SUPDET 2014 Extended Abstract

Storage Protection Using Horizontal Barriers and Large K-Factor, Extended Coverage In-Rack Sprinklers

The Challenge:

The protection challenges for storage commodities have increased with the storage of more plastics, whether cartoned or uncartoned expanded or unexpanded. The building heights have also increased, particularly with the use of high bay storage using automated storage and retrieval systems.

The use of ceiling only sprinklers has not been an effective method for suppression or control of rack storage fires when the ceiling height exceeds certain limits and/or the stored commodities are exposed or expanded plastics.

First Phase:

The concept for using horizontal barriers and large k factor extended coverage storage sprinklers as in-rack protection came from the observations and early results of The Fire Protection Research Foundation's (FPRF) Exposed Expanded Group A Plastic Test Series. This research testing was being conducted to look at ceiling sprinkler-only protection for rack storage of exposed expanded group A plastics. Protection schemes for these applications have been outside the scope of NFPA 13, chapter 17. FM Global Data Sheet 8-9 does provide design criteria for ceiling-only protection of exposed expanded plastics with ceiling heights up to 40' using a specified brand of sprinkler. However, the water demand is extremely high. The FPRF wanted to reduce the water demand and elected to test using horizontal barriers on every other rack upright or approximately 16' apart.

After a series of several tests, the FPRF proposed a suggested design for NFPA 13 using vertical barriers. The basics of the design: 40' ceiling height, 35' storage height, 8' aisle width, vertical barriers at 16' intervals, K-25.2 ESFR sprinklers installed at the ceiling, 60 psi minimum per sprinkler, the flow to be calculated for a minimum of 15 sprinklers, and a hose stream allowance of 250 gpm with a 60 minute water supply duration.

Because of water distribution tests that Reliable was internally conducting on the performance of its Model N252 EC Pendent Storage sprinkler as an in-rack sprinkler, a decision was made to run a fire test at UL using a horizontal barrier and not the vertical barriers being used in the FPRF test series. We felt that the N252 EC Pendent sprinkler would provide superior performance because of its extended coverage spray pattern, its ability to flow a large quantity of water at low pressure because of the 25.2 K factor, and its quick response characteristics;

The Sprinkler:

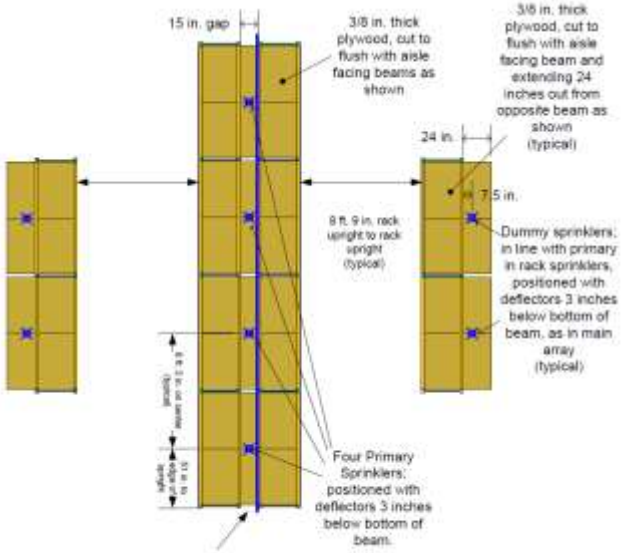
Reliable's patented Model N252 EC Pendent Storage Sprinkler. A K-25.2 EC pendent sprinkler approved for storage applications by FM Global and NFPA13. Following is the ceiling design criteria of both NFPA 13 and FM Global DS 8-9.

Design Criteria for Class 1-4 and Cartoned Unexpanded Plastics in Open Frame Racks						
Max. Ceiling Hgt.	Max. Storage Hgt.	Minimum Pressure	Max. Spacing	Number of Design Sprinklers	Hose Stream Allowance	Water Supply Duration
25'	20'	25 psi	14'x14'	6	250 gpm	1 hour
30'	25'	30 psi	14'x14'	6	250 gpm	1 hour
35'	30'	40 psi	12'x12'	8	250 gpm	1 hour

Test 1:Testing for Rack Storage of Exposed Expanded Plastics:

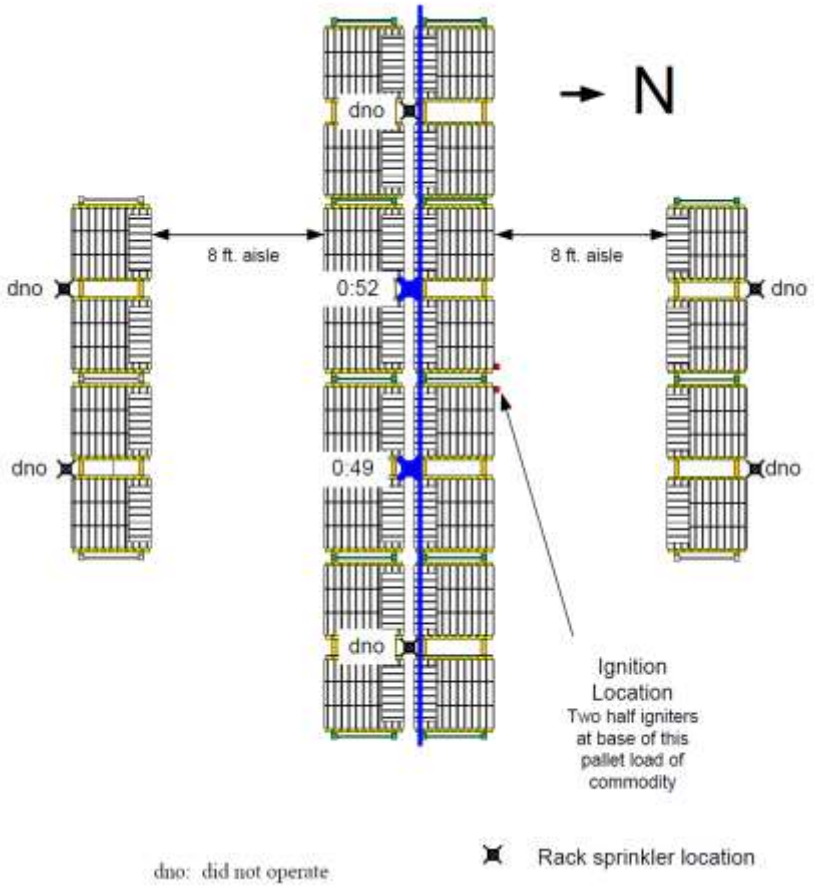
We used a horizontal barrier with materials and installation requirements as defined in NFPA 13 and FM Global DS 8-9. For the test, we used a standard 3/8" plywood barrier. The ceiling height was 40', the storage height was 35', and the aisle width was 8'. The commodity was the UL test package of encapsulated meat trays on pallets stored in double row racks. Two half igniters were located at the base and at a rack upright at the face (aisle) of the commodities.

The ceiling sprinklers were K-16.8 ESFR sprinklers spaced at 10' x 10' and set to flow at 50 psi. The sprinkler and the pressure were based upon what might be found in existing 40' ceiling height storage installations. The in-rack sprinklers were installed under the horizontal barrier that was set at the 20' level in the rack. The sprinklers were spaced equally between the rack uprights (8-3" on center) and were pressurized at 30 psi.

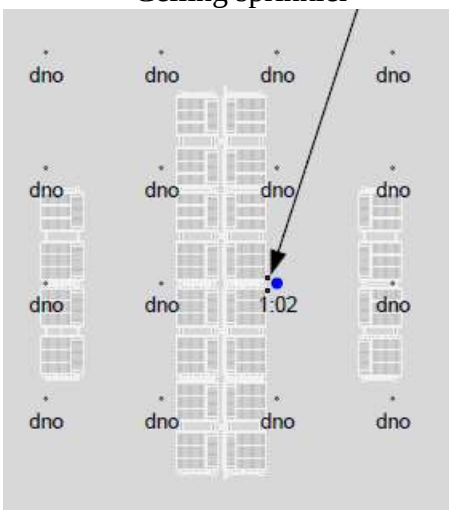


The results were excellent. Two sprinklers opened in the rack; one a 49 seconds and one at 52 seconds. Each sprinkler was flowing 138 gpm for a total of 276 gpm. One sprinkler operated at the ceiling in 62 seconds. The ceiling sprinkler flow was 119 gpm. The test ran for 31 minutes with a peak steel temperature at the ceiling of 102°F. The fire did not travel to the extremity of the array, there was no ignition of the target commodity, and the destruction of the commodity was minimal.

