



High Ceiling Protection

tyco
Fire Protection Products

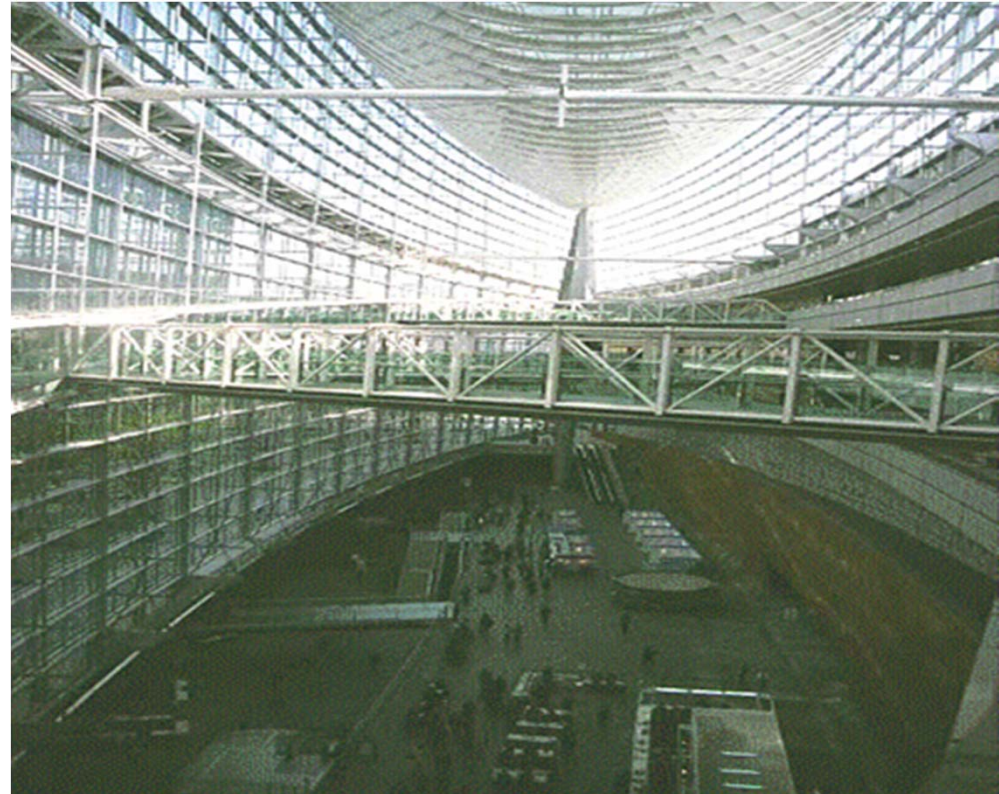
// High Ceiling Protection

An Investigation of Automatic Sprinkler Protection of Buildings with Non-Storage Occupancies and High Clearances



// Background

- // New architectural designs create real fire protection challenges to fire engineers. “The Taller” seems to be “The Better”
- // Sprinkler performance and effectiveness in buildings with high roofs and non-storage occupancies such as atria, convention centers, casinos auditoriums, theaters, exposition halls and others, is not well understood.
- // Project conducted by FMG Research at the 18.3 m high ceiling FM test site in Rhode Island, USA



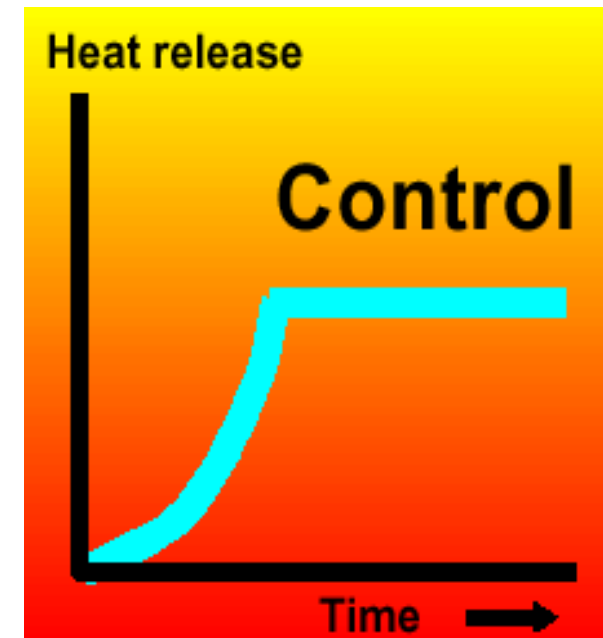
// A Series of Tests to answer Questions related to Sprinkler Performance

// Need to investigate the adequacy of the different approaches for protection in FM Global Data Sheet 3-26 prior to Jan. 2005

// Tests results to answer:

- Will automatic sprinklers ever operate?
- What would be the ceiling temp.?
- What type of sprinkler and design criteria to use and will sprinklers be effective in controlling the fire?

// Will “skipping” be a factor in the performance of the sprinkler *(sprinkler in the fire area being cooled by adjacent activated sprinklers preventing it from operating)*



// FM Global Property Loss Prevention Data Sheets 3-26 - 2005

Table 2. Fire Protection Water Demand for Nonstorage Sprinklered Properties (Cont'd.)

Occupancy	General Occupancy		Exception to the General Occupancy		
	Water Demand	QRAS*	Description	Water Demand	QRAS*
H. Mercantile areas					
Retail stores and similar ordinary hazard buildings open to the public except as noted.	Table 4	Yes*	1. "Warehouse stores" or wholesale mercantile buildings where merchandise is displayed on racks or shelves typical of those found in warehouses. Stock rooms and warehouse areas in retail stores.	Applicable storage data sheets	No
Examples: Grocery, department, clothing, hardware, drug and similar retail stores; bowling alleys, theaters, auditoriums and display areas.			2. Non-storage areas with high floor to ceiling clearance such as school and university gymnasiums, atria in a high rise building, movie or TV studio	Table 11	

January 2005. Protection criteria has been provided for light, moderately and heavily loaded non-storage areas with floor to ceiling clearances up to 60 ft (18.3 m). Storage type, storage and building height and corresponding protection criteria are provided in Table 11.

// FM Global Property Loss Prevention Data Sheets 3-26 - 2005

Table 11. Minimum Protection Criteria for Non-Storage Areas with High Floor to Ceiling Clearance

Hazard	Building Height ft (m)	Protection Criteria gpm/ft ² (mm/min/m ²)	Type of Sprinkler to Use and Hose Demand
Lightly or Moderately Loaded Areas With Ordinary Combustibles Non-storage Occupancies with fire hazards equivalent to in-process Class 3 commodity no more than 8 ft (2.4m) high or lesser hazard, i.e., mostly wood, cardboard products and small amounts of plastics.	Up to 35 (10.7)	Wet Pipe Systems 0.15/2500 (6/230) Dry Pipe Systems 0.15/3500 (6/330)	Control Mode Density Area Automatic Sprinklers Quick response ordinary temperature
	35 to 60 (10.7 – 18.3)	Wet Pipe Systems 0.15/3000 (6/280) Dry Pipe Systems 0.15/4000 (6/370)	K-8.0 (115) (non-extended coverage for densities of 0.3 gpm/ft ² (12 mm/min) or less
Heavily Loaded Areas With or Without Plastics. Non-storage occupancies with higher concentration of combustibles or shielding of combustibles, where the fire hazard could approach the equivalent of 6 ft (1.8 m) high in-process storage of unexpanded plastic commodities. Similar to the first hazard but with the presence of plastics in upholstery, furnishings, packaging, stage settings, etc.	Up to 35 (10.7)	Wet Pipe Systems 0.3/2500 (12/230) Dry Pipe Systems 0.3/3500 (12/330)	Spacing of K-8.0 (115) sprinklers: - Not to exceed 130 ft ² (12.1 m ²) - Minimum spacing of 10 ft (3 m) between sprinklers on a branch line or between branch lines. Quick response ordinary temperature rated
	Over 35 to 60 (10.7- 18.3)	Wet Pipe Systems 0.45/2500 (18/230) Dry Pipe Systems 0.45/3500 (18/330)	K-11.0 (162) (non-extended coverage with densities greater than 0.3 gpm/ft ² (12 mm/min) Spacing: 10 ft x 10 ft (3 m x 3 m)

Note: Non-storage occupancies include, but are not limited to the following. Seating areas in theaters, auditoriums and sports arenas; school and university gymnasiums. Atria in high-rise buildings; meeting rooms in convention centers and hotels (including those used for exhibits); movie and TV studios; casinos; large exhibit and concert halls; back-stage of theaters and auditoriums; large (non-aquatic) sports arenas.

