

Different Sprinkler Densities for Different Building Heights in Non-Storage Occupancies

FM Global Data Sheet 3-26 Criteria

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RESILIENCE IS A CHOICE.

Impact of Clearance on Sprinkler Performance



FM Global Data Sheet (DS) 8-9

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

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

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

Storage Height?

Fire Testing with Cartoned Unexpanded Plastics

Test Conditions

- Storage Arrangement: Open-frame double-row racks
- Aisle Width: 1.2 m (4 ft)
- Ceiling Height: 12.2 m (40 ft)
- Ceiling Sprinkler: QR K200 (K14.0) pendent (ESFR)
- Sprinkler Spacing: 3.0 x 3.0 m (10 x 10 ft)
- Sprinkler Operating Pressure: 5.2 bar (75 psi)

Fire Testing with Cartoned Unexpanded Plastics

Test No.	Ceiling Height, m (ft)	Sprinkler Type	Test Pressure, bar (psi)	Storage Height, m (ft)	No. of Open Sprinklers
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Fire Testing with Cartoned Unexpanded Plastics

Test No.	Ceiling Height, m (ft)	Sprinkler Type	Test Pressure, bar (psi)	Storage Height, m (ft)	No. of Open Sprinklers
1	12.2 (40)	QR K200 (K14.0) Pendent	5.2 (75)	10.7 (35)	6 or less
2	12.2 (40)	QR K200 (K14.0) Pendent	5.2 (75)	9.1 (30)	6 or less
3	12.2 (40)	QR K200 (K14.0) Pendent	5.2 (75)	6.1 (20)	17
4	12.2 (40)	QR K200 (K14.0) Pendent	6.2 (90) then 5.2 (75)	6.1 (20)	18

Nonstorage Occupancies Too?

Impact of Clearance on Sprinkler Performance

Manufacturing operation
w/ in-process plastic
storage

Per EN 12845:
OH 3 Protection

Density:
5 mm/min (0.125 gpm/ft²)

Design Area:
216 m² (2,300 ft²)

Regardless of ceiling height



Impact of Clearance

Manufacturing operation
w/ in-process plastic
storage

Per FM Global DS 3-26:
Hazard Category 3

Density:

12 mm/min (0.30 gpm/ft²)

Design Area:

Depends on ceiling height

Why would FM Global look at
ceiling height in non-storage
occupancies?

[PUBLIC]

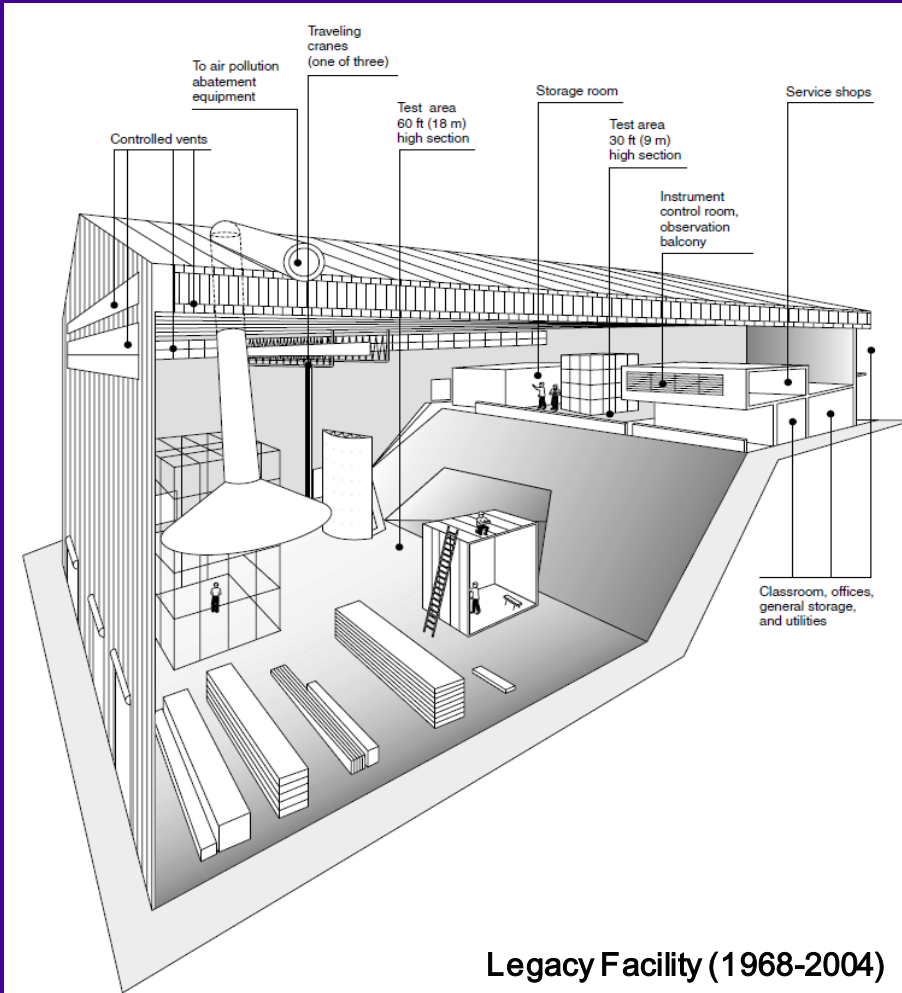


Research on Non-Storage Protection

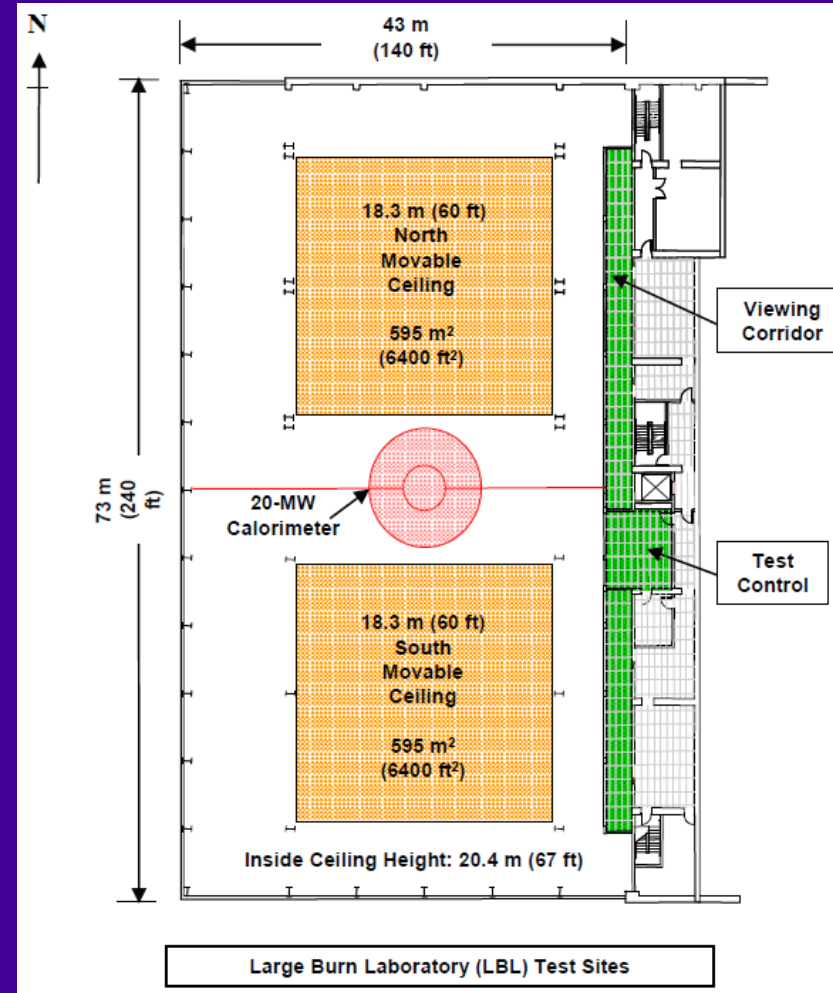
- **Multiple projects using large-scale fire testing**
 - Non-storage occupancies with high clearance (S. Nam, 2000)
 - Extended coverage (EC) sprinkler applications (J. Newman, 2010)
 - Protection of uncartoned plastic commodities (Y. Gopala, 2016)
 - Performance evaluation at low pressure limits (D. Han, 2019)

- **Systematic extension of test results**
 - Methodology and practice

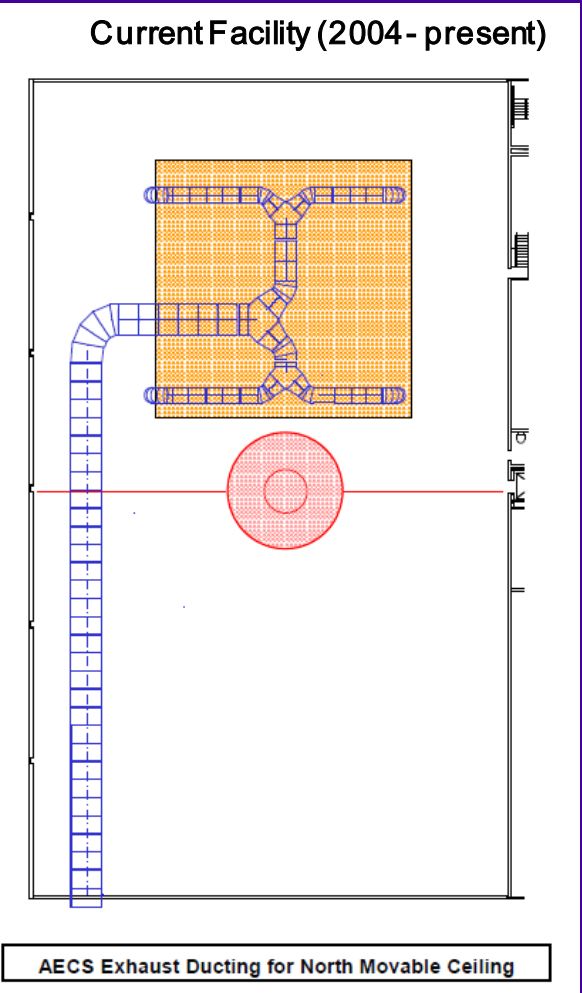
FM Global Testing Facilities



Legacy Facility (1968-2004)



