AFSA Presents

Fire Protection of Storage Facilities
Session 1

Presented by
Speaker

James Golinveaux
Sr. Vice President Research & Development
Tyco Fire & Building Products

Speaker

James Golinveaux has been involved in the sprinkler industry since the early 1980s. He co-authored the published article, "Fire Test Performance of Extra Large Orifice Sprinklers, in Rack Storage of Group A Plastics in Warehouse-Type Retail Occupancies," and is also named on two U.S. patents relating to automatic sprinklers. He is a member on numerous committees such as NFPA, NFPE, ICBO, SFPE and SBCCI.
Initial Considerations

- Determining commodity classification
- Identifying storage arrangements
- Storage height & clearance
- Automatic Sprinklers for Storage Protection
- NFPA 13-2002, Chapter 12

Some Storage Hazards not addressed by NFPA 13

- Sloped Ceilings
- Shelf Storage over 15’ (4.57 m)
- Rack Storage of Exposed Expanded Plastics
- Rack Storage of Plastics with Control Mode Density/Area Sprinklers with Clearance greater than 10’
- Open top five sided combustible containers
Commodity Classification

• How will the product burn
• How will the burning product respond to the application of sprinkler discharge

CLASS I Commodity

• Examples:
  – Alcoholic Beverages
    Cartoned or uncartoned
    • Up to 20 percent alcohol in metal, glass, or ceramic containers
  – Canned Foods In ordinary cartons
  – Frozen Foods Non-waxed, non-plastic packaging
  – Plastic Containers
    • Noncombustible liquids or semi liquids in plastic containers less than 5 gal (18.9 L) capacity
CLASS II Commodity

• Examples:
  – Alcoholic Beverages
    • Up to 20 percent alcohol in wood containers
  – Frozen Foods Waxed-paper containers, cartoned
  – Plastic Containers
    • Noncombustible liquids or semiliquids (such as ketchup) in plastic containers with nominal wall thickness of 1/4 in. (6.4 mm) or less and larger than 5 gal (18.9 L) capacity

CLASS III Commodity

• Examples:
  – Aerosols Cartoned or uncartoned - Level 1
  – Frozen Foods - Plastic trays
  – Paper Products
    • Books, magazines, stationery, plastic-coated paper food containers, newspapers, cardboard games, cartoned tissue products
  – PVC (polyvinyl chloride)
    • Flexible (e.g., cable jackets, plasticized sheets)
    • Rigid (e.g., pipe, pipe fittings)
    • Bagged resins
CLASS IV Commodity

A mixture of paper and plastic cups
(5 - 15 % by weight & 5 - 25 % by volume)
on wood pallets.

• Examples:
  – Liquor -100 proof or less, 1 gal (3.8 L) or less, cartoned
    • Glass (palletized)
    • Plastic bottles
  – Diapers
    • Disposable with plastics and non-woven fabric (in cartons)
  – Paints - Friction-top cans, cartoned
    • Oil based

Plastics

• Plastic Types
  – Group A - most severe hazard
  – Group B - similar to Class IV commodities
  – Group C - similar to Class III commodities

• Plastic materials
  – Cartoned vs. Uncartonened (Exposed)
  – Expended vs. Unexpended
Unexpanded Group A Plastics

16-oz Polystyrene Plastic Jars in compartmented cardboard cartons

Expanded Group A Plastics

Expanded Polystyrene Trays Exposed
Storing Materials on Plastic Pallets

• One class upgrade for unreinforced plastic pallets
  – Class II -> Class III
  – Class IV -> Group A Plastics

• Two class upgrade for reinforced plastic pallets
  – Class II -> Class IV
  – Class IV -> Group A Plastics

Plastic Pallet Types

• Un-reinforced plastic pallets
  – Melt fairly easily in a fire and are less of a fire challenge
  – Material
    • Polypropylene
    • high-density polyethylene

• Reinforced plastic pallets
  – Hold their structure and integrity longer allowing air gaps to remain longer within the pallet, which fuels the flames and creates a more intense fire
  – Material
    • Polypropylene
    • high-density polyethylene

• Classification by Listing
**Encapsulation**

- Plastic sheet completely enclosing the sides and top of a pallet load containing a combustible commodity
- Combustible commodities individually wrapped in plastic sheeting and stored exposed in a pallet load
- Where there are holes or voids in the plastic on the top of the carton that exceed more than half of the area of the cover, the term *encapsulated* does not apply