Small amounts of plastic could include foam plastic found in the seat cushion of a chair or plastic trim in an exhibit display booth.

// Goals of the FM Test Program

- Conduct 5 full scale fire tests at the Factory Mutual facility to investigate sprinkler performance in **Ordinary Hazard, non-storage buildings with high clearances, up to 60 ft. (18.3 m).** building height containing potential fuel stacks lower than 10 ft (3 m high).

// Description of Full Scale Fire Test 1

// Fuel Arrangement: FMRC Class 2 commodity

// Fuel Height: 2.26 m

// Clearance to ceiling: 15.4 m

// Arrangement of fuel package: 8 by 8, solid pile, 2 tiers

// Density: 12 mm/min

// Sprinklers: K115, RTI 140 (m-s)^{1/2} Standard Response,
Upright

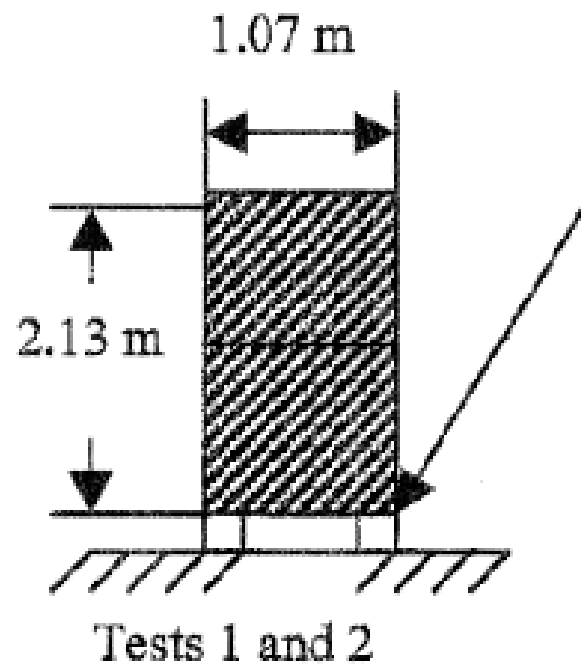
// Spacing: 3.0 m x 3.0 m

// FMRC CLASS II Commodity-Fuel Package



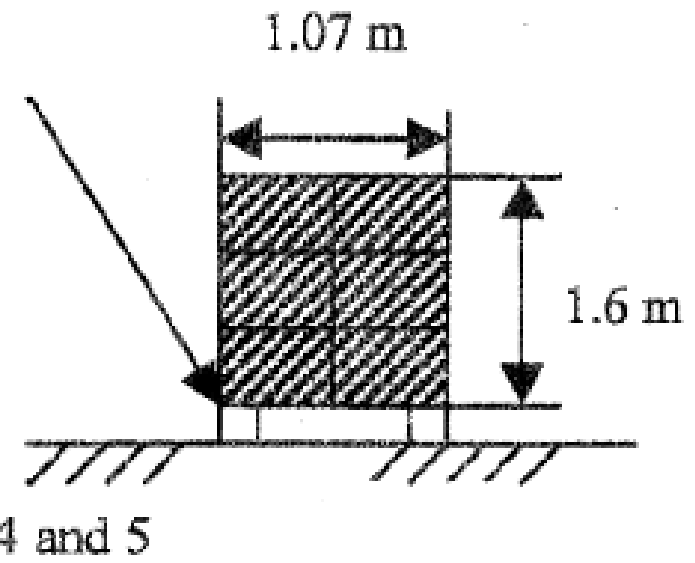
Metal-lined double tri-wall corrugated carton on a wood pallet

// Side View of Fuel Array



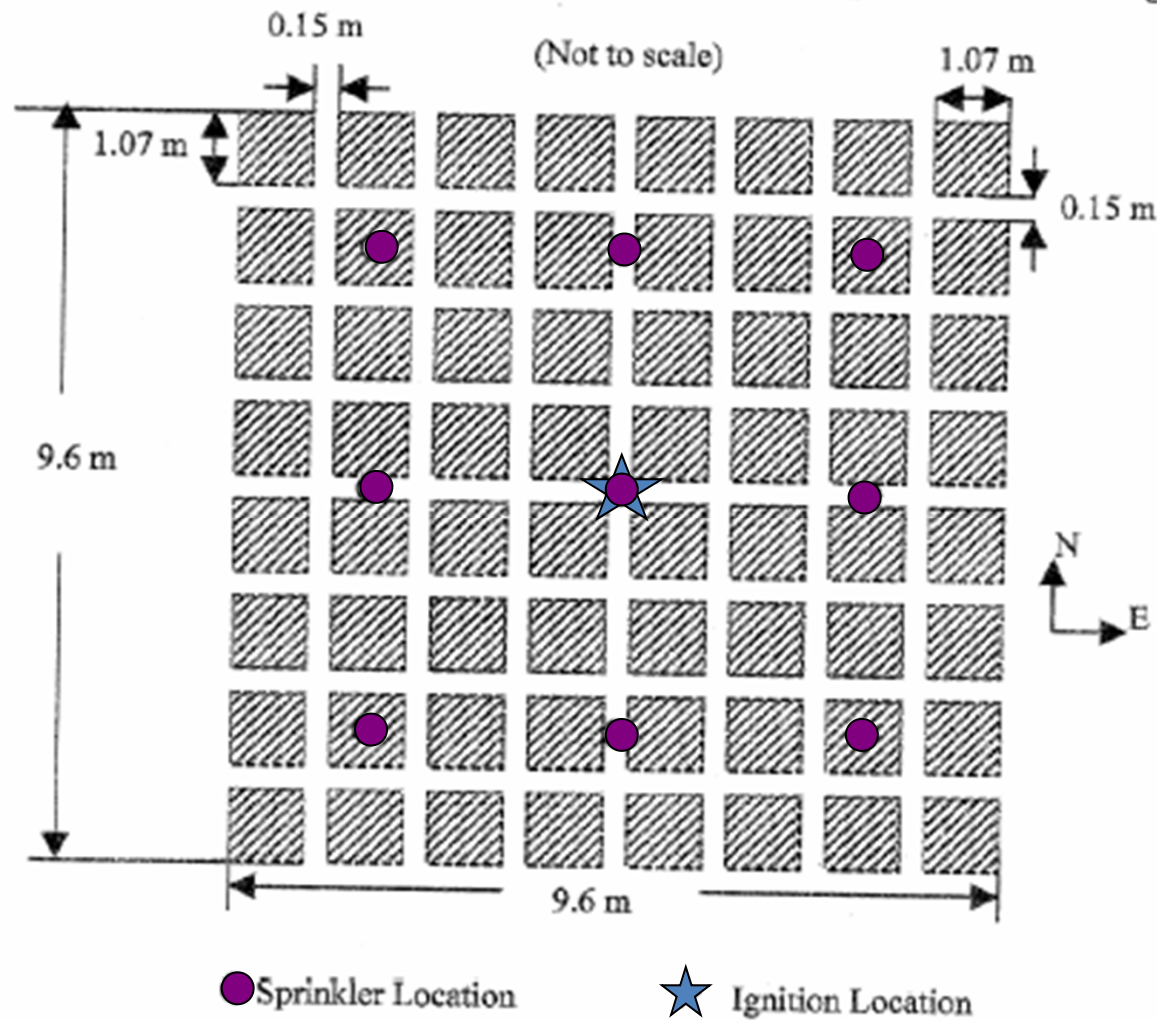
Class II

Wood Pallet
(0.13 m high)

