Lessons Learned from 20 years of Large Scale Fire Testing

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Overview of Presentation

Theme = Legacy vs. Today

- UL's large scale fire test facility
- Fire test scenarios utilized to investigate ceiling sprinkler performance
- Large K-factor sprinkler technology
- Sprinkler-to-storage clearance
- High temperature vs. ordinary/intermediate temperature rated sprinklers
- Antifreeze
- Water Delivery time for dry systems (high storage)

UL's Large Scale Fire Test Facility

Opened in 1996

Uniquely designed for test flexibility and repeatability

Sophisticated environmental control systems for combustion products and discharged water

UL's Large Scale Fire Test Facility (cont.)

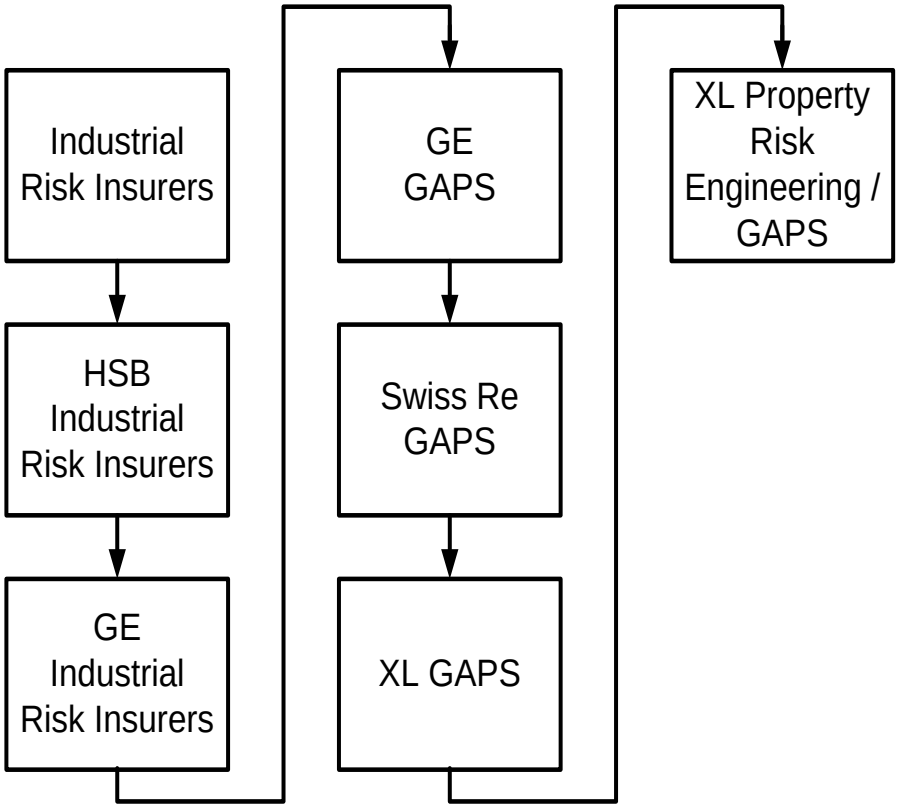
- 120 by 120 by 55 ft. (36 by 36 by 16 m) test cell
- 100 by 100 ft. (30 by 30 m) ceiling that is adjustable from 6 ft. (1.8 m) to 48 ft. (14.6 m) from floor
- Accommodates wide range of sprinkler spacing and test pressures
- Symmetrical combustion air intake and exhaust

UL's Large Scale Fire Test Facility (cont.)

10 MW calorimeter

UL's Large Scale Fire Test Facility (cont.)

- $5 million provided to UL by IRI (know today as XL Property Risk Engineering/GAPS) to support research conducted at UL for 20 years.



UL's Large Scale Fire Test Facility (cont.)

- Majority of IRI/XL Property Risk Engineering/GAPS) research has been shared with the fire protection community

- Research highlights
  - More than 130 separate projects
  - Supported several FPRF projects
  - Wood pallets
  - Oxidizers
  - Sprinkler obstruction assessments
  - Large number of commodity classification assessments

Fire Test Scenarios Utilized to Investigate Ceiling Sprinkler Performance

Legacy

Focused on conducting fire tests with ignition located between four sprinklers. Detailed guidance not provided in NFPA 13 with regard to storage sprinkler fire testing.

Today

Multiple fire test scenarios are used to investigate sprinkler performance. Detailed requirements/guidance provided in NFPA 13 for fire tests associated with storage sprinklers.

Chapter 21 of NFPA 13 - 2016

21.1.6 A series of large-scale fire tests involving challenging test scenarios that address the range of variables associated with the intended application of the sprinkler shall be conducted to evaluate the ability of the sprinkler to protect storage fire risks that are representative of those described in the manufacturer's installation and design parameter instructions and referenced in the listing.

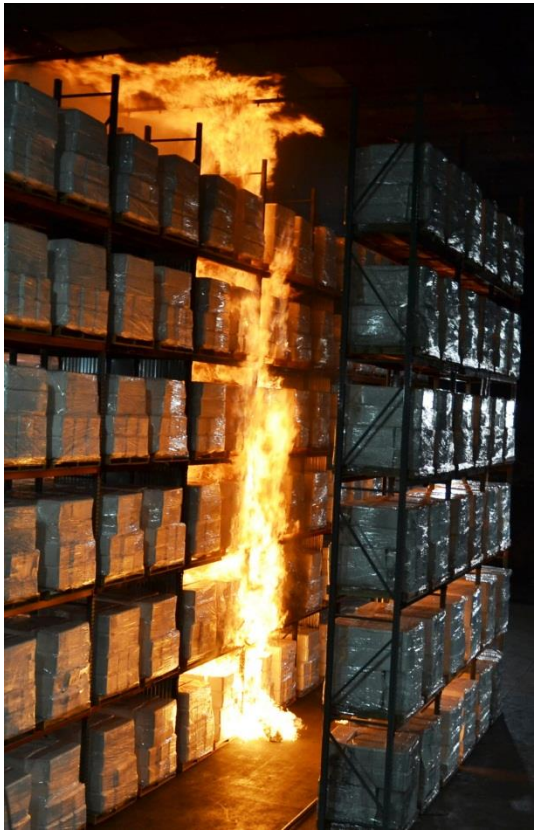
Text Source: NFPA 13 – 2016

Chapter 21 of NFPA 13 - 2016

Sprinkler system design is to be validated through large-scale fire testing--typically 3 or 4 large scale fire tests.

Test parameters that are to be considered during the test series include:

- Ignition location
- Maximum storage height
- Sprinkler spacing
- Sprinkler temperature rating
- Ceiling height
- Clearance from storage to ceiling
- Sprinkler distance below ceiling
- Minimum operating pressure of sprinkler
- Highest commodity hazard
- Storage arrangement type
- Aisle width



Why is it Important to Conduct Large Scale Fire Testing Using Multiple Ignition Locations?

Due to the unique discharge characteristics of each sprinkler design, the weakest level of protection with respect to location of fire origin relative to the sprinkler can vary depending on the sprinkler's construction characteristics:

- The discharge characteristics of the water throughout sprinkler's coverage area is not uniform.
- The overlap of water spray from adjacent sprinklers varies within the sprinkler coverage area.
- Water discharged from a sprinkler is obstructed by the sprinkler frame as well as the piping for upright style sprinklers.
- Response time of the sprinkler can vary depending upon ignition location.

Example of Fire Test Series for Sprinkler Protecting 35 ft. (10.7 m) Rack Storage Under a 40 ft. (12.2 m) Ceiling

Test Parameters	Test 1	Test 2	Test 3	Test 4
Storage Type	Double Row Rack	Double Row Rack	Double Row Rack	Double Row Rack
Nominal Storage Height, ft (m)	30 (9.1)	35 (10.7)	30 (9.1)	20 (6.1)
Nominal Ceiling Height, ft (m)	40 (12.2)	Minimum distance from sprinkler deflector to commodity	40 (12.2)	40 (12.2)
Nominal Deflector Distance to Ceiling, in (cm)	Within 12 (30.5)	Maximum specified by manufacturer	Maximum specified by manufacturer	Maximum specified by manufacturer
Sprinkler Temperature Rating	Minimum	Maximum	Minimum	Minimum
Sprinkler Spacing, ft (m)	10 by 10 (3 by 3)	10 by 10 (3 by 3)	10 by 10 (3 by 3)	10 by 10 (3 by 3)
Nominal Discharge Pressure, psig (kPa)	Minimum design	Minimum design	Minimum design	Minimum design
Ignition location	Under one	Between 4	Between two on same branch line	Between two on same branch line
Test Duration, min	30	30	30	30

Test 1 – Investigates ability of sprinkler to effectively attack a fire originating in a location beneath a sprinkler.