**Mixed Commodities**

- Mixed commodity storage protected using highest classified commodity & storage arrangement.
- The protection requirements for the lower commodity may be used when:
  - No more than 10 pallet loads of a higher hazard commodity in area > 40,000 ft² (3716 m²) &
  - Higher hazard commodity is randomly dispersed with no adjacent loads in any direction (including diagonally) &
  - Where the ceiling protection is based on Class I - II commodities, the allowable number of pallet loads for Class IV or Group A plastics is reduced to five.
Other types of Commodities

- Idle Pallet
- Based Cotton
- Rolled Paper
- Rubber Tire

Aisles

- The clear space normally maintained between commodities stored in racks or on the floor for the transfer of commodities to or from the rack or storage pile.
Flue Spaces

- The open spaces between rows of storage.
- Rack Storage
  - Longitudinal flue spaces are perpendicular to the direction of loading
  - Transverse flue spaces are parallel to the direction of loading
- Solid-piled & palletized storage
  - Vertical flue spaces may run in either direction

Array

- **Closed Array.** A storage arrangement where air movement through the pile is restricted because of 6-in. (152-mm) or less vertical flues.
- **Open Array.** A storage arrangement where air movement through the pile is enhanced because of vertical flues larger than 6 in. (152 mm).
Pile Stability

• **Stable Piles:** Arrays where collapse, spillage of content, or leaning of stacks across flue spaces is not likely to occur soon after initial fire development.

• **Unstable Piles:** Arrays where collapse, spillage of contents, or leaning of stacks across flue spaces occurs soon after initial fire development.

Storage Arrangements

• Miscellaneous Storage
• Idle Pallet Storage
• Solid Pile Storage
• Palletized Pile Storage
• Rack Storage
Miscellaneous Storage

- Storage must be incidental to another occupancy use group.

Idle Pallet storage

- Wood Pallets
- Plastic Pallets
Solid-Pile, Palletized, Bin Box & Shelf Storage

• **Shelf Storage.** Storage on structures less than 30” (76.2 cm) deep with shelves usually 2’ (0.6 m) apart vertically and separated by approximately 30” (76.2-cm) aisles.
Rack Storage - Single-Row Rack

- Racks that have no longitudinal flue space and that have a width up to 6 ft (1.8 m) with aisles at least 3.5 ft (1.1 m) from other storage.

Rack Storage - Double-Row Rack

- Two single-row racks placed back-to-back having a combined width up to 12 ft (3.7 m), with aisles at least 3.5 ft (1.1 m) on each side.
Rack Storage - Multiple-Row Rack

- Racks greater than 12 ft (3.7 m) wide or single- or double-row racks separated by aisles less than 3.5 ft (1.1 m) wide having an overall width greater than 12 ft (3.7 m).

Movable Racks & Portable Racks
Solid Shelving

- Fixed in place, slatted, wire mesh or other type of shelves located within racks.
- The area of a solid shelf is defined by perimeter aisle or flue space on all four sides.
- Solid shelves having an area equal to or less than 20 sq. ft. are open racks.
- Shelves of wire mesh, slates, or other materials more than 50% open, where the flue spaces are maintained are open racks.

Storage Height & Clearance

- The higher the storage the more challenging the fire
- Increased clearance delays sprinkler operation time, resulting in a larger fire size at the time of operation
- Increased clearance results in a larger fire plume above the top of storage, which reduces the ability of water from sprinklers to reach the seat of a fire.
- The minimum clearance between the sprinkler deflector and top of storage allows the proper spray pattern to develop.
Sprinkler Types used in Storage Occupancies

• Control-Mode Sprinklers
  – Standard Coverage Upright & Pendent Sprinklers
  – Extended Coverage Upright & Pendent Sprinklers
  – Control-Mode Specific-Application (CMSA) Sprinklers
  – Intermediate Level/In-rack Sprinklers

• Suppression-Mode Sprinklers

Control Mode Sprinklers

• Limiting the size of a fire by distribution of water so as to control the heat release rate and pre-wet adjacent combustibles, while controlling ceiling gas temperatures to avoid structural damage.
NFPA 13 K-factor Requirements for Storage Protection

<table>
<thead>
<tr>
<th>Density</th>
<th>K-factor</th>
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<tbody>
<tr>
<td>12.1.13.1 Storage Density 0.2 gpm/sq.ft. (8.2 mm/min) or less</td>
<td>5.6 &amp; larger</td>
</tr>
<tr>
<td>12.1.13.2 Storage Density 0.34 gpm/sq.ft. (13.9 mm/min) or less</td>
<td>8.0 &amp; larger</td>
</tr>
<tr>
<td>12.1.13.3 Storage Density greater than 0.34 gpm/sq.ft. (13.9 mm/min)</td>
<td>11.2 &amp; larger</td>
</tr>
</tbody>
</table>