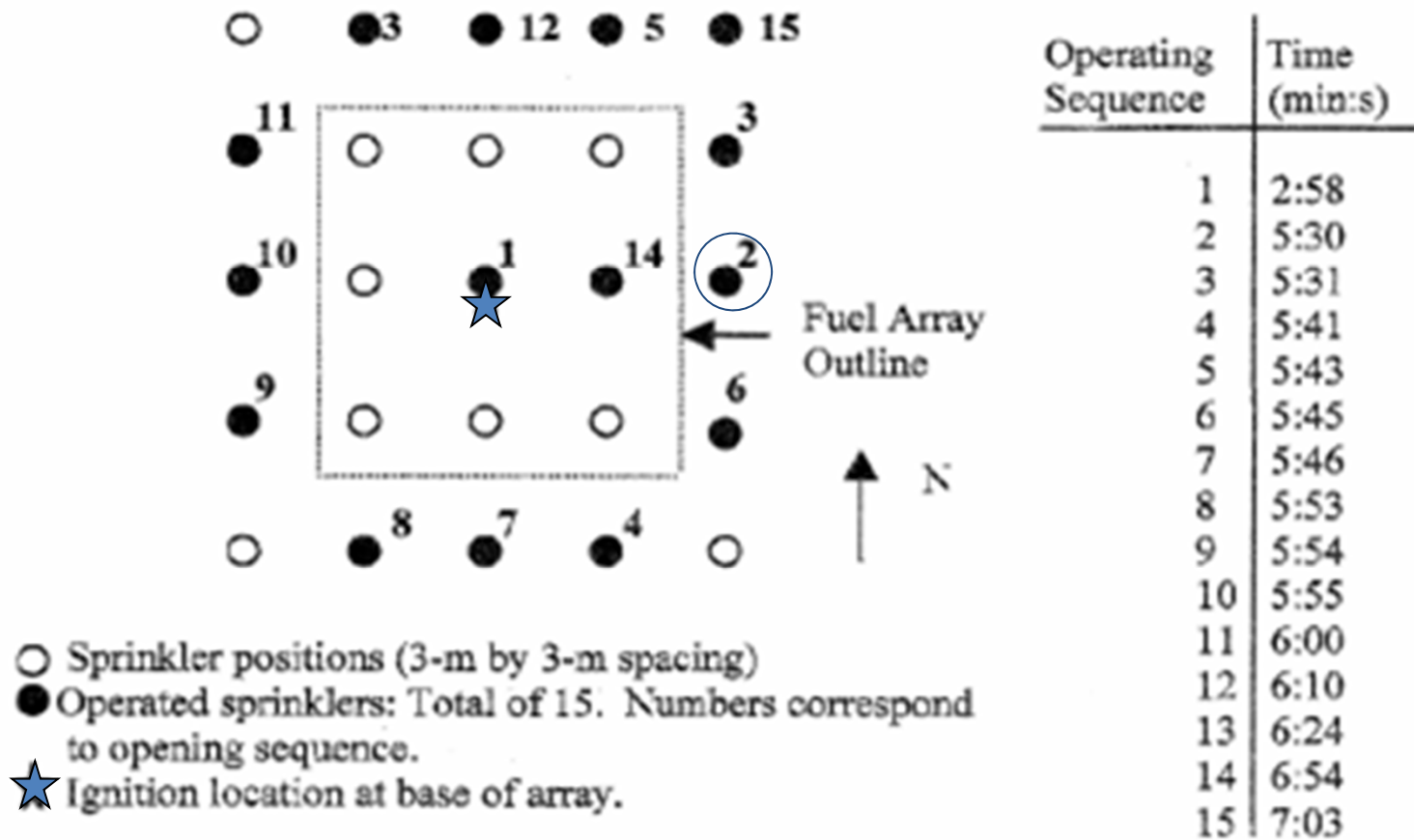


Group A Plastics

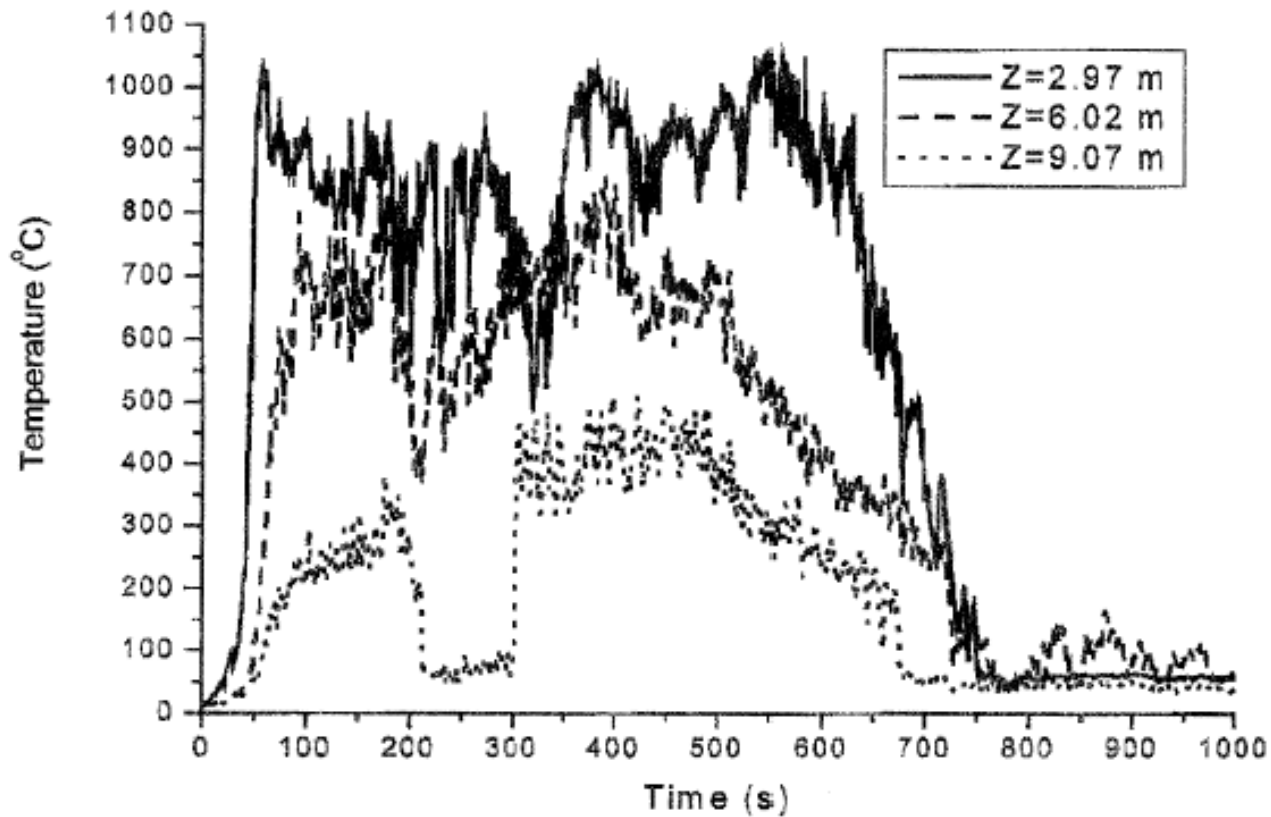
// Plan View of Fuel Array – Test 1



// Plan View of Sprinkler Operation – Test 1



/// Temperature Measurements in Test 1



// Results Test 1

- // Number of Sprinklers Operated: 15
- // Ceiling temperature: Within acceptable limits
- // Fire Damage: Fire well confined to ignition array
- // Skipping of sprinklers: Considerable

Key Take Away: According to the criteria given, very favorable results were achieved for the moderately loaded hazard.

