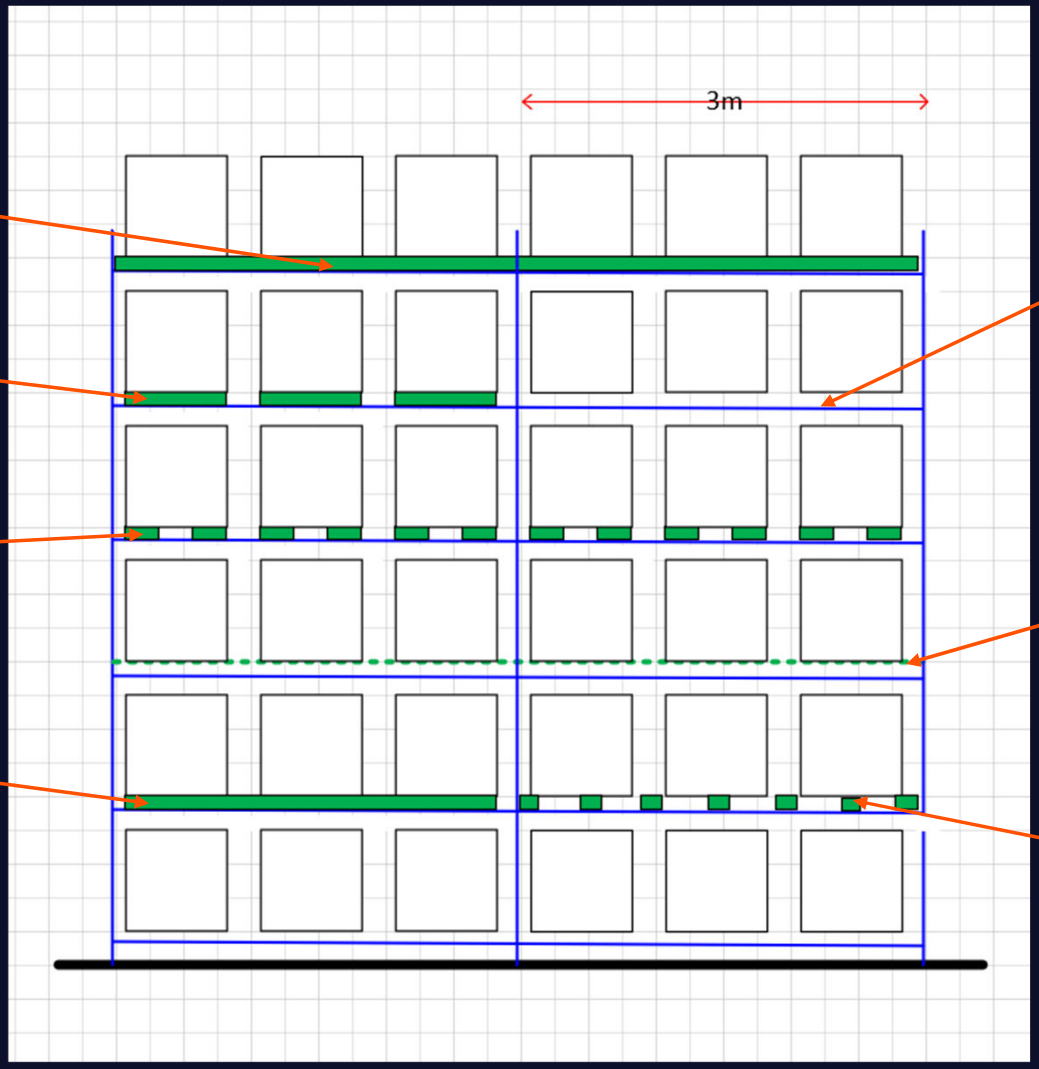


Continuous Solid Shelf

Solid shelf less than $2m^2$, not blocking flues

Slatted shelves not blocking flues

Solid Shelf > $2m^2$, <$6m^2$



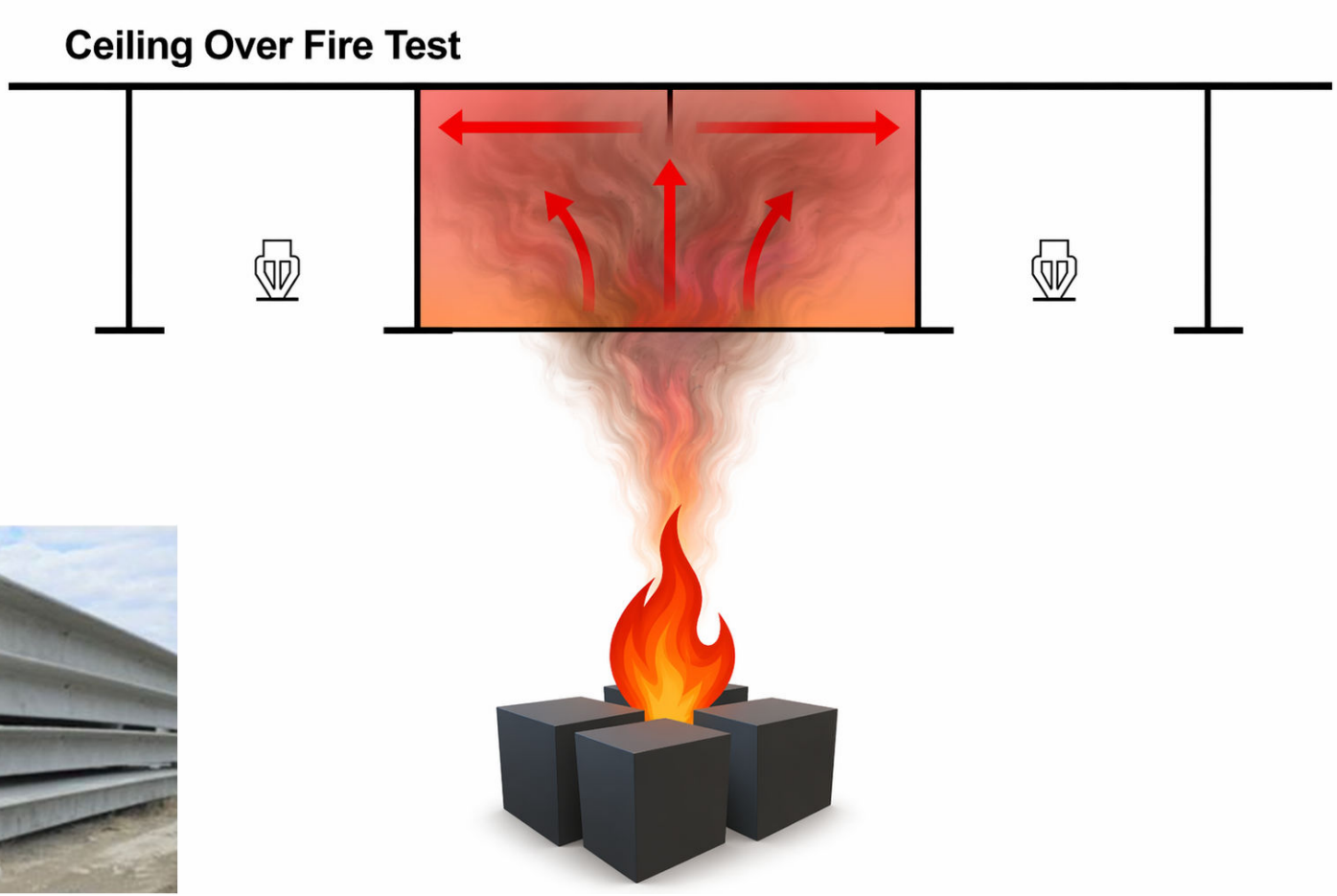
No shelf

Mesh shelf more than 70% open

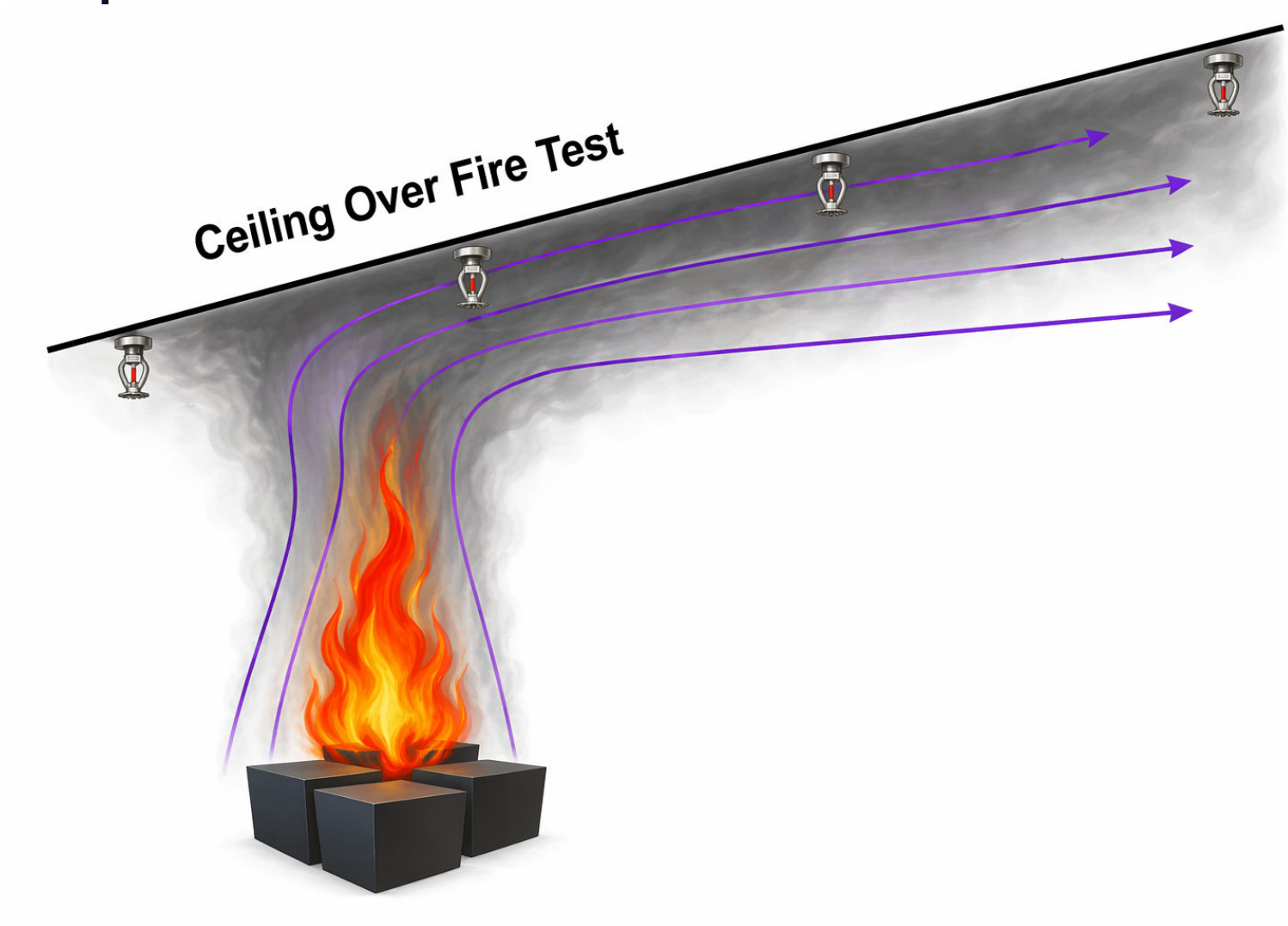
Slatted shelf blocking flues

Obstructed construction and Obstructions to the sprinklers

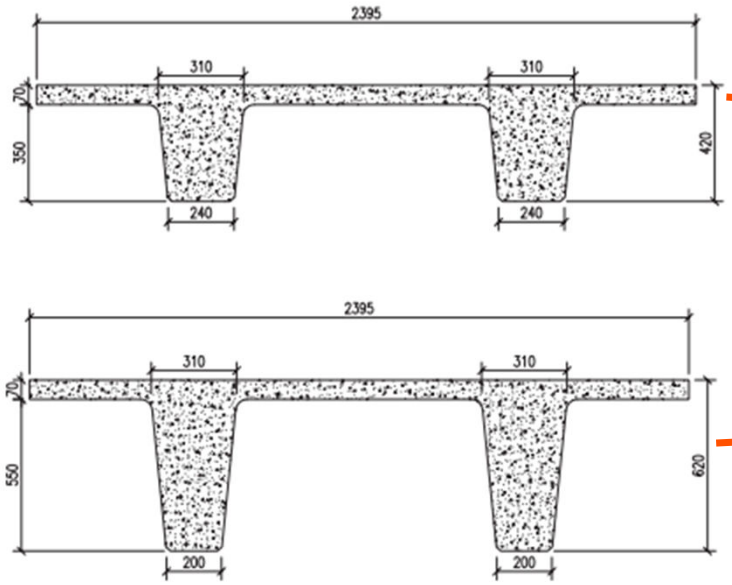
Obstructed Construction



Ceiling Slope



Obstructed construction and ceiling slope



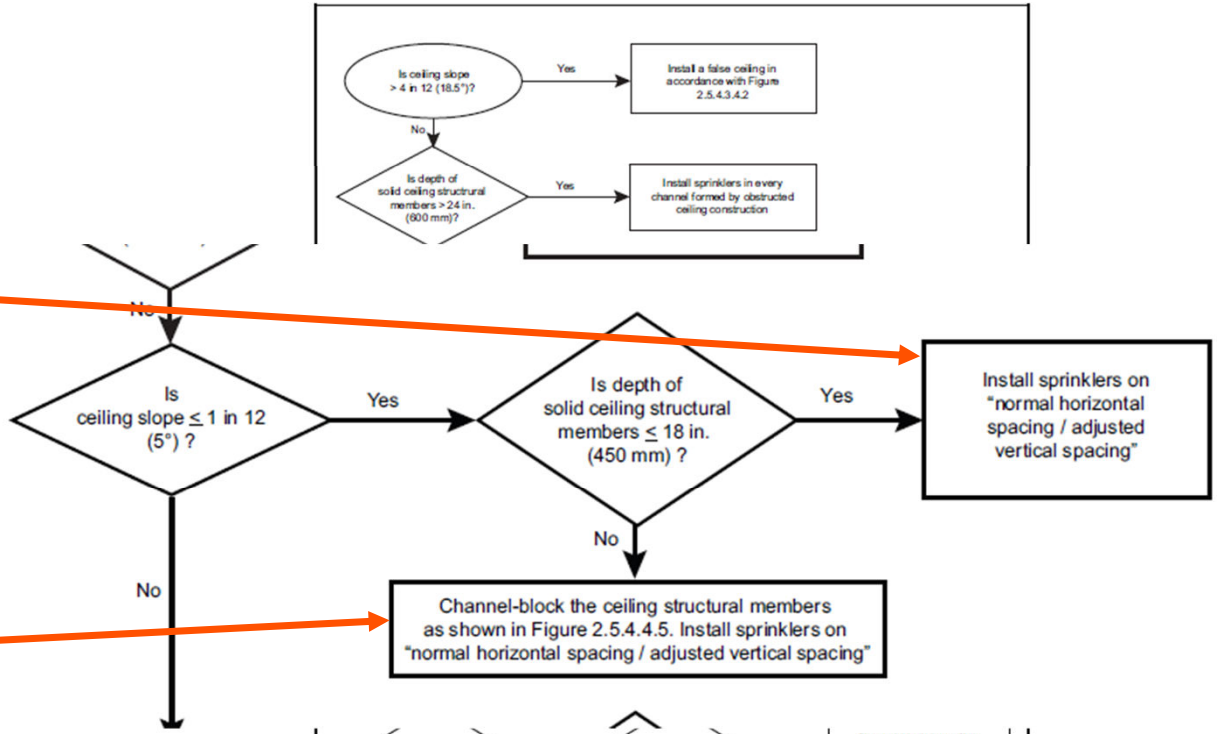
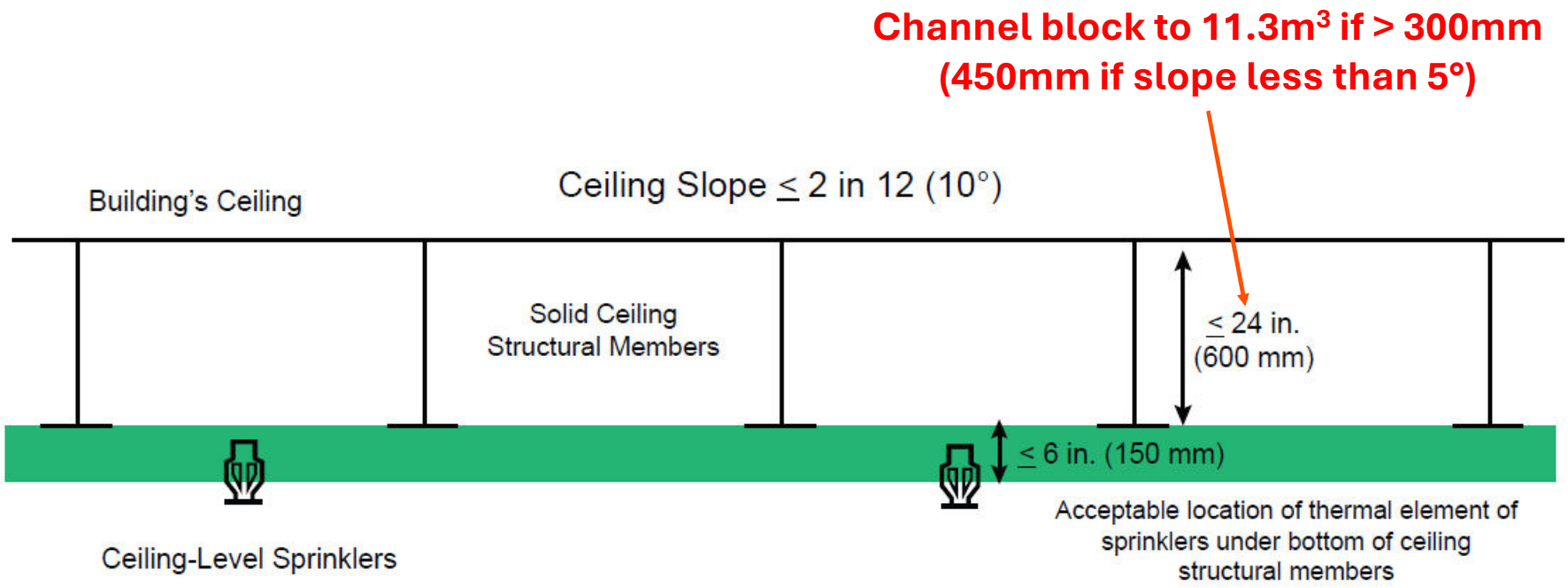


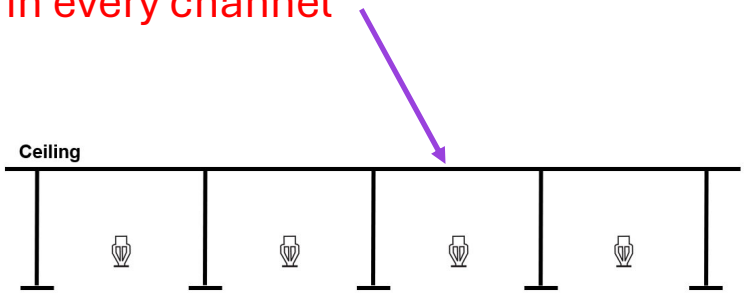