Standard Spray Standard Coverage Sprinklers

- **TFP TY-L & Viking M Up & Pend**: 5.6 & 8.0 K-factor
- **TFP ELO-231 & Viking M Up & Pend**: 11.2 K-factor
- **Reliable G VELO Pend**: 14.0 K-factor
- **TFP K17-231 UP & Pend**: 16.8 K-factor
### Standard Coverage Upright & Pendent Sprinklers

<table>
<thead>
<tr>
<th>Construction Type</th>
<th>Protection Area</th>
<th>Spacing (maximum)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ft² m²</td>
<td>ft m</td>
</tr>
<tr>
<td>All</td>
<td>100 9.3</td>
<td>12 3.7</td>
</tr>
</tbody>
</table>
|                   |         | Final buildings bay 25 ft (7.6 m) wide 12 ft (3.7 m)
|                   |         | shall be permitted |
| All               | 130 12.1 | 15 4.6 |
|                   |         | Hydraulically calculated with density <0.25 |

### Pressure Comparison at 100 sq. ft. Spacing

<table>
<thead>
<tr>
<th>Pressure (PSI)</th>
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Extended Coverage Sprinklers for Extra Hazard & Storage Occupancies

- Traditional Sprinklers limited to 100 sq.ft. (9.3 m²)
- EC-25 can cover up to 196 sq.ft. (18.2 m²)
- Max. distance Between Sprinklers: 14’ (4.3 m)
- Same spacing rules as Standard Spray (SxL)
- Obstruction Rules:
  - FM: Standard Coverage (3x)
  - UL: Extended Coverage (4x)

Control Mode Specific Application (CMSA) sprinklers

- **Specific Application Control Mode Sprinkler For Storage Use.** A type of spray sprinkler listed at a minimum operating pressure or density with a specific number of operating sprinklers for a given protection scheme.
- **Large Drop Sprinkler.** A type of specific application control mode sprinkler that is capable of producing characteristic large water droplets and that is listed for its capability to provide fire control of specific high-challenge fire hazards.
CMSA Sprinklers

<table>
<thead>
<tr>
<th>Construction Type</th>
<th>Protection Area</th>
<th>Maximum Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ft²</td>
<td>m²</td>
</tr>
<tr>
<td>Noncombustible unobstructed</td>
<td>130</td>
<td>12.1</td>
</tr>
<tr>
<td>Noncombustible obstructed</td>
<td>130</td>
<td>12.1</td>
</tr>
<tr>
<td>Combustible unobstructed</td>
<td>130</td>
<td>12.1</td>
</tr>
<tr>
<td>Combustible obstructed</td>
<td>100</td>
<td>9.3</td>
</tr>
<tr>
<td>Rack storage applications</td>
<td>100</td>
<td>9.3</td>
</tr>
</tbody>
</table>

Intermediate Level Sprinkler/Rack Storage Sprinklers

A sprinkler equipped with integral shields to protect its operating elements from the discharge of sprinklers installed at higher elevations.

- **TFP TY-L**
  - Intermediate Level Pendent
- **Viking M**
  - Intermediate Level Upright
Intermediate Level Sprinkler/Rack Storage Sprinklers

A sprinkler equipped with integral shields to protect its operating elements from the discharge of sprinklers installed at higher elevations.

Suppression Sprinklers

- Vertical fire spread is reversed
- Sprinklers operate quickly, while heat release is small & reduce heat radiation
- High density water delivered direct to the base area of fire
- Fewer sprinklers operate, less water damage
- Design parameters much more critical
**Required Delivered Density - RDD**

- *Required Delivered Density* - the minimum amount of water needed to suppress a fire of a particular storage commodity.

**Actual Delivered Density - ADD**

*Actual Delivered Density* – the rate water is actually deposited from operating sprinklers onto the horizontal surface of a burning combustible array.
Fire Plume Penetration

Response Time Index - RTI

- RTI - measures the speed of response of the heat sensitive element

- Traditionally Fast Response Sprinklers have a thermal element with an RTI of 50 (meters-seconds)$^{1/2}$ or less. ESFR's must have a thermal element with an RTI of 36 (meters-seconds)$^{1/2}$ or less

- Standard Response Sprinklers have a thermal element with an RTI of 80 (meters-seconds)$^{1/2}$ or more.

Strut – 110 m-$s^{1/2}$  
Glass Bulb (5mm) - 105 m-$s^{1/2}$  
Fusible Link – 26 m-$s^{1/2}$  
Glass Bulb (3mm) - 36 m-$s^{1/2}$  
Glass Bulb (2.5mm) - 22 m-$s^{1/2}$  
Heat Fin - 26 m-$s^{1/2}$
RDD, ADD, and RTI

- The smaller the fire, the less water is needed (= lower RDD)
- The larger the fire, the less water actually reaches it (= lower ADD)
- If the response is quick enough, early suppression can be achieved

Why Choose an ESFR?