Example of Fire Test Series for Sprinkler Protecting 35 ft. (10.7 m) Rack Storage Under a 40 ft. (12.2 m) Ceiling

Test Parameters	Test 1	Test 2	Test 3	Test 4
Storage Type	Double Row Rack	Double Row Rack	Double Row Rack	Double Row Rack
Nominal Storage Height, ft (m)	30 (9.1)	35 (10.7)	30 (9.1)	20 (6.1)
Nominal Ceiling Height, ft (m)	40 (12.2)	Minimum distance from sprinkler deflector to commodity	40 (12.2)	40 (12.2)
Nominal Deflector Distance to Ceiling, in (cm)	Within 12 (30.5)	Maximum specified by manufacturer	Maximum specified by manufacturer	Maximum specified by manufacturer
Sprinkler Temperature Rating	Minimum	Maximum	Minimum	Minimum
Sprinkler Spacing, ft (m)	10 by 10 (3 by 3)	10 by 10 (3 by 3)	10 by 10 (3 by 3)	10 by 10 (3 by 3)
Nominal Discharge Pressure, psig (kPa)	Minimum design	Minimum design	Minimum design	Minimum design
Ignition location	Under one	Between 4	Between two on same branch line	Between two on same branch line
Test Duration, min	30	30	30	30

Test 2 – Investigates ability of sprinkler to effectively attack a fire originating between four sprinklers with the highest storage height and smallest sprinkler clearance to top of commodity clearance which generally creates the greatest HRR from the fire prior to sprinkler operation.

Example of Fire Test Series for Sprinkler Protecting 35 ft. (10.7 m) Rack Storage Under a 40 ft. (12.2 m) Ceiling

Test Parameters	Test 1	Test 2	Test 3	Test 4
Storage Type	Double Row Rack	Double Row Rack	Double Row Rack	Double Row Rack
Nominal Storage Height, ft (m)	30 (9.1)	35 (10.7)	30 (9.1)	20 (6.1)
Nominal Ceiling Height, ft (m)	40 (12.2)	Minimum distance from sprinkler deflector to commodity	40 (12.2)	40 (12.2)
Nominal Deflector Distance to Ceiling, in (cm)	Within 12 (30.5)	Maximum specified by manufacturer	Maximum specified by manufacturer	Maximum specified by manufacturer
Sprinkler Temperature Rating	Minimum	Maximum	Minimum	Minimum
Sprinkler Spacing, ft (m)	10 by 10 (3 by 3)	10 by 10 (3 by 3)	10 by 10 (3 by 3)	10 by 10 (3 by 3)
Nominal Discharge Pressure, psig (kPa)	Minimum design	Minimum design	Minimum design	Minimum design
Ignition location	Under one	Between 4	Between two on same branch line	Between two on same branch line
Test Duration, min	30	30	30	30

Test 3 – Investigates ability of the sprinkler to attack a fire originating in an area between two sprinklers where the sprinkler discharge is impacted by the sprinkler frame arms and obstructed by the supply pipe if it is an upright style sprinkler.

Example of Fire Test Series for Sprinkler Protecting 35 ft. (10.7 m) Rack Storage Under a 40 ft. (12.2 m) Ceiling

Test Parameters	Test 1	Test 2	Test 3	Test 4
Storage Type	Double Row Rack	Double Row Rack	Double Row Rack	Double Row Rack
Nominal Storage Height, ft (m)	30 (9.1)	35 (10.7)	30 (9.1)	20 (6.1)
Nominal Ceiling Height, ft (m)	40 (12.2)	Minimum distance from sprinkler deflector to commodity	40 (12.2)	40 (12.2)
Nominal Deflector Distance to Ceiling, in (cm)	Within 12 (30.5)	Maximum specified by manufacturer	Maximum specified by manufacturer	Maximum specified by manufacturer
Sprinkler Temperature Rating	Minimum	Maximum	Minimum	Minimum
Sprinkler Spacing, ft (m)	10 by 10 (3 by 3)	10 by 10 (3 by 3)	10 by 10 (3 by 3)	10 by 10 (3 by 3)
Nominal Discharge Pressure, psig (kPa)	Minimum design	Minimum design	Minimum design	Minimum design
Ignition location	Under one	Between 4	Between two on same branch line	Between two on same branch line
Test Duration, min	30	30	30	30

Test 4 – Investigates ability of the sprinkler to attack a fire with a high clearance between the sprinkler deflector and top of storage.

Large K-factor Sprinkler Technology

Legacy

Storage fire risks protected with nominal K=5.6 (80) and K=8.0 (115) sprinklers.

Today

A broad range of large K-factor sprinklers are available to provide more cost efficient and effective protection for storage fire risks.

Large K-factor Sprinkler Technology

NFPA 13-2016

12.6.3 For general storage applications, rack storage, rubber tire storage, roll paper storage, and baled cotton storage being protected with upright and pendent spray sprinklers with required densities greater than 0.34 gpm/ft^2 (13.9 mm/min), standard-response spray sprinklers with a K-factor of K-11.2 (161) or larger that are listed for storage applications shall be used.

Knowledge Check: Storage Sprinklers

How many ceiling sprinkler technologies are currently referenced in NFPA 13-2016 for use in storage applications at discharge densities of greater than 0.34 gpm/sq. ft.?

A. 1-5
B. 6-10
C. 11-15
D. 16-20
E. Greater than 20

Note: Each nominal K-factor, style (upright or pendent) and type (CMDA, CMSA & ESFR) is considered a different sprinkler.

Ceiling Sprinkler Types Currently Referenced in NFPA 13 for Use in Storage Applications at Discharge Densities of Greater than 0.34 gpm/sq. ft.

No.	Nominal K-factor	Style	Initial Availability	Type	NFPA 13 Objective
1	11.2	Pendent	Early 1990s	CMDA	Fire Control
2	11.2	Upright	Early 1990s	CMDA	Fire Control
3	14.0	Pendent	1996	CMDA	Fire Control
4	16.8	Pendent	1997	CMDA	Fire Control
5	16.8	Upright	1997	CMDA	Fire Control
6	25.2	EC Pendent	2006	CMDA	Fire Control
7	25.2	EC Upright	2001	CMDA	Fire Control

Ceiling Sprinkler Types Currently Referenced in NFPA 13 for Use in Storage Applications at Discharge Densities of Greater than 0.34 gpm/sq. ft.

No.	Nominal K-factor	Style	Initial Availability	Type	NFPA 13 Objective
8	11.2	Upright	1981	CMSA (Large Drop)	Fire Control
9	16.8	Upright	1997	CMSA	Fire Control
10	19.6	Pendent	2008	CMSA	Fire Control
11	25.2	Pendent	2009	CMSA	Fire Control
12	25.2	Upright	2009	CMSA	Fire Control
13	25.2	EC Pendent	2010	CMSA	Fire Control
14	25.2	EC Upright	2011	CMSA	Fire Control

Ceiling Sprinkler Types Currently Referenced in NFPA 13 for Use in Storage Applications at Discharge Densities of Greater than 0.34 gpm/sq. ft.

No.	Nominal K-factor	Style	Initial Availability	Type	NFPA 13 Objective
15	14.0	Pendent	1987	ESFR	Fire Suppression
16	14.0	Upright	1999	ESFR	Fire Suppression
17	16.8	Pendent	2000	ESFR	Fire Suppression
18	16.8	Upright	2002	ESFR	Fire Suppression
19	22.4	Pendent	2001	ESFR	Fire Suppression
20	25.2	Pendent	1998	ESFR	Fire Suppression
21	28.0	Pendent	2015	ESFR	Fire Suppression

Response Time Index Comparison

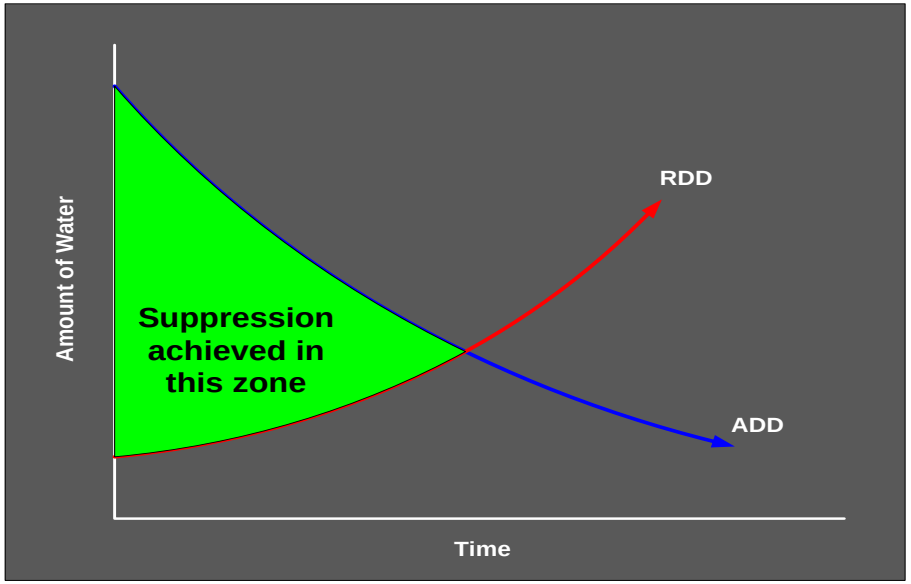
Type	Criteria	Typical RTI
ESFR	≤36 $(m \cdot s)^{1/2}$ or 50 $(m \cdot s)^{1/2}$	Link = ~25 $(m \cdot s)^{1/2}$ or less
Quick Response	≤50 $(m \cdot s)^{1/2}$	3 mm bulb = ~40 $(m \cdot s)^{1/2}$
Standard Response	≥80 $(m \cdot s)^{1/2}$ to ≤350 $(m \cdot s)^{1/2}$	5 mm bulb = ~110 $(m \cdot s)^{1/2}$