Fig. 2.5.4.4.2. Determining the horizontal and vertical location of Storage sprinklers in the presence of obstructed ceiling construction

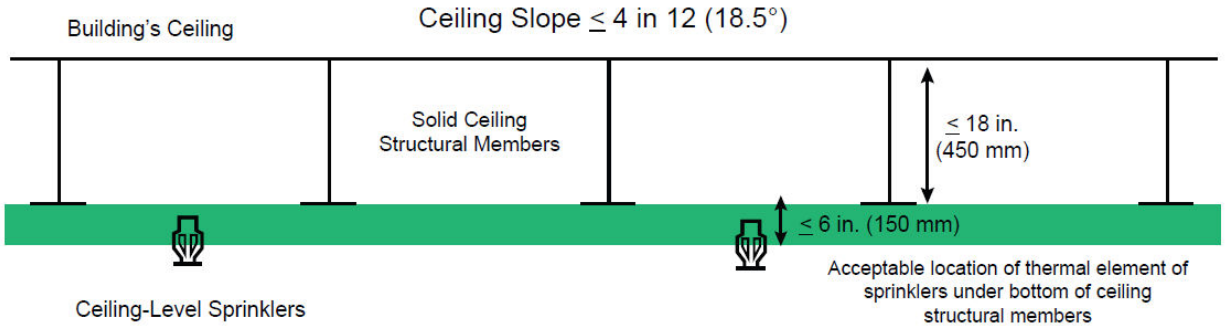
Storage Sprinklers under 10° Sloped, Obstructed Ceiling



Storage Sprinklers under 18° Sloped, Obstructed Ceiling

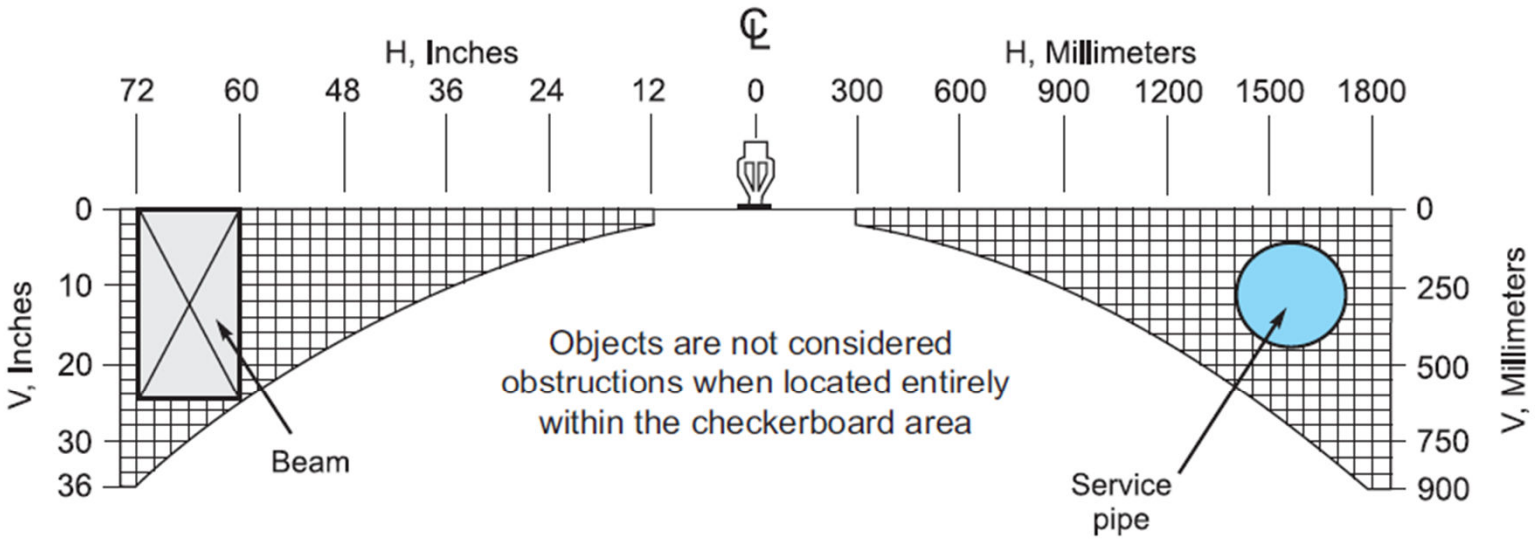
- Fire stopping to 8.5m^3 needed
- Structural members must run across slope
- Otherwise, sprinklers needed in every channel





Storage Sprinklers Under Obstructed Ceiling Construction

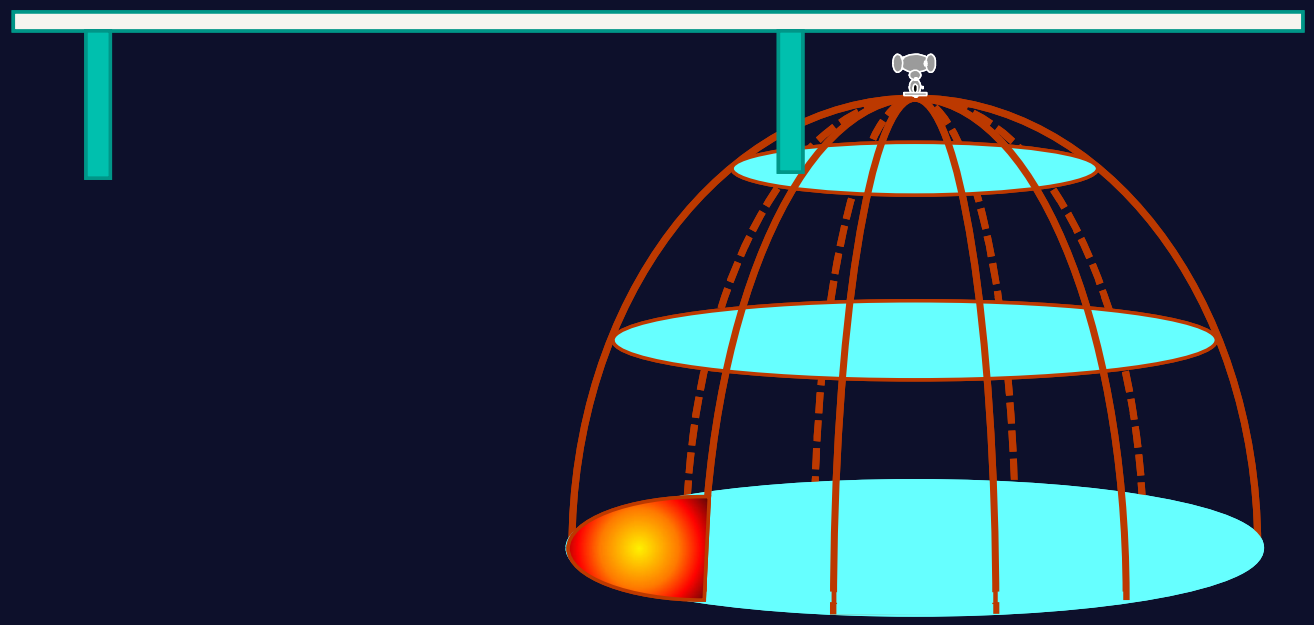
Storage Sprinklers Obstructions to Discharge Pattern