- 11.2 & 14 K Spray Sprinklers
  - 27' (8.2 m) Build.
  - 6.1 m (20') Stor.
  - 0.6 gpm/ft²
  - (24, 4 mm/min)

- 16.8 K Spray Sprinkler
  - 30' (9.1 m) Build.
  - 25' (7.6 m) Stor.
  - 0.8 gpm/ft²
  - (32,6 mm/min)

- 14 & 16.8 K ESFR's
  - 40' (12.2 m) Build.
  - 35' (10.7 m) Stor.
  - ESFR-1
  - 75 psi (5,17 bar)

- 25.2 K ESFR's
  - 45' (13.7 m) Build.
  - 40' (12.2 m) Stor.
  - ESFR-17
  - 52 psi (3,59 bar)
  - 40 psi (2,76 bar)
ESFR Sprinklers

Early Suppression Fast-Response (ESFR) Sprinkler. A type of fast-response sprinkler that is listed for its capability to provide fire suppression of specific high-challenge fire hazards.

ESFR Sprinklers

<table>
<thead>
<tr>
<th>Construction Type</th>
<th>Protection Area (ft²)</th>
<th>Spacing (ft)</th>
<th>Spacing (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noncombustible unobstructed</td>
<td>100</td>
<td>12</td>
<td>3.7</td>
</tr>
<tr>
<td>Noncombustible obstructed</td>
<td>100</td>
<td>12</td>
<td>3.7</td>
</tr>
<tr>
<td>Combustible unobstructed</td>
<td>100</td>
<td>12</td>
<td>N/A</td>
</tr>
<tr>
<td>Combustible obstructed</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Ceiling-Roof Heights up to 30 ft (9.1 m)

<table>
<thead>
<tr>
<th>Construction Type</th>
<th>Protection Area (ft²)</th>
<th>Spacing (ft)</th>
<th>Spacing (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noncombustible unobstructed</td>
<td>100</td>
<td>10</td>
<td>3.1</td>
</tr>
<tr>
<td>Noncombustible obstructed</td>
<td>100</td>
<td>10</td>
<td>3.1</td>
</tr>
<tr>
<td>Combustible unobstructed</td>
<td>100</td>
<td>10</td>
<td>N/A</td>
</tr>
<tr>
<td>Combustible obstructed</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Ceiling-Roof Heights over 30 ft (9.1 m)
Distribution Pattern – ESFR Sprinklers

- ESFR sprinklers combine fast response with water delivery properties to provide a heavy, well distributed discharge pattern that ensures sufficient penetration of water to suppress the fire
- Both of these criteria must be satisfied to achieve fire suppression

Chapter 12 - Storage

- 12.1 - General
- 12.2 - Fire Control Approach for the Protection of Commodities That are Stored Palletized, Solid Piled, Bin Boxes, or Shelf Storage
- 12.3 - Protection of Commodities Stored on Racks
- 12.4 - Protection of Rubber Tire Storage
- 12.5 - Protection of Baled Cotton Storage
- 12.6 - Protection of Roll Paper Storage
- 12.7 - Special Designs
12.1 General

• The requirements of Section 12.1 shall apply to all storage arrangements and commodities unless modified by specific section in Chapter 12.

12.1.1 Roof Vents and Draft Curtains

• Sprinkler protection criteria are based on the assumption that roof vents and draft curtains are not being used.
12.1.2 Building Height

- Max. building height measured to the underside of the roof deck or ceiling.
- ESFR sprinklers shall be used only in buildings equal to, or less than, the height of the building for which they have been listed.
- Large drop, control mode specific application & ESFR sprinklers can protect:
  - ordinary hazard
  - storage of Class I - IV commodities
  - plastic commodities
  - miscellaneous storage
  - other storage as specified in Chapter 12 or by other NFPA standards.

12.1.3 Hose Connections

- Small hose connections 1-1/2 in. (38 mm) shall be provided for first aid firefighting & overhaul operations.
- Where required by Chapter 12, small (1-1/2 in.) hose lines shall be available to reach all portions of the storage area.
12.1.4 Wet Pipe Systems.

• Sprinkler systems shall be:
  – wet pipe systems.
  – In areas that are subject to freezing or where special conditions exist, dry-pipe systems and preaction systems shall be permitted to protect storage occupancies.
• ESFR sprinklers shall only be permitted to be wet pipe systems.