In view of the good results, the same level of protection can be extended to Class III commodity

// Description of Full Scale Fire Test 2

// Fuel Arrangement: FMRC Class 2 commodity

// Fuel Height: 2.26 m

// Clearance to ceiling: 15.4 m

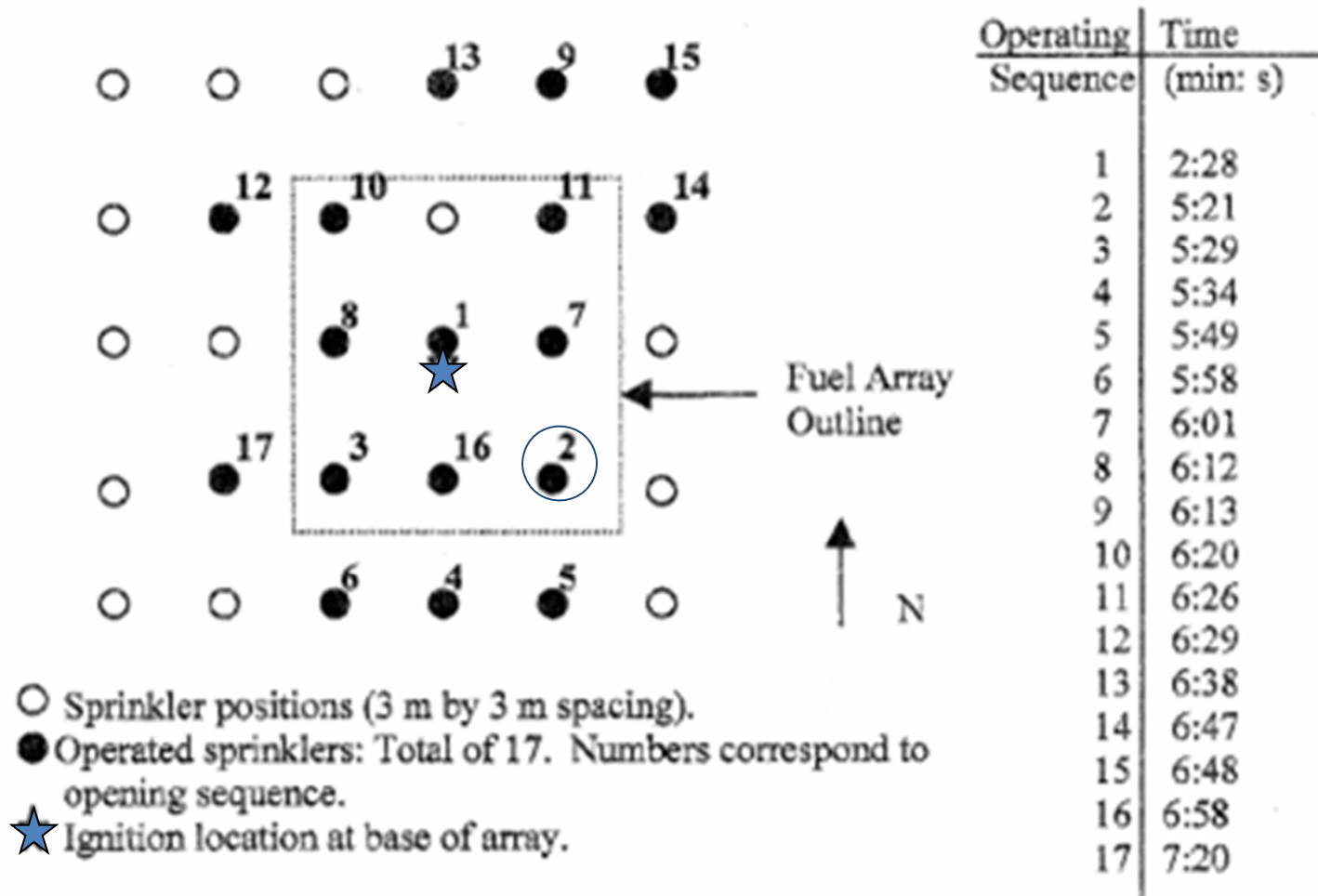
// Arrangement: 8 by 8, solid pile, 2 tiers

// Density: 6 mm/min

// Sprinklers: **K= 80**, RTI 140 (m-s)^{1/2} Standard
Response, Upright

// Spacing: 3.0 m x 3.0 m

// Plan View of Sprinkler Operation – Test 2



// Results Test 2

// Number of sprinklers Operated: 17

// Ceiling temperature: Within acceptable levels

// Fire damage: Fire well confined to ignition array

// Skipping of sprinklers: Observed.

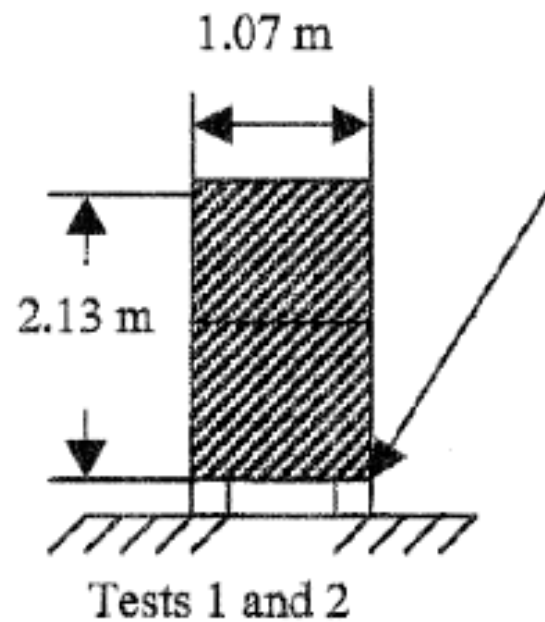
Key Take Away: According to the criteria given, reasonable performance was achieved for the moderately loaded hazard.

// FMRC Cartoned Unexpanded Group A Plastics



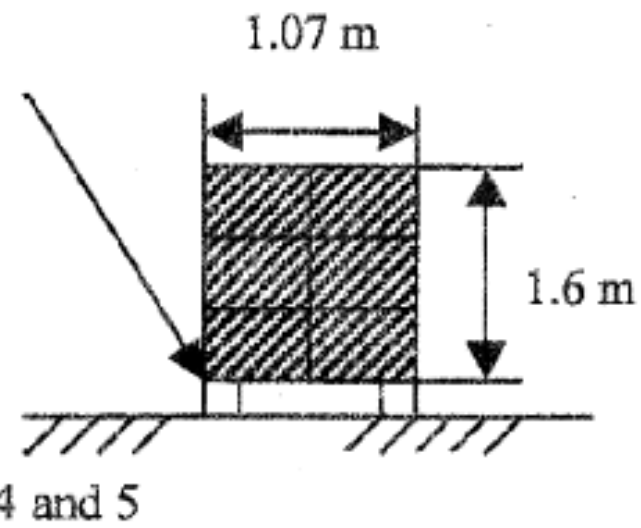
16-oz Polystyrene Plastic Jars in compartmented cardboard cartons