Storage Occupancy

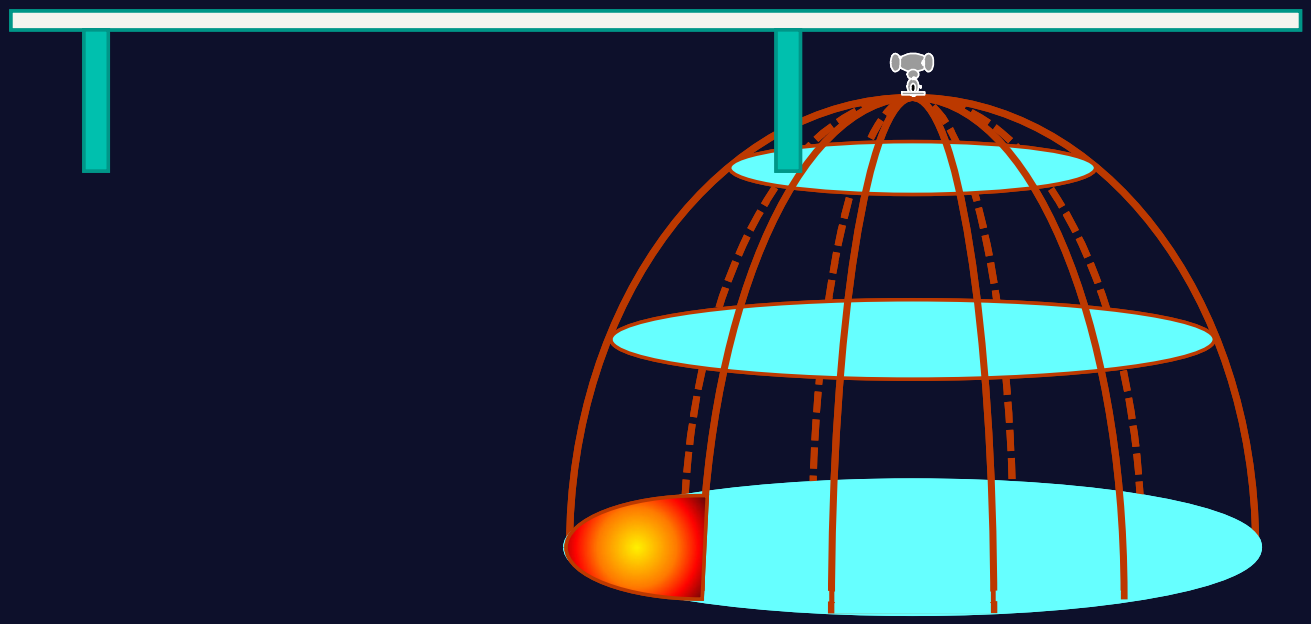
Elevation View

Obstructions to sprinkler discharge pattern



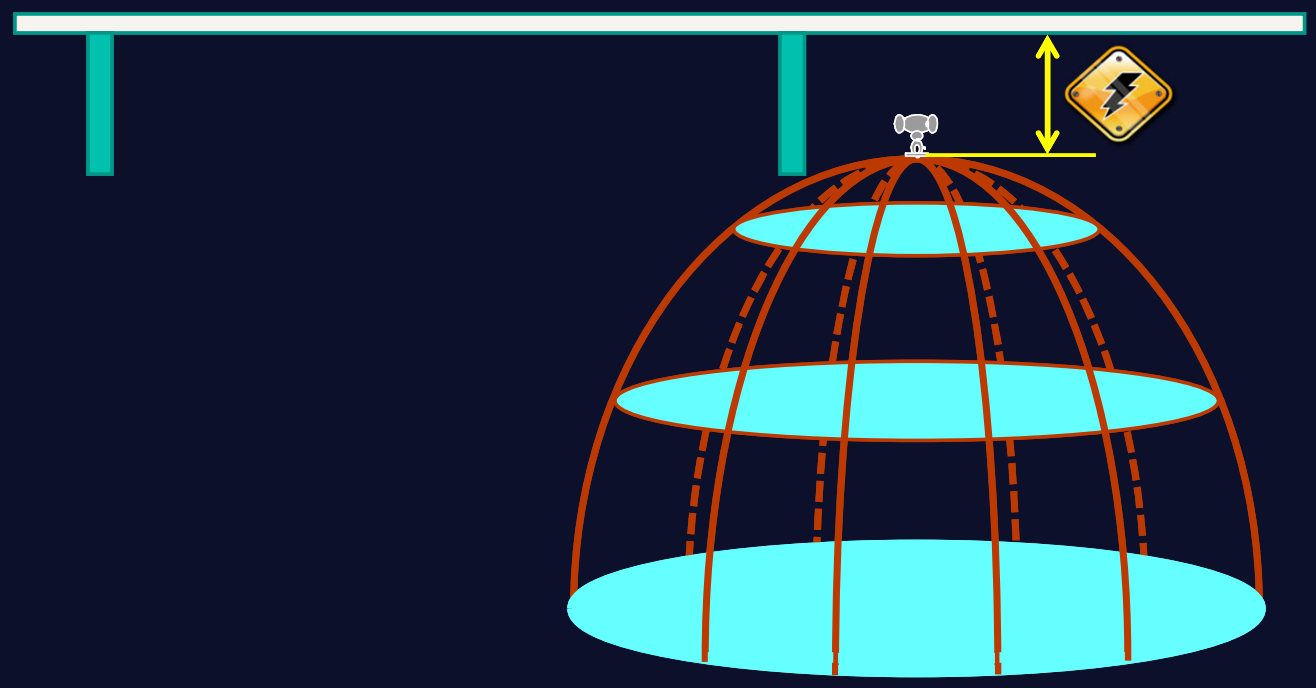
Obstruction at ceiling causes dry spot on floor area

Obstructions to sprinkler discharge pattern



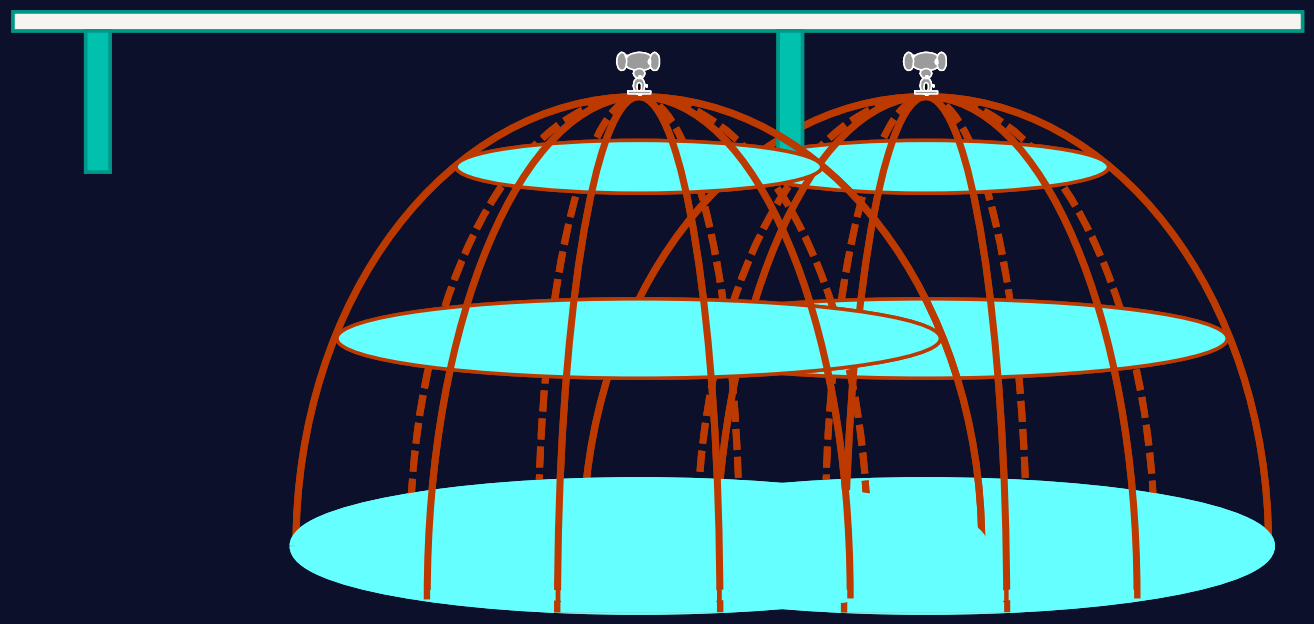
Moving the sprinkler downwards solves the obstruction problem, but…

Obstructions to sprinkler discharge pattern



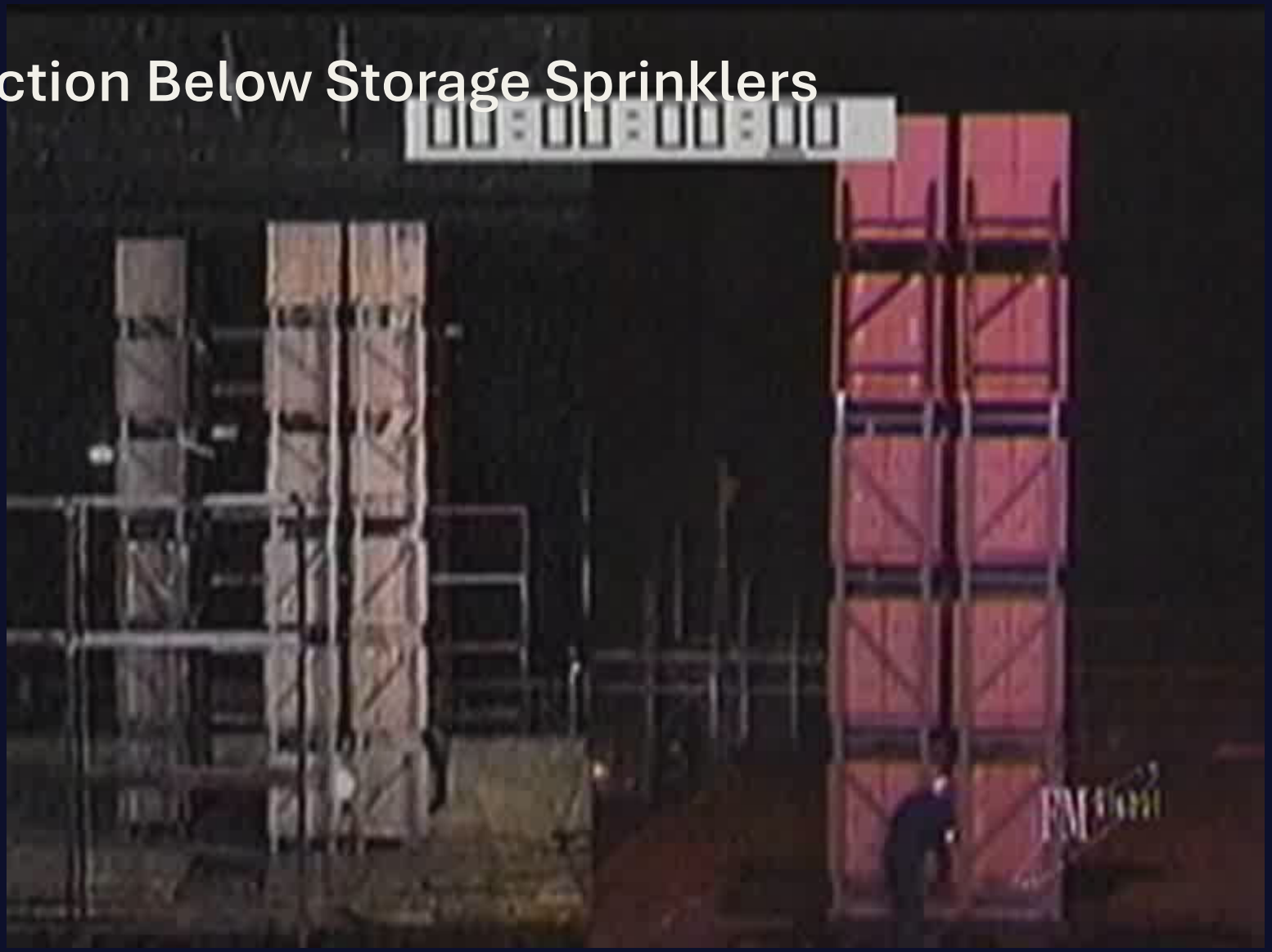
...there is now excessive clearance between ceiling and sprinkler

Obstructions to sprinkler discharge pattern



The solution is to place the neighboring sprinkler to cover the dry spot from the first sprinkler, still complying with the sprinkler spacing requirements