Large Burn Laboratory (LBL) Test Sites



AECS Exhaust Ducting for North Movable Ceiling

Representative Commodities



**Class 2 –
HC2**

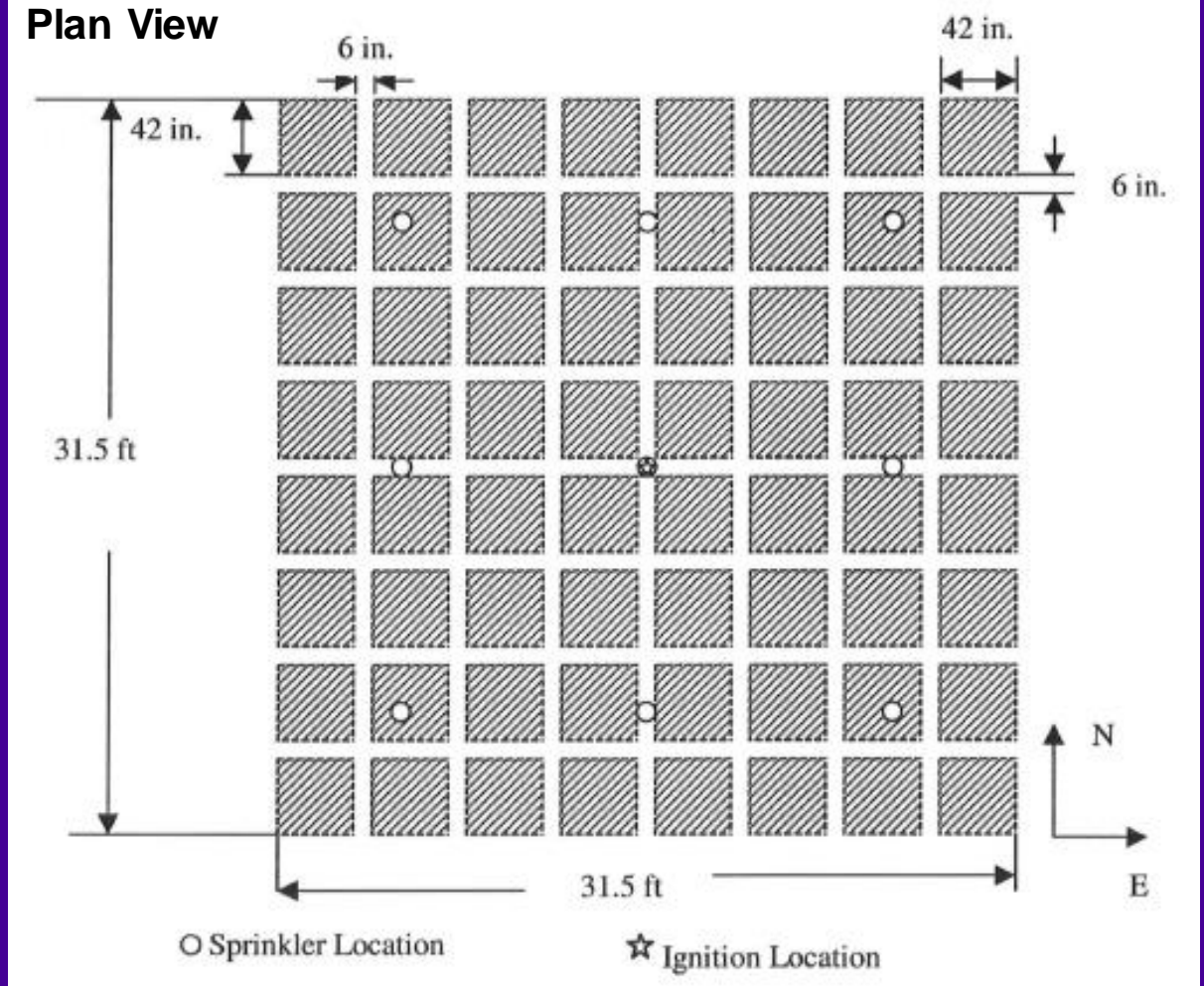
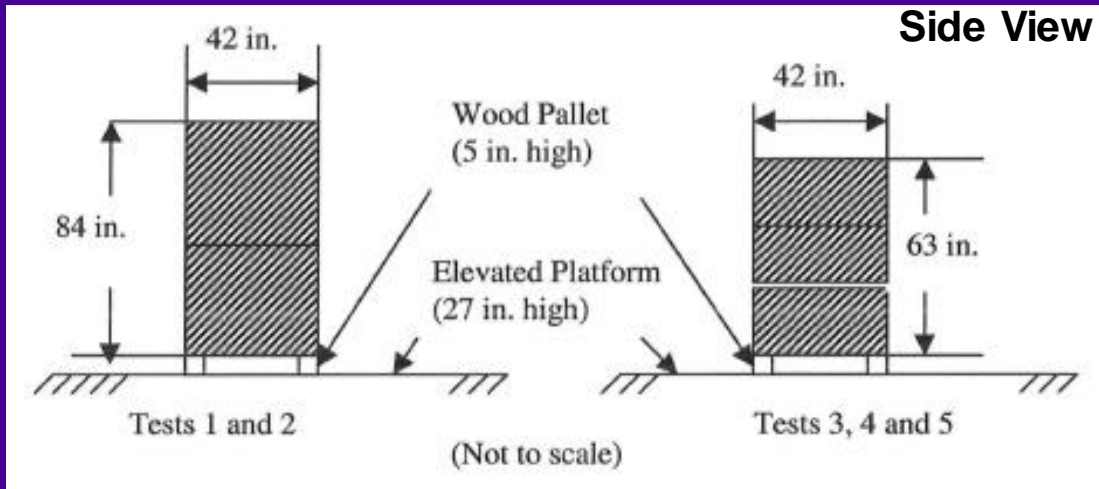
**Cartoned Unexpanded
Plastic (CUP) – HC3**

