IN-RACK FIRE PROTECTION STORAGE SOLUTIONS

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Shaun Kramer, Viking Corporation, Senior Director of Technical Services & Training, has been with Viking Corporation for over 20 years. Shaun is Nicet Level III Certified in both Water – Based Systems Layout, and Special Hazards Suppression Systems. Prior to joining Viking, Shaun was an Estimator/Project Manager/Sprinkler System Designer for 8 years with two sprinkler contractors. Shaun is a member on the NFPA 13 Technical Committee for Sprinkler Discharge Criteria, NFPA 13 Correlating Committee, and the NFSA Engineering & Standards Committee.

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National Fire Protection Association
The authority on fire, electrical, and building safety

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In-Rack Storage Sprinkler Protection

Learning Outcomes:

To be able to describe the history of in-rack fire sprinkler protection.

To understand the challenges faced today with ceiling-only fire protection.

To recognize some of the solutions that are being worked on for the challenges faced today.

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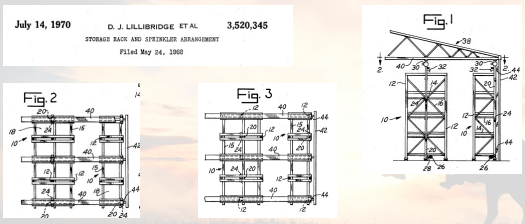
History of In-Rack Storage Sprinkler Protection



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History of In-Rack Storage Sprinkler Protection

1960's

Initially sprinklers used for the protection of storage were your standard CMDA sprinklers.

Standard Response, Standard Orifice 5.6 K-factor

Standard Response, Large Orifice 8.0 K-factor

Ceiling-only protection typically: 20'-0" ceiling/15'-0" storage

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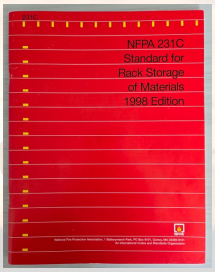
History of In-Rack Storage Sprinkler Protection

The first edition of NFPA 231C – Standard for Rack Storage of Materials was introduced in 1972.

Based upon full scale fire testing from the NFPA committee on Rack Storage Materials which was developed in 1968.

The last edition of NFPA 231C was the 1998 edition. After this edition storage protection criteria was adopted into the 1999 edition of NFPA 13.



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History of In-Rack Storage Sprinkler Protection

1970's

First CMSA sprinkler was developed

Standard Response, Large Drop 11.2 K-factor

Ceiling-only protection: 30'-0" ceiling/25'-0" storage

Later testing allowed for 35'-0" ceiling/30'-0" storage

Larger Water Droplets

Lower Pressures

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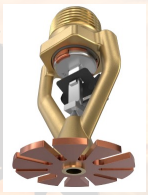
History of In-Rack Storage Sprinkler Protection

1980's

Prior to ESFR sprinklers the highest ceiling-only protection was 35'-0" before in-rack sprinklers were needed.

With the introduction of ESFR sprinklers, ceiling-only protection was increased in certain applications to a 45'-0" ceiling height.

ESFR sprinklers were initially included in NFPA 231C in the 1991 edition.



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History of In-Rack Storage Sprinkler Protection

1990's – 2000's

The original ESFR sprinkler had a 14.0 K-factor

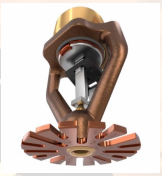
50 – 90 psi design pressures.

Building heights continued to increase.

K-factors: 16.8, 22.4, & 25.2 were developed.

Lower pressures

Higher Commodity Classifications



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History of In-Rack Storage Sprinkler Protection

2010 – 2020

ESFR K-28.0 & K-33.6 Sprinklers

Allow up to 55'-0" building height FMDS 8-9

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History of In-Rack Storage Sprinkler Protection

2007 - 2022

Not only were heated buildings being built higher, but so were coolers and freezers.

The box-in-box type application led to a new type of ESFR sprinklers.

K-14.0 Dry ESFR – 2007

K-16.8 Dry ESFR – 2013

K-25.2 Dry ESFR - 2022

Same designs as standard ESFR sprinklers.

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History of In-Rack Storage Sprinkler Protection

The goal was always to be able to provide ceiling only protection to higher ceiling & storage heights without the need for in-rack sprinklers.

Downside of In-Rack Sprinklers

- Potential Damage
- Less room in tiers for storage
- Requires listed guard and/or shield
- Additional pipe equals additional corrosion potential
- Increased water demand when balancing with ceiling

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In-Rack Storage Sprinkler Protection

Ceiling-only protection has become more difficult for a few reasons lately:

Larger orifice sprinklers require higher minimum pressures

Building heights are exceeding the capabilities of ceiling-only protection

Types of storage that are difficult to protect with ceiling-only sprinklers

Fire Extinguishment rather than just control or suppression.