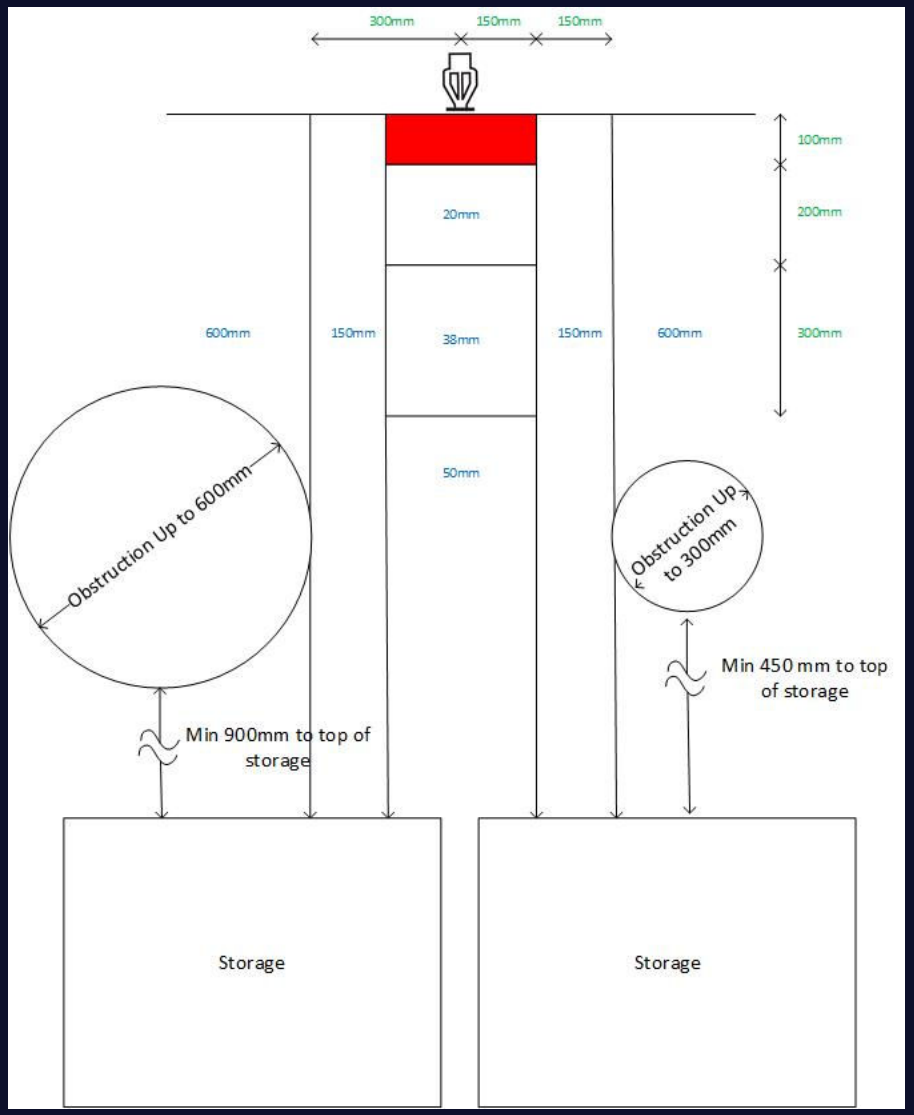
Obstruction Below Storage Sprinklers



GENERAL INSTALLATION RULES

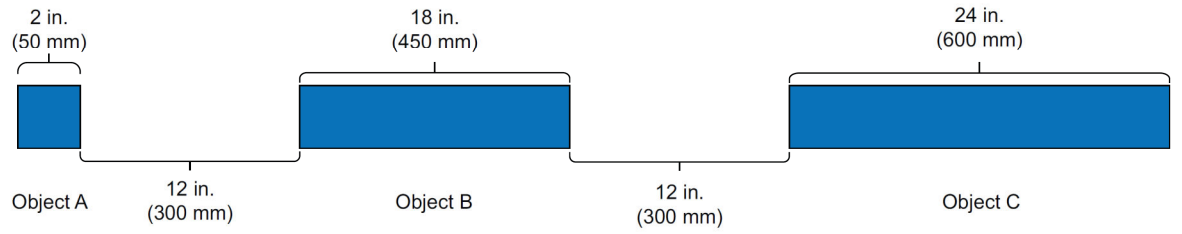
Obstructions Below Storage Sprinkler Umbrella Spray Pattern

- Diagram illustrates the maximum width (in blue) of obstruction allowed in an area below a sprinkler
- Object “width” is the lesser of width or length when viewed from above
- 300 to 600mm wide obstruction should be minimum 900mm above the top of storage
- 150 to 300mm obstructions should be minimum 450mm above the top of storage
- If obstructions are too large or too close to the top of storage install sprinklers below them



Grouped Obstructions

- Object is treated separately if
  - More than 3 x its width from the next object of the same or larger size
- Total width of a group does not need to include the spaces between each object



Object A = Individual Object
12 in. (300 mm) ≥ 3 x 2 in. (50 mm)

Objects B + C = Grouped Object
12 in. (300 mm) < 3 x 18 in. (450 mm)

Width of Grouped Object B + C = 42 in. (1050 mm)
18 in. (450 mm) + 24 in. (600 mm)

Storage Occupancy

Elevation View

Quick and standard response sprinklers in same area (Different RTI rating)

- Option 1:
  - Minimum 0.6m solid draft curtain between the areas.
  - 2.3m free of combustibles on the side of SR sprinklers
- Option 2:
  - Min 0.6m of elevation difference between the adjacent ceilings
  - SR sprinklers under the higher ceiling
  - 2.3m free of combustibles on the side of SR sprinklers

If QR

Heat/Smoke vents

- Preferably no smoke/heat vents
- Depending on size of the vent use flow chart based on:
  - Vent size
  - Wet or Dry sprinkler system
  - Vent always closed or open
- Potential for heat/smoke vents up to 3.7 m^2 without sprinklers

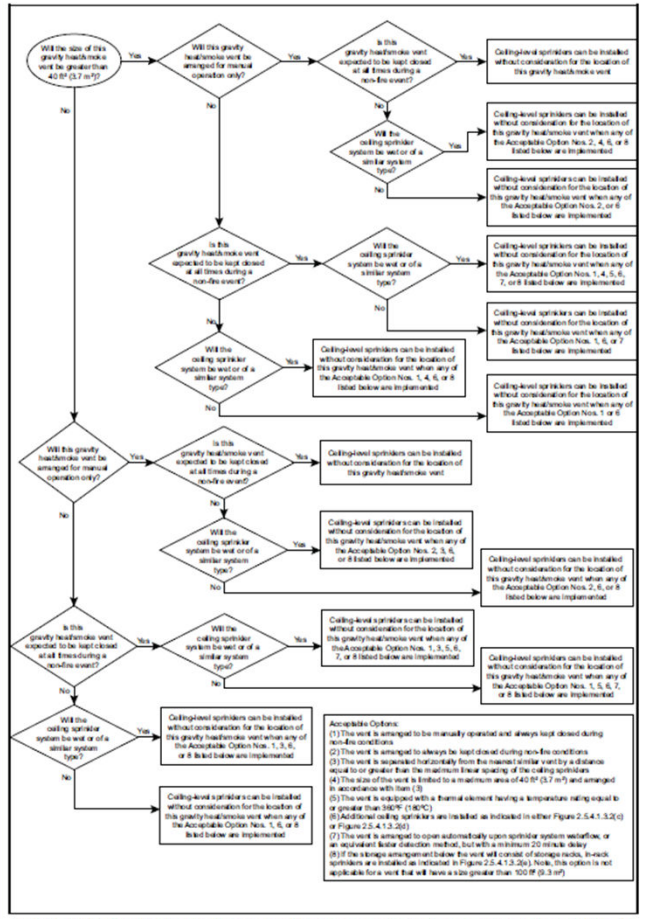
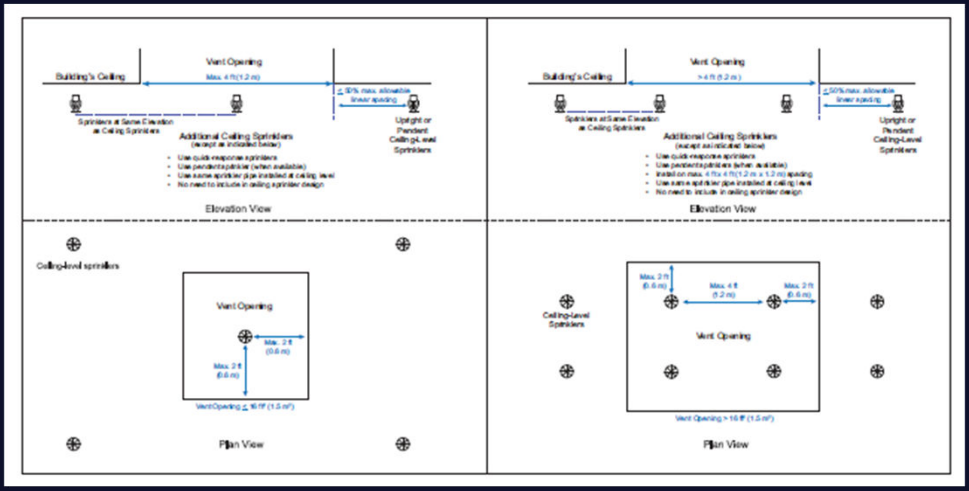


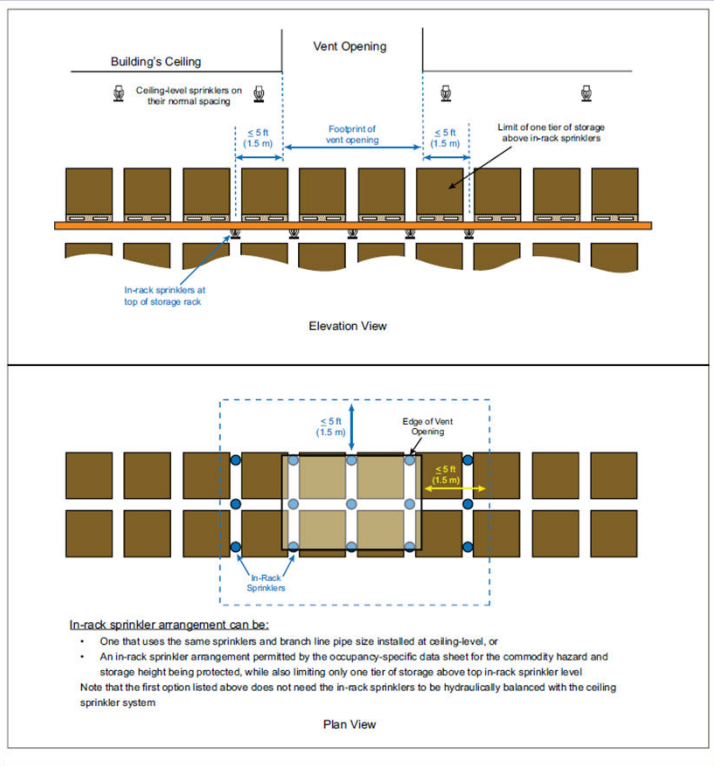
Fig. 2.5.4.1.3.2(b). Flowchart for potential recommendations when a gravity heat/smoke vent larger than 4 ft² (0.4 m²) in size must be installed over a storage occupancy

Heat/Smoke vents

The essentials:

- If needed per local requirements:
  - Operate manually and kept closed during non-fire condition
  - If above not possible:
    - Additional sprinklers under vent
    - Sprinklers in the rack under the vent area





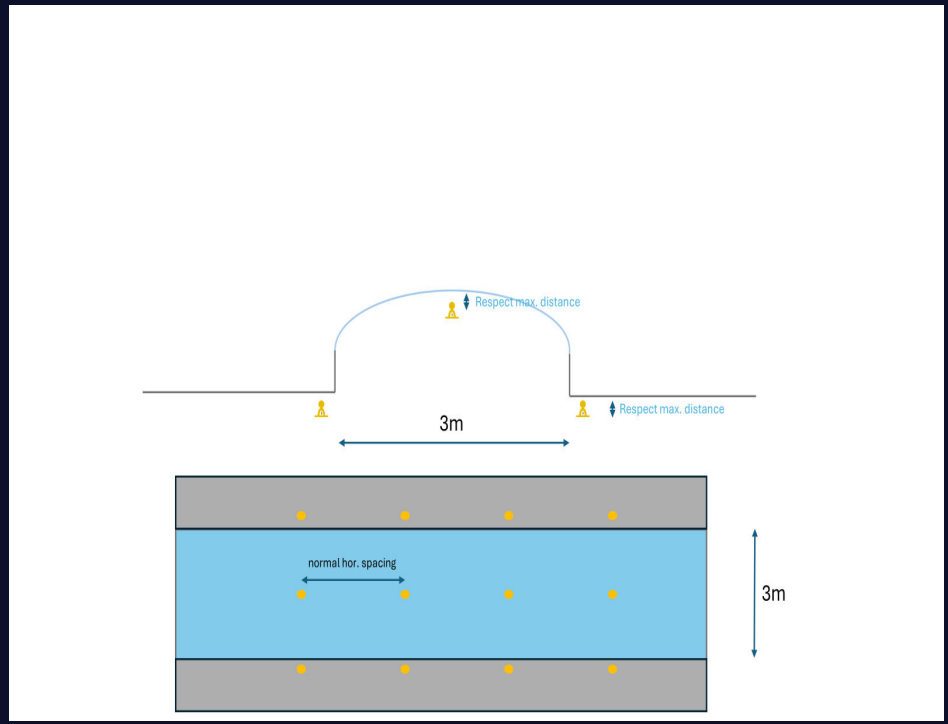
Skylights / Ceiling Pockets

If flat with the roof , no additional requirements except for recommendations of DS 1-57.