**Uncartoned Unexpanded
Plastic (UUP)**

Test Setup – Class 2 w/ High Clearance

FM Global Legacy Test

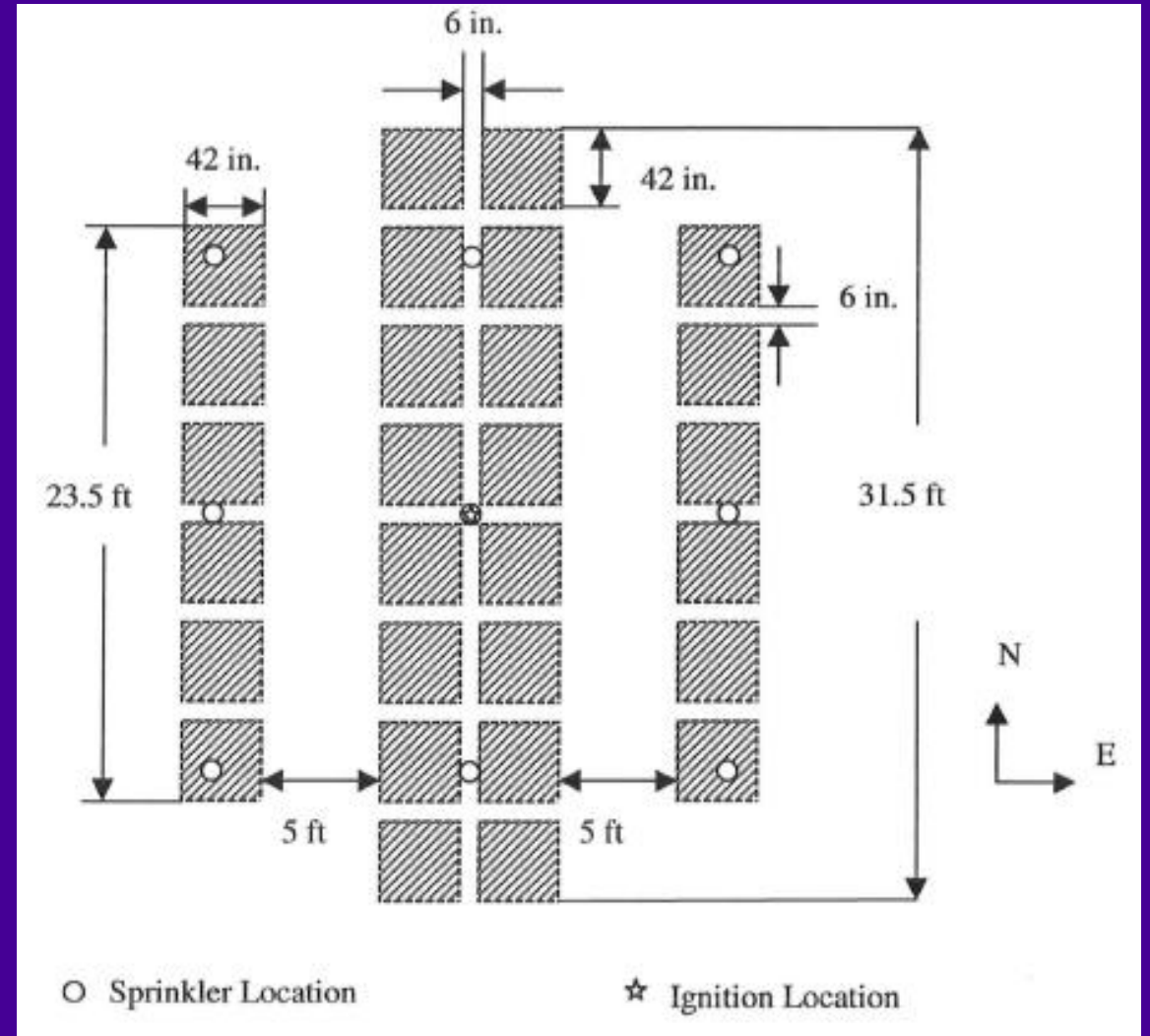
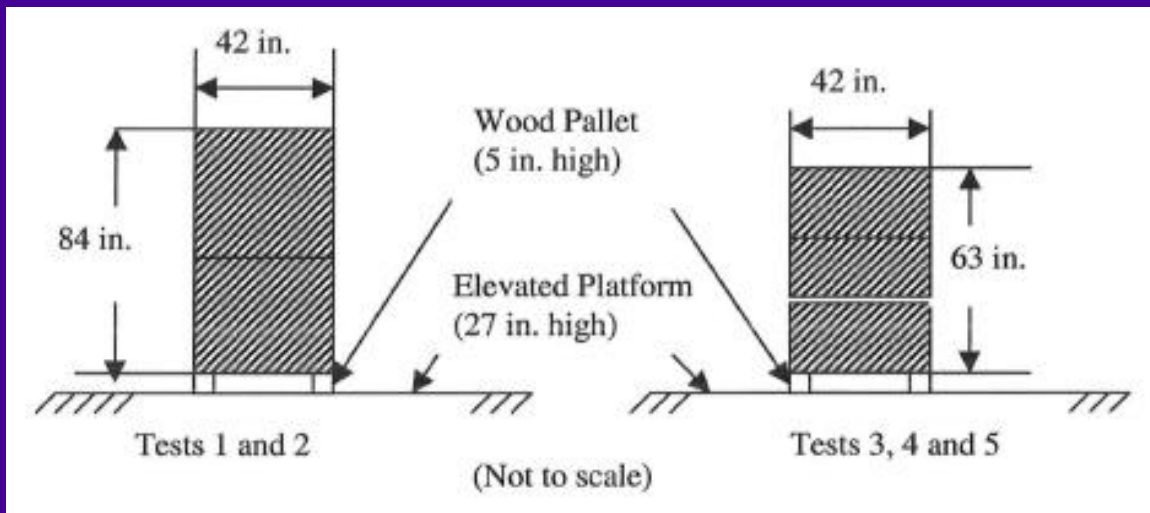
- 18.3-m (60') site
- Class 2: tri-wall carton, 2X
- Ignition under-1



Test Setup – CUP w/ High Clearance

FM Global Legacy Test

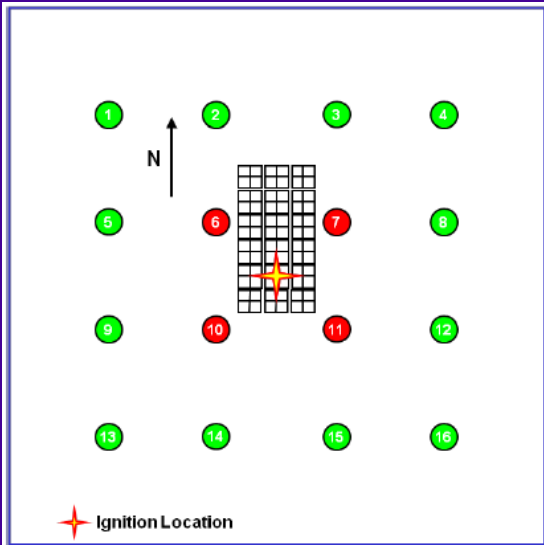
- CUP: double-row rack
- Target: 1.5-m (5') aisle CUP
- Ignition under-1



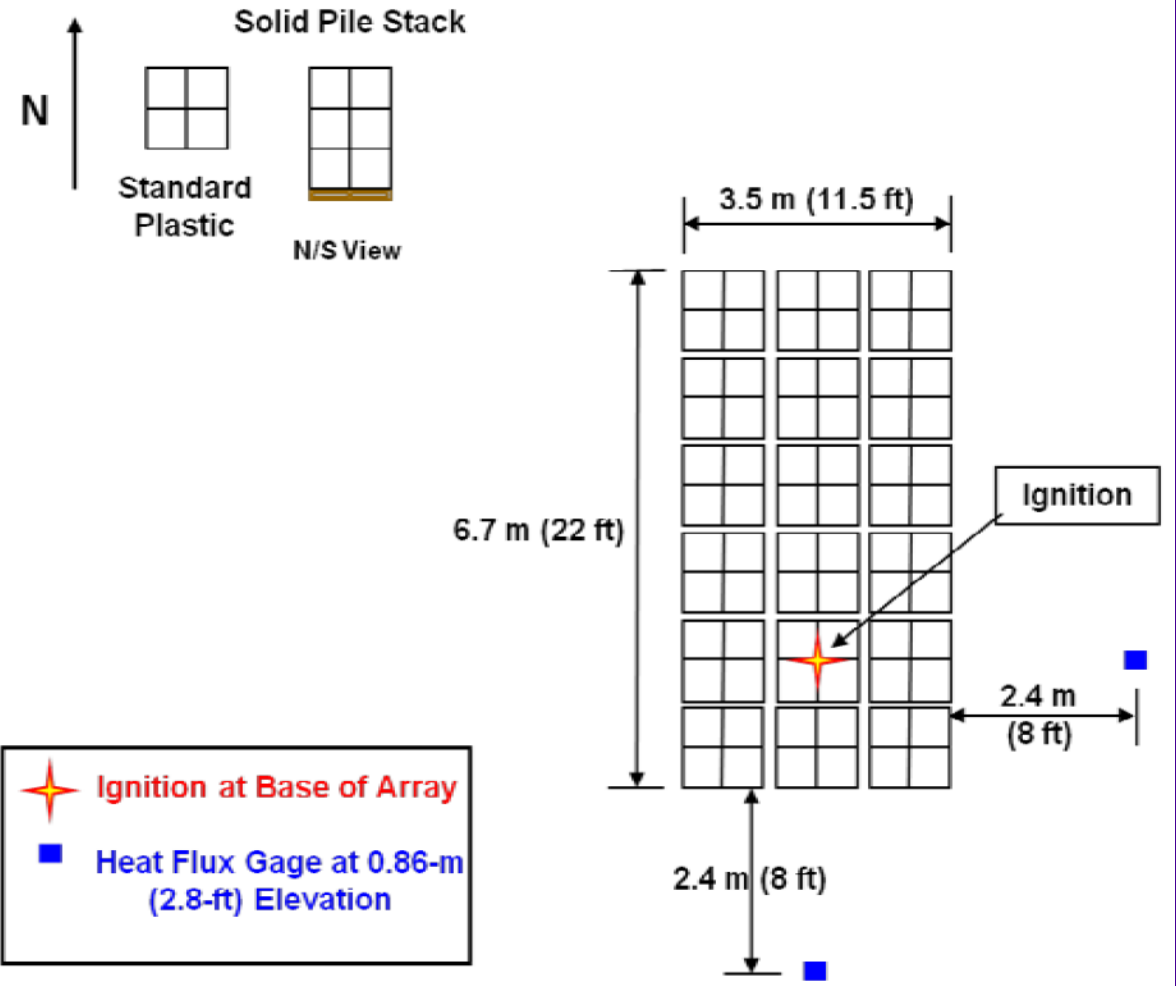
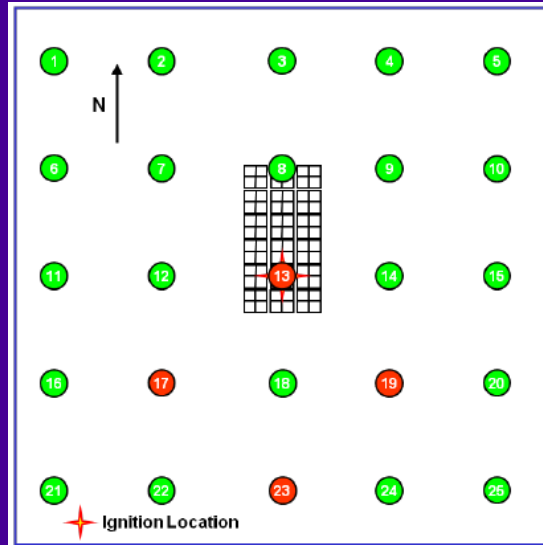
Test Setup – CUP using EC Sprinklers