In-rack sprinklers



Ceiling sprinkler



We met our goal of providing a method of rack storage protection for exposed expanded group A plastics in a 40' high building using a much lower water demand than other current protection methods.

FM DS 8-9 ***ceiling only***	min. pressure	flow/spr	no. of sprs calculated	Hose Stream	Total System Demand
K-25.2 ESFR	75 psi	219 gpm	20	500 gpm	**4880+ gpm***

2 hour duration

*flows will be increased based upon actual hydraulic calculation and are for comparison purposes only

FPRF ***vertical barrier ceiling only***	min. pressure	flow/spr	no. of sprs calculated	Hose Stream	Total System Demand
K-25.2 ESFR	60 psi	195 gpm	15	250 gpm	**3175+ gpm***

Reliable ***horizontal barrier***	min. pressure	flow/spr	no. of sprs calculated	Hose Stream	Total System Demand
K-16.8 ESFR	50 psi	119 gpm	12	250 gpm	**1678+ gpm***

When using horizontal barriers, the in-rack sprinkler demand is not required to be added to the ceiling sprinkler demand and does not need to be balanced to the ceiling sprinklers.

The in-rack sprinklers would be designed to the following criteria:

Reliable In-rack sprs	min. pressure	flow/spr	no. of sprs calculated	Total In-Rack Demand
N252 EC P	30 psi	138 gpm	3	**414+ gpm***

3 sprinklers would be calculated: 2 opened x 150% = 3 for design purposes

Second Phase:

With the positive results obtained from this test, we saw the potential for a new research objective: To develop fire protection options for double row rack storage of cartoned unexpanded plastics in buildings higher than 48 feet. This would include high bay buildings with automatic storage and retrieval systems.

The primary goals were:

1. To reduce the number of in-rack sprinklers required when compared to standard in-rack schemes and to also reduce the required water demands.
2. To have a significant reduction of water demand for buildings that can currently be protected by ceiling only sprinklers up to 48'.
3. Protect buildings higher than 48' with low water demands.
4. Retrofit existing facilities, where the storage commodities had changed, without changing the existing ceiling sprinklers or increasing water flows or pressures.

Thus far, five fire tests have been conducted to prove the concept of using large k-factor, K-25.2, extended coverage, pendent sprinklers for in-rack protection. The sprinklers are installed in the longitudinal flues and under horizontal barriers as defined by NFPA 13 and FM 8-9. The majority of tests were conducted with UL's standard cartoned, unexpanded group A plastic commodity with barriers at 20 feet or 30 feet intervals. Much of this testing was done in partnership with P&G, Global Fire Protection. Testing to date has shown minimal loss of commodity with a very low total water demand for the system. See Table A (following).

Table A, Test Results:

	Test No. 1	Test No. 2	Test No.3	Test No.4	Test No.5
	Test Date: August 8, 2012	Test Date: April 25, 2013	Test Date: July 1, 2013	Test Date: August 9, 2013	Test Date: October 24, 2013
TEST PARAMETERS					
Storage Type	Double Row Rack	Double Row Rack	Double Row Rack	Double Row Rack	Double Row Rack
Commodity Type	Exposed Expanded Group A Plastic	Cartoned Unexpanded Group A Plastic	Cartoned Unexpanded Group A Plastic (Polystyrene Cups in Corrugated Containers)	Cartoned Unexpanded Group A Plastic (Polystyrene Cups in Corrugated Containers)	Cartoned Unexpanded Group A Plastic (Polystyrene Cups in Corrugated Containers)
Pallet Type	2 way entry, stringer, hardwood	2 Way Entry, Stringer, Hardwood	2 way entry, stringer, hardwood	2 way entry, stringer, hardwood	2 way entry, stringer, hardwood
Horizontal Barrier Within Rack	3/8 inch Plywood at 30ft. Elevation	3/8 inch Plywood at 30ft. Elevation	3/8 inch Plywood at nominal 20 and 40 ft. Elevation	3/8 inch Plywood at nominal 20 and 40 ft. Elevation Continuous across uprights	3/8 inch Plywood at nominal 30ft. Elevation Continuous across uprights
Nominal Storage Height, ft.	35	43	43	43	43
Ceiling Height, ft.	48	48	48	48	48
Nominal Clearance, ft.	5	5	5	5	5
Aisle Width, ft.	8	8	4	4	4
Ignition Location	Between 2 Ceiling and In Rack Sprinklers (Face Fire In Aisle Space)	Between 2 Ceiling and In Rack Sprinklers (Face of Commodity in Aisle Space)	Between 2 Sprinklers (offset in transverse Flue)	Between 2 Sprinklers (offset in transverse Flue)	Between 2 Sprinklers (offset in transverse Flue)
CEILING SPRINKLER SYSTEM					
Sprinkler Type	K = 16.8 ESFR Pendent	K = 25.2 Extended Coverage Pendent	K = 25.2 Extended Coverage Pendent	K = 25.2 Extended Coverage Pendent	K = 25.2 Extended Coverage Pendent
Deflector to Ceiling, In.	14	14	14	14	14
Ceiling Sprinkler Spacing, sprinkler by branchline ft. by ft.	10 by 10	14 by 14	14 by 14	14 by 14	14 by 14
Temperature Rating, F	212	212	212	212	212
Sprinkler Response Type	QR (link)	QR (link)	QR (link)	QR (link)	QR (link)
Nominal Sprinkler Discharge Coefficient K, gpm/psig 0.5	16.8	25.2	25.2	25.2	25.2
Nominal Discharge Density, gpm/ft	1.19	0.7	0.7	0.64	0.7
Nominal Discharge Pressure, psig	50	30	30	25	30
			Ceiling Sprinkler System (initially Dry - Activated after significant fire load at the ceiling)	Ceiling Sprinkler System (initially 7 psig, planned to increase to 25 psig if upper tiers became involved)	Ceiling Sprinkler System (initially 7 psig, planned to increase to 30 psig if upper tiers became involved)
IN RACK SPRINKLER SYSTEM					
Sprinkler Type	K = 25.2 Extended Coverage Pendent	K = 25.2 Extended Coverage Pendent	K = 25.2 Extended Coverage Pendent	K = 25.2 Extended Coverage Pendent	K = 25.2 Extended Coverage Pendent
Deflector to Commodity, In.	8.5	7.5	8 (nominal)	8 (nominal)	8 (nominal)
Sprinkler Spacing, ft.	8 ft. 3 in. (centered on the rack bays)	8 ft. 3 in. (centered on the rack bays)	8 ft. 3 in. (centered on the rack bays)(6 sprinklers, centered on the bay of commodity)	8 ft. 3 in. (centered on the rack bays)	8 ft. 3 in. (centered on the rack bays)(4 sprinklers, centered on the bay of commodity)
Temperature Rating, F	212	212	165	212	212
Sprinkler Response Type	QR (link)	QR (link)	QR (link)	QR (link)	QR (link)
Nominal Sprinkler Discharge Coefficient K, gpm/psig	25.2	25.2	25.2	25.2	25.2
Nominal Discharge Pressure, psig	30	30	30 (at 40 ft. elevation) 39 (at 20 ft. elevation)	30 (at 40 ft. elevation)	30 (at 40 ft. elevation)
Nominal Discharge Flowrate, gpm	138 at 30 ft. elevation	138 at 20 ft. elevation	138 (at 40 ft. elevation) 157 (at 20 ft. elevation)	138 (at 40 ft. elevation)	138 (at 40 ft. elevation)
			In Rack Sprinkler System (at nominal 20 and 40 ft. levels)	In Rack Sprinkler System (at nominal 20 and 40 ft. levels)	In Rack Sprinkler System (at nominal 30 ft. level)
TEST RESULTS					
Length of Test, minutes	31	34	60	60	40
Peak Gas Temperature at Ceiling Above Ignition, °F	410	722	1583	107	173
Maximum 1 minute Average Gas Temperature at Ceiling Above Ignition, °F	218	353	1083	106	128
Peak Steel Temperature at Ceiling Above Ignition, °F	102	152	450	82	82
Maximum 1 minute Average Steel Temperature at Ceiling Above Ignition, °F	102	150	446	82	82
Fire Travel to Extremities of Test Array	No	No	No	No	No
Ignition of Target Commodity	No	No	No	No	No
CEILING SPRINKLER SYSTEM					
First Sprinkler Operation Time, min:sec	1:02	3:01	20:40	Not applicable	Not applicable
Last Sprinkler Operation Time, min:sec	1:02	3:01	21:15	Not applicable	Not applicable
Number of Operated Sprinklers	1	1	3	0	0
			Ceiling Sprinkler System (Initial Operating Time without Water). Water Began Discharging at 31 min 15 sec after ignition		
IN RACK SPRINKLER SYSTEM					
First Sprinkler Operation Time, min:sec	0:49 (East Central Sprinkler)	2:53 (West Central Sprinkler)	1:13 (East Central Sprinkler - 20 ft. Elevation)	1:26 (West, West Central and East Sprinklers - 20 ft. Elevation)	1:14 (East Sprinkler)
Last Sprinkler Operation Time, min:sec	0:52 (West Central Sprinkler)	2:59 (East Central Sprinkler)	13:40 (East Central Sprinkler - 40 ft. Elevation)	1:36 (East Central Sprinkler - 20 ft. Elevation)	1:15 (West Central and East Central Sprinklers)
Number of Operated Sprinklers	2 (out of 4 active in main array)	2 (out of 4 active in main array)	5 (out of 8 active in main array) No operation of Target In Rack Sprinklers	4 (out of 8 active in main array) No operation of Target "Dummy" In Rack Sprinklers	3 (out of 4 active in main array) No operation of Target "Dummy" In Rack Sprinklers