If higher than the ceiling, Install sprinklers in the footprint or use the drawing of ridge vents for sprinkler in the skylights.

For PC, FRP, PVC, PET, no dimension limit

For PMMA (acrylic) max 2.4m separated by 4.8m of noncombustible material.



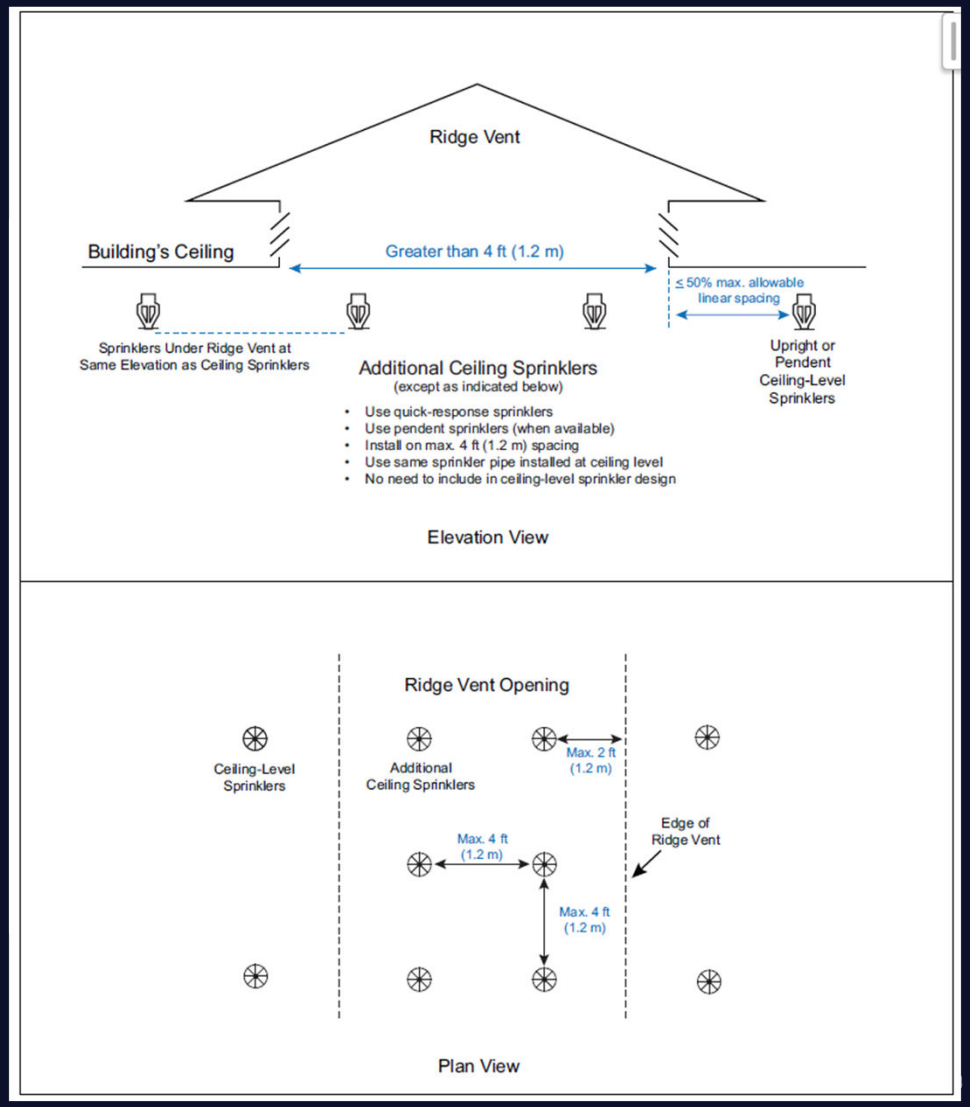
Skylights / Ceiling Pockets

If flat with the roof , no additional requirements except for recommendations of DS 1-57.

If higher than the ceiling, Install sprinklers in the footprint or use the drawing of ridge vents for sprinkler in the skylights.

For PC, FRP, PVC, PET, no dimension limit

For PMMA (acrylic) max 2.4m separated by 4.8m of noncombustible material.



In-Rack sprinkler design and alternative In-Rack design

In-Rack Sprinkler Designs

- Ceiling only protection solutions run out for up to cartoned unexpanded plastics to 15.2m in 16.9m buildings (Table 17b)
- Storage with solid shelves or open top containers in racks runs out of ceiling options at much lower heights
- Up to cartoned unexpanded plastic commodities in double row racks up to 2.7m wide can be usually protected with longitudinal flue only sprinklers, similar to EN12845
  - Special application 2.3.6.3 in DS8-9
- Uncartoned unexpanded plastic and over in buildings over 9m likely to need face sprinklers or horizontal barriers over the longitudinal flue only sprinklers
- Typical design is 2 x 7 sprinklers at 114 litres/min

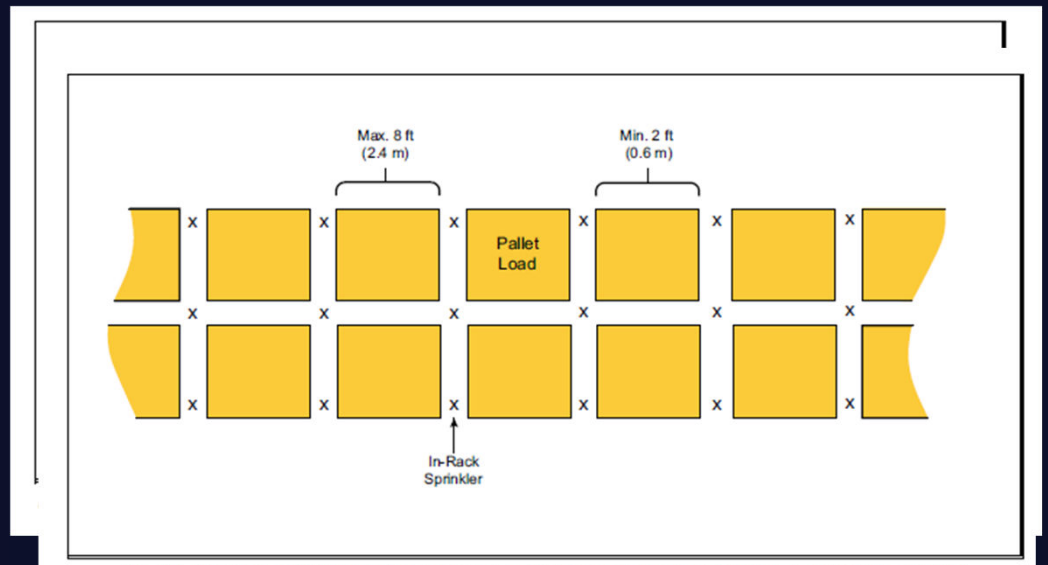
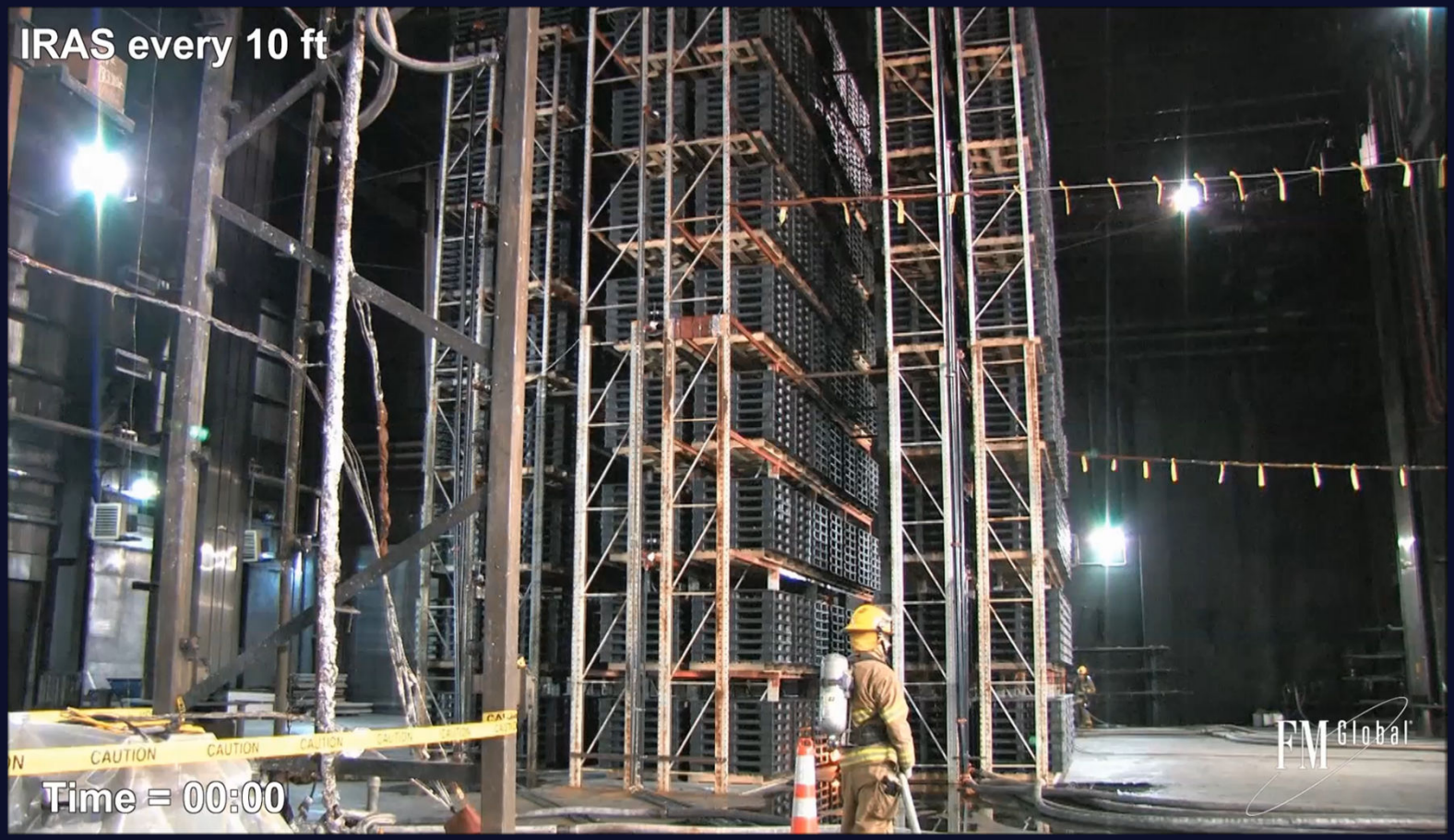


Fig. 13. Plan view of IRAS(E) horizontal in-rack sprinkler arrangement for double-row racks (face and flue)

EN12845 In-rack protection for FM UUP (2015)



In-rack sprinklers also needed

[redacted]

Balancing Ceiling and In-Rack Sprinklers

- **Some designs do not require ceiling and in-racks to be balanced**
  - Treat top level of in-racks as the floor in order to choose ceiling design
- **Most designs need to be balanced**
  - Ceiling demands are typically taken from the "ceiling only" tables
  - Based on
    - commodity,
    - in-rack arrangement,
    - storage height over the top level of in-racks
    - clearance from top of storage to ceiling

Table 13. Determining Applicable Protection Table and Ceiling Height for Ceiling Sprinkler Designs when Ceiling-Level Sprinkler Systems are Supplemented with In-Rack Sprinklers

Commodity Hazard	*IRAS Arrangement*	*Maximum Storage Height Above Top IRAS Level, ft (m)*	*Maximum Clearance Between Top of Storage and Ceiling, ft (m)**	*Applicable Ceiling-Level Sprinkler Protection Table*	*Ceiling Height in Applicable Protection Table, ft (m)*
Class 1, 2 and 3	IRAS(EO)	5 (1.5)	5 (1.5)	7	10 (3.0)
			20 (6.0)	7	20 (6.0)
		10 (3.0)	20 (6.0)	7	20 (6.0)
	IRAS(E)	5 (1.5)	10 (3.0)	7	10 (3.0)
			20 (6.0)	7	20 (6.0)
		10 (3.0)	20 (6.0)	7	20 (6.0)
Class 4, Cartoned Unexpanded Plastics and Cartoned Expanded Plastics	IRAS (EO)	5 (1.5)	5 (1.5)	8	10 (3.0)
			20 (6.0)	8	15 (4.5)
		10 (3.0)	15 (4.5)	8	15 (4.5)
			20 (6.0)	8	20 (6.0)
	IRAS (E)	5 (1.5)	10 (3.0)	8	10 (3.0)
			20 (6.0)	8	15 (4.5)
		10 (3.0)	20 (6.0)	8	15 (4.5)
Uncartoned Unexpanded Plastics and Uncartoned Expanded Plastics	IRAS (EO)	5 (1.5)	5 (1.5)	8	10 (3.0)
			20 (6.0)	8	15 (4.5)
		10 (3.0)	5 (1.5)	8	15 (4.5)
			15 (4.5)	10	15 (4.5)
			20 (6.0)	10	20 (6.0)
	IRAS (E)	5 (1.5)	5 (1.5)	8	10 (3.0)
			20 (6.0)	8	15 (4.5)
		10 (3.0)	5 (1.5)	8	15 (4.5)
			10 (3.0)	8	20 (6.0)
			15 (4.5)	10	15 (4.5)
			20 (6.0)	10	20 (6.0)

* When this distance is greater than 20 ft (6.0 m), see Section 2.3.3.7.3 for guidance.