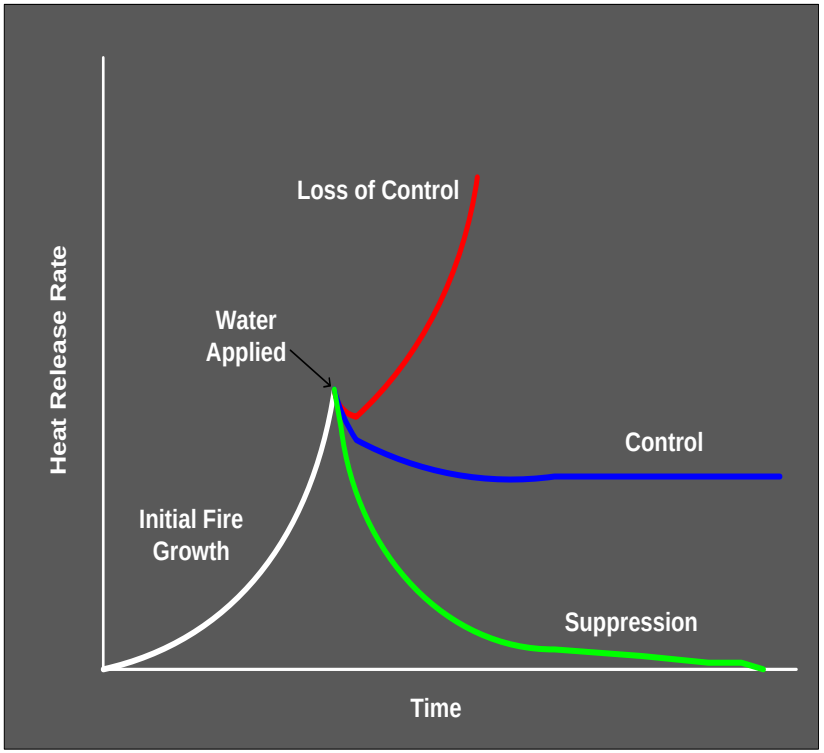
Fire Control vs. Fire Suppression

NFPA 13 – 2013

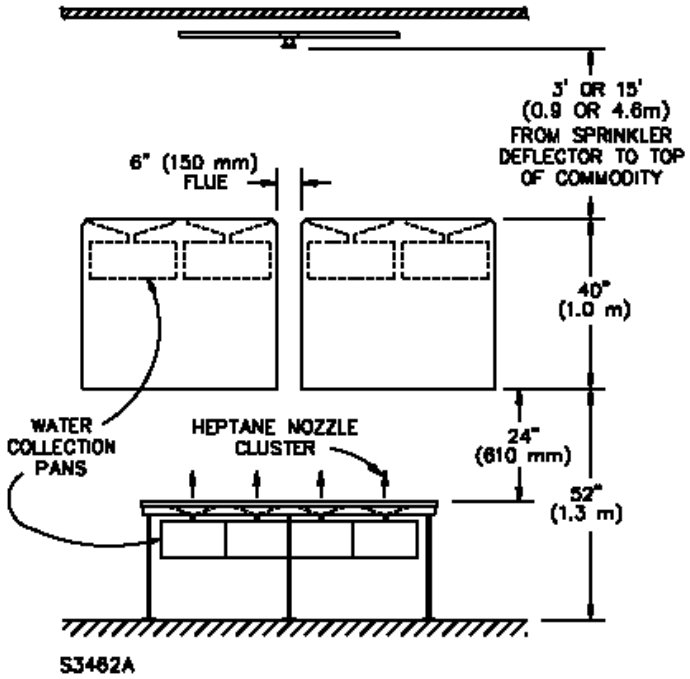
3.3.11 Fire Control. Limiting the size of a fire by distribution of water so as to decrease the heat release rate and pre-wet adjacent combustibles, while controlling ceiling gas temperatures to avoid structural damage.

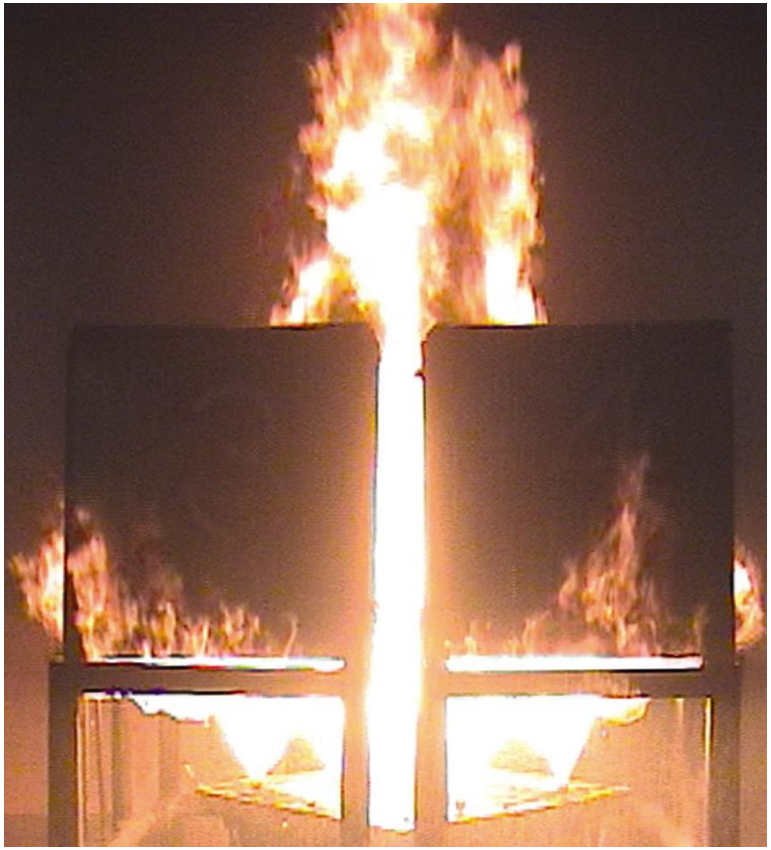
3.3.12 Fire Suppression. Sharply reducing the heat release rate of a fire and preventing its regrowth by means of direct and sufficient application of water through the fire plume to the burning fuel surface.





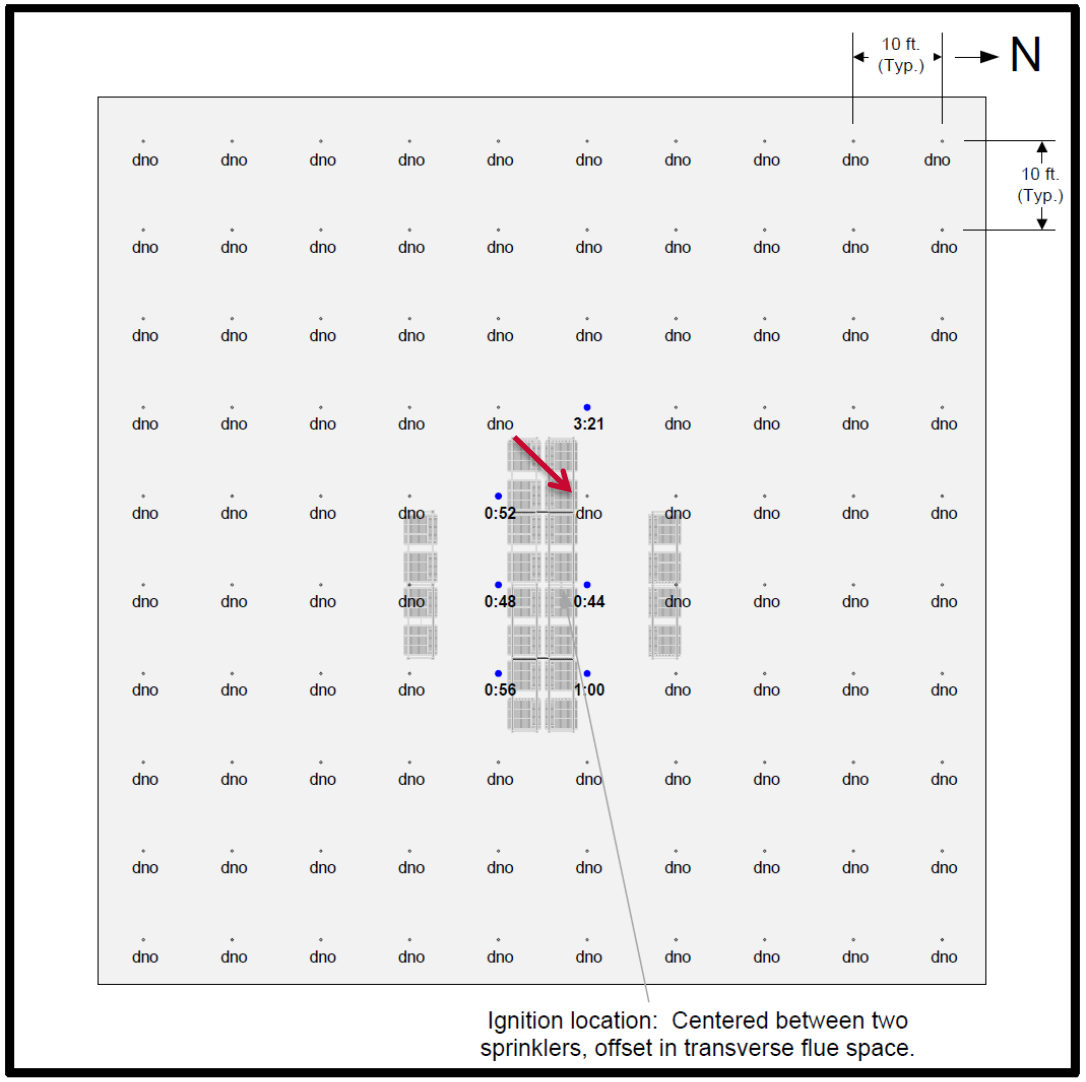
Actual Delivered Density (ADD) Testing -- A Dynamic Water Distribution Test for Storage Type Sprinklers