Test 2: Cartoned Unexpanded Plastics in Open Frame Racks:

This test was conducted with 43' of storage, a 48' ceiling (highest possible at UL) and a horizontal barrier at the 30' level. N252 EC sprinklers were used at the ceiling and as the in-rack sprinklers. Two sprinklers operated within the rack and one ceiling sprinkler. See Table A, Test 2. The barrier acts as a false ceiling and can effectively turn a 48' high building into a 13' storage height area sitting on top of a 30' high storage area. Following that premise; a building of more than 48' in height could be a storage area of 25' high sitting on top of a 30' high storage area.

Suggested Design:

Ceiling Sprinklers	min. pressure	flow/spr	no. of sprs calculated	Hose Stream	Total System Demand
N 252 EC P	30 psi	138 gpm	6@ 14'x14'	250 gpm	**828+ gpm***

*flows will be increased based upon actual hydraulic calculation and are for comparison purposes only

When using horizontal barriers, the in-rack sprinkler demand is not required to be added to the ceiling sprinkler demand and does not need to be balanced to the ceiling sprinklers.

The in-rack sprinklers would be designed to the following criteria:

Reliable In-rack sprs	min. pressure	flow/spr	no. of sprs calculated	Total In-Rack Demand
N252 EC P	30 psi	138 gpm	3	**414+ gpm***