- **Current Research Campus**
 - Ceiling: 9.1~13.7-m (30'-45')
 - CUP: 1.5-m (5') storage

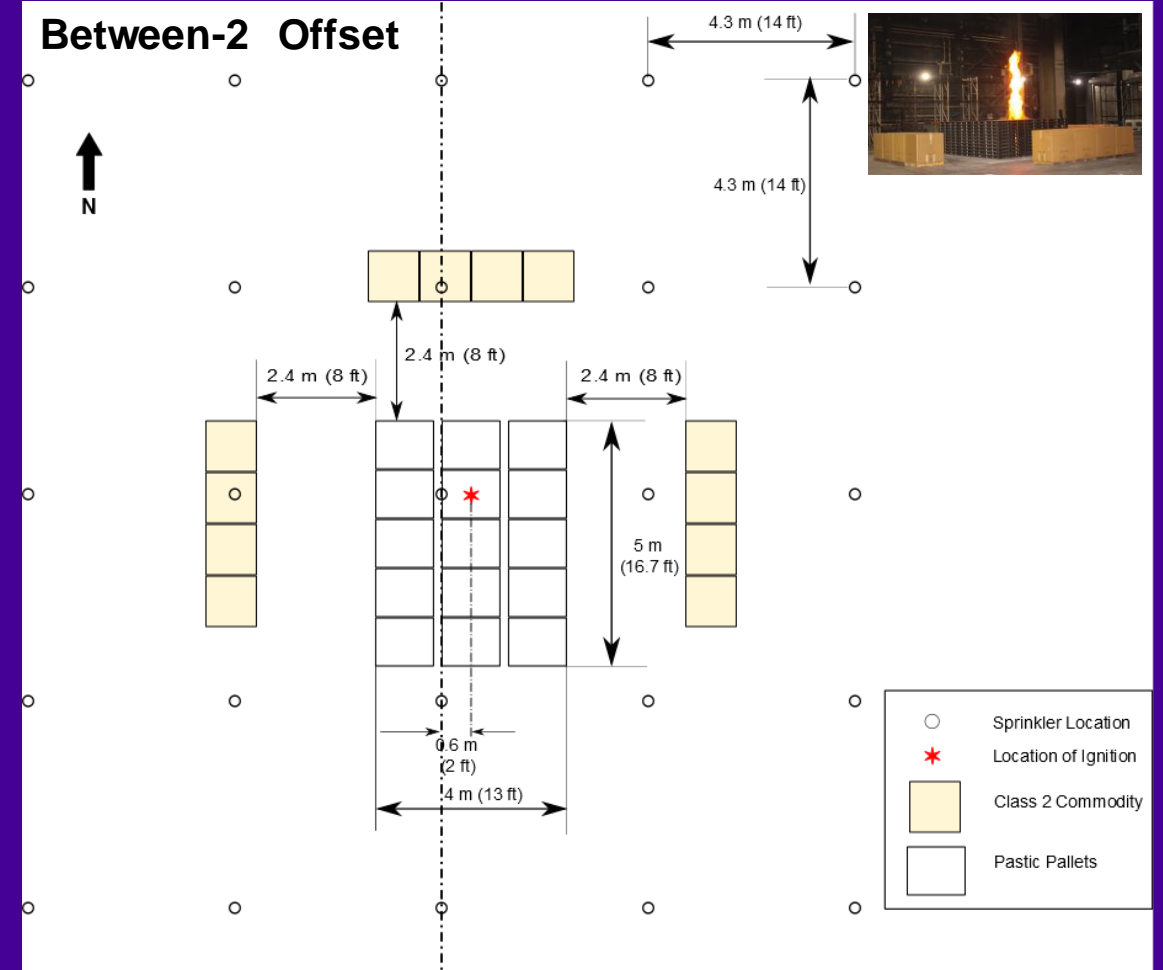
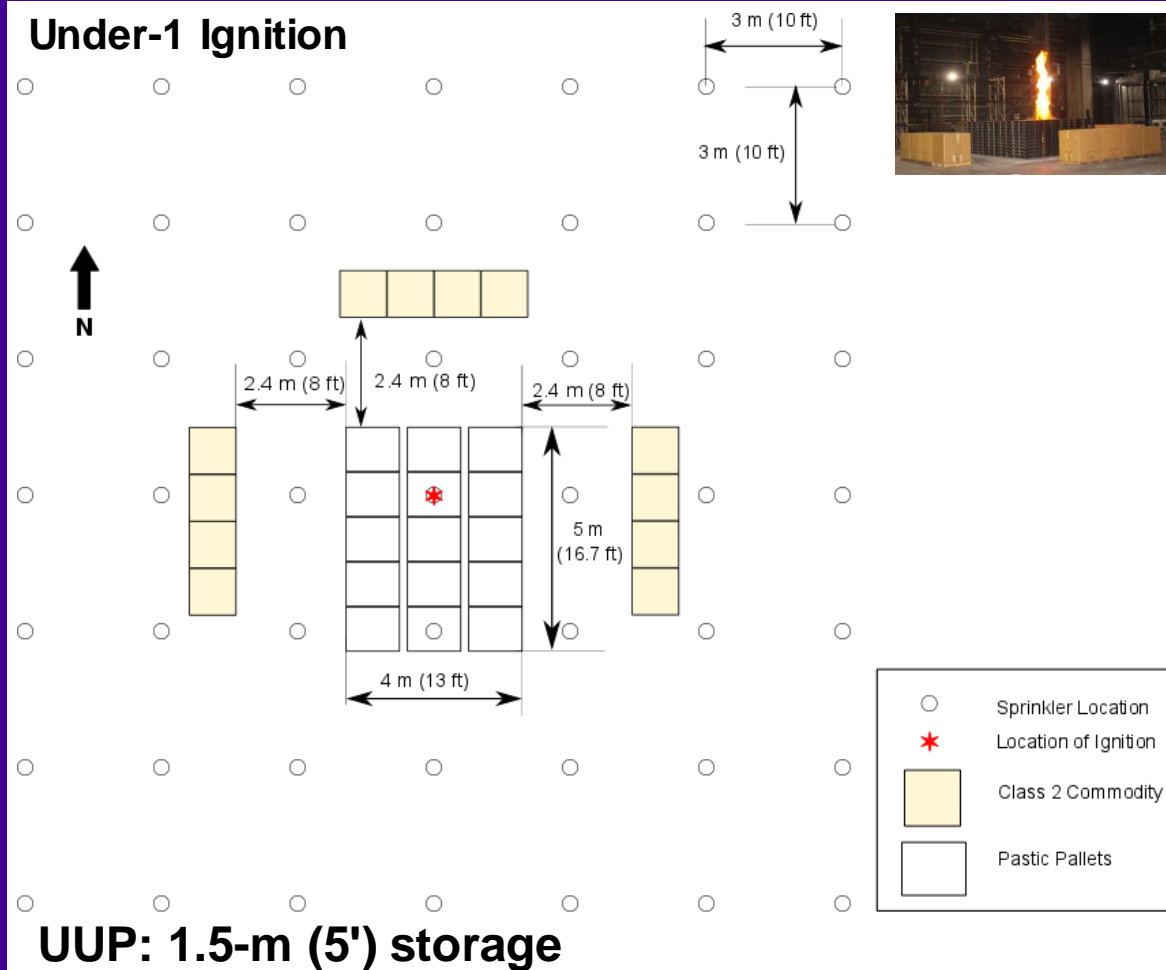
Ignition under-1