ADD testing is a useful tool to investigate a sprinkler's discharge characteristics; however, this testing is conducted with open sprinklers which does not investigate the potential for sprinkler skipping or blocked flues.

Illustration of Sprinkler Skipping – Test 2 from Recent FPRF Exposed Expanded Plastics Project



dno: did not operate

Illustration of Sprinkler Skipping – Test 3 from FPRF Exposed Expanded Group A Plastics Project Using ESFR Sprinklers

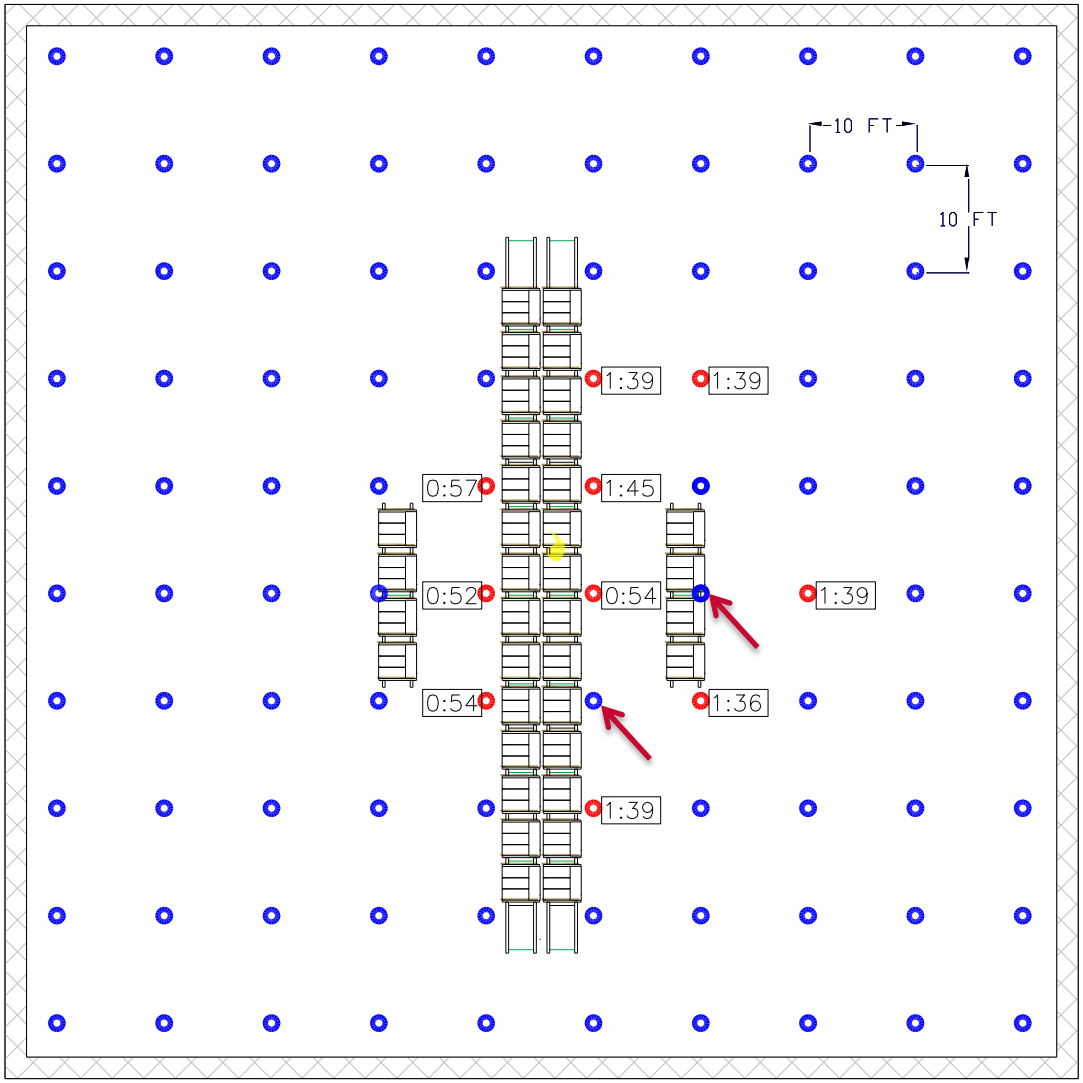
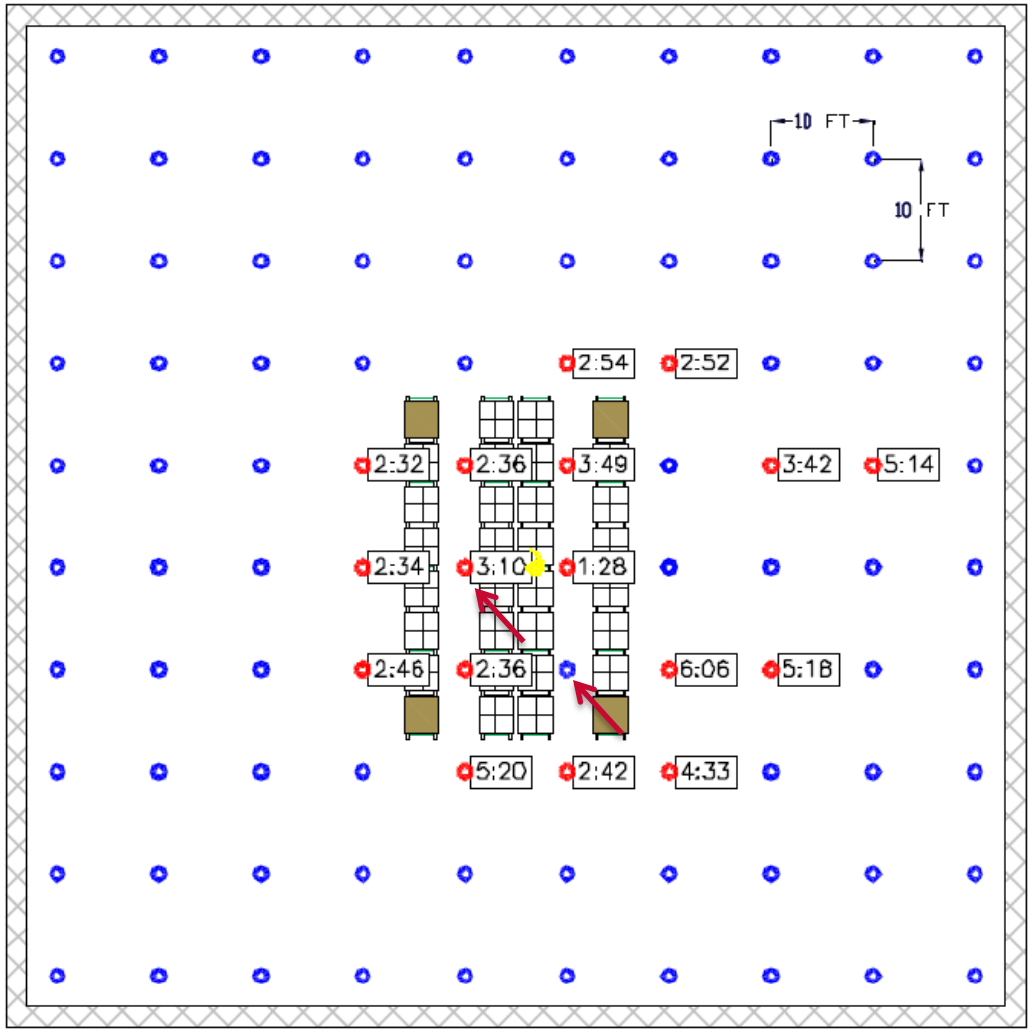