Ceiling Design for Racks with In-Rack Sprinklers – Example 1

- **18m tall warehouse**
- **Cartoned unexpanded plastic commodity**
- **Longitudinal flue only protection, in-rack sprinklers in every transverse flue i.e. IRAS(E)**
- **1.2m of storage over top level of in-rack sprinklers**
- **Storage to 14.5m**
- **3.5m between top of storage and ceiling**

Table 13. Determining Applicable Protection Table and Ceiling Height for Ceiling Sprinkler Designs when Ceiling-Level Sprinkler Systems are Supplemented with In-Rack Sprinklers

Commodity Hazard	*IRAS Arrangement*	*Maximum Storage Height Above Top IRAS Level, ft (m)*	*Maximum Clearance Between Top of Storage and Ceiling, ft (m)**	*Applicable Ceiling-Level Sprinkler Protection Table*	*Ceiling Height in Applicable Protection Table, ft (m)*
Class 1, 2 and 3	IRAS(EO)	5 (1.5)	5 (1.5)	7	10 (3.0)
			20 (6.0)	7	20 (6.0)
		10 (3.0)	20 (6.0)	7	20 (6.0)
	IRAS(E)	5 (1.5)	10 (3.0)	7	10 (3.0)
			20 (6.0)	7	20 (6.0)
		10 (3.0)	20 (6.0)	7	20 (6.0)
Class 4, Cartoned Unexpanded Plastics and Cartoned Expanded Plastics	IRAS (EO)	5 (1.5)	5 (1.5)	8	10 (3.0)
			20 (6.0)	8	15 (4.5)
		10 (3.0)	15 (4.5)	8	15 (4.5)
			20 (6.0)	8	20 (6.0)
	IRAS (E)	5 (1.5)	10 (3.0)	8	10 (3.0)
			20 (6.0)	8	15 (4.5)
		10 (3.0)	20 (6.0)	8	15 (4.5)
Uncartoned Unexpanded Plastics and Uncartoned Expanded Plastics	IRAS (EO)	5 (1.5)	5 (1.5)	8	10 (3.0)
			20 (6.0)	8	15 (4.5)
		10 (3.0)	5 (1.5)	8	15 (4.5)
			15 (4.5)	10	15 (4.5)
			20 (6.0)	10	20 (6.0)
	IRAS (E)	5 (1.5)	5 (1.5)	8	10 (3.0)
			20 (6.0)	8	15 (4.5)
		10 (3.0)	5 (1.5)	8	15 (4.5)
			10 (3.0)	8	20 (6.0)
			15 (4.5)	10	15 (4.5)
			20 (6.0)	10	20 (6.0)

* When this distance is greater than 20 ft (6.0 m), see Section 2.3.3.7.3 for guidance.

Ceiling Design for Racks with In-Rack Sprinklers – Example 1

- **Result**
  - Table 8
  - 4.5m ceiling height

Table 8. Ceiling-Level Protection Guidelines for Class 4 and Cartoned Unexpanded Plastic Commodities in Open-Frame Rack Storage Arrangements

Max. Ceiling Height, ft (m)	Protection of Class 4 and Cartoned Unexpanded Plastic Commodities in Open-Frame Storage Racks; No. of AS @ psi (bar)																			
	Wet System, 160°F (70°C) Nominally Rated, Pendent Sprinklers										Wet System, 160°F (70°C) Nominally Rated, Upright Sprinklers							Dry System, 280°F (140°C) Nominally Rated, Upright Sprinklers		
	Quick Response						Standard Response				Quick Response				Standard Response			Standard Response		
	K11.2 (K160)	K14.0 (K200)	K16.8 (K240)	K22.4 (K320)	K25.2 (K360)	K25.2EC (K360EC)	K11.2 (K160)	K14.0 (K200)	K19.6 (K280)	K25.2 (K360)	K11.2 (K160)	K14.0 (K200)	K16.8 (K240)	K25.2EC (K360EC)	K11.2 (K160)	K16.8 (K240)	K25.2 (K360)	K11.2 (K160)	K16.8 (K240)	K25.2 (K360)
10 (3.0)	12 @ 7 (0.5)	9 @ 7 (0.5)	9 @ 7 (0.5)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 20 (1.4)	12 @ 7 (0.5)	9 @ 7 (0.5)	9 @ 16 (1.1)	9 @ 7 (0.5)	12 @ 7 (0.5)	9 @ 7 (0.5)	9 @ 7 (0.5)	6 @ 20 (1.4)	12 @ 7 (0.5)	9 @ 7 (0.5)	9 @ 7 (0.5)	16 @ 7 (0.5)	16 @ 7 (0.5)	16 @ 7 (0.5)
15 (4.5)	15 @ 16 (1.1)	12 @ 16 (1.1)	12 @ 11 (0.8)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 20 (1.4)	15 @ 16 (1.1)	12 @ 16 (1.1)	9 @ 16 (1.1)	10 @ 7 (0.5)	15 @ 16 (1.1)	12 @ 16 (1.1)	12 @ 11 (0.8)	6 @ 20 (1.4)	15 @ 16 (1.1)	12 @ 11 (0.8)	10 @ 7 (0.5)	20 @ 16 (1.1)	20 @ 7 (0.5)	20 @ 7 (0.5)
20 (6.0)	12 @ 30 (2.1)	12 @ 18 (1.2)	12 @ 13 (0.9)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 22 (1.5)	12 @ 30 (2.1)	12 @ 18 (1.2)	9 @ 16 (1.1)	12 @ 7 (0.5)	12 @ 30 (2.1)	12 @ 18 (1.2)	12 @ 13 (0.9)	6 @ 22 (1.5)	12 @ 30 (2.1)	12 @ 13 (0.9)	12 @ 7 (0.5)	20 @ 30 (2.1)	20 @ 13 (0.9)	20 @ 7 (0.5)
25 (7.5)	15 @ 65 (4.5)	9 @ 35 (2.4)	9 @ 24 (1.7)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 22 (1.5)	15 @ 65 (4.5)	15 @ 42 (2.9)	9 @ 16 (1.1)	12 @ 10 (0.7)	15 @ 65 (4.5)	12 @ 50 (3.5)	12 @ 35 (2.4)	6 @ 22 (1.5)	15 @ 65 (4.5)	15 @ 29 (2.0)	12 @ 20 (1.4)	20 @ 65 (4.5)	20 @ 29 (2.0)	20 @ 13 (0.9)
30 (9.0)		12 @ 50 (3.5)	12 @ 35 (2.4)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 30 (2.1)			9 @ 16 (1.1)	12 @ 15 (1.0)				6 @ 30 (2.1)			12 @ 20 (1.4)			30 @ 20 (1.4)
35 (10.5)		12 @ 75 (5.2)	12 @ 52 (3.6)	12 @ 29 (2.0)	12 @ 23 (1.6)	6 @ 60 (4.1)[a]			15 @ 25 (1.7)	9 @ 30 (2.1)				8 @ 40 (2.8)						
40 (12.0)		12 @ 75 (5.2)	12 @ 52 (3.6)	9 @ 50 (3.5)	9 @ 40 (2.8)					9 @ 30 (2.1)										

[a] An acceptable alternative design is 8 @ 40 (2.8) when a 12 ft (3.6 m) maximum linear spacing is used

Ceiling Design for Racks with In-Rack Sprinklers – Example 2

- **22m tall warehouse**
- **Uncartoned unexpanded plastic commodity**
- **Longitudinal and face sprinkler protection, in-rack sprinklers in every transverse flue i.e. IRAS(E)**
- **2.1 m of storage over top level of in-rack sprinklers**
- **Storage to 20m**
- **2m from top of storage to ceiling**

Table 13. Determining Applicable Protection Table and Ceiling Height for Ceiling Sprinkler Designs when Ceiling-Level Sprinkler Systems are Supplemented with In-Rack Sprinklers

Commodity Hazard	*IRAS Arrangement*	*Maximum Storage Height Above Top IRAS Level, ft (m)*	*Maximum Clearance Between Top of Storage and Ceiling, ft (m)**	*Applicable Ceiling-Level Sprinkler Protection Table*	*Ceiling Height in Applicable Protection Table, ft (m)*
Class 1, 2 and 3	IRAS(EO)	5 (1.5)	5 (1.5)	7	10 (3.0)
			20 (6.0)	7	20 (6.0)
		10 (3.0)	20 (6.0)	7	20 (6.0)
	IRAS(E)	5 (1.5)	10 (3.0)	7	10 (3.0)
			20 (6.0)	7	20 (6.0)
		10 (3.0)	20 (6.0)	7	20 (6.0)
Class 4, Cartoned Unexpanded Plastics and Cartoned Expanded Plastics	IRAS (EO)	5 (1.5)	5 (1.5)	8	10 (3.0)
			20 (6.0)	8	15 (4.5)
		10 (3.0)	15 (4.5)	8	15 (4.5)
			20 (6.0)	8	20 (6.0)
	IRAS (E)	5 (1			
		10 (3			
Uncartoned Unexpanded Plastics and Uncartoned Expanded Plastics	IRAS (EO)	5 (1.5)	5 (1.5)	8	10 (3.0)
			20 (6.0)	8	15 (4.5)
		10 (3.0)	5 (1.5)	8	15 (4.5)
			15 (4.5)	10	15 (4.5)
			20 (6.0)	10	20 (6.0)
	IRAS (E)	5 (1.5)	5 (1.5)	8	10 (3.0)
			20 (6.0)	8	15 (4.5)
		10 (3.0)	5 (1.5)	8	15 (4.5)
			10 (3.0)	8	20 (6.0)
			15 (4.5)	10	15 (4.5)
			20 (6.0)	10	20 (6.0)

* When this distance is greater than 20 ft (6.0 m), see Section 2.3.3.7.3 for guidance.

Add extra line of in-rack sprinklers

Ceiling Design for Racks with In-Rack Sprinklers – Example 1

- **Result**
  - Table 8
  - 6m ceiling height
- **Note this is the cartoned unexpanded plastics table despite the actual commodity being uncartoned**

Table 8. Ceiling-Level Protection Guidelines for Class 4 and Cartoned Unexpanded Plastic Commodities in Open-Frame Rack Storage Arrangements