12.1.5 Adjacent Occupancies.

• Where areas are not separated by a barrier capable of delaying heat from a fire in one area from fusing sprinklers in the adjacent area
  – Required sprinkler protection for the more demanding occupancy shall extend 15 ft (4.6 m) beyond its perimeter
12.1.6 Dry Pipe & Preaction Systems

• The area of sprinkler operation shall be increased by 30% without revising the density.
• Densities & areas shall be selected so that the final area of operation after the 30% increase is not greater than 6000 ft² (557.4 m²).
• Increase not required where it can be demonstrated that the detection system that activates the preaction system causes water to be discharged from sprinklers as quickly as the discharge from a wet pipe system.

12.1.7 Ceiling Slope

• The sprinkler system criteria specified in this chapter are intended to apply to buildings with ceiling slopes not exceeding 2 in 12 (16.7%).
12.1.8 Multiple Adjustments.

• Where multiple adjustments to the area of operation are required to be made, these adjustments shall be compounded based on the area of operation originally selected.
• If the building has unsprinklered combustible concealed spaces, additional rules of Chapter 11 shall be applied after all other modifications have been made.

12.1.9 Protection of Idle Pallets (Formally Part of NFPA 231)

• 12.1.9.1 Wood Pallets
• 12.1.9.2 Plastic Pallets
12.1.9.1 Idle Wood Pallets Storage

- Store Pallets Outside
- Store Pallets in Detached Structure
- Store Pallets Indoors
  - Standard Spray Sprinklers
  - Control mode specific application sprinklers
  - ESFR sprinklers
  - Alternative:
    - Pallets shall be stored no higher than 6 ft (1.8 m).
    - Each pallet pile of no more than four stacks shall be separated from other pallet piles by at least 8 ft (1.4 m) of clear space or 25 ft (7.6 m) of commodity.
    - Idle wood pallets shall not be stored in racks unless they are protected by ESFR’s

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Table 12.1.9.1.2(a) Control Mode Density-Area Protection of Indoor Storage of Idle Wood Pallets

<table>
<thead>
<tr>
<th>Type of Sprinkler</th>
<th>Location of Storage</th>
<th>Nominal K-Factor</th>
<th>Minimum Storage Height</th>
<th>Sprinkler Density</th>
<th>Fire Exposures</th>
<th>Ordinary</th>
<th>High Temperature</th>
<th>Area of Operation</th>
<th>Hose Stream Demand</th>
<th>Water Supply Duration (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control mode</td>
<td>Indoor</td>
<td>8.8 or larger</td>
<td>12 ft to 100 ft</td>
<td>6 ft</td>
<td>2000</td>
<td>2000</td>
<td>1000</td>
<td>2000</td>
<td>500</td>
<td>3 1/2</td>
</tr>
<tr>
<td>Standard</td>
<td>Indoor</td>
<td>8.8 or larger</td>
<td>12 ft to 100 ft</td>
<td>6 ft</td>
<td>2000</td>
<td>2000</td>
<td>1000</td>
<td>2000</td>
<td>500</td>
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<td>2000</td>
<td>1000</td>
<td>2000</td>
<td>500</td>
<td>3 1/2</td>
</tr>
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### Table 12.1.9.1.2(b) Control Mode Specific Application Protection of Indoor Storage of Idle Wood Pallets

<table>
<thead>
<tr>
<th>Type of Sprinkler (Orientation)</th>
<th>Location of Storage</th>
<th>Nominal K-factor</th>
<th>Minimum Storage Height</th>
<th>Maximum Ceiling/ Roof Height</th>
<th>Minimum Operating Pressure</th>
<th>Hose Supply Demand (gpm)</th>
<th>Water Supply Duration (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESFR (pendant)</td>
<td>On floor or rack without solid shelves</td>
<td>14.0</td>
<td>25</td>
<td>7.6</td>
<td>30</td>
<td>9.1</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>25</td>
<td>7.6</td>
<td>32</td>
<td>9.8</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>35</td>
<td>10.7</td>
<td>40</td>
<td>12.2</td>
<td>75</td>
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<td>7.6</td>
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<td></td>
<td></td>
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<td>7.6</td>
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<td>10</td>
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<td></td>
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<td>35</td>
<td>10.7</td>
<td>40</td>
<td>12.2</td>
<td>75</td>
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<tr>
<td>ESFR (upright)</td>
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<td>6.1</td>
<td>30</td>
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<td></td>
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### Table 12.1.9.1.2(c) ESFR Protection of Indoor Storage of Idle Wood Pallets