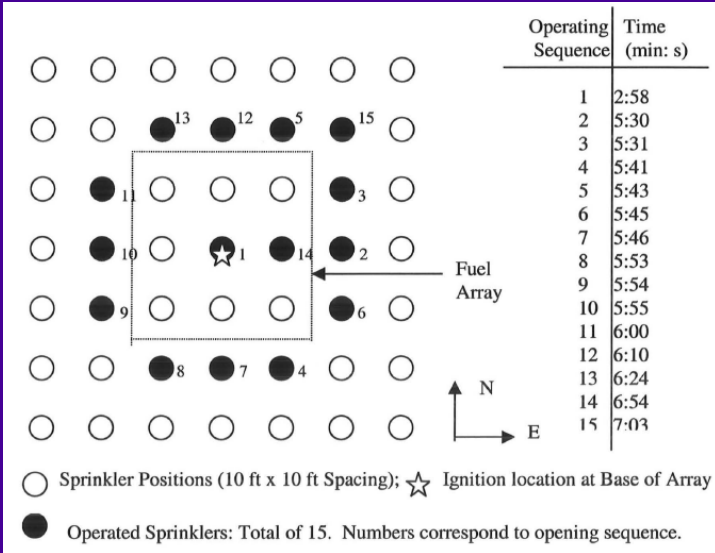
Ignition among 4



Test Setup – Uncartoned Plastics

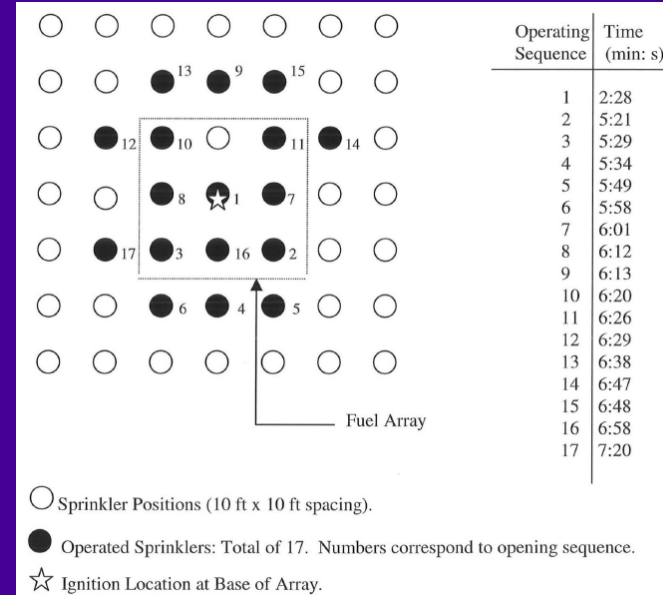
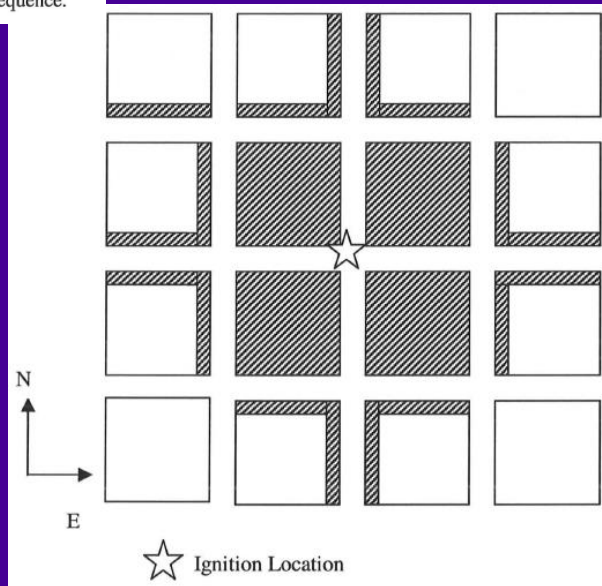


Test Results – Class 2 under 18.3-m (60') Ceiling



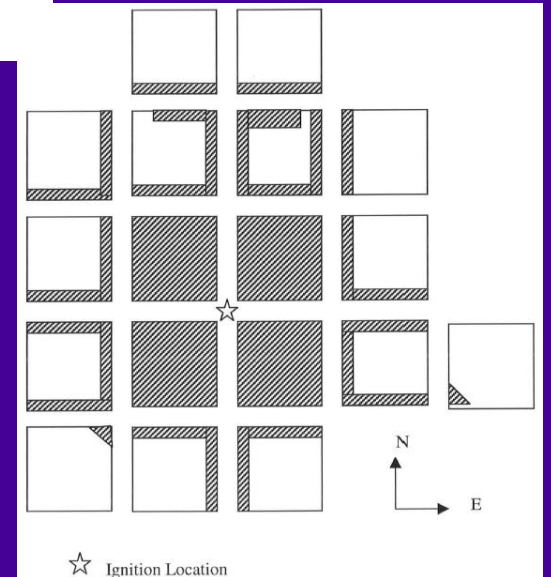
Test Conditions:

- Ignition under-1,
- K-115, 74°C
- $\dot{m}''=12\text{mm/min}$



Test Conditions:

- Ignition under-1
- K-80, 74°C
- $\dot{m}''=6\text{mm/min}$



Test Results – CUP under 9.1-m (30') Ceiling

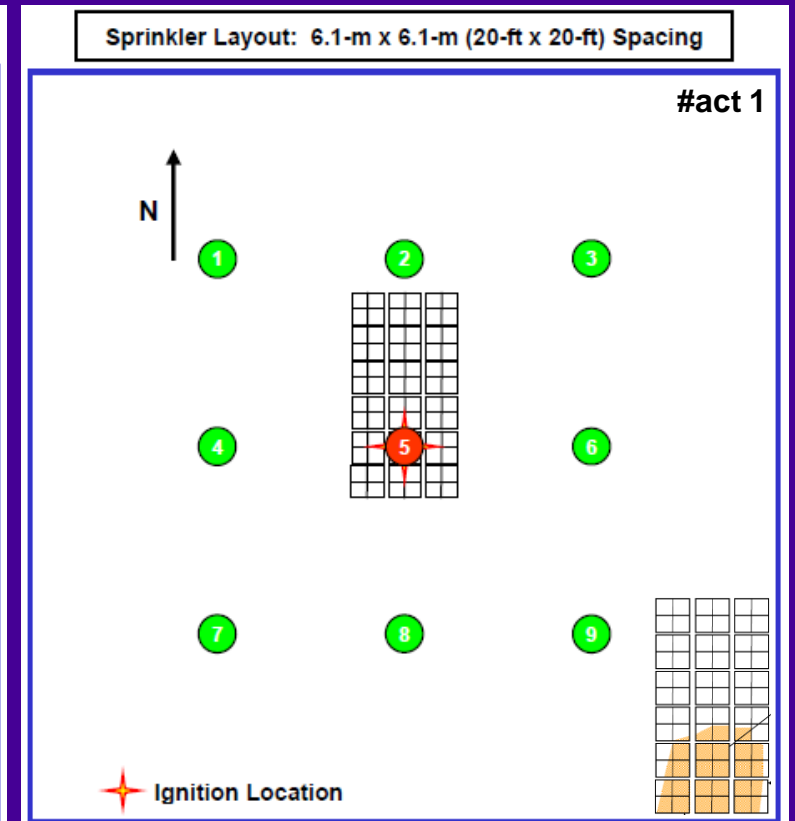
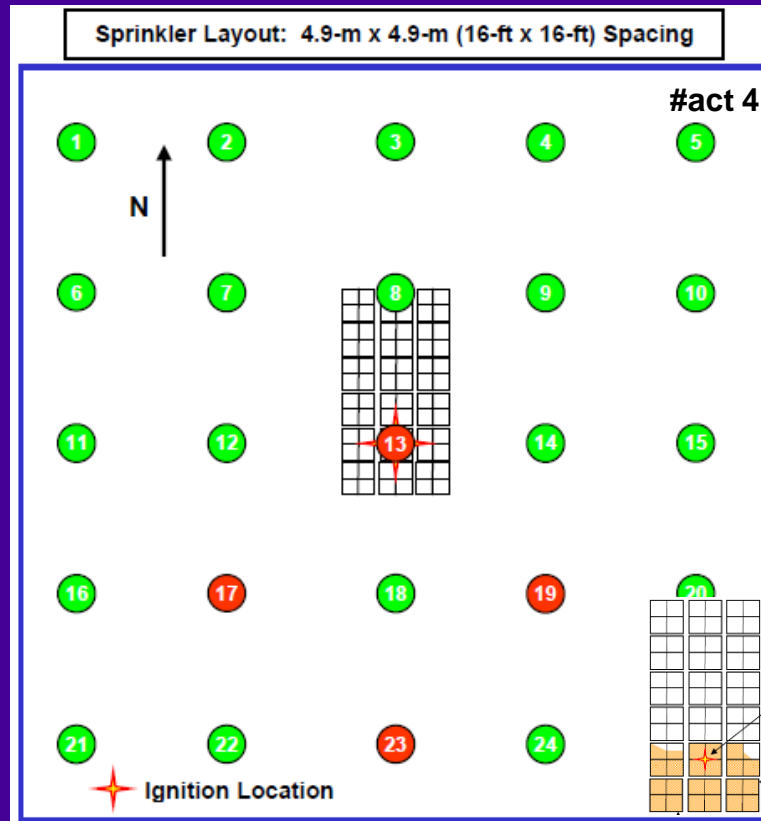
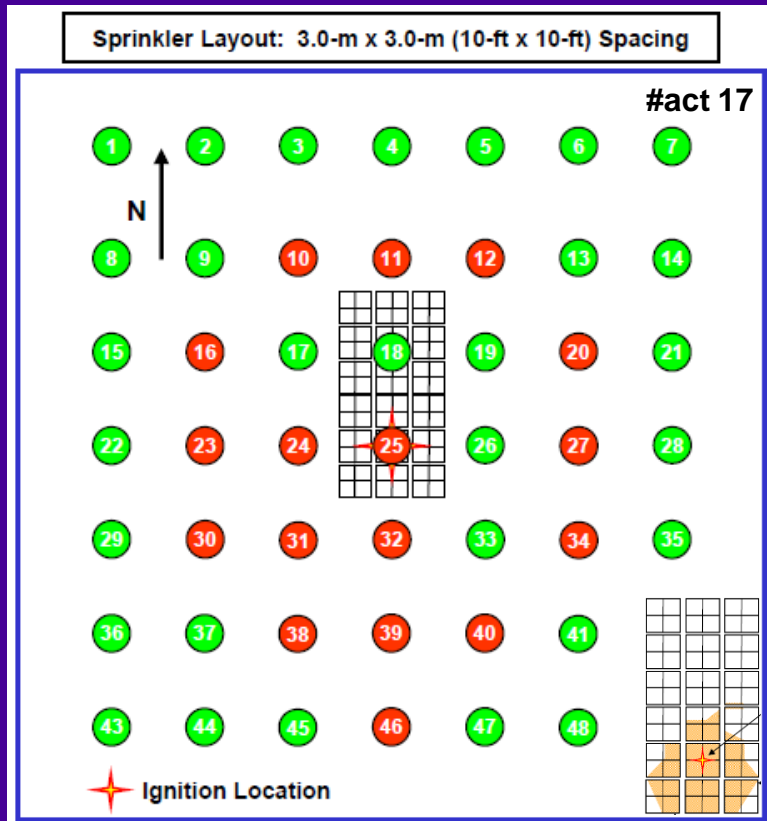