Illustration of Sprinkler Skipping – Nominal K=14.0 ESFR Sprinkler with Cartoned, Unexpanded Plastic and 40 ft. Ceiling Height



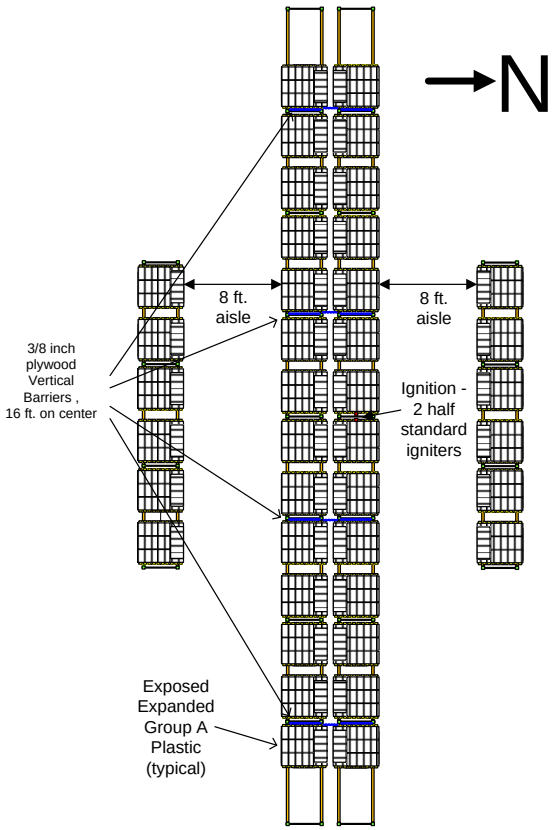
FIRE TEST NUMBER	Test 1	Test 2	Test 3	Test 5	Test 6	Test 7
Test Date	July 9, 2012	July 13, 2012	July 18, 2012	October 31, 2012	November 8, 2012	June 8, 2013
Test Parameters						
Storage Type	Double Row Rack	Double Row Rack	Double Row Rack	Double Row Rack	Double Row Rack	Double Row Rack
Commodity Type	Exposed Expanded Group A Plastic	Exposed Expanded Group A Plastic	Exposed Expanded Group A Plastic	Exposed Expanded Group A Plastic	Exposed Expanded Group A Plastic	Exposed Expanded Group A Plastic
Vertical Barriers	16 ft. on center - Main Array (Non-combustible)	16 ft. on center - Main Array (Non-combustible)	16 ft. on center - Main Array (Non-combustible)	24 ft. on center - Main Array (3/8 in. plywood)	16 ft. on center - Main Array (3/8 in. plywood)	16 ft. on center - Main Array (3/8 in. plywood)
Number of Blocked Traverse Flue Spaces	**18**	**12**	**72**	**98**	**60**	None
Length of Main Storage Array, ft.	32	32	56	56	56	56
Nominal Storage Height, ft.	20	20	35	40	30	30
Ceiling Height, ft.	40	40	40	45	40	40
Aisle Width, ft.	8	8	8	8	8	8
Ignition Location	Between 2 Sprinklers (offset)	Between 2 Sprinklers (offset)	Between 2 Sprinklers (offset)	Under 1 Sprinkler (offset)	Under 1 Sprinkler (offset)	Under 1 Sprinkler (offset)
Sprinkler Type	ESFR	ESFR	ESFR	ESFR	ESFR	ESFR
Sprinkler Orientation	Pendent	Pendent	Pendent	Pendent	Pendent	Pendent
Deflector to Ceiling, in.	14	14	14	14	14	14
Sprinkler Spacing, sprinkler by branchline ft. by ft.	10 by 10	10 by 10	10 by 10	10 by 10	10 by 10	10 by 10
Temperature Rating, F	212	214	214	214	214	214
Nominal Sprinkler Discharge Coefficient K, gpm/psig $^{0.5}$	22.4	25.2	25.2	25.2	25.2	25.2
Nominal Discharge Pressure, psig	50	60	60	60	60	60

Exposed Expanded Group A Plastics Stored in Racks

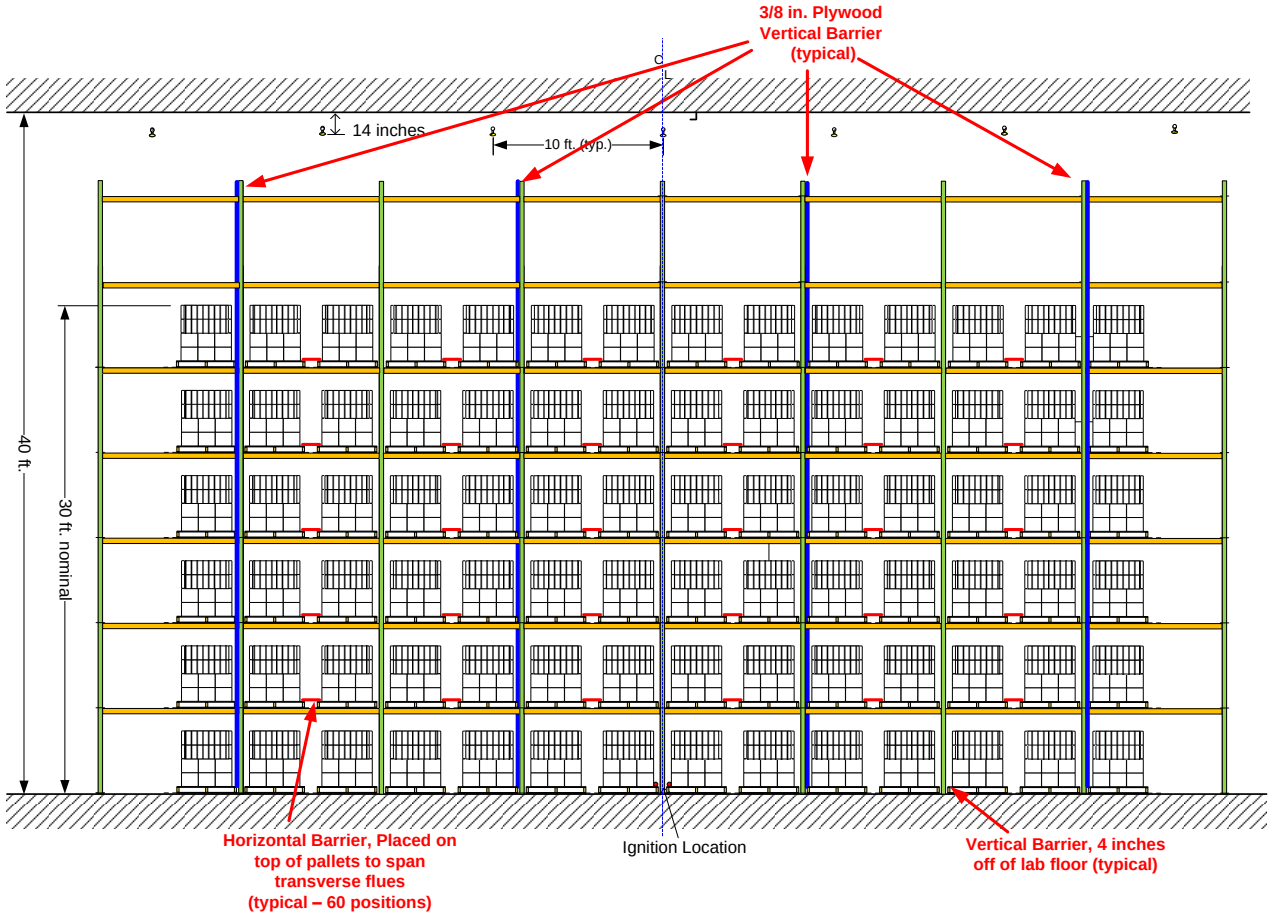
FIRE TEST NUMBER	Test 1	Test 2	Test 3	Test 5	Test 6	Test 7
Test Date	July 9, 2012	July 13, 2012	July 18, 2012	October 31, 2012	November 8, 2012	June 8, 2013
Test Results						
Length of Test, minutes	31	31	31	31	31	31
First Sprinkler Operation Time, min:sec	0:39	0:44	0:52	0:47	0:48	0.47
Last Sprinkler Operation Time, min:sec	8:23	3:21	1:45	1:39	4:35	1:28
Number of Operated Sprinklers	12	6	10	18	11	7
Peak Gas Temperature at Ceiling Above Ignition, °F	564	558	1138	1002	241	414
Maximum 1 minute Average Gas Temperature at Ceiling Above Ignition, °F	255	220	353	489	151	190
Peak Steel Temperature at Ceiling Above Ignition, °F	126	119	145	160	129	131
Maximum 1 minute Average Steel Temperature at Ceiling Above Ignition, °F	124	117	141	156	127	127
Ignition Time of Target Array, minutes:seconds	None	None	None	1:01 (North Target)	1:27 (South Target)	None
Fire Travel to Extremities of Test Array	Yes (East and West end of Main)	Yes (West end of Main)	No	Yes (North Target Array Burned Through to Extremities)	Yes (South Target Array Burned Through to Extremities)	No