// Side View of Fuel Array



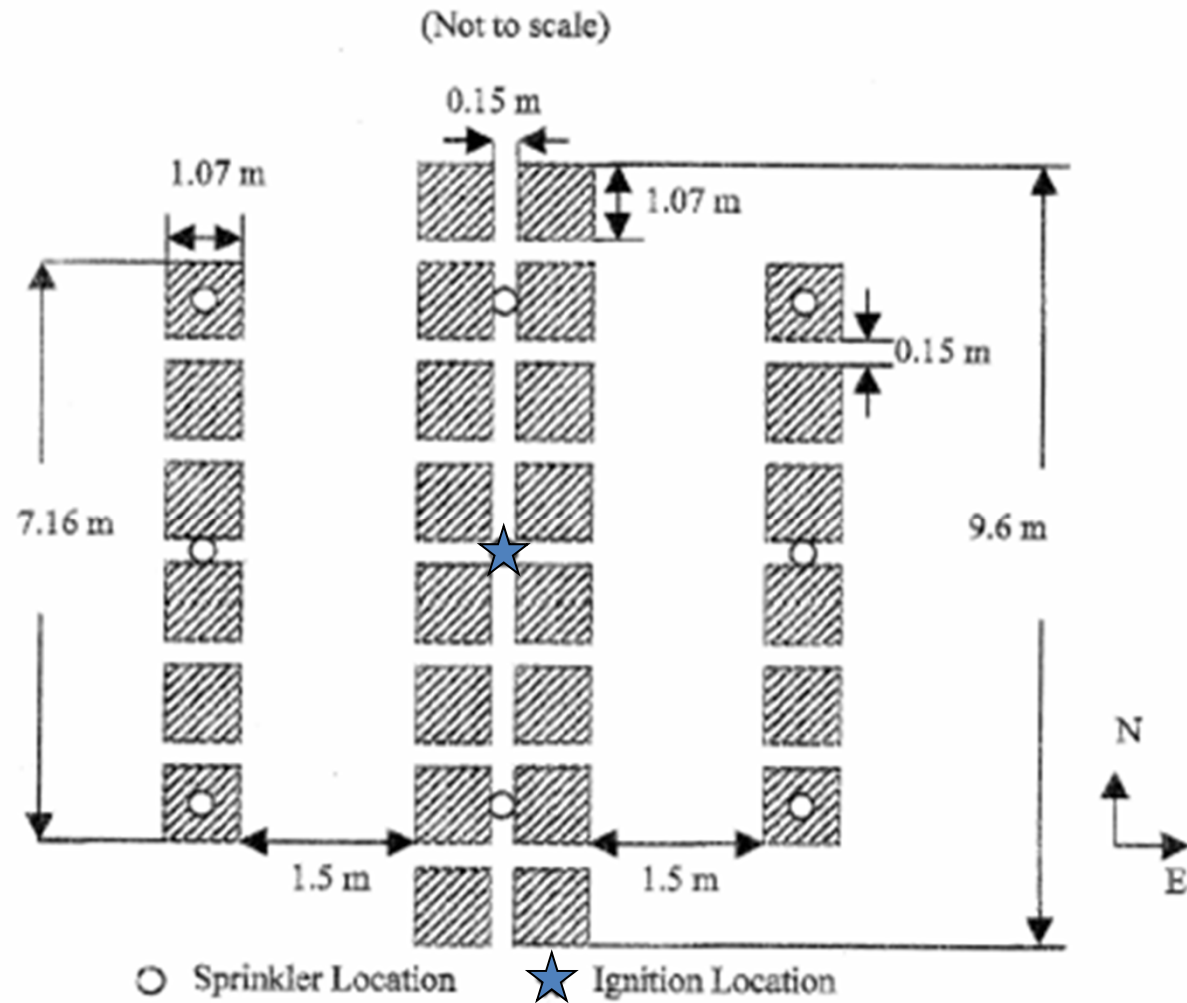
Class II

Wood Pallet
(0.13 m high)



Group A Plastics

// Plan View of Fuel Array – Test 3 & 4



// Description of Full Scale Fire Test 3

// Fuel Arrangement: FMRC Group A Plastics

// Fuel Height: 1.73 m

// Clearance to ceiling: 15.9 m

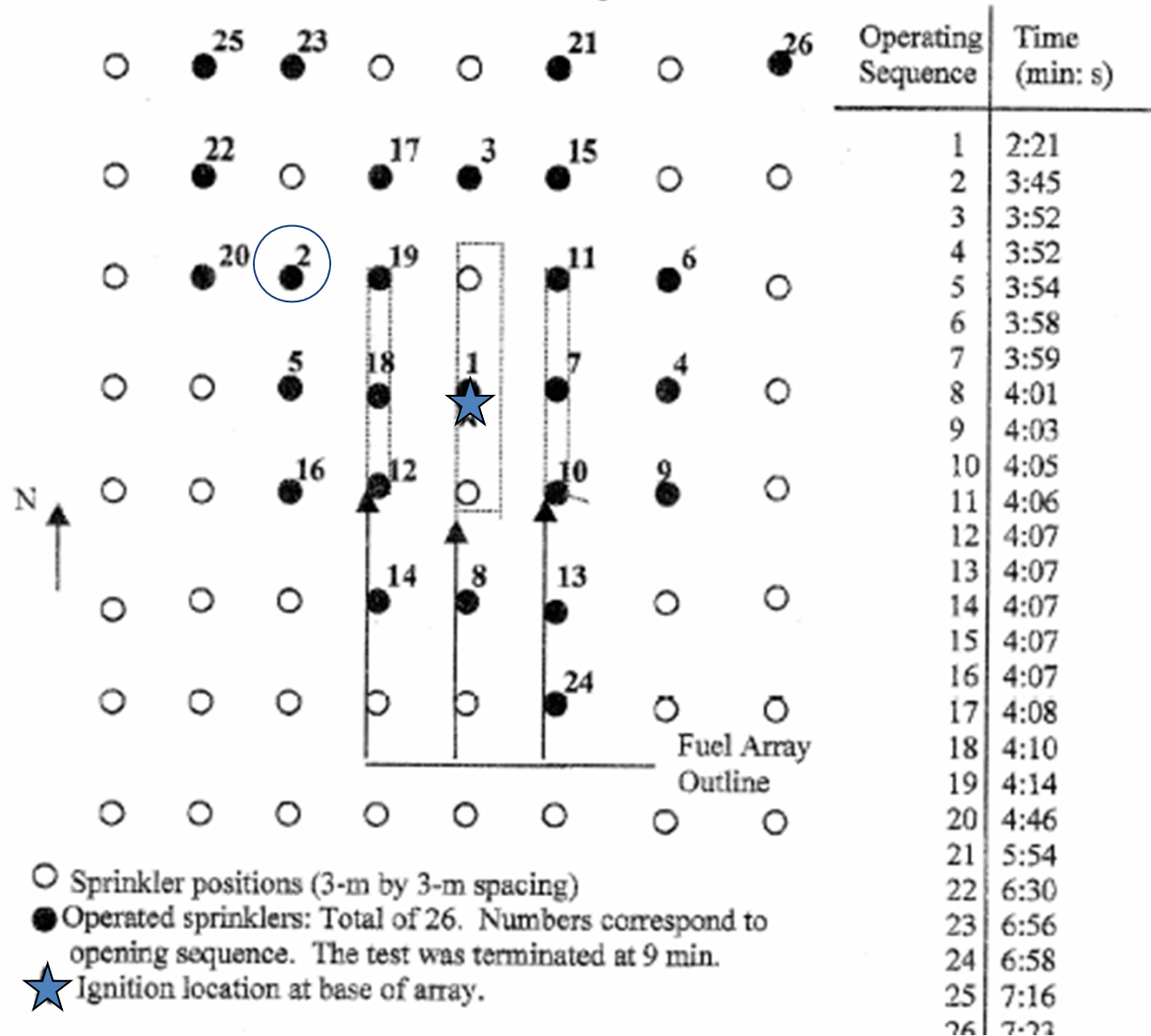
// Arrangement: 2 by 8, solid pile, 1 tier

// Density: 12 mm/min

// Sprinklers: K115, RTI 140 (m-s)^{1/2} Standard
Response element, Upright

// Spacing: 3.0 m x 3.0 m

// Plan View of Sprinkler Operation – Test 3



// Results Test 3

// Number of Sprinklers Operated: 26 !