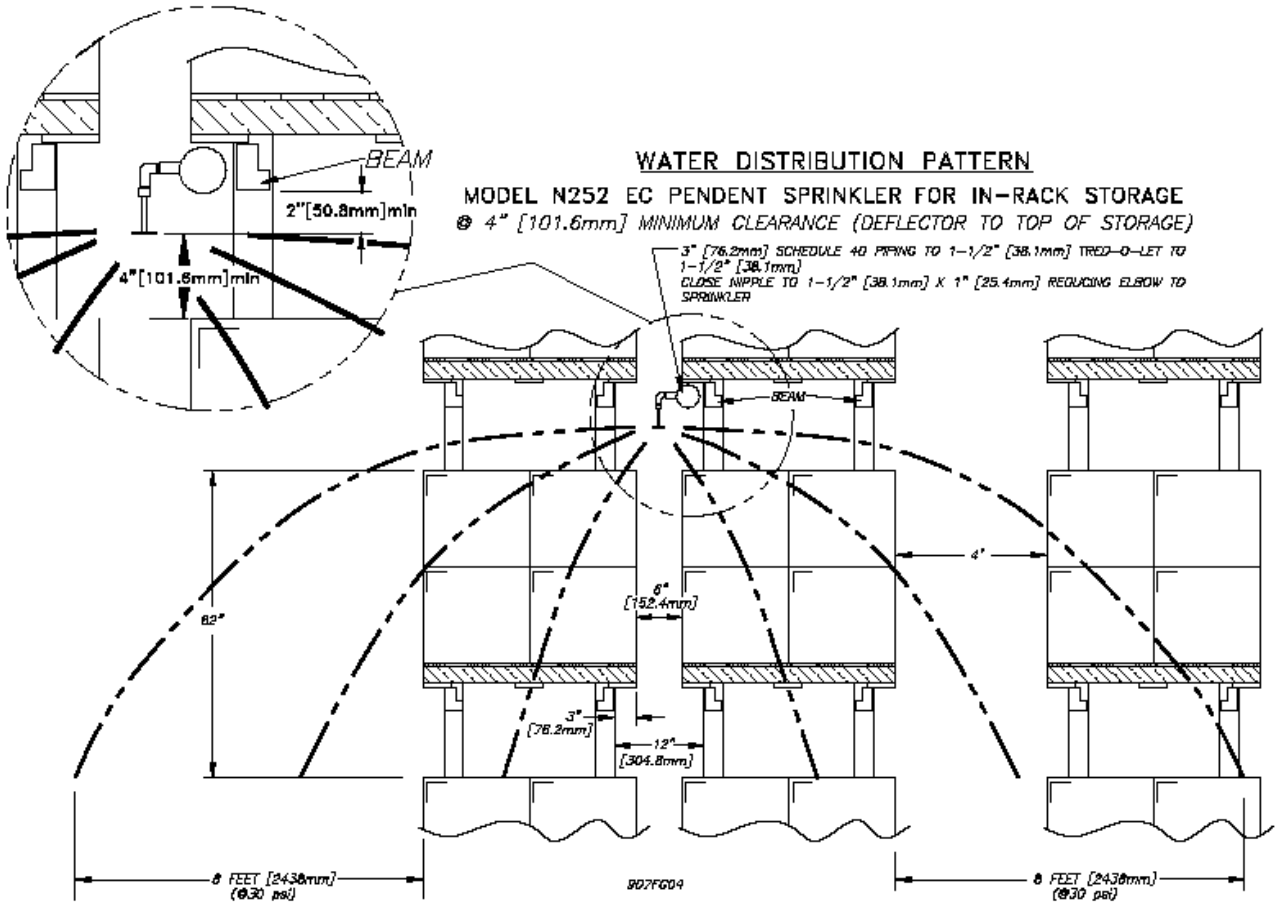
3 sprinklers would be calculated: 2 opened x 150% = 3 for design purposes

Tests 3, 4, and 5: Cartoned Unexpanded Plastics in Open Frame Racks:

Three tests were conducted to verify the use of multiple layers of horizontal barriers for high bay buildings used with ASR systems. High bay buildings with ASR systems may reach heights of 110'+. Loss mitigation and fire department reaction is difficult. The use of horizontal barriers offers a means to suppress fires within a 20' to 30' vertical area with no horizontal spread of the fire. The N252 EC pendent sprinkler was used for the ceiling sprinklers in these three tests. The sprinklers were spaced at 14' x 14' and with a design discharge pressure of 30 psi. The use of the N252 EC Pendent sprinkler as the in-rack sprinkler, because of its unique spray pattern and large volume of water, prevents ignition of the target arrays. The ignition site for all of these fires was between two sprinklers offset in the transverse flue.

Aisles widths of 4' or 8' did not have any combustion of the target arrays and no sprinklers activated in the target arrays. The Model N252 EC pendent sprinkler maintains an excellent spray pattern with a minimum 4"deflector clearance above the commodity and a minimum 2" deflector distance below the rack beam support.

Because of the rapid growth of these fires and the effectiveness of the horizontal barriers in trapping and channeling the heat, we elected to use 212°F sprinklers for all of the current testing. The intent was to minimize the number of operating sprinklers.



Target Array

Test 3 was conducted using horizontal barriers at the 20' and 40' levels with a storage height of 43' under a 48' ceiling. The ceiling sprinklers were not pressurized. This was to simulate the installation of multiple horizontal barriers in high bay buildings. A lot was learned from this test. In particular, one tiny piece of burning cardboard can smolder for over 12 minutes before igniting the commodities in the second level of storage. Also, with open transverse flue spaces you should have active ceiling sprinklers.

Even with the operation of two in-rack levels of sprinklers and the ceiling sprinklers that were delayed by more than 2 minutes waiting for pressurized water, the results were not bad. The first level had three operating sprinklers, the second level had two operating sprinklers, and the ceiling had three operating sprinklers. See Table A, Test 3.