Test 6 Arrangement

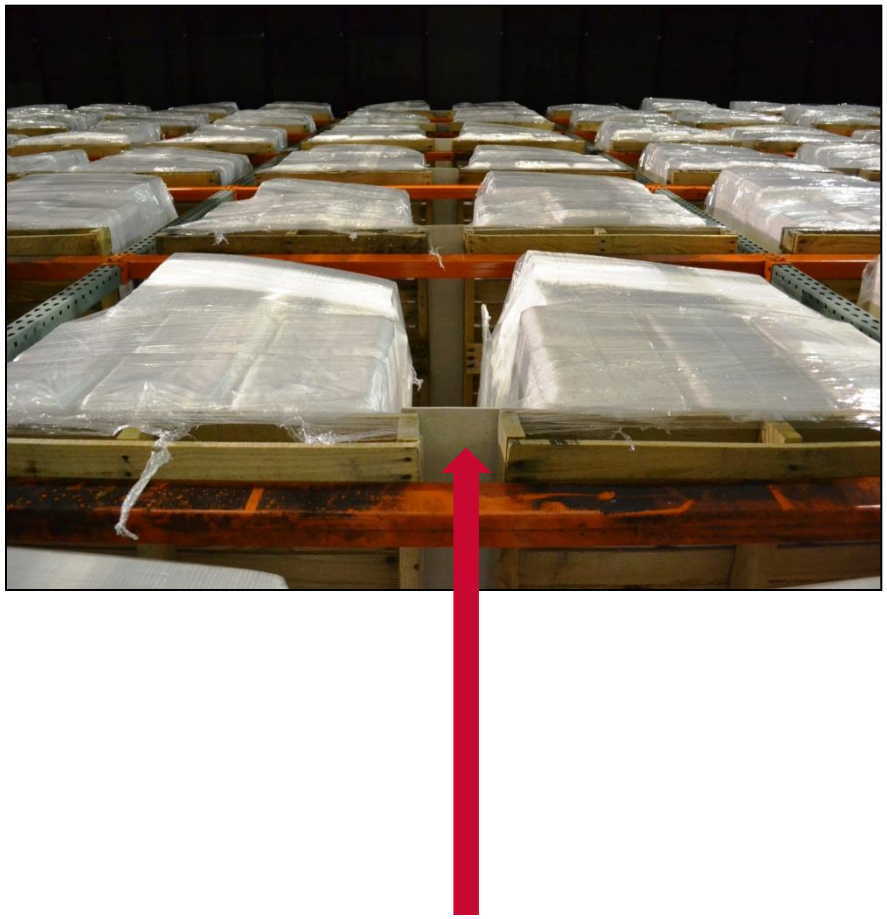
Plan View



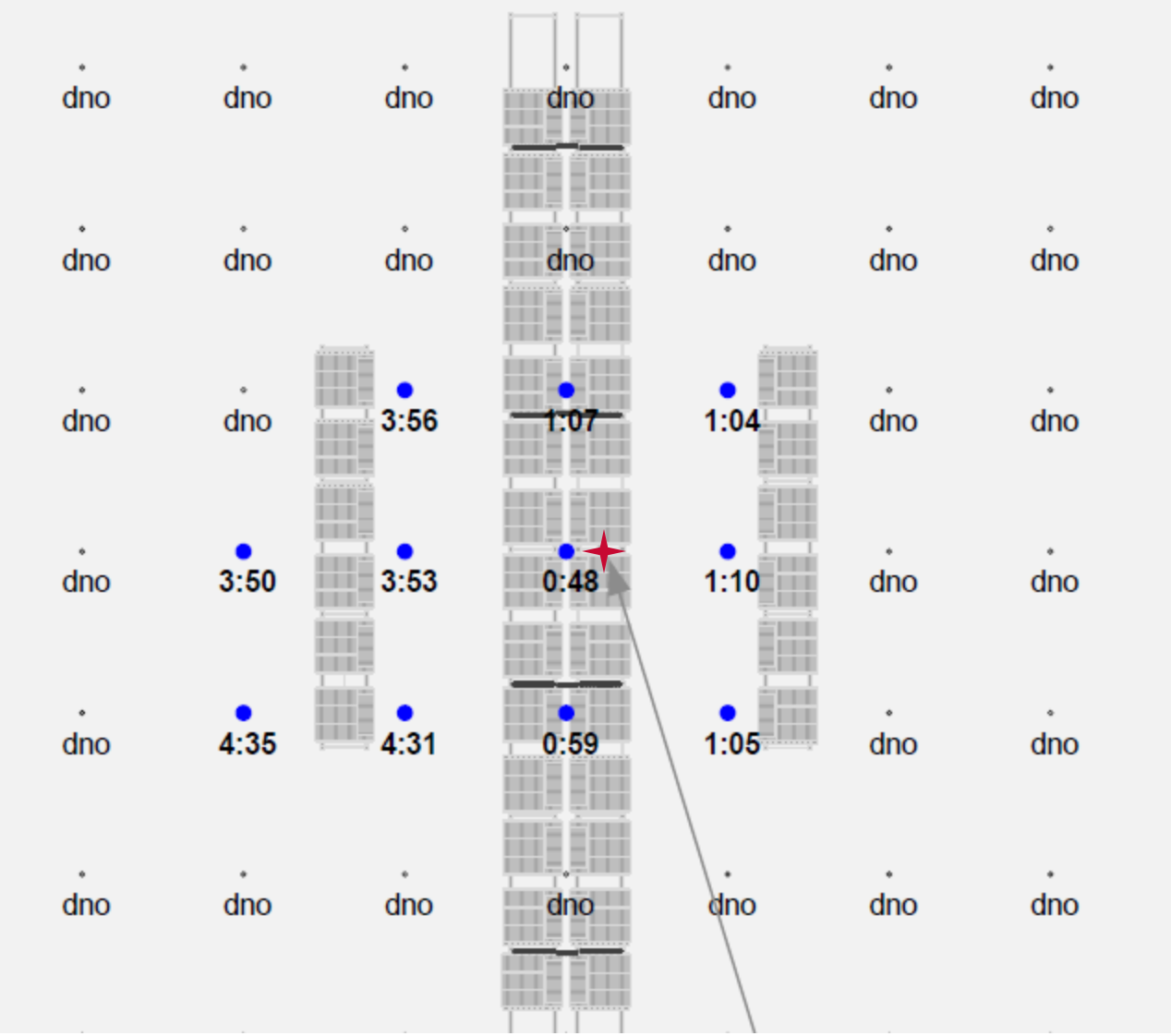
Elevation View



Transverse Flue Space Blocking



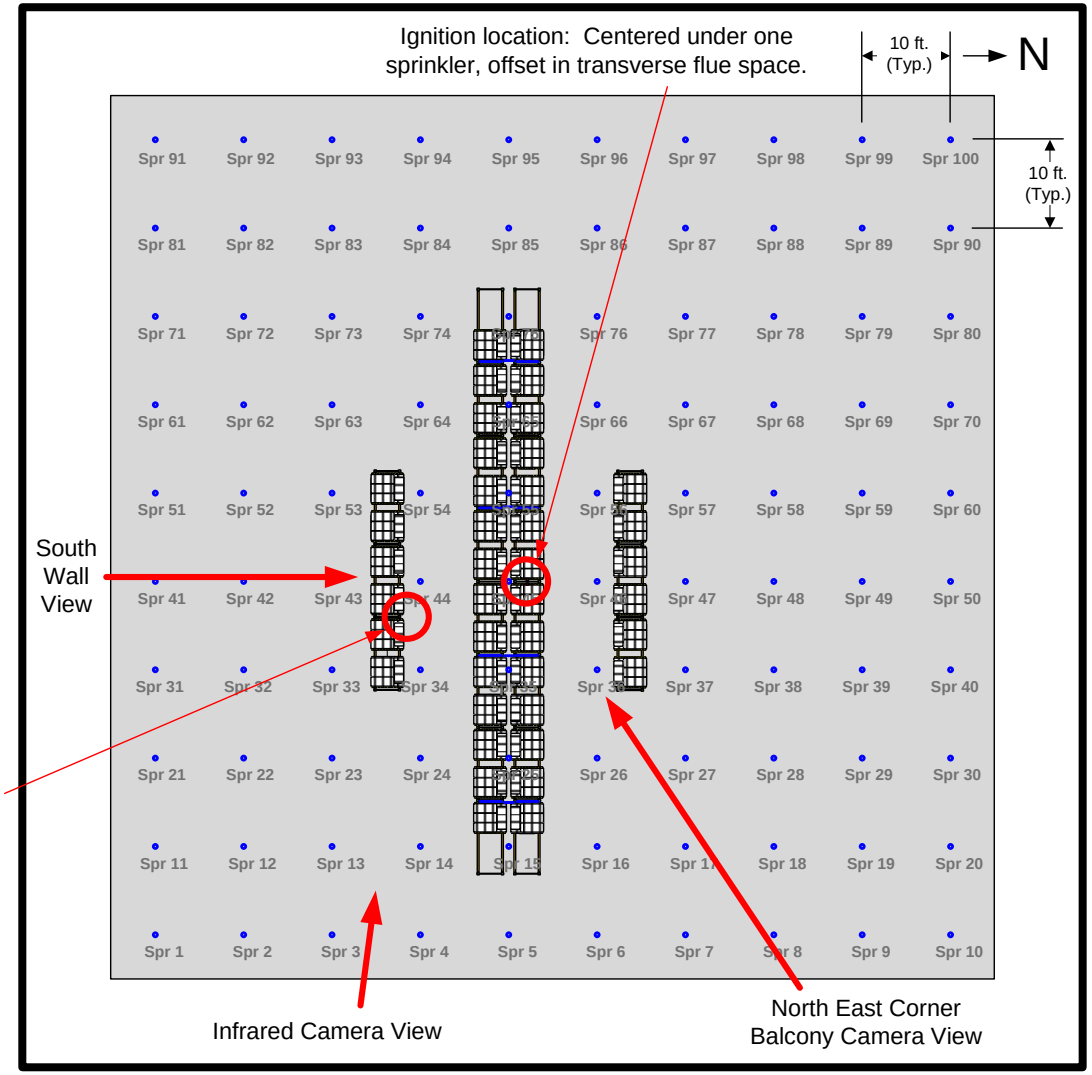
Test 6 – Sprinkler Operations (11)