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History of In-Rack Storage Sprinkler Protection

Benefits of In-Rack Sprinklers

- Faster response time
- Reduced water damage
- Allows unlimited building height
- Protects storage arrangements that ceiling-only cannot protect (e.g. solid shelves)
- Helps contain fire at the tier level where it started

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In-Rack Storage Sprinkler Protection

Larger orifice sprinklers require higher minimum pressures

28K – Minimum Design Pressure: 35 psi

34K – Minimum Design Pressure: 55 psi

FMDS 8-9 – April 2026

Table 17b. Quick-Response, Standard-Coverage Pendent Storage Sprinkler Ceiling-Only Designs for Ceiling Heights Over 40 ft (12.2 m)

Storage Arrangement	Commodity	Max. Ceiling Height, ft (m)	Ceiling Sprinkler K-Factor	Max. Vertical Distance from Ceiling to Sprinkler's Thermal Element, in. (mm)*	Min. Aisle Width, When Protecting Racks, ft (m)**	Sprinkler System Design: Ceiling Sprinkler System, No. of AS @ psi (bar)	Sprinkler System Design: Hose Demand, gpm (L/min)	Sprinkler System Design: System Duration, min
Solid-Piled, Palletized, Bin-Box, Shelf, and Open-Frame Racks***	Class 1, 2, 3, 4 and Cartoned Unexpanded Plastics	50 (15.2)	22.4 (320)	13 (325)	6 (1.8)	10 @ 63 (4.3)	250 (950)	60
			25.2 (360)	13 (325)	6 (1.8)	10 @ 50 (3.5)		
				17 (425)	6 (1.8)	10 @ 75 (5.2)		
			28.0**** (400****)	13 (325)	6 (1.8)	10 @ 40 (2.8)		
			33.6 (480)	17 (425)	6 (1.8)	9 @ 55 (3.8)		
		55 (16.8)	28.0 (400)	13 (325)	8 (2.4)	9 @ 60 (5.5)		
			33.6 (480)	17 (425))	6 (1.8)	9 @ 55 (3.8)		

* See the guidelines in Section 2.3.3.3.2 if the ceiling has obstructed type construction.

** See the guidelines in Section 2.2.3.2 to confirm that any multiple-row racks being protected in accordance with this table meet the requirements to be considered open-frame.If the multiple-row racks are not provided with adequate longitudinal flue spaces, the minimum aisle width for them is 8 ft (2.4 m) and is not oversided by the values indicated in the Min. Aisle Width column.

*** The design of 10 AS @ 43 psi (2.0 bar) can be reduced to 9 AS @ 43 psi (2.8 bar) when the water supply can also provide a minimum pressure of 80 psi (5.5 bar) from the most remote 4 sprinklers (2 sprinklers on 2 lines).

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In-Rack Storage Sprinkler Protection

Building heights are exceeding the capabilities of ceiling-only protection

What if the ceiling height is over 55'-0?

NFPA 13, 2025 Edition – 45'-0"
FMDS 8-9, April 2026 – 55'-0"

What are your options?

Add a false ceiling, or...

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In-Rack Storage Sprinkler Protection

FM Global – In-Rack Test Program 2011 – 2015

- Taller Warehouses
- Larger K-factors
- Maximize Vertical Spacing
- Increase Storage Height Above
- Independent Design
- Reduce In-Rack Sprinkler Damage
- Reduce Installation Costs

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In-Rack Storage Sprinkler Protection

FM Global – In-Rack Test Program 2011 – 2015

- Class I-IV, Unexpanded Plastics, Cartoned Expanded Plastics, Uncartoned Plastics
- 14.0 K-factor & larger
- Vertical Spacing between levels 30'-0" – 40'-0"
- Ceiling design based upon top level of IRAS being considered the floor
- No balancing of ceiling and in-rack sprinklers
- Can be used for retro-fit applications

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In-Rack Storage Sprinkler Protection

Introduced into NFPA 13, 2019 Edition

- 2019 - Table 25.6.2.2
- 2025 – Table 25.7.2

- Option 2A – Minimum 14.0 K-factor – 30'-0" Vertical

- Option 2B – Minimum 22.4 K-factor – 30'-0" or 40'-0" Vertical

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Ceiling-Only Protection Challenges

Carousel Rack Storage

Open-top containers

Shielded fire when covered

Difficult to protect with rotation

Delayed activation

Little to no flue spaces

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Ceiling-Only Protection Challenges

ASRS (Automatic Storage and Retrieval Systems)

Types:

Unit Load – fixed aisle or moveable aisle crane unit-load

Mini-Load

Robotic Shuttle

Floor robots – AMR (Autonomous mobile robots)

Flor Robots - AGV (Automated Guided vehicle)

Horizontal & Vertical Carousel

Vertical Lift

Micro-Load Stacker

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Ceiling-Only Protection Challenges

ASRS (Automatic Storage and Retrieval Systems)

Challenges:

Open-top containers

150 feet tall & 1,000 feet long

Li-ion batteries in robots

Robot charging stations

Very narrow or no aisle spaces

Delayed Fire service

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Ceiling-Only Protection Challenges

Automated Retrieval System Challenges:

No aisles

Tight flue spaces, if any.