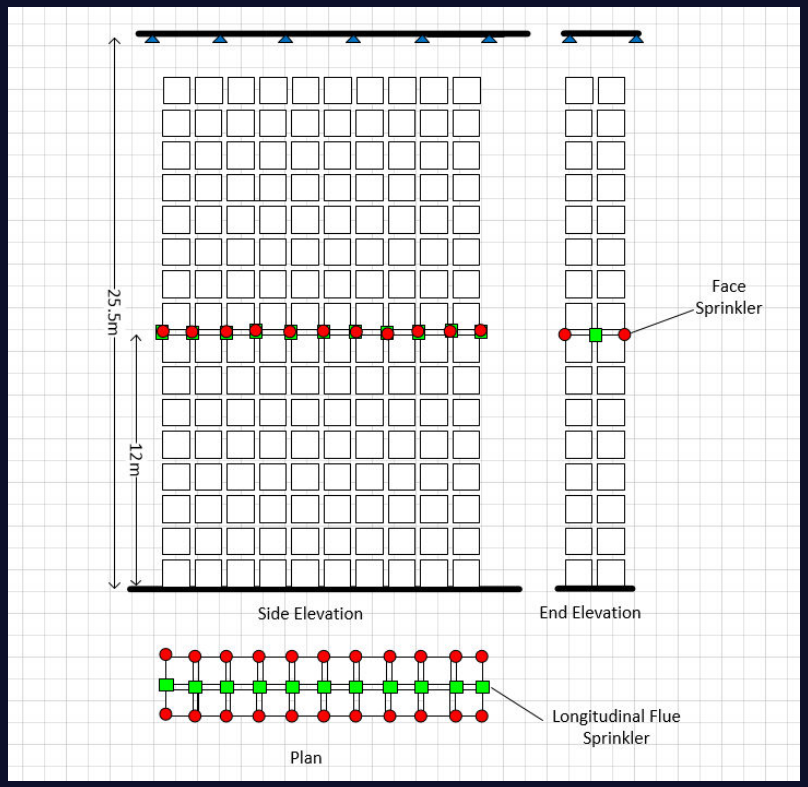
Max. Ceiling Height, ft (m)	Protection of Class 4 and Cartoned Unexpanded Plastic Commodities in Open-Frame Storage Racks; No. of AS @ psi (bar)																			
	Wet System, 160°F (70°C) Nominally Rated, Pendent Sprinklers										Wet System, 160°F (70°C) Nominally Rated, Upright Sprinklers							Dry System, 280°F (140°C) Nominally Rated, Upright Sprinklers		
	Quick Response						Standard Response				Quick Response				Standard Response			Standard Response		
	K11.2 (K160)	K14.0 (K200)	K16.8 (K240)	K22.4 (K320)	K25.2 (K360)	K25.2EC (K360EC)	K11.2 (K160)	K14.0 (K200)	K19.6 (K280)	K25.2 (K360)	K11.2 (K160)	K14.0 (K200)	K16.8 (K240)	K25.2EC (K360EC)	K11.2 (K160)	K16.8 (K240)	K25.2 (K360)	K11.2 (K160)	K16.8 (K240)	K25.2 (K360)
10 (3.0)	12 @ 7 (0.5)	9 @ 7 (0.5)	9 @ 7 (0.5)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 20 (1.4)	12 @ 7 (0.5)	9 @ 7 (0.5)	9 @ 16 (1.1)	9 @ 7 (0.5)	12 @ 7 (0.5)	9 @ 7 (0.5)	9 @ 7 (0.5)	6 @ 20 (1.4)	12 @ 7 (0.5)	9 @ 7 (0.5)	9 @ 7 (0.5)	16 @ 7 (0.5)	16 @ 7 (0.5)	16 @ 7 (0.5)
15 (4.5)	15 @ 16 (1.1)	12 @ 16 (1.1)	12 @ 11 (0.8)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 20 (1.4)	15 @ 16 (1.1)	12 @ 16 (1.1)	9 @ 16 (1.1)	10 @ 7 (0.5)	15 @ 16 (1.1)	12 @ 16 (1.1)	12 @ 11 (0.8)	6 @ 20 (1.4)	15 @ 16 (1.1)	12 @ 11 (0.8)	10 @ 7 (0.5)	20 @ 16 (1.1)	20 @ 7 (0.5)	20 @ 7 (0.5)
20 (6.0)	12 @ 30 (2.1)	12 @ 18 (1.2)	12 @ 13 (0.9)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 22 (1.5)	12 @ 30 (2.1)	12 @ 18 (1.2)	9 @ 16 (1.1)	12 @ 7 (0.5)	12 @ 30 (2.1)	12 @ 18 (1.2)	12 @ 13 (0.9)	6 @ 22 (1.5)	12 @ 30 (2.1)	12 @ 13 (0.9)	12 @ 7 (0.5)	20 @ 30 (2.1)	20 @ 13 (0.9)	20 @ 7 (0.5)
25 (7.5)	15 @ 65 (4.5)	9 @ 35 (2.4)	9 @ 24 (1.7)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 22 (1.5)	15 @ 65 (4.5)	15 @ 42 (2.9)	9 @ 16 (1.1)	12 @ 10 (0.7)	15 @ 65 (4.5)	12 @ 50 (3.5)	12 @ 35 (2.4)	6 @ 22 (1.5)	15 @ 65 (4.5)	15 @ 29 (2.0)	12 @ 20 (1.4)	20 @ 65 (4.5)	20 @ 29 (2.0)	20 @ 13 (0.9)
30 (9.0)		12 @ 50 (3.5)	12 @ 35 (2.4)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 30 (2.1)			9 @ 16 (1.1)	12 @ 15 (1.0)				6 @ 30 (2.1)			12 @ 20 (1.4)			30 @ 20 (1.4)
35 (10.5)		12 @ 75 (5.2)	12 @ 52 (3.6)	12 @ 29 (2.0)	12 @ 23 (1.6)	6 @ 60 (4.1)[a]			15 @ 25 (1.7)	9 @ 30 (2.1)				8 @ 40 (2.8)						
40 (12.0)		12 @ 75 (5.2)	12 @ 52 (3.6)	9 @ 50 (3.5)	9 @ 40 (2.8)					9 @ 30 (2.1)										

[a] An acceptable alternative design is 8 @ 40 (2.8) when a 12 ft (3.6 m) maximum linear spacing is used

FM Alternative In-Rack Schemes

- Traditional in-rack designs typically have sprinklers at 3m vertical intervals
- Alternative in-rack schemes can use up to 12m vertical spacing
- Can be used for all commodities covered by FM Global Data Sheet 8-9 but not open top combustible containers or racks with solid shelves
- Large sprinklers in flue and at face in every transverse flue
- Typical design for uncartoned unexpanded plastics
  - 10 heads at 455 lpm/head (5 heads each side of an aisle)
  - 9m vertical intervals
- Treat top level of in-rack sprinklers as the “floor” for the purposes of designing the ceiling system

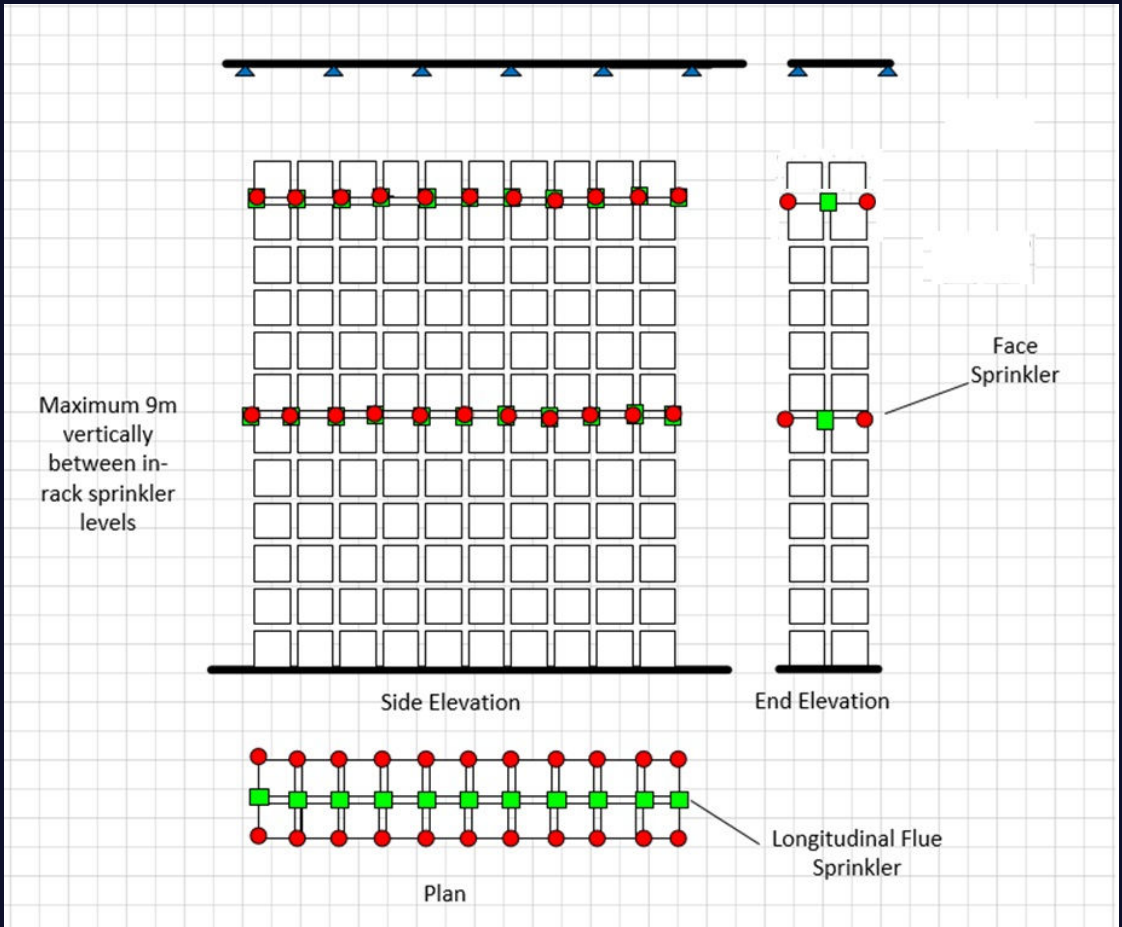
Typical Layout for Cartoned Unexpanded Plastics and Lower Hazard Commodities

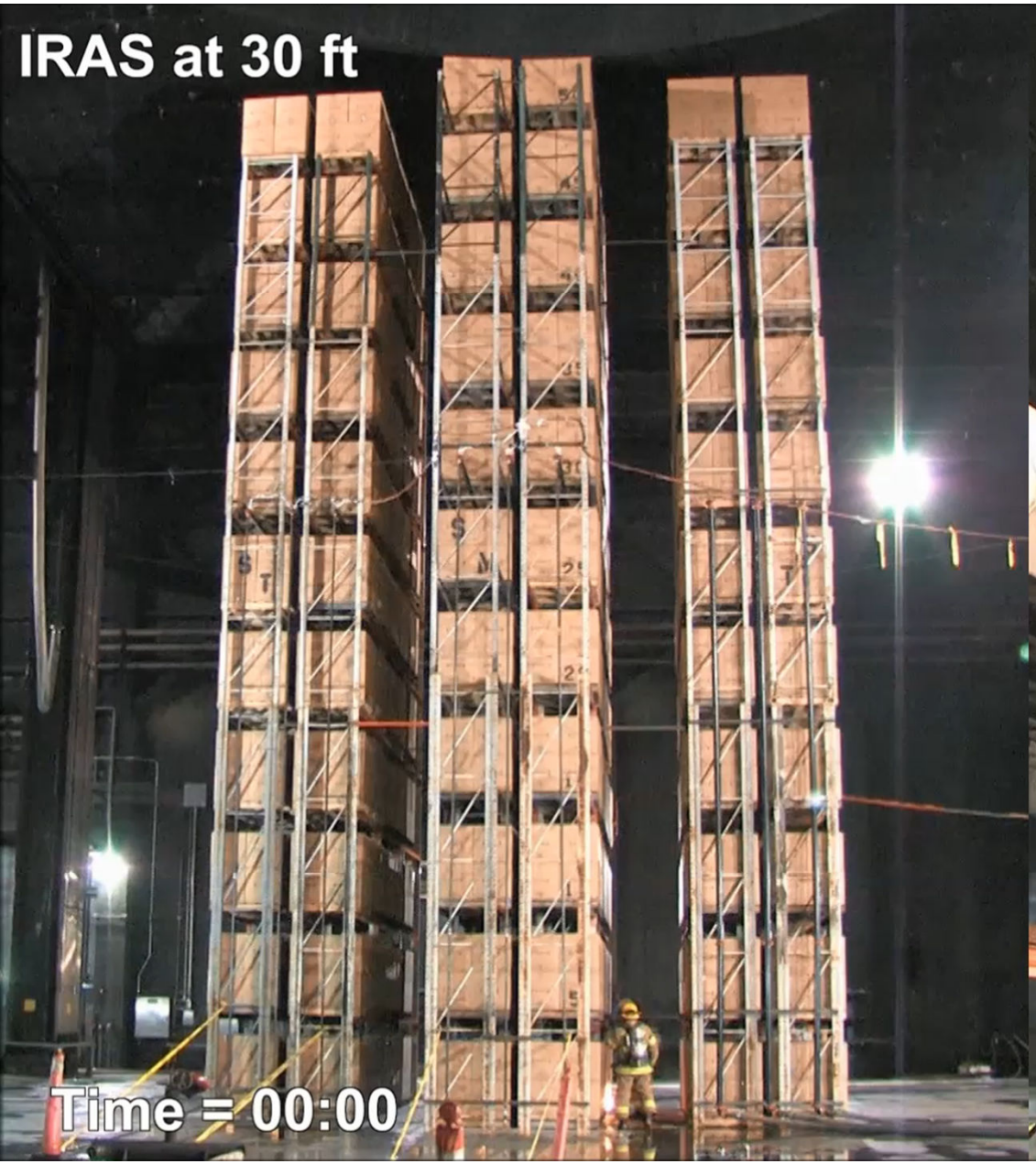


Future Proof!

- Design for the worst case, not for the most common. If CUP, can you trust it will be like this in the future?
- How does the storage look like in other warehouses?