Protection: All Upright, 68°C, SR, 12 mm/min, Under-1

Protection: **K-80**

Protection: **K-160, EC**

Protection: **K-200, EC**



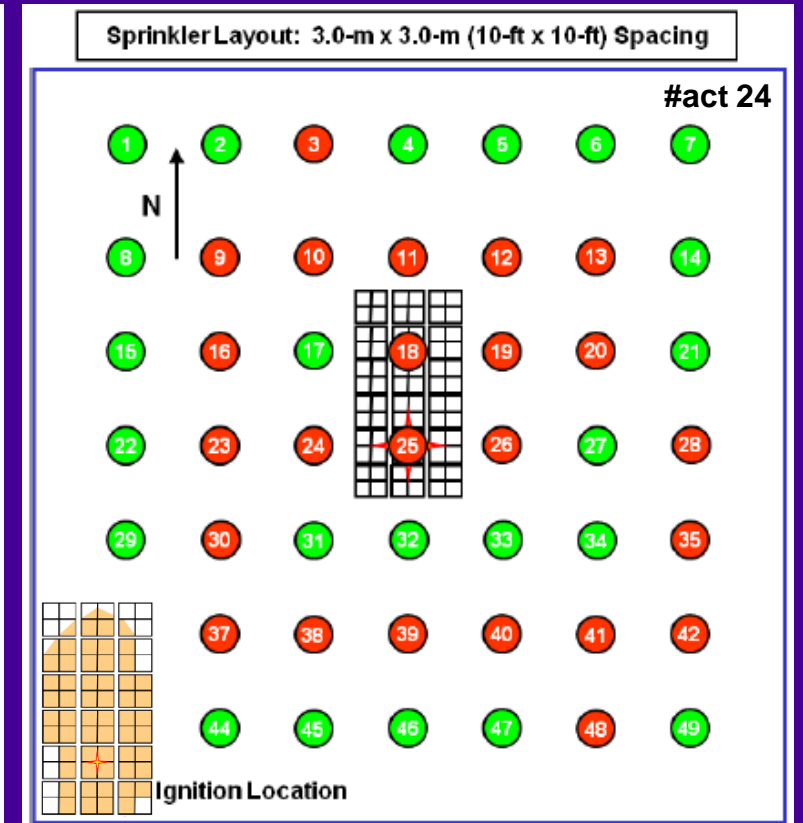
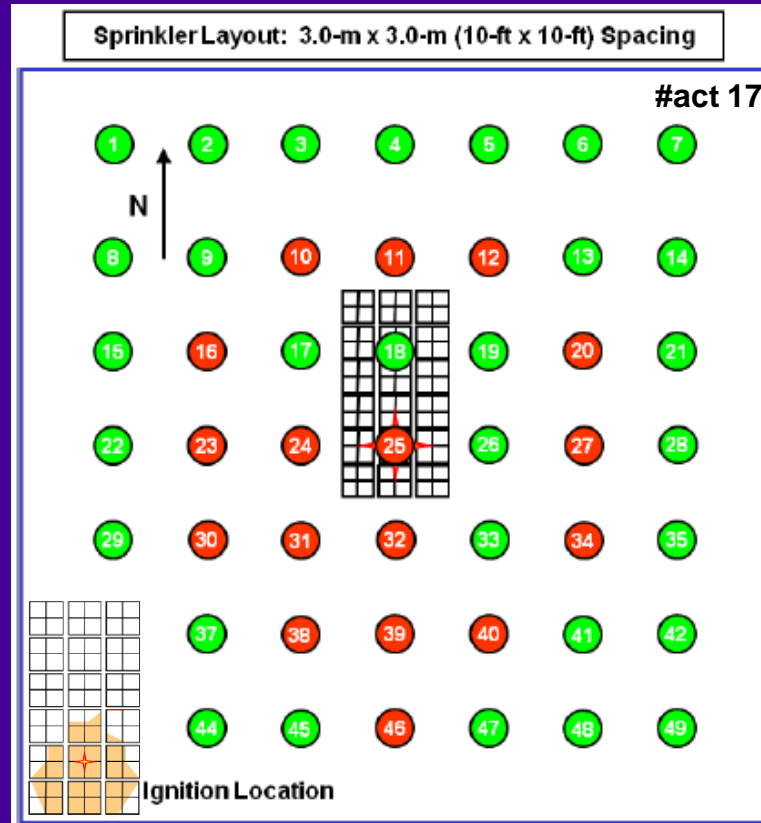
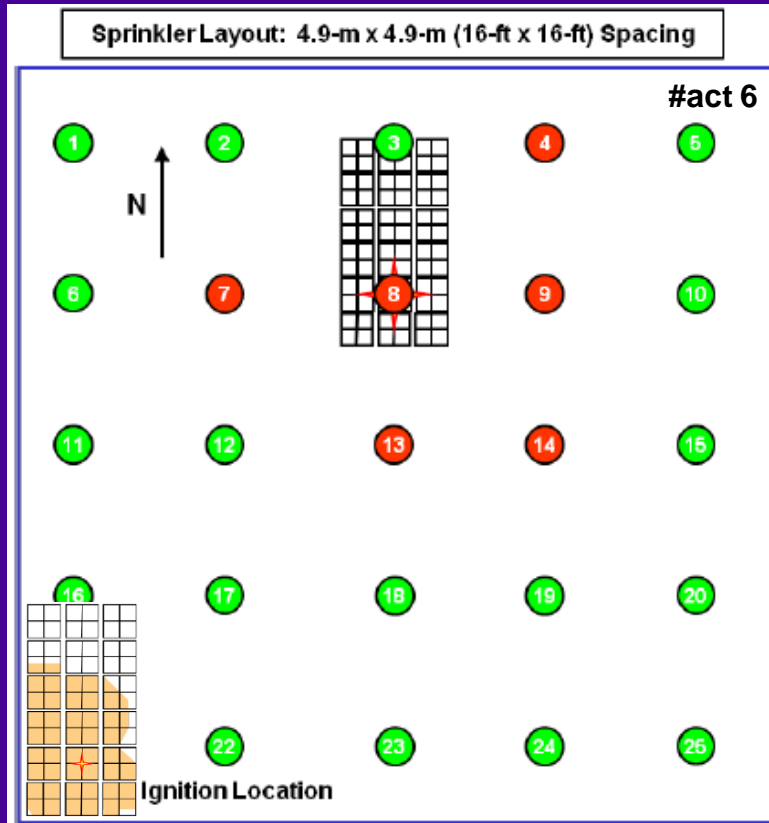
Test Results – CUP under 9.1-&13.7-m (30'&45') Ceiling