Open-top containers

Structural integrity to support piping

Compact grid blocks installation of traditional in-rack sprinklers

High storage densities preventing water penetration

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Ceiling-Only Protection Challenges

Automated Pallet Shuttle Challenges:

- Very high storage densities
- Obstructed flue spaces
- Open-top containers
- Limited clearances
- Deep lane storage channels limiting airflow & water
- Shuttle carts powered by Li-ion batteries
- Charging stations
- Shielding effect from pallets above
- Delayed manual access

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Ceiling-Only Protection Challenges

Crane Style Automatic Retrieval Challenges:

- Narrow Aisles
- Solid shelving occasionally
- Blocked flue spaces
- Delayed manual access
- Deep lane storage channels limiting airflow & water
- Open-top containers

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Ceiling-Only Protection Challenges

Autonomous Mobile Robot (AMR) Scissor Lift Challenges:

- Heavy robots
- Charging Stations
- Blocked flue spaces
- Delayed manual access
- Deep lane storage channels limiting airflow & water
- Open-top containers
- Tight aisle spaces

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Ceiling-Only Protection Challenges

Autonomous Mobile Robot (AMR) Parcel Delivery Challenges:

- Li-ion battery
- Charging Stations
- Solid shelves
- Narrow aisles
- Difficult to address fire – always moving
- Fire can be easily spread

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Ceiling-Only Protection Challenges

Cold Storage Protection Challenges:

- Shielded Fires – Drip Pans
- Excessive ceiling height
- ASRS Systems
- Narrow aisles
- Water delivery delay

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Ceiling-Only Protection Challenges

Solid Shelf Storage Protection Challenges:

- Shielded Fires
- Delayed Activation
- Rapid horizontal spreading

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Ceiling-Only Protection Challenges

Carpet Storage Protection Challenges:

Tight roll configurations

Commonly solid shelving

Rapid horizontal spreading

Rapid heat release rate – high plastic loads

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In-Rack Storage Sprinkler Solutions

Fire Extinguishment rather than just control or suppression.

Fire Control: Limiting the size of a fire by distribution of water so as to decrease the heat release rate and pre-wet adjacent combustibles, while controlling ceiling gas temperatures to avoid structural damage.

Fire Suppression: Sharply reducing the heat release rate of a fire and preventing its regrowth by means of direct and sufficient application of water through the fire plume to the burning fuel surface.

Fire Extinguishment: The complete suppression of a fire until there is no burning combustibles.

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In-Rack Storage Sprinkler Solutions

Internal Robot Fire Protection

Fire protection inside the robots themselves.

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In-Rack Storage Sprinkler Solutions

Enclosed Suppression

Clean Agent Systems

Using aspirating smoke detection to detect early.

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In-Rack Storage Sprinkler Solutions

Remote Controlled Monitors

Equipped with thermal and optical sensors to detect and aim.

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In-Rack Storage Sprinkler Solutions

Remove the Sprinkler Guard & Water shield

Guards take up room in the racks

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In-Rack Storage Sprinkler Solutions
Remove the Sprinkler…
Sprinklers take up room in the racks
Sprinklers can be damaged in the racks
AFSA45

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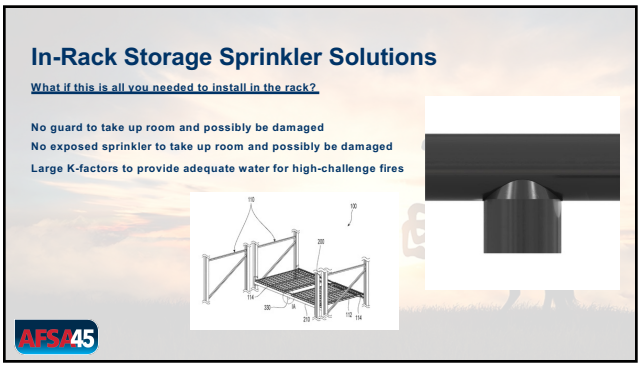
In-Rack Storage Sprinkler Solutions
What if this is all you needed to install in the rack?
No guard to take up room and possibly be damaged
No exposed sprinkler to take up room and possibly be damaged
Large K-factors to provide adequate water for high-challenge fires
AFSA45

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✓ Badge scanned at start of seminar
✓ Attend full seminar
✓ Complete evaluation 1 of 2 ways:
✓ Evaluation link is emailed to attendees with scanned badges
✓ Event App by EventsAir
• Login to app (using your email & 6-character app pin)
Only attendees who were scanned in will have evaluation access at end of session.
Thank you!
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Scan QR code to submit questions for Ask the Experts!