// Skipping of Sprinklers: extreme

// Test terminated at 9 minutes before it yielded conclusive results

Key Take Away: Test failed

// Description of Full Scale Fire Test 4

// Fuel Arrangement: FMRC Group A Plastics

// Fuel Height: 1.73 m

// Clearance to ceiling: 16.6 m

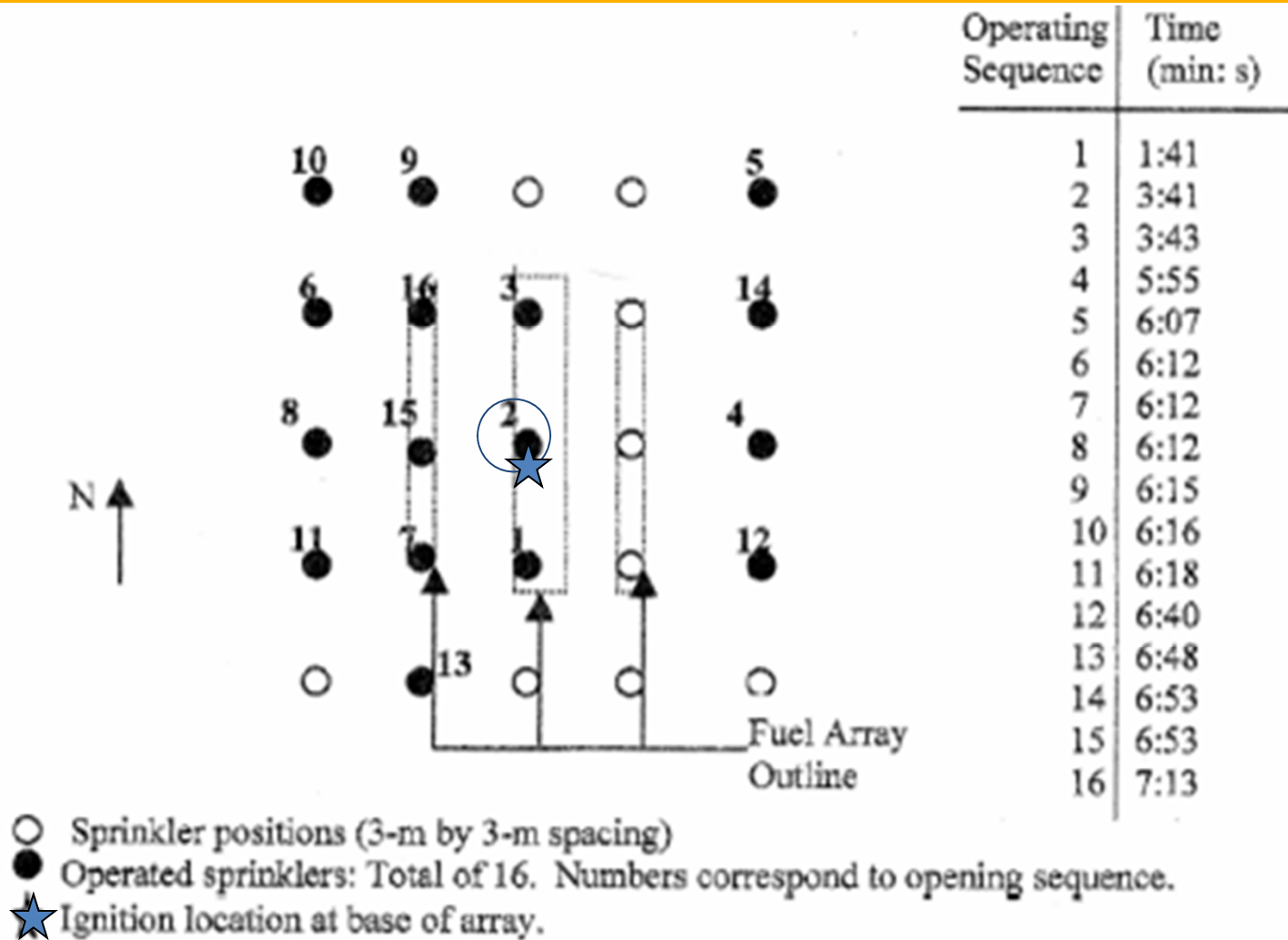
// Arrangement: 2 by 8, solid pile, 1 tier

// Density: 18 mm/min

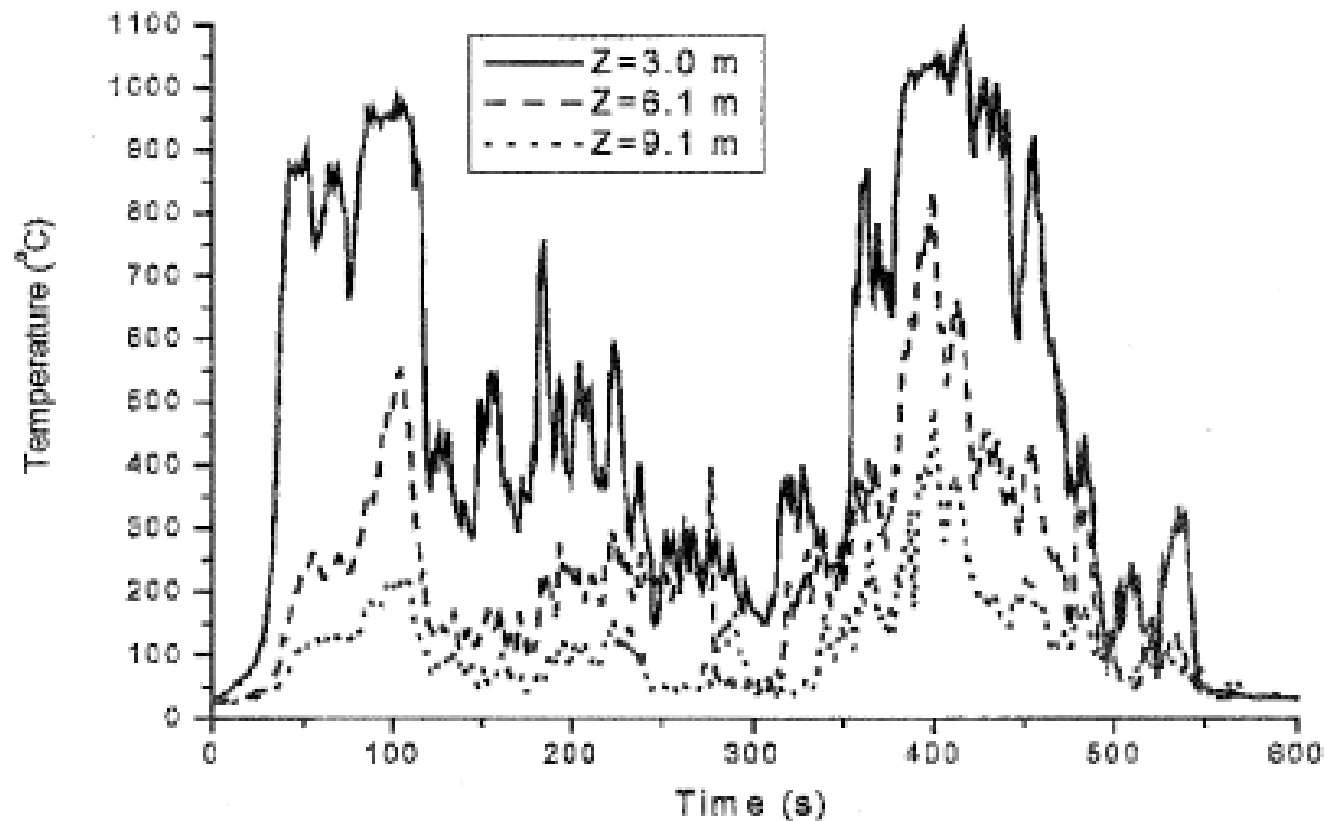
// Sprinklers: QR/ELO, K= 160, RTI 28 (m-s)^{1/2} Fast
Response element, Upright

// Spacing: 3.0 m x 3.0 m

// Plan View of Sprinkler Operation – Test 4



// Temperature Measurements in Test 4



// Results Test 4

// Number of sprinklers operated: 16

// Ceiling temperature: Within acceptable levels

// Fire damage: Fire well confined to ignition array

// Skipping of sprinklers: Severe

Key Take Away: in Heavily Loaded areas, ELO sprinklers with 12mm/min over an operating area of 230 sqm is effective against the fire hazard equivalent to the limited amount of FMRC Standard Plastic Commodity