To meet the goal of using horizontal barriers to suppress fires within a 20' to 30' vertical area with no horizontal spread of the fire, the decision was made to use a horizontal barrier that enclosed a good portion of the transverse flues located at the uprights.

Test 4 was a repeat of test 3 using horizontal barriers at the 20' and 40' levels with a storage height of 43' under a 48' ceiling. The ceiling sprinklers were not pressurized.
For this test the horizontal barrier was enclosed at the rack uprights and the transverse flue. Four in-rack sprinklers at the 20' barrier operated within 1minute and 36 seconds. The fire was suppressed with no spread to the upper level, ceiling, or target array. See Table A, Test 4.
We also learned from this test that the two outboard sprinklers activate because of the heat trapped under the barrier but are not necessarily contributing to the suppression or limiting the spread of the fire. The maximum steel temperature at the ceiling was 82° F.

Test 5 was conducted to determine how the performance would be affected by increasing the horizontal barriers to 30' levels. The overall storage height remained 43' under a 48' ceiling. The ceiling sprinklers were not pressurized.
For this test the horizontal barrier was enclosed at the rack uprights and the transverse flue. Three in-rack sprinklers at the 30' barrier operated within 1minute and 15 seconds. The fire was suppressed with no spread to the upper level, ceiling, or target array. The maximum steel temperature at the ceiling was 82° F. See Table A, Test 5.

The results of tests 4 and 5 offer further proof to the theory of creating lower ceiling height areas using horizontal barriers with N252 EC pendent sprinklers for in-rack protection in high bay buildings. When the barrier is enclosed at the rack uprights and the transverse flue space, each barrier acts as a false ceiling and can effectively turn a high building into a series of 20' to 30' high storage areas.

The design professional will determine the number of sprinklers that should be calculated under each horizontal barrier. As an example:

Ceiling Sprinklers	min. pressure	flow/spr	no. of sprs calculated	Hose Stream	Total System Demand
N 252 EC P	30 psi	138 gpm	6@ 14'x14'	250 gpm	**828+ gpm***

*flows will be increased based upon actual hydraulic calculation and are for comparison purposes only

When using horizontal barriers, the in-rack sprinkler demand is not required to be added to the ceiling sprinkler demand and does not need to be balanced to the ceiling sprinklers.

The in-rack sprinklers could be designed to the following criteria:

Reliable In-rack sprs	min. pressure	flow/spr	no. of sprs calculated	Total In-Rack Demand
N252 EC P	30 psi	138 gpm	3/4/5	414+/552+/690+ gpm*

In Conclusion:

The primary goals were:

1. To reduce the number of in-rack sprinklers required when compared to standard in-rack schemes and to also reduce the required water demands.
2. To have a significant reduction of water demand for buildings that can currently be protected by ceiling only sprinklers up to 48'.
3. Protect buildings higher than 48' with low water demands.
4. Retrofit existing facilities, where the storage commodities had changed, without changing the existing ceiling sprinklers or increasing water flows or pressures.

By using Reliable's patented Model N252 EC Pendent Sprinkler in conjunction with the patent pending N-RACK-EC™ Fire Protection System:

1. The number of in-rack sprinklers may be reduced by as much as 15+ to 1. There are no face sprinklers required and no sprinklers are required in the transverse flue.
2. Water demand for cartoned unexpanded and exposed expanded plastics in double row racks can be reduced by over 50%. Also by using the N252 EC Pendent as the ceiling sprinkler, the quantity of sprinklers will be reduced along with the starting pressure.
3. Use standard horizontal barrier configurations and add the water demand from each 20' or 30' vertical separation. Or, when the barrier is enclosed at the rack uprights and the transverse flue space, each barrier acts as a false ceiling and can effectively turn a high building into a series of 20' to 30' high storage areas.
4. Most water supplies will be able to support a 414 gpm to 690 gpm in-rack water demand. If the existing ceiling sprinklers are inadequate for the storage application, adding a horizontal barrier to the top level of the racks may resolve the problem.

Ultimately, the design professional will determine the design parameters based upon commodity, method of storage, building (ceiling) height, horizontal barrier heights, and whether to enclose the transverse flues and the rack uprights.

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