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<th>Maximum Ceiling/ Roof Height</th>
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<td></td>
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<td>7.6</td>
<td>30</td>
<td>9.1</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>25</td>
<td>7.6</td>
<td>32</td>
<td>9.8</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>35</td>
<td>10.7</td>
<td>40</td>
<td>12.2</td>
<td>75</td>
</tr>
<tr>
<td>ESFR (upright)</td>
<td>On floor only</td>
<td>14.0</td>
<td>20</td>
<td>6.1</td>
<td>30</td>
<td>9.1</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>20</td>
<td>6.1</td>
<td>35</td>
<td>10.7</td>
<td>75</td>
</tr>
</tbody>
</table>
Idle Plastic Pallets Storage

• Store Plastic Pallets Outside
• Store Plastic Pallets in Detached Structure
• Store Plastic Pallets Indoors
  – Stored in cutoff room
    • Must have at least 1 exterior wall
    • 3-hour separation required
    • 0.6 gpm/sq. ft. over entire room, high expansion foam, or ESFR protection
    • Max. Storage Height – 12’
    • Columns must be protected
  – Stored without cutoff room
    • Max. Storage Height – 4’
    • High temperature rated sprinklers
    • Each pallet pile of no more than two stacks must be separated from other pallet piles by at least 8’ or 25’ of stored commodity.

12.1.9.2.1 (5) Idle Plastic Pallets Storage

• Indoor storage of plastic pallets shall be permitted to be protected in accordance with the following arrangement:
  – Maximum storage height of 10’
  – Maximum ceiling height of 30’
  – Sprinkler density 0.6 gpm/sq. ft. over 2000 sq. ft.
  – Minimum sprinkler K-factor of 16.8
Table 12.1.9.2.1 ESFR Protection of Indoor Storage of Idle Plastic Pallets

<table>
<thead>
<tr>
<th>Type of Sprinkler (Orientation)</th>
<th>Location of Storage</th>
<th>Nominal K-Factor</th>
<th>Maximum Storage Height</th>
<th>Maximum Ceiling / Roof Height</th>
<th>Minimum Operating Pressure</th>
<th>Hose Stream Demand</th>
<th>Water Supply Duration (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.1.10 ESFR (pendant) On floor or rack without solid shelves</td>
<td>11.0</td>
<td>25</td>
<td>7.6</td>
<td>30</td>
<td>9.1</td>
<td>50</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25</td>
<td>7.6</td>
<td>32</td>
<td>9.8</td>
<td>60</td>
<td>4.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>35</td>
<td>10.7</td>
<td>40</td>
<td>12.2</td>
<td>75</td>
<td>5.2</td>
</tr>
<tr>
<td>12.1.10.1.2 12.1.10.1.1 For protection of miscellaneous storage up to 12 ft (3.7 m) in height of Group A plastic, rubber tires, rolled paper, and storage of idle pallets up to 6 ft (1.4 m) in height, the discharge criteria in Table 12.1.10.1.1 &amp; Figure 12.1.10 shall apply.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

12.1.10 Miscellaneous Storage & Storage of Class I through IV up to 12 ft in Height

- **12.1.10.1 Discharge Criteria.**
- **12.1.10.1.1** For protection of miscellaneous storage up to 12 ft (3.7 m) in height of Group A plastic, rubber tires, rolled paper, and storage of idle pallets up to 6 ft (1.4 m) in height, the discharge criteria in Table 12.1.10.1.1 & Figure 12.1.10 shall apply.
- **12.1.10.1.2** For the protection of storage of Class I through IV commodities up to 12 ft (3.7 m) in height, the discharge criteria in Table 12.1.10.1.1 & Figure 12.1.10 shall apply.
FIGURE 12.1.10 Miscellaneous Storage & Commodity Classes I - IV Storage
12 ft (3.7 m) or Less in Height

Table 12.1.10.1.1 Discharge Criteria for Commodity Classes I - IV Storage
12 ft (3.7 m) or Less in Height