// Description of Full Scale Fire Test 5

intended to provide a reference point for future work

// Fuel Arrangement: FMRC Group A Plastics identical to test4

// Fuel Height: 1.73 m

// Clearance to ceiling: 16.6 m

// Clearance to deflector: 16.4 m

// Arrangement: 2 by 8, solid pile, 1 tier

// Density: 18 mm/min

// Sprinklers: K= 360 (EC-25), RTI 28 (m-s)^{1/2} Fast
Response element, Upright

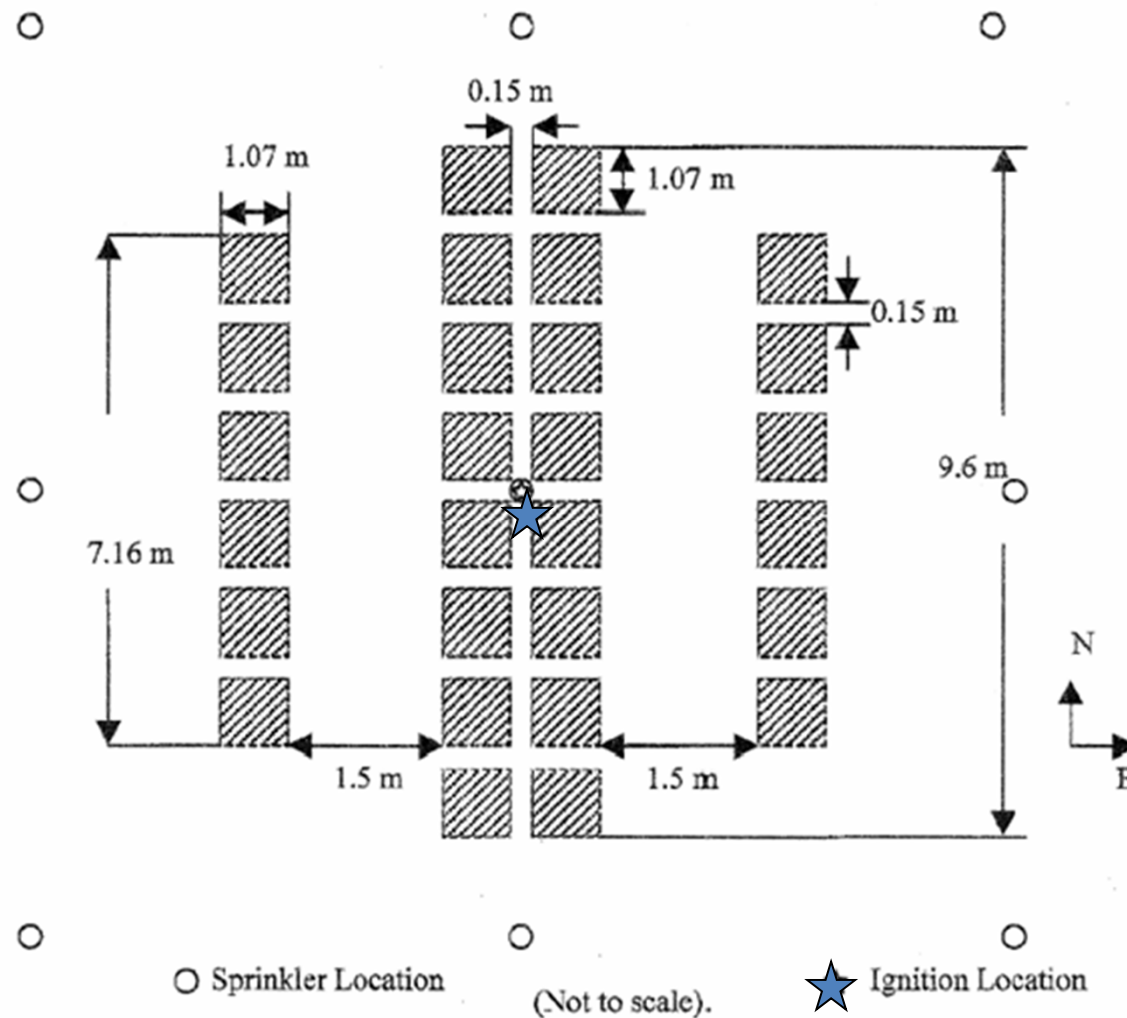
// Spacing: 6.1 m x 6.1 m

// EC-25 (Extended Coverage Extra Hazard Sprinkler)

- // Control Mode (Density/Area)
- // Extended Coverage
- // K-factor – 360 LPM/bar^{1/2}
- // RTI: 28 (m-s)^{1/2} – Fast Response element
- // Temperature Ratings 74° C or 101° C
- // Position: Upright
- // Finish: Natural Brass
- // Pipe Thread Connection: 1" NPT or ISO 7-R1



// Plan View of Sprinkler Operation – Test 5



// Results Test 5

- // Number of Sprinklers Operated: 1
- // Ceiling temperature: Within acceptable levels
- // Fire damage: Fire well confined to ignition array
- // No Skipping of sprinklers since only one operated

Key Take Away: Favorable results, fire losing intensity at 2 min. 10s. , one head operating, fire well confined but additional test needed to verify protection scheme

// Test Summary

	Test 1	Test 2	Test 3	Test 4	Exploratory Test 5 EC 25
Commodity (as per NFPA)	Class II & III	Class II	Group A Plastic	Group A Plastic	Group A Plastic
Fuel Height	2.26	2.26	1.73	1.73	1.73
Ceiling	15.4	15.4	15.9	16.6	16.6
Deflector	15.2	15.2	15.7	16.4	16.4
Arrangement	8X8,solid, 2 tiers	8X8,solid, 2 tiers	2X8, solid, 1 tier	2X8, solid, 1 tier	2X8, solid, 1 tier
density	12 mm/min	6 mm/min	12 mm/min	18 mm/min.	18 mm/min.
K-factor	K115, RTI 140	K 80, RTI 140	K115, RTI 140	K 160, RTI 28	K 360, RTI 28
Spacing	3.0 X 3.0	3.0 X 3.0	3.0 X 3.0	3.0 X 3.0	6.1 X 6.1
Conclusion	Passed 15 heads operating Skipping Adequate	Passed 17 heads operating Skipping Adequate	Failed 26 heads operating Skipping	Passed 16 heads operating Skipping Adequate	<u>1 head operating</u> No skipping Needs further research

// Conclusion #1: Results validated but more Research needed

1. For the test conditions, automatic sprinkler design criteria of
 - 6 mm/min over 232 m² was validated for moderately loaded areas equivalent to Class II, 12 mm/min was validated for moderately loaded areas equivalent to Class III
 - 18 mm/min over 232 m² criteria was validated for heavily loaded areas
2. However, high clearances induce temporary or permanent skipping of automatic sprinklers and more work is needed to evaluate its effect on fire control

// Conclusion #2: Even more Research needed!

3. Preliminary results seem to demonstrate that:

- **Large Orifice** : A K-factor of 360 at 18mm/min discharge density ensures large droplet sizes sufficient to penetrate the fire plume,
- **Extended Coverage**: Spacing of up to 6X6 m. reduces skipping,
- **Fast Response** element is required at larger spacing to guarantee early operation,

From the tests, the EC25 offers an efficient protection scheme for high ceiling clearances of up to 18.3 m

// DS 3-26 Table 2, 2a and EB 04-12. Standard Coverage, EC and K25.2 Sprinkler Design Demands for Hazard Categories

DS 3-26 Table 2, 2a and EB 04-12. Standard Coverage, EC and K25.2 Sprinkler Design Demands for Hazard Categories										
Hazard Category	Sprinkler Type		Standard Coverage Sprinkler Design Demand (gpm/ft ²)/ft ² (mm/min)/m ²							
			Ceiling Height up to 30 ft (9 m)		Ceiling Height 30–45 ft (9–13.5 m)		Ceiling Height 45–60 ft (13.5–18 m)		Ceiling Height 60–100 ft (18–30 m)	
			Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
HC-1	Standard Coverage Sprinkler Design Demand (gpm/ft ²)/ft ² (mm/min)/m ²		0.1/1500 (4/140)	0.1/1500 (4/140)	0.2/2500 (8/230)	0.2/3500 (8/330)	0.2/2500 (8/230)	0.2/3500 (8/330)	See Table 2a	Not an option
	EC Pendent Sprinklers 160°F (70°C)	K11.2EC (K160EC)	0.1/1500 (4/140)	Not an option	Not an option	Not an option	Not an option	Not an option	Not an option	Not an option
	EC Pendent Sprinklers 160°F (70°C)	K14.0EC (K200EC)	0.1/1500 (4/140)	Not an option	Not an option	Not an option	Not an option	Not an option	Not an option	Not an option
	EC Pendent Sprinklers 160°F (70°C)	K25.2EC (K360EC)	6 @ 7 psi (0.5)	Not an option	6 @ 7 psi (0.5)	Not an option	6 @ 7 psi (0.5)	Not an option	6 @ 7 psi (0.5)	Not an option
	Pendent Sprinklers QR 160°F (70°C)	K25.2 (K360)	12 @ 7 psi (0.5)	Not an option	12 @ 7 psi (0.5)	Not an option	12 @ 7 psi (0.5)	Not an option	12 @ 7 psi (0.5)	Not an option
	EC Upright Sprinklers 160°F (70°C)	K11.2EC (K160EC)	0.1/1500 (4/140)	Not an option	0.2/2500 (8/230)	Not an option	Not an option	Not an option	Not an option	Not an option
	EC Upright Sprinklers 160°F (70°C)	K14.0EC (K200EC)	0.1/1500 (4/140)	Not an option	0.2/2500 (8/230)	Not an option	Not an option	Not an option	Not an option	Not an option

// DS 3-26 Table 2, 2a and EB 04-12. Standard Coverage, EC and K25.2 Sprinkler Design Demands for Hazard Categories