Test 6 – South Target Array Damage

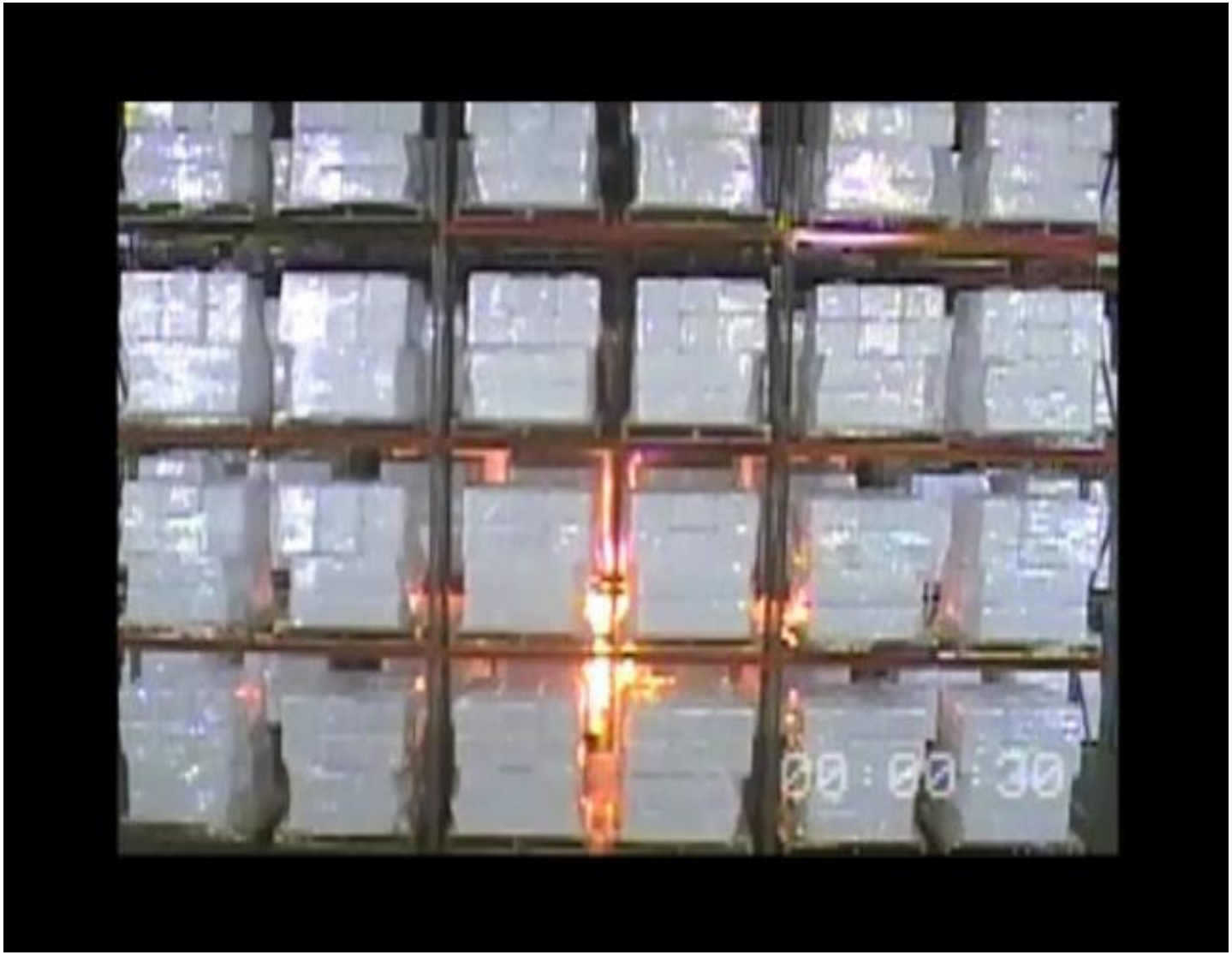
View from Outside Arrangement

Test 6 – Camera Locations



Test 6 View from NE Balcony

Test 6 – View from South Target Array



Test 6 – View from South East Corner - Infrared

Sprinkler-to-Storage Clearance

Legacy

Limited criteria in NFPA 13 addressing high clearances between the top of storage and the sprinkler.

Today

More detailed criteria provided in Chapter 12 of NFPA 13-2016 addressing high clearances between the top of storage and sprinkler; and the ceiling height limitation for the nominal K=14 ESFR sprinkler has been reduced to 35 ft. (10.7 m).

Sprinkler-to-storage Clearance (Cont.)

Example of Clearance Criteria in NFPA 13-2016

12.1.3.4.5 Where the clearance to ceiling exceeds 10 ft. (3.0 m) for Section 16.3 or Section 17.2, protection shall be based upon the storage height that would result in a clearance to ceiling of 10 ft. (3.0 m) or providing one level of supplemental, quick-response in-rack sprinklers located directly below the top tier of storage and at every flue space intersection.

NFPA 13 Revisions Based Upon Large Scale Fire Test Data

For nominal K=14 (200) Pendent ESFR sprinklers, NFPA 13 was revised to limit the use of these sprinklers in new installations to a maximum ceiling height of 35 ft. (10.7 m) rather than the previously referenced 40 ft. (12.2 m) ceilings.

Fire Test Results of Nominal K=14(200) ESFR Pendent Sprinkler 20 ft. (6.1 m) Clearance

FIRE TEST NUMBER	Test 1	Test 2
TEST PARAMETERS		
Storage Type	Double Row Rack	Double Row Rack
Commodity Type	Cartoned, Unexpanded Group A Plastic	Cartoned, Unexpanded Group A Plastic
Nominal Storage Height, ft(m)	20 (6.1)	20 (6.1)
Nominal Ceiling Height, ft(m)	40 (12.2)	40 (12.2)
Aisle Width, ft(m)	4 (1.2)	4 (1.2)
Ignition Location	Offset Between 2	Offset Between 2
Temperature Rating, °F (°C)	165 (74)	165 (74)
Deflector to Ceiling, in (cm)	14 (36)	14 (36)
Nominal Sprinkler Discharge Coefficient K, 200 gpm/psig $^{0.5}$ (lpm/ bar$^{1/2)}$	14 (200)	14 (200)
Nominal Discharge Pressure, psig (bar)	75 (5.2)	100 (6.9) for first 4 operated sprinklers, 75 (5.2) when more than four sprinklers have operated
Sprinkler Spacing, m (ft)	10 by 10 (3 by 3)	10 by 10 (3 by 3)
TEST RESULTS		
First Sprinkler Operation, min:sec	1:28	0:55
Last Sprinkler Operation, min:sec	6:06	6:20
Number of Operated Sprinklers	17	18
Maximum I Minute Average Steel Temperature Above Ignition, °F(°C)	81 (178)	83 (181)
Fire Spread Across the Aisle	Yes	Yes

High Temperature vs. Ordinary/Intermediate Temperature Rated Sprinklers

Legacy

Nominal K=5.6 (80) and K=8.0 (115) sprinklers in the high temperature rating provided improved performance in storage fire tests compared to ordinary temperature rated sprinklers. NFPA 13 included sprinkler system design incentives for high temperature rated sprinklers.

Today

Larger K-factor storage sprinkler technology has demonstrated the ability to provide enhanced protection using ordinary temperature rated sprinklers. NFPA 13 generally permits either temperature rating to be used with the same design criteria.

High Temperature vs. Ordinary Temperature Rated Sprinklers (cont.)