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Type of Storage</th>
<th>Storage Height</th>
<th>Maximum Ceiling Height</th>
<th>Design Curve</th>
<th>Note</th>
<th>Inside Hose (gpm)</th>
<th>Total Combined Inside and Outside Hose (gpm)</th>
<th>Duration (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I</td>
<td>Palletized, bin, box, and shelf</td>
<td>&gt;10 to ≤12</td>
<td>&lt;8.0 ft to ≤5.7</td>
<td>Curve 3</td>
<td>0.56 or 100</td>
<td>250</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>Class II</td>
<td>Palletized, bin, box, and shelf</td>
<td>&gt;10 to ≤12</td>
<td>&lt;8.0 ft to ≤5.7</td>
<td>Curve 3</td>
<td>0.56 or 100</td>
<td>250</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>Class III</td>
<td>Palletized, bin, box, and shelf</td>
<td>&gt;10 to ≤12</td>
<td>&lt;8.0 ft to ≤5.7</td>
<td>Curve 3</td>
<td>0.56 or 100</td>
<td>250</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>Class IV</td>
<td>Palletized, bin, box, and shelf</td>
<td>&gt;10 to ≤12</td>
<td>&lt;8.0 ft to ≤5.7</td>
<td>Curve 3</td>
<td>0.56 or 100</td>
<td>250</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Back</td>
<td>&gt;10 to ≤12</td>
<td>&lt;8.0 ft to ≤5.7</td>
<td>Curve 4</td>
<td>0.56 or 100</td>
<td>500</td>
<td>90</td>
<td></td>
</tr>
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</table>
### Table 12.1.10.1.1 Discharge Criteria for Miscellaneous Group A Plastic Storage

<table>
<thead>
<tr>
<th>Condition</th>
<th>Solid and expanded</th>
<th>Fullness, top, bottom, and deck</th>
<th>$d_{16}$</th>
<th>$d_{50}$</th>
<th>$d_{85}$</th>
<th>Curve</th>
<th>$a$</th>
<th>$b$</th>
<th>$c$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contained</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fullness, top, bottom, and deck</td>
<td>$d_{16}$</td>
<td>$d_{50}$</td>
<td>$d_{85}$</td>
<td>Curve</td>
<td>$a$</td>
<td>$b$</td>
<td>$c$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 to 15</td>
<td>17</td>
<td>5.2</td>
<td>Curve 3</td>
<td>0.50, or 100</td>
<td>590</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 to 15</td>
<td>17</td>
<td>5.2</td>
<td>Curve 3</td>
<td>0.50, or 100</td>
<td>590</td>
<td>120</td>
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<td></td>
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<td>10 to 15</td>
<td>17</td>
<td>5.2</td>
<td>Curve 3</td>
<td>0.50, or 100</td>
<td>590</td>
<td>120</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>10 to 15</td>
<td>17</td>
<td>5.2</td>
<td>Curve 3</td>
<td>0.50, or 100</td>
<td>590</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 to 15</td>
<td>17</td>
<td>5.2</td>
<td>Curve 3</td>
<td>0.50, or 100</td>
<td>590</td>
<td>120</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>10 to 15</td>
<td>17</td>
<td>5.2</td>
<td>Curve 3</td>
<td>0.50, or 100</td>
<td>590</td>
<td>120</td>
<td></td>
</tr>
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<td></td>
<td></td>
<td>10 to 15</td>
<td>17</td>
<td>5.2</td>
<td>Curve 3</td>
<td>0.50, or 100</td>
<td>590</td>
<td>120</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>10 to 15</td>
<td>17</td>
<td>5.2</td>
<td>Curve 3</td>
<td>0.50, or 100</td>
<td>590</td>
<td>120</td>
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<tr>
<td></td>
<td></td>
<td>10 to 15</td>
<td>17</td>
<td>5.2</td>
<td>Curve 3</td>
<td>0.50, or 100</td>
<td>590</td>
<td>120</td>
<td></td>
</tr>
</tbody>
</table>

### Table 12.1.10.1.1 Discharge Criteria for Miscellaneous Tire Storage

<table>
<thead>
<tr>
<th>Condition</th>
<th>Solid and expanded</th>
<th>Fullness, top, bottom, and deck</th>
<th>$d_{16}$</th>
<th>$d_{50}$</th>
<th>$d_{85}$</th>
<th>Curve</th>
<th>$a$</th>
<th>$b$</th>
<th>$c$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contained</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fullness, top, bottom, and deck</td>
<td>$d_{16}$</td>
<td>$d_{50}$</td>
<td>$d_{85}$</td>
<td>Curve</td>
<td>$a$</td>
<td>$b$</td>
<td>$c$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 to 15</td>
<td>11</td>
<td>4.6</td>
<td>Curve 4</td>
<td>0.50, or 100</td>
<td>590</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 to 15</td>
<td>11</td>
<td>4.6</td>
<td>Curve 4</td>
<td>0.50, or 100</td>
<td>590</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 to 15</td>
<td>11</td>
<td>4.6</td>
<td>Curve 4</td>
<td>0.50, or 100</td>
<td>590</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 to 15</td>
<td>11</td>
<td>4.6</td>
<td>Curve 4</td>
<td>0.50, or 100</td>
<td>590</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 to 15</td>
<td>11</td>
<td>4.6</td>
<td>Curve 4</td>
<td>0.50, or 100</td>
<td>590</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 to 15</td>
<td>11</td>
<td>4.6</td>
<td>Curve 4</td>
<td>0.50, or 100</td>
<td>590</td>
<td>120</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>5 to 15</td>
<td>11</td>
<td>4.6</td>
<td>Curve 4</td>
<td>0.50, or 100</td>
<td>590</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 to 15</td>
<td>11</td>
<td>4.6</td>
<td>Curve 4</td>
<td>0.50, or 100</td>
<td>590</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 to 15</td>
<td>11</td>
<td>4.6</td>
<td>Curve 4</td>
<td>0.50, or 100</td>
<td>590</td>
<td>120</td>
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</tbody>
</table>
Table 12.1.10.1.1 Discharge Criteria for Miscellaneous Rolled Paper & Idle Pallet Storage