Protection: All Upright, 68°C, SR, 12 mm/min, Under-1

Protection: **K-160, EC, 9.1m**

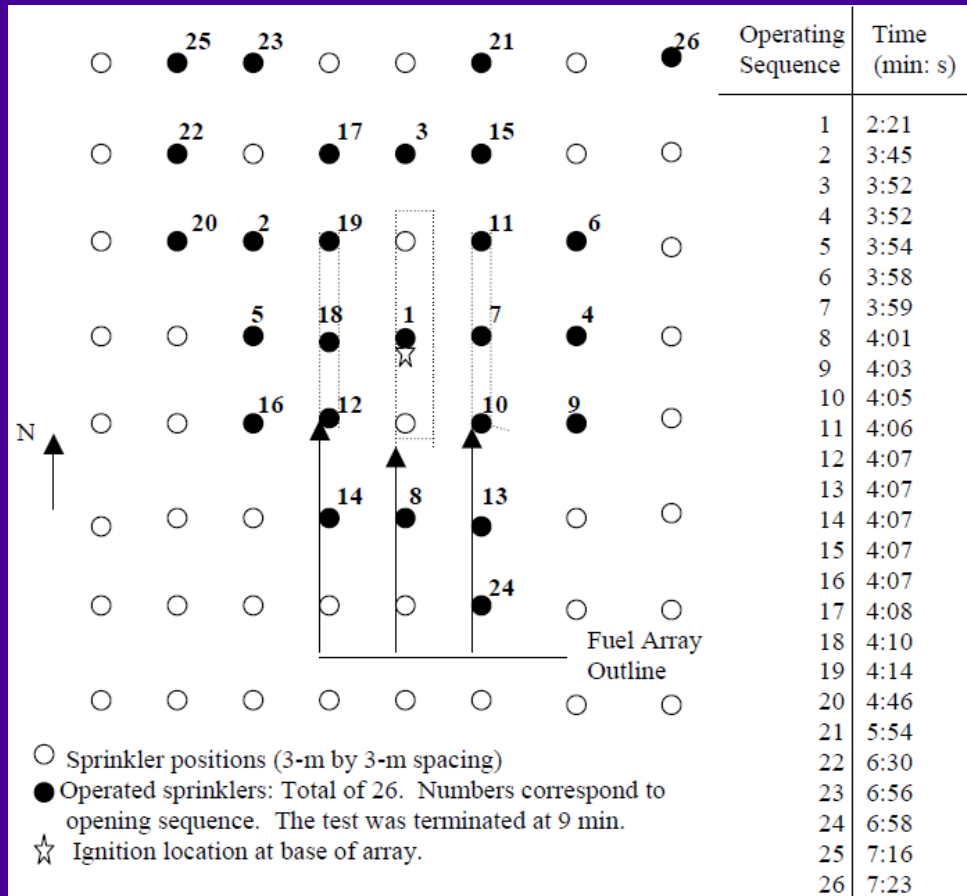
Protection: **K-80, 9.1m**

Protection: **K-80, 13.7m**



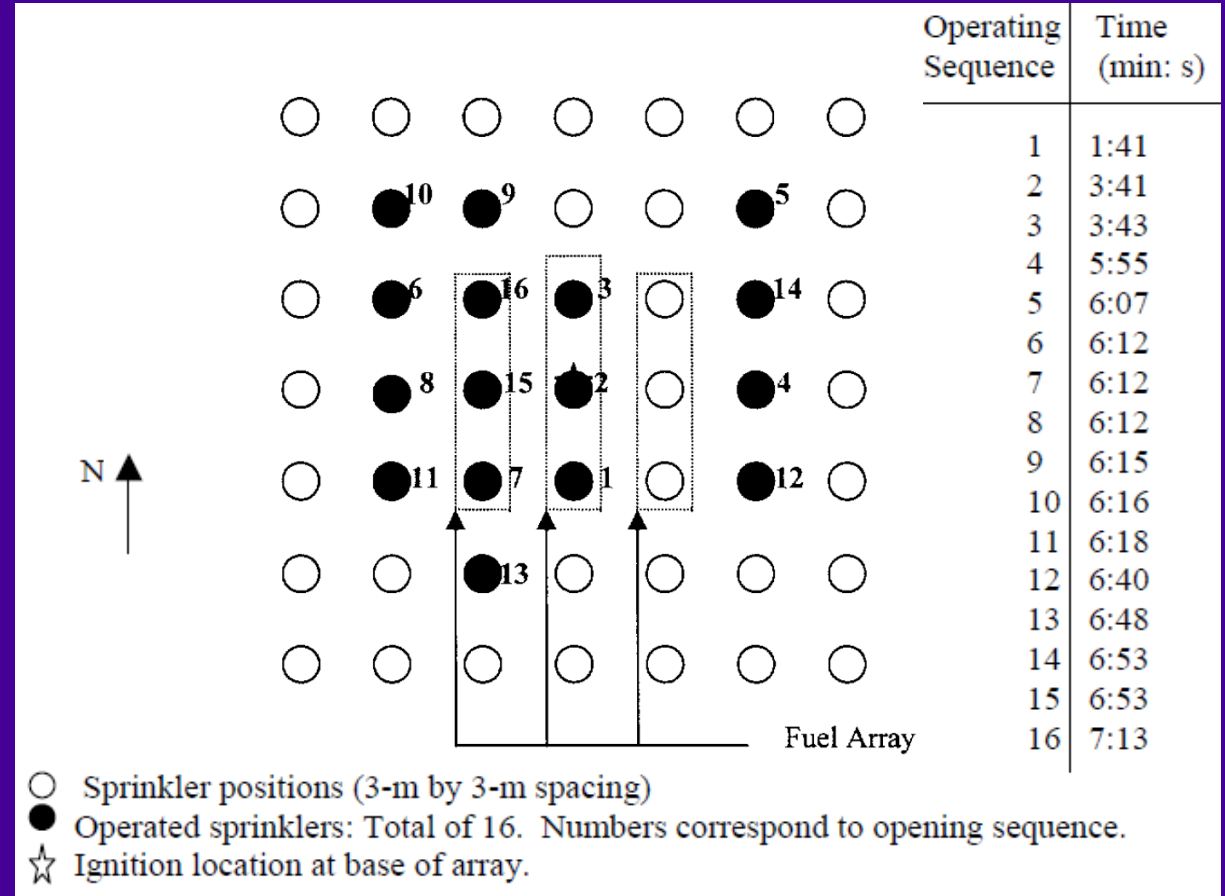
Test Results – CUP under 18.3-m (60') Ceiling

Protection: **K-115, 74°C, SR, $\dot{m}''=12\text{mm/min}$**



Protection: **K-360, QR, 18mm/min, EC 6.1m**

Protection: **K-160, 74°C, QR, 18mm/min**



04:12

QR K360 (K25.2) Pendent AS
@ 1.3 bar (19 psi)

1.5 m (5 ft)
Plastic Pallets

13.7 m Ceiling Height

05:19

QR K360 (K25.2) Pendent AS
@ 1.3 bar (19 psi)

1.5 m (5 ft)
Plastic Pallets

18.3 m Ceiling Height

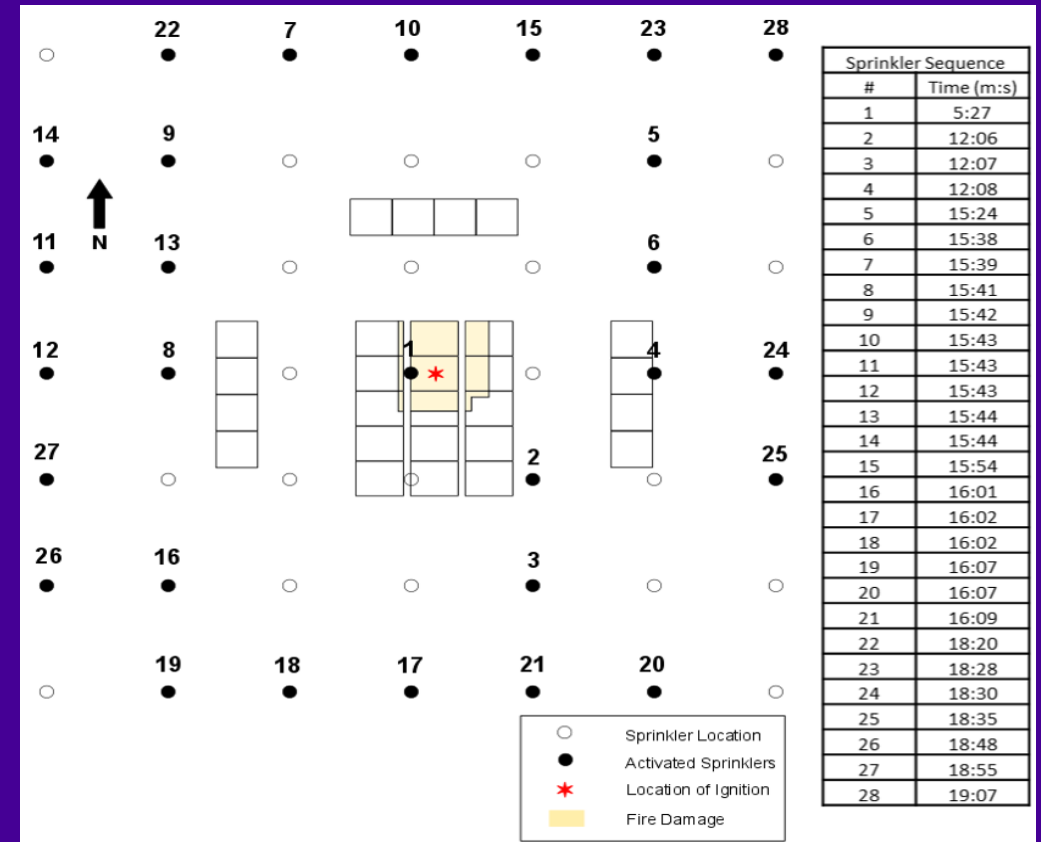
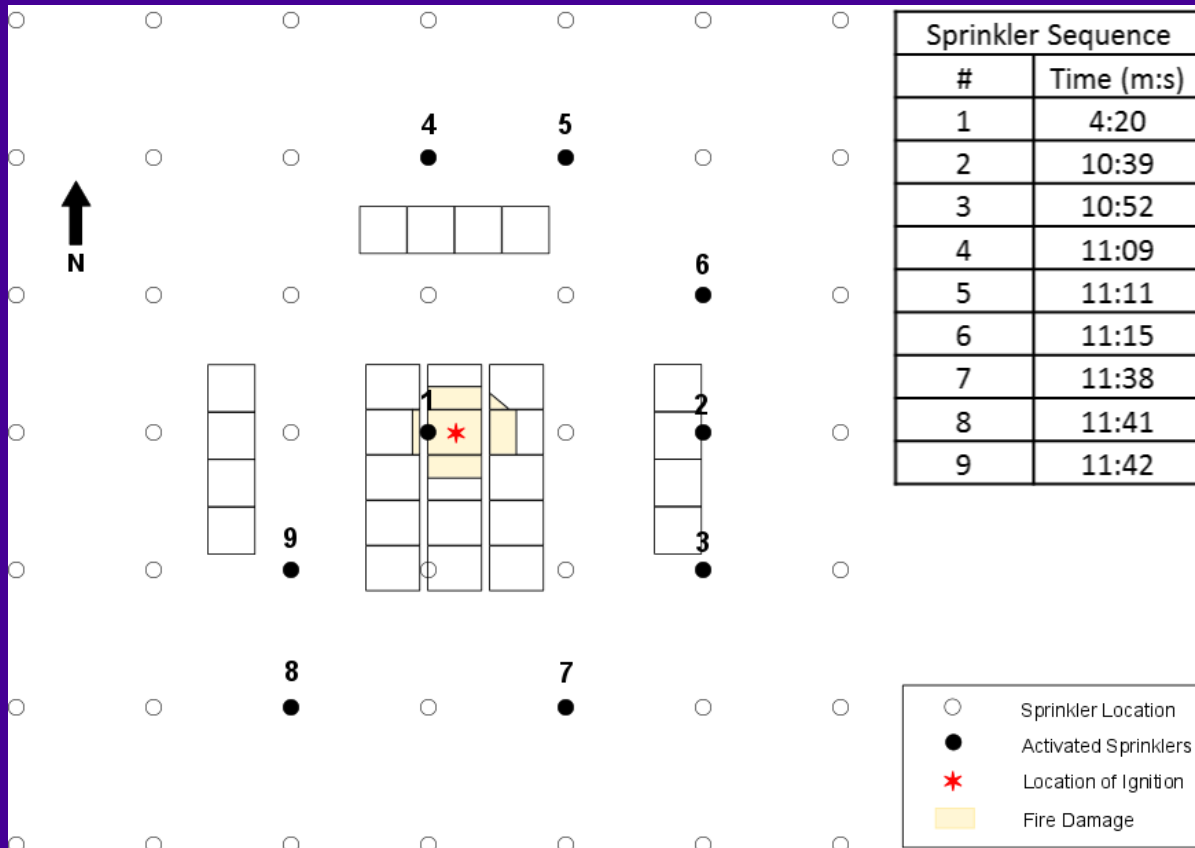