NFPA 13-2016

12.6.9 Ordinary- and intermediate-temperature sprinklers with K-factors of K-11.2 (161) or larger, where listed for storage, shall be permitted to use the densities for high temperature sprinklers.

Comparison Test Results Using Idle Wood Pallets

Selected Information from Table A.12.12 of NFPA 13-2016

Nominal Storage Height, ft (m)	Ceiling Height ft(m)	Sprinkler Information	Number of Operated Sprinklers	Time of First Sprinkler Operation, Min:sec	Time of Last Sprinkler Operation, Min:sec	Max. 1 Min. Ave. Steel Temp. ºF (ºC)
8 (2.4)	30 (9.1)	286ºF, K=11.2 (141ºC, K=160)	12	5:00	23:03	220 (104)
8 (2.4)	30 (9.1)	286ºF, K=11.2 (141ºC, K=160)	13	5:05	19:10	208 (98)
8 (2.4)	30 (9.1)	286ºF, K=11.2 (141ºC, K=160)	16	5:48	19:04	228 (109)
8 (2.4)	30 (9.1)	200ºF, K=11.2 (93ºC, K=160)	4	4:10	4:10	134 (57)
8 (2.4)	30 (9.1)	200ºF, K=11.2 (93ºC, K=160)	4	3:34	3:34	135 (57)
8 (2.4)	30 (9.1)	155ºF, K=11.2 (68ºC, K=160)	4	3:46	3:46	115 (46)
8 (2.4)	30 (9.1)	155ºF, K=11.2 (68ºC, K=160)	4	3:09	3:09	113 (45)

Antifreeze

Legacy

High concentrations of propylene glycol (60% maximum) and glycerin (70% maximum) were permitted in NFPA 13 for decades.

Today

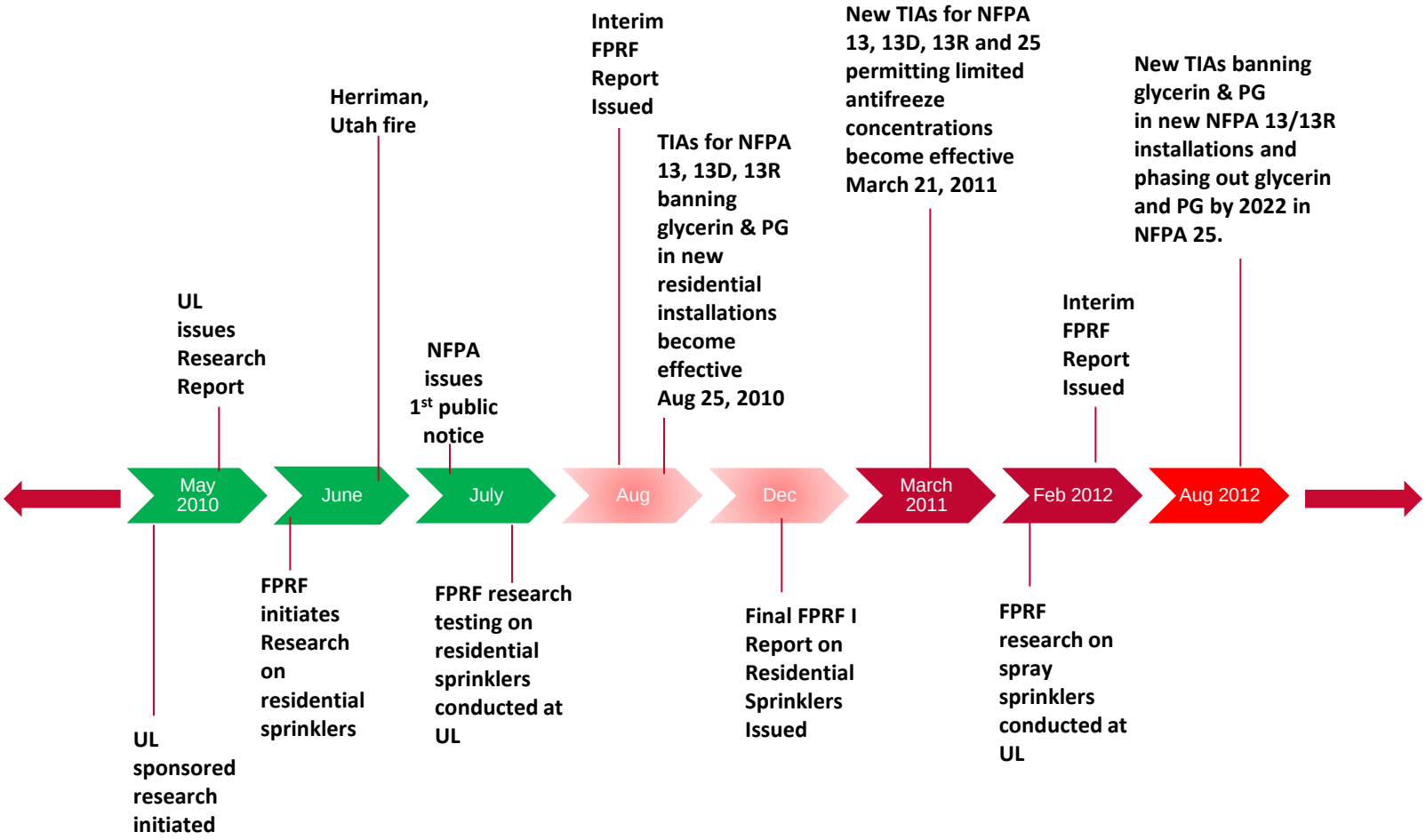
Except for an ESFR sprinkler listed for use with a premixed propylene glycol solution for a specific application, antifreeze solutions in new sprinkler system installations in accordance NFPA 13 are required to be listed.

Apartment Complex Protected by a NFPA 13 Sprinkler System With Antifreeze

General Details of Fire Occurrence

- Fire and explosion occurred in the first floor apartment of a 12-unit complex on August 2009.
- Sprinkler system was supplied with glycerin antifreeze.
- Fire involving a skillet containing cooking oil and onions originated on the range top.

Historical Timeline



Antifreeze in Sprinkler Systems

Fire Test Parameters

- **Test Configuration:** Residential Sprinkler Discharging onto Fire Source
- **Liquid Discharged:** 60% PG/40% Water Mixture
- **Fire Source:** 6 in. (15 cm) Wide by 8 ft. (2.4 m) Long Pan of Heptane
- **Sprinkler Type:** Nominal K=3.1 Residential
- **Sprinkler Pressure:** 10 - 80 psig (69 – 552 kPa)
- **Nominal HRR of Fire:** 500 kW
- **Sprinkler to Pan Distance:** 5 ft. (1.5 m)

Antifreeze in Sprinkler Systems

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Summary

1. Solution Characterization (viscosity, specific gravity, freeze point, etc.)
2. Stability of Solutions (temperature extremes)
3. Conductivity (electrical shock risk is ≤ water)
4. Exposure Tests (corrosion, material compatibility)
5. Health Effects (dermal contact, ingestion, inhalation)
6. Fire Performance (contribution and fire attack characteristics)
7. Other (viscosity at temperature range, resistance to leakage)
8. Installation Instructions described proper use

Water Delivery Time for Dry Systems (High Storage)

Legacy

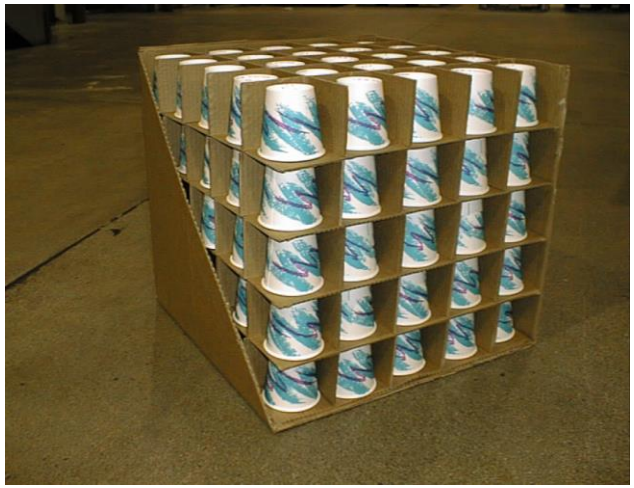
Maximum water delivery time was typically 60 seconds for storage applications.

Today

Shorter water delivery time utilized to reduce the number of sprinklers to be included in the hydraulic calculation.

Dry System Rack Storage Test

Ceiling Height	45 ft. (13.7 m)
Storage Height	40 ft. (12.2 m)
Storage Type	Double Row Rack
Commodity Type	Class III
Sprinkler System	Ceiling Sprinklers Only
Sprinkler Type	Nominal K=16.8 gpm/psi$^{1/2}$ (242 lpm/ bar$^{1/2}$) Upright, 286°F (141°C)
Sprinkler Spacing	10 ft. by 10 ft. (3 m by 3 m)
Deflector Distance	7 in. (17.8 cm) below ceiling
Ignition Location	Between Four Sprinklers
Intended Pressure	30 psig (2.1 bar)



Dry System Rack Storage Test

Thank You!

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