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2027 Training Schedule

WEBINARS

1/6	Updates to NFPA 20
1/20	Calculating Pressure Reducing Hose Valves
2/3	Consumer Alert: Nitrogen in Sprinkler Systems
2/17	Reviewing Hydraulic Calculations
3/3	Updates to NFPA 13, 2028 Ed.
3/17	Updates to NFPA 13R & 13D, 2028 Eds.
4/7	Topic Coming Soon
4/21	NFPA 25: Roles & Responsibilities
5/5	Standpipe Flow Test Procedures
5/19	Storage 101
6/2	NFPA Technical Meeting - Voting Guide
6/16	Topic Coming Soon
6/30	Topic Coming Soon
7/7	Updates to NFPA 14, 2027 Edition
7/21	Adjacent Hazards & Design Methods
8/4	Acceptance Testing
8/18	Modifications to Existing Systems
9/22	Topic Coming Soon
10/6	Seismic 101
10/20	Proposed Updates to NFPA 25, 2029 Ed.
11/3	Evaluating Fire Pump Flow Tests
11/17	Top 10 Tech Reviews
12/1	Designing Water Storage Tanks
12/15	Pump Room Layout

PROGRAMS

Feb 9 - Mar 5 Apr 20 - May 14 Aug 3 - Aug 27** Oct 26 - Nov 19	Beginning Design School*
Apr 26 - May 7 Nov 1 - 12	Intermediate Design School*
Feb 8 - 10** Apr 12 - 14 Jul 12 - 14 Oct 11 - 13	Sprinkler Hydraulics Calculations Workshop
Apr 19 - 21 Oct 18 - 20	Advanced Hydraulics Calculations Workshop
Feb 11** Apr 30 Jul 23 Sep 24	Introduction to the Fire Sprinkler Industry
Mar 1 - 3 May 17 - 19 Aug 16 - 18 Oct 18 - 20**	NFPA 25 Essentials Workshop
Jun 7 - 10 Sep 20 - 23	Experienced Inspector Skills Lab
Mar 4 - 5 May 20 - 21 Aug 19 - 20 Oct 21 - 22**	NFPA 25 Fire Pump Workshop
Spring Summer Fall	ITM Inspector Development Program* *This program is 20 months.*

** Hybrid course **At General Air Products Lab, Exton, PA*

AFSA46

September 8-11	Manchester Grand Hyatt San Diego, CA

For More Details Visit:
firesprinkler.org

AFSA
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Dates subject to change. Programs subject to minimum registrations.

rev 9/14/2026

Virtual Instruction Path (VIP)

for Sprinkler Fitting Apprentices

Level 1 - Begins January 2027

Level 2 - Begins February 2027

Level 3 - Begins January 2027

Level 4 - Begins March 2027

www.firesprinkler.org/VIP

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HANDS-ON WORKSHOPS FOR 2027

FEATURING AFSA'S TRAINING LAB

NFPA 25 Essentials Workshop

Mar | May | Aug | Oct

Description: Understand roles, responsibilities, and NFPA 25 ITM procedures through hands-on testing of wet systems, dry systems, and fire pumps.

NFPA 25 Fire Pump Workshop

Mar | May | Aug | Oct

Description: Develop practical NFPA 25 fire pump ITM skills, including no-flow and full-flow testing, water supply graphing, and performance evaluation.

Introduction to the Fire Sprinkler Industry

Feb | Apr | Jul | Sep

Description: This course is designed for those new to the industry. An introductory, wide-ranging 8-hour course that provides a broad overview of core fire sprinkler industry concepts for those new to the field.

Experienced Inspector Skills Lab NEW

Mar | Sep

Description: Take your ITM expertise beyond the basics. Designed for experienced technicians, this course combines focused classroom instruction with hands-on system lab training to strengthen your application of current NFPA 25 inspection, testing, and maintenance requirements. Refine fire sprinkler testing practices, improve documentation, deliver more consistent service, and help reduce liability while reinforcing knowledge commonly covered on certification exams.

Learn more about AFSA's fire sprinkler lab featuring functional risers, a spray room, fire pumps, and an interactive classroom.

firesprinkler.org/lab