Typical Layout for Uncartoned Plastics and Cartoned Expanded Plastics

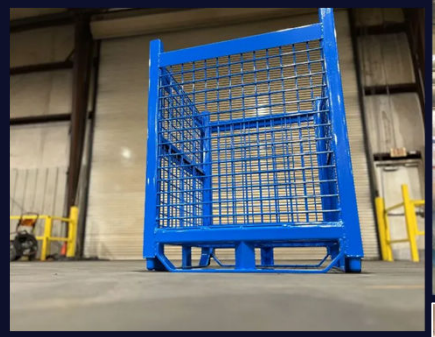


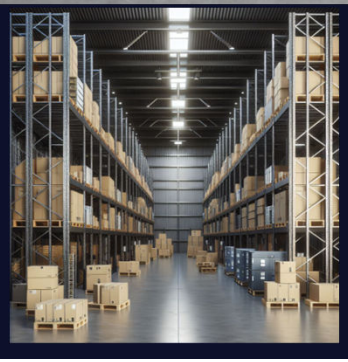

IRAS at 30 ft
Time = 00:00

IRAS at 40 ft
FM Global

Storage factors affecting the design

- Commodity
- Storage configuration
  - Solid piled/Palletized
  - Shelf storage
  - Rack storage
    - Single/double row racks
    - Multiple row racks
    - Drive through racks
  - Special cases
    - Open top Containers
    - Portable racks





Workshop

> To powerpoint master

Workshop

The Mansfield Company plans to enlarge its production and distribution facilities to enter global markets. The first step of the expansion includes the erection of a greenfield site in Belgium. The final location has not been decided yet; negotiations are still ongoing.

However, the project details have been finalized and include the erection of a storage Building No. 2 to occupy rack storage of finished products. This building is part of a distribution center and is used to store finished products awaiting final shipment to customers.

The storage building will house open frame rack storage of finished products, such as cable plugs and connectors (including attached cable trees) in cardboard boxes on wooden pallets.

FM Property Loss Prevention Data Sheets:

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

Workshop

- What is the commodity?
- Sprinkler design? Table used?
  - K-Factor, operating pressure, Operating sprinklers, temp rating, Sprinkler orientation, Response Time Index.
- How many sprinklers per branch line for hydraulic calculation?
- What is the hose demand and duration of water supply?
- Minimum and Maximum linear and area spacing requirements?

Workshop

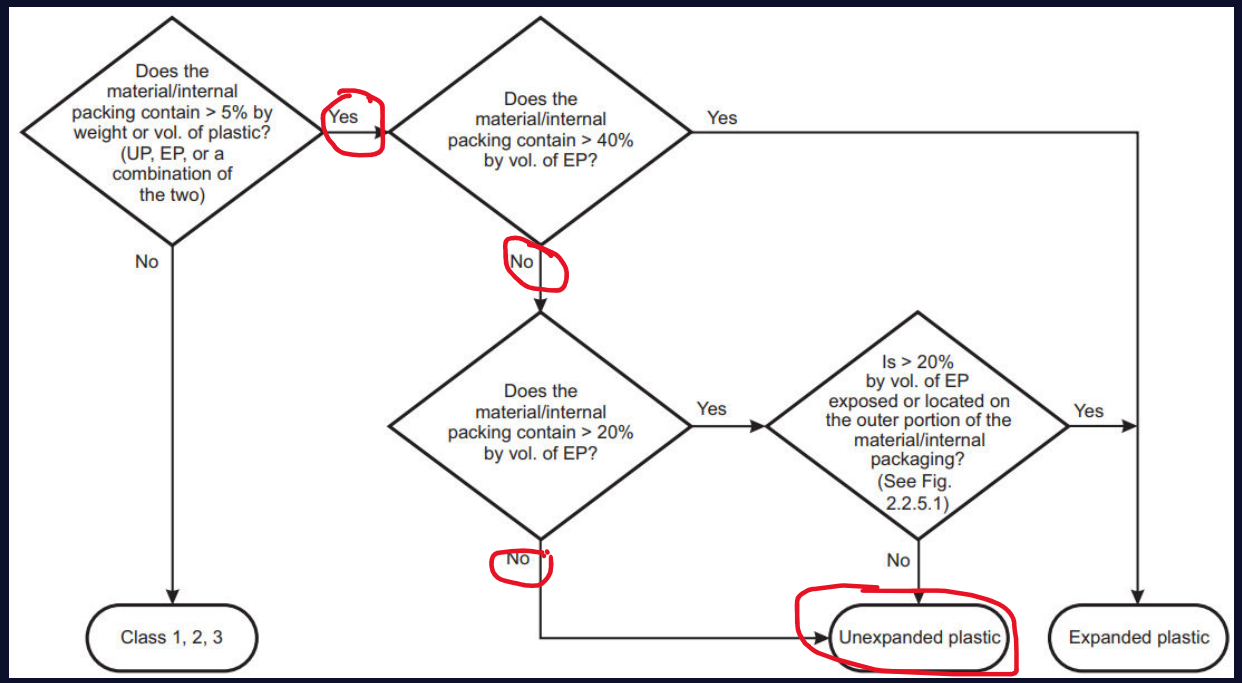
BUILDING AREA	8000 M^2
Ceiling height	10,5 m
Ceiling slope	5°
Building utilities	Heating, ventilation, pneumatic and power supply installations.
Wall construction	Mineral wool insulated metal panels on steel frame support construction (noncombustible).
Ceiling construction	Mineral wool insulated steel deck with polyethylene vapor barrier and glass fiber reinforced PVC roof cover, mechanically fastened, on steel beam support construction (noncombustible, unobstructed ceiling).
Occupancy	Storage of finished products in cardboard boxes on wooden pallets.
Storage arrangement	Open frame double-row rack storage up to 9 m high in overall 6 tiers. Racks are fixed-in-place.
Storage commodity description	Plastic plugs and connectors (including attached cable trees) in cardboard boxes on wooden pallets, made of polyethylene and polypropylene, cable insulations are PVC. For transport protection, cardboard boxes are fitted with a 1 cm thick extruded polystyrene foam liner. Plastic content per pallet load: Unexpanded plastic: 55% of total pallet load weight (excl. pallet) Expanded plastic: 15% of total pallet load volume (excl. pallet)

- What is the commodity?
- Sprinkler design? Table used?
  - K-Factor, operating pressure, Operating sprinklers, temp rating, Sprinkler orientation, Response Time Index.
- How many sprinklers per branch line for hydraulic calculation?
- What is the hose demand and duration of water supply?
- Minimum and Maximum linear and area spacing requirements?

Workshop answer key

Commodity

FM Data Sheet 8-1, Figure 2.2.7



+ Cardboard box

=

CUP

Workshop answer key

Sprinkler design

Table 8. Ceiling-Level Protection Guidelines for Class 4 and Cartoned Unexpanded Plastic Commodities in Open-Frame Rack Storage Arrangements

Protection of Class 4 and Cartoned Unexpanded Plastic Commodities in Open-Frame Storage Racks; No. of AS @ psi (bar)

Max. Ceiling Height, ft (m)	Wet System, 160ºF (70ºC) Nominally Rated, Pendent Sprinklers										Wet System, 160ºF (70ºC) Nominally Rated, Upright Sprinklers							Dry System, 280ºF (140ºC) Nominally Rated, Upright Sprinklers		
	Quick Response						Standard Response				Quick Response				Standard Response			Standard Response		
	K11.2 (K160)	K14.0 (K200)	K16.8 (K240)	K22.4 (K320)	K25.2 (K360)	K25.2EC (K360EC)	K11.2 (K160)	K14.0 (K200)	K19.6 (K280)	K25.2 (K360)	K11.2 (K160)	K14.0 (K200)	K16.8 (K240)	K25.2EC (K360EC)	K11.2 (K160)	K16.8 (K240)	K25.2 (K360)	K11.2 (K160)	K16.8 (K240)	K25.2 (K360)
10 (3.0)	12 @ 7 (0.5)	9 @ 7 (0.5)	9 @ 7 (0.5)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 20 (1.4)	12 @ 7 (0.5)	9 @ 7 (0.5)	9 @ 16 (1.1)	9 @ 7 (0.5)	12 @ 7 (0.5)	9 @ 7 (0.5)	9 @ 7 (0.5)	6 @ 20 (1.4)	12 @ 7 (0.5)	9 @ 7 (0.5)	9 @ 7 (0.5)	16 @ 7 (0.5)	16 @ 7 (0.5)	16 @ 7 (0.5)
15 (4.5)	15 @ 16 (1.1)	12 @ 16 (1.1)	12 @ 11 (0.8)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 20 (1.4)	15 @ 16 (1.1)	12 @ 16 (1.1)	9 @ 16 (1.1)	10 @ 7 (0.5)	15 @ 16 (1.1)	12 @ 16 (1.1)	12 @ 11 (0.8)	6 @ 20 (1.4)	15 @ 16 (1.1)	12 @ 11 (0.8)	10 @ 7 (0.5)	20 @ 16 (1.1)	20 @ 7 (0.5)	20 @ 7 (0.5)
20 (6.0)	12 @ 30 (2.1)	12 @ 18 (1.2)	12 @ 13 (0.9)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 22 (1.5)	12 @ 30 (2.1)	12 @ 18 (1.2)	9 @ 16 (1.1)	12 @ 7 (0.5)	12 @ 30 (2.1)	12 @ 18 (1.2)	12 @ 13 (0.9)	6 @ 22 (1.5)	12 @ 30 (2.1)	12 @ 13 (0.9)	12 @ 7 (0.5)	20 @ 30 (2.1)	20 @ 13 (0.9)	20 @ 7 (0.5)
25 (7.5)	15 @ 65 (4.5)	9 @ 35 (2.4)	9 @ 24 (1.7)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 22 (1.5)	15 @ 65 (4.5)	15 @ 42 (2.9)	9 @ 16 (1.1)	12 @ 10 (0.7)	15 @ 65 (4.5)	12 @ 50 (3.5)	12 @ 35 (2.4)	6 @ 22 (1.5)	15 @ 65 (4.5)	15 @ 29 (2.0)	12 @ 20 (1.4)	20 @ 65 (4.5)	20 @ 29 (2.0)	20 @ 13 (0.9)
30 (9.0)		12 @ 50 (3.5)	12 @ 35 (2.4)	9 @ 20 (1.4)	9 @ 20 (1.4)	6 @ 30 (2.1)			9 @ 16 (1.1)	12 @ 15 (1.0)				6 @ 30 (2.1)			12 @ 20 (1.4)			30 @ 20 (1.4)
35 (10.5)		12 @ 75 (5.2)	12 @ 52 (3.6)	12 @ 29 (2.0)	12 @ 23 (1.6)	6 @ 60 (4.1)[a]			15 @ 25 (1.7)	9 @ 30 (2.1)				8 @ 40 (2.8)						
40 (12.0)		12 @ 75 (5.2)	12 @ 52 (3.6)	9 @ 50 (3.5)	9 @ 40 (2.8)					9 @ 30 (2.1)										

[a] An acceptable alternative design is 8 @ 40 (2.8) when a 12 ft (3.6 m) maximum linear spacing is used

Workshop answer key

Sprinkler design

FM Data Sheet 8-9, Section 2.3.3, Table 1
(Determining number of sprinklers per branchline for ceiling sprinkler system hydraulic design)

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

FM Data Sheet 8-9, Table 14
(Hose demand and water supply duration design guidelines)

Sprinkler Type by Spacing	*No. of Sprinklers in Ceiling Design*	*Hose Demand, gpm (L/ min)*	*Duration, min*
Standard-coverage	Up to 12	250 (950)	60
	13 to 19	500 (1,900)	90
	20 or more	500 (1,900)	120
Extended-coverage	Up to 6	250 (950)	60
	[a]7 to 9	500 (1,900)	90
	10 or more	500 (1,900)	120

Workshop answer key

Sprinkler design

FM Data Sheet 2.0, Section 2.5.4.3.1, Table 2.5.4.3.1.1
(Spacing of ceiling-level storage sprinklers under unobstructed ceiling construction)

Ceiling Height, ft (m)	*Sprinkler K-Factor*	*Sprinkler Orientation*	*Sprinkler RTI Response*	*Sprinkler Linear Spacing, ft (m)*		*Sprinkler Area Spacing, ft² (m²)*	
				Min.	Max.	Min.	Max.
Up to 30 (9.0)	11.2 (160), 14.0 (200), 16.8 (240), 19.6 (280), 22.4 (320), 25.2 (360), or 33.6 (480)	Pendent or Upright	Quick or Standard	8 (2.4)	12 (3.7)	64 (6.0)	100 (9.3)
	25.2EC (360EC)	Pendent or Upright	Quick	10 (3.0)	14 (4.3)	100 (9.3)	196 (18.2)
Over 30 (9.0)	11.2 (160), 14.0 (200), 16.8 (240), 19.6 (280), 22.4 (320), 25.2 (360), or 33.6 (480)	Pendent or Upright	Quick or Standard	8 (2.4)	10 (3.0)	64 (6.0)	100 (9.3)
	25.2EC (360EC)	Pendent or Upright	Quick	10 (3.0)	14 (4.3)	100 (9.3)	196 (18.2)

Workshop

- What is the commodity?
- Sprinkler design? Table used?
  - K-Factor, operating pressure, Operating sprinklers, temp rating, Sprinkler orientation, Response Time Index.
- How many sprinklers per branch line for hydraulic calculation?
- What is the hose demand and duration of water supply?
- Minimum and Maximum linear and area spacing requirements?

- Carton Unexpanded Plastic
- Table 8
- ex. 12 K360 @1.6 bar, 70°C, QR pendent
- 4
- 950l/min and 60 min
- Minimum 2.4m, maximum 3m spacing and maximum 9,3m^2 per sprinkler

> To er