<table>
<thead>
<tr>
<th>Weight and Type</th>
<th>On End</th>
<th>≤500</th>
<th>0.50 or 100</th>
<th>0.50 or 100</th>
<th>120</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tissue and light weight</td>
<td>≤500</td>
<td>500</td>
<td>120</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Plastic Pallets</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single-row rack, flared</td>
<td>≤1.5</td>
<td>50</td>
<td>120</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Plastic Pallets</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single-row rack, flared</td>
<td>≤1.2</td>
<td>50</td>
<td>120</td>
<td>120</td>
<td></td>
</tr>
</tbody>
</table>

12.1.10.2 Hose Stream Demand & Water Supply Duration.

- **12.1.10.2.1** The hose stream demand and water supply duration for the protection of palletized, solid piled, bin box, shelf storage, or rack storage of Class I - IV commodities, miscellaneous storage of Group A plastics, and miscellaneous rack storage of Class I - IV commodities, up to 12 ft (3.7 m) in height shall be in accordance with the requirements of Table 12.1.10.1.1.
- **12.1.10.2.2** The hose stream demand and water supply duration for the protection of miscellaneous storage of rubber tires, rolled paper, and idle pallets shall be in accordance with the requirements of Table 12.1.10.1.1.
12.1.11 High-Expansion Foam Systems

- **12.1.11.1** High-expansion foam systems that are installed in addition to automatic sprinklers shall be installed in accordance with NFPA11A, *Standard for Medium- and High-Expansion Foam*.
- **12.1.11.2** High-expansion foam systems shall be automatic in operation.
- **12.1.11.3** A reduction in ceiling density to one-half that required for Class I - IV commodities, idle pallets, or plastics shall be permitted without revising the design area, but the density shall be no less than 0.15 gpm/ft² (6.1 mm/min).
- **12.1.11.4** High-expansion foam used to protect the idle pallet shall have a maximum fill time of 4 minutes.

12.1.12 In-Rack Sprinklers

- In-rack sprinklers mandated by this standard shall meet the requirements of this section & the applicable storage protection and arrangement sections of this chapter.
- **12.1.12.1 Operating Pressure.** In-rack sprinklers shall operate at a minimum of 15 psi (1 bar).
- **12.1.12.2 Water Demand.** Where one level of in-rack sprinklers is installed for miscellaneous storage, water demand shall be based on simultaneous operation of the hydraulically most demanding four adjacent sprinklers.
12.1.13 Storage Applications

<table>
<thead>
<tr>
<th>Density</th>
<th>K-factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.1.13.1 Storage Density</td>
<td>5.6 &amp; larger</td>
</tr>
<tr>
<td>.2 gpm/sq.ft. (8.2 mm/min) or less</td>
<td></td>
</tr>
<tr>
<td>12.1.13.2 Storage Density</td>
<td>8.0 &amp; larger</td>
</tr>
<tr>
<td>.34 gpm/sq.ft. (13.9 mm/min) or less</td>
<td></td>
</tr>
<tr>
<td>12.1.13.3 Storage Density</td>
<td>11.2 &amp; larger</td>
</tr>
<tr>
<td>greater than .34 gpm/sq.ft. (13.9 mm/min)</td>
<td></td>
</tr>
</tbody>
</table>

• **12.1.13.4** Unless the requirements of 12.1.13.5 are met, the requirements of 12.1.13.2 & 12.1.13.3 shall not apply to modifications to existing storage application systems, using sprinklers with K-factors of 8.0 or less.

• **12.1.13.5** Where applying the requirements of Figure 12.3.3.1.5(b) & Figure 12.3.3.1.5(c) utilizing the design criteria of 0.6 gpm/ft² per 2000 sq. ft. (186m²) to existing storage applications, the requirements of 12.1.13.3 shall apply.

• **12.1.13.6** The use of quick-response spray sprinklers for storage applications shall be permitted when listed for such use.