Test Results – Ceiling Height Impact on UUP Protection

Protection: Pendent, 74°C, QR, K-360, Under-1

Protection: 45 mm/min, 13.7-m ceiling

Protection: 45 mm/min, 18.3-m ceiling



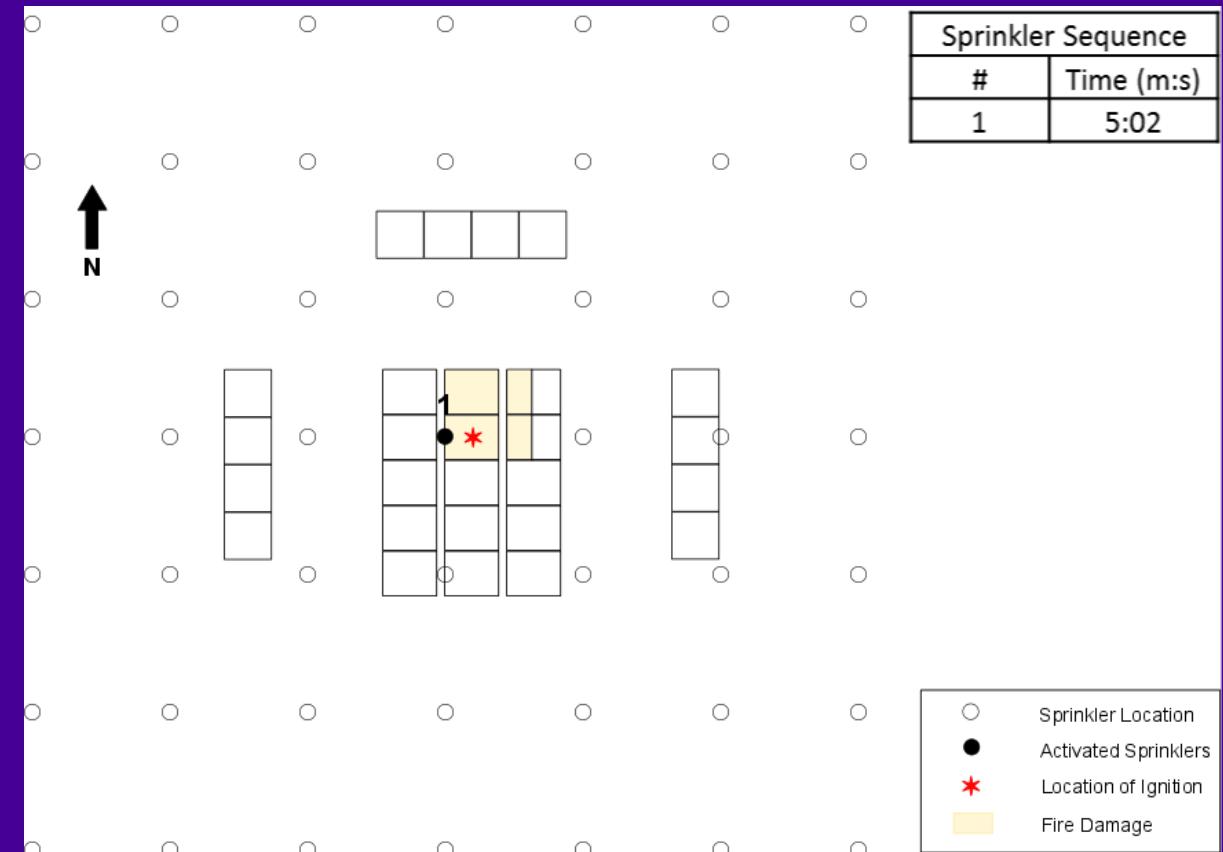
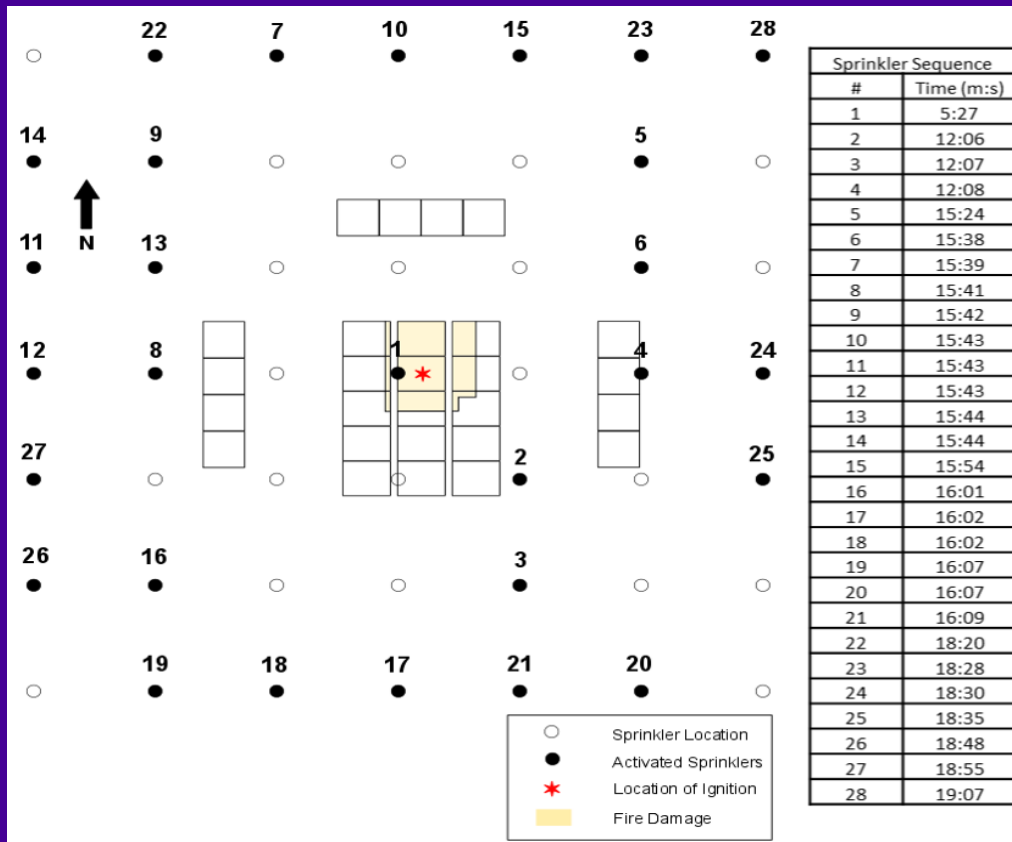
Test Results – Adequate Protection for UUP



Protection: Pendent, 74°C, QR, K-360, Under-1

Protection: 45 mm/min, 18.3-m ceiling

Protection: 65 mm/min, 18.3-m ceiling



Extend Test Results to Additional Conditions



- Anchor protection points using test data
- Maintain equivalent flow rate for diff. K-factors
- Select conservative protection when needed

UUP	30 (9)	25 @ 50 (3.4)	10 @ 62 (4.3)	10 @ 43 (3)	14 @ 24 (1.7)	14 @ 19 (1.3)
	45 (14)		10 @ 62 (4.3)	10 @ 43 (3)	14 @ 24 (1.7)	14 @ 19 (1.3)
	60 (18)				10 @ 50 (3.4)	10 @ 40 (2.8)

- **High ceiling clearances affect protection effectiveness**
- **Large-scale fire tests demonstrated key impacting factors**
 - **Ceiling clearance and storage height**
 - **Commodity type (hazard category)**
 - **Protection options: sprinkler characteristics; water densities**
- **Impact reflected in FMDS 3-26, Fire Protection for Non-Storage Occupancies**



Thank you. Any questions?

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