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			Ceiling Height up to 30 ft (9 m)		Ceiling Height 30–45 ft (9–13.5 m)		Ceiling Height 45–60 ft (13.5–18 m)		Ceiling Height 60–100 ft (18–30 m)	
			Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
HC-2	Standard Coverage Sprinkler Design Demand (gpm/ft ²)/ft ² (mm/min)/m ²		0.2/2500 (8/230)	0.2/3500 (8/330)	0.2/2500 (8/230)	0.2/3500 (8/330)	0.2/2500 (8/230)	0.2/3500 (8/330)	See Table 2a	Not an option
	EC Pendent Sprinklers 160°F (70°C)	K11.2EC (K160EC)	Not an option	Not an option	Not an option	Not an option	Not an option	Not an option	Not an option	Not an option
	EC Pendent Sprinklers 160°F (70°C)	K14.0EC (K200EC)	0.2/2500 (8/230)	Not an option	Not an option	Not an option	Not an option	Not an option	Not an option	Not an option
	EC Pendent Sprinklers 160°F (70°C)	K25.2EC (K360EC)	6 @ 7 psi (0.5)	Not an option	6 @ 7 psi (0.5)	Not an option	6 @ 7 psi (0.5)	Not an option	6 @ 7 psi (0.5)	Not an option
	Pendent Sprinklers QR 160°F (70°C)	K25.2 (K360)	12 @ 7 psi (0.5)	Not an option	12 @ 7 psi (0.5)	Not an option	12 @ 7 psi (0.5)	Not an option	12 @ 7 psi (0.5)	Not an option
	EC Upright Sprinklers 160°F (70°C)	K11.2EC (K160EC)	0.3/1500 (12/140)	Not an option	0.2/2500 (8/230)	Not an option	Not an option	Not an option	Not an option	Not an option
	EC Upright Sprinklers 160°F (70°C)	K14.0EC (K200EC)	0.3/1000 (12/90)	Not an option	0.2/2500 (8/230)	Not an option	Not an option	Not an option	Not an option	Not an option

// DS 3-26 Table 2, 2a and EB 04-12. Standard Coverage, EC and K25.2 Sprinkler Design Demands for Hazard Categories

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			Ceiling Height up to 30 ft (9 m)		Ceiling Height 30–45 ft (9–13.5 m)		Ceiling Height 45–60 ft (13.5–18 m)		Ceiling Height 60–100 ft (18–30 m)	
			Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
HC-3	Standard Coverage Sprinkler Design Demand (gpm/ft ²)/ft ² (mm/min)/m ²		0.3/2500 (12/230)	0.3/3500 (12/330)	0.3/3600 (12/340)	0.3/4600 (12/430)	0.5/3000 (20/280)	0.5/4000 (20/370)	See Table 2a	Not an option
	EC Pendent Sprinklers 160°F (70°C)	K11.2EC (K160EC)	Not an option	Not an option	Not an option	Not an option	Not an option	Not an option	Not an option	Not an option
	EC Pendent Sprinklers 160°F (70°C)	K14.0EC (K200EC)	0.3/2500 (12/230)	Not an option	Not an option	Not an option	Not an option	Not an option	Not an option	Not an option
	EC Pendent Sprinklers 160°F (70°C)	K25.2EC (K360EC)	6 @ 7 psi (0.5)	Not an option	6 @ 7 psi (0.5)	Not an option	6 @ 7 psi (0.5)	Not an option	6 @ 7 psi (0.5)	Not an option
	Pendent Sprinklers QR 160°F (70°C)	K25.2 (K360)	12 @ 7 psi (0.5)	Not an option	12 @ 7 psi (0.5)	Not an option	12 @ 7 psi (0.5)	Not an option	12 @ 7 psi (0.5)	Not an option
	EC Upright Sprinklers 160°F (70°C)	K11.2EC (K160EC)	0.3/1500 (12/140)	Not an option	0.3/2500 (12/230)	Not an option	Not an option	Not an option	Not an option	Not an option
	EC Upright Sprinklers 160°F (70°C)	K14.0EC (K200EC)	0.3/1000 (12/90)	Not an option	0.3/2500 (12/230)	Not an option	Not an option	Not an option	Not an option	Not an option

//FM 3-26 July 2011 – Updated EB 04-12

FM 3-26 July 2011 Table 1. Hazard Categories Based on Occupancy

Occupancy	Description of Occupancy	Exceptions	HazardCategory
<ul style="list-style-type: none">– Apartments – Atriums – Churches – Concealed spaces – Gymnasiums – Hospitals and hospital laboratories – Hotel rooms – Institutions – Kitchens – Libraries – Meeting rooms in convention centers and hotels – Metalworking shops with non-hydraulic cutting operations – Mineral processing such as: glass, cement, ore treating, gypsum processing, etc. – Museums – Nursing or convalescent homes – Offices – Restaurant seating areas – Schools and universities classrooms – Unused attics	Lightly loaded nonstorage and nonmanufacturing areas with ordinary combustibles. Expect fires with relatively low rates of heat release in these occupancies.	Libraries with stack rooms larger in size than defined in Appendix A; Facilities with storage of electronic and plastic media (see DS 8-9). Hospital laboratories where exposed storage and processing of flammable liquids is considered excessive (see the applicable flammable liquids data sheet). Facilities with operations involving hydraulic fluid or flammable liquid, see DS7-32, DS 7-29, and DS 7-98; and for storage, see DS 7-32, DS 7-29, and DS 7-98.	HC-1

//FM 3-26 July 2011 – Updated EB 04-12

FM 3-26 July 2011 Table 1. Hazard Categories Based on Occupancy

Occupancy	Description of Occupancy	Exceptions	HazardCategory
<ul style="list-style-type: none"> – Auto parking garages – Back stage of theaters and auditoriums – Boat mfg. and assembly – Boiler buildings – Casinos – Clubs – Convention centers – Display halls – Electronic-electrical mfg. and assembly – Food processing – Leather tanning and working – Mercantile areas – Metalworking shops with hydraulic operations – Movie and TV Studios – Paper processing – Retail areas – Rubber processing – Sports Arenas – Theater & auditoriums* – Utility and equipment rooms 	<p>Lightly and moderately loaded nonstorage, nonmanufacturing, and manufacturing areas with ordinary combustibles. Occupancies with fire hazards equivalent to in-process Class 2 commodities no more than 6 ft (1.8 m) high, or lesser hazard (e.g., mostly wood, cardboard products and small amounts of plastic, including foam plastic found in the seat cushion of a chair or plastic trim in an exhibit display booth). Manufacturing occupancies with movable picking racks not higher than 6 ft (1.8 m) containing rigid plastic open top containers. Do not allow expanded plastic inside the containers. Additionally, if the racks/carts are not separated by at least a distance equal to the least dimension of the rack/cart, treat as storage per DS 8-9.</p>	<p>Operations involving hydraulic fluid or flammable liquid (see DS 7-32, DS 7-29, and DS 7-98); aluminum rolling mills (see DS 7-64/13-28); paper machine areas that involve inks with flashpoints below 110°F (42°C) (see DS 7-4 and DS 7-96); aircraft hangars (see DS 7-93N). Oil cookers and distilling operations (see the applicable flammable liquid data sheet). Bulk retailers where merchandise is displayed on racks typically found in warehouses (see DS 8-9 and DS 8-3). Telephone switchgear rooms and generator rooms (see DS 5-12, DS 5-14, or DS 5-23).</p>	HC-2

//FM 3-26 July 2011 – Updated EB 04-12

FM 3-26 July 2011 Table 1. Hazard Categories Based on Occupancy

Occupancy	Description of Occupancy	Exceptions	Hazard Category
– Cable manufacturing – Car-sized vehicle repair garages and assembly operations where vehicles are repaired, tested, or assembled with relatively small amounts of fuel in tanks – Interior loading docks – Modular building subassembly – Plastics processing and molding – Highway trailers, trucks, boxcars, some mobile homes or similar metal vehicles with combustible interiors with the potential for shielded fire	Heavily loaded areas with or without plastics. Manufacturing and nonmanufacturing facilities with higher concentrations of combustibles or shielding of combustibles where the fire hazard could approach the equivalent of nominal 5 ft (1.5 m) high in-process storage of cartoned unexpanded plastic commodities.	Facilities that use hydraulic and flammable liquids (see DS 7-98). For electronic media storage see DS 8-9. For haul-truck repair shops or manufacturing facilities housing vehicles that may contain several hundred gallons of flammable liquid, see DS 7-12 or DS7-32, as applicable.	HC-3

// Questions





Thank You