Piping. Systems. Solutions.

FOR OVER 85 YEARS

Sprinkler Protection of Non-storage Occupancies with High Ceiling Clearance

SUPDET 2014, March 4, 2014

Peter Thomas

Victaulic

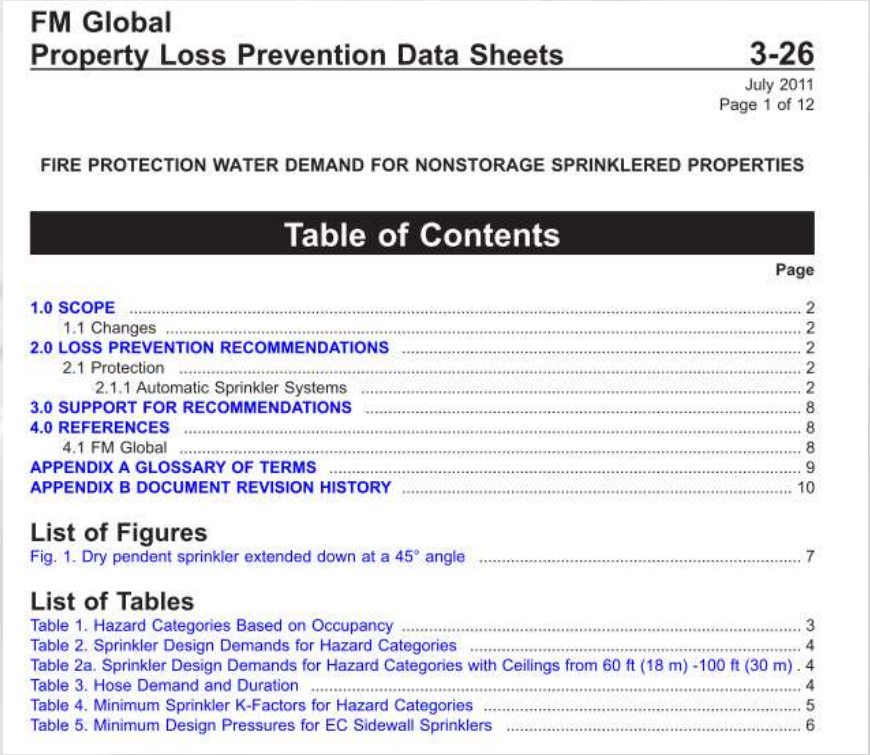
Background

- **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.**

Introduction – Current Situation

- NFPA
- CEN
- China GB 50084
- Singapore CP 52
- FM



FM Global
Property Loss Prevention Data Sheets 3-26

July 2011
Page 1 of 12

FIRE PROTECTION WATER DEMAND FOR NONSTORAGE SPRINKLERED PROPERTIES

Table of Contents

Page

1.0 SCOPE 2
1.1 Changes 2
2.0 LOSS PREVENTION RECOMMENDATIONS 2
2.1 Protection 2
2.1.1 Automatic Sprinkler Systems 2
3.0 SUPPORT FOR RECOMMENDATIONS 8
4.0 REFERENCES 8
4.1 FM Global 8
APPENDIX A GLOSSARY OF TERMS 9
APPENDIX B DOCUMENT REVISION HISTORY 10

List of Figures

Fig. 1. Dry pendent sprinkler extended down at a 45° angle 7

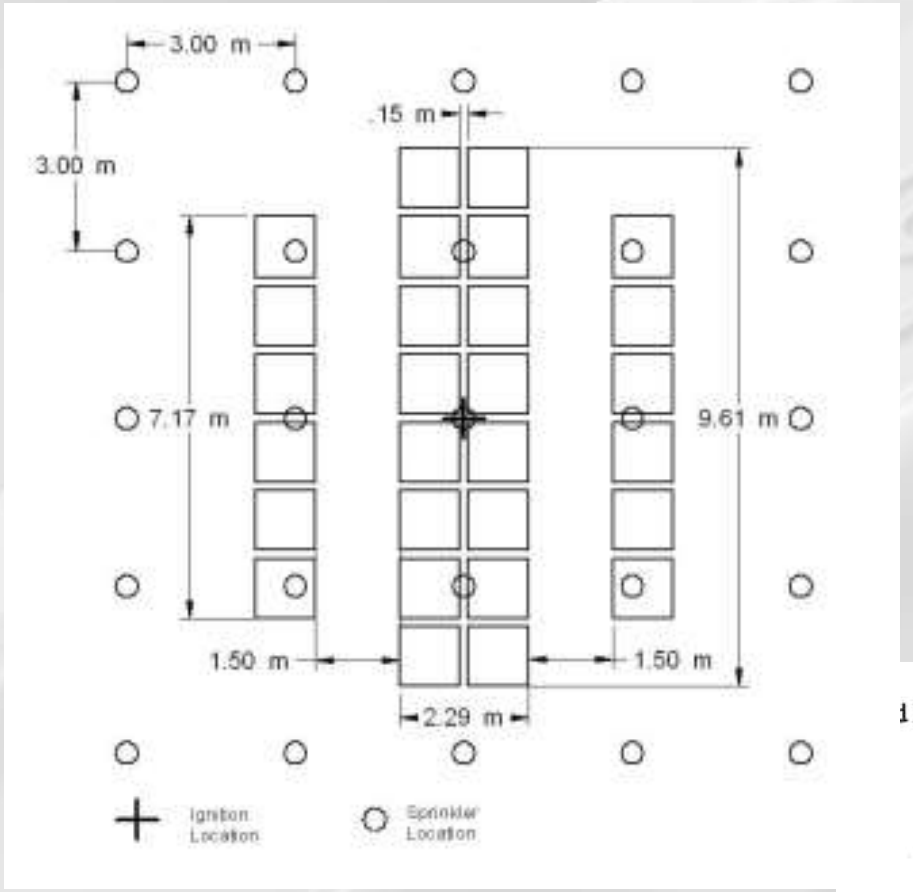
List of Tables

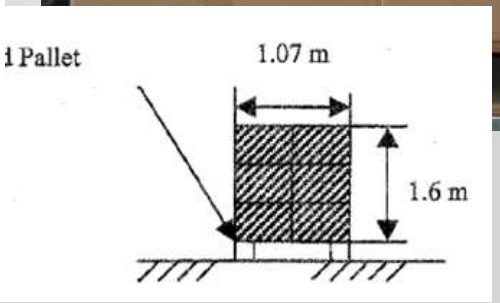
Table 1. Hazard Categories Based on Occupancy 3
Table 2. Sprinkler Design Demands for Hazard Categories 4
Table 2a. Sprinkler Design Demands for Hazard Categories with Ceilings from 60 ft (18 m) -100 ft (30 m) . 4
Table 3. Hose Demand and Duration 4
Table 4. Minimum Sprinkler K-Factors for Hazard Categories 5
Table 5. Minimum Design Pressures for EC Sidewall Sprinklers 6

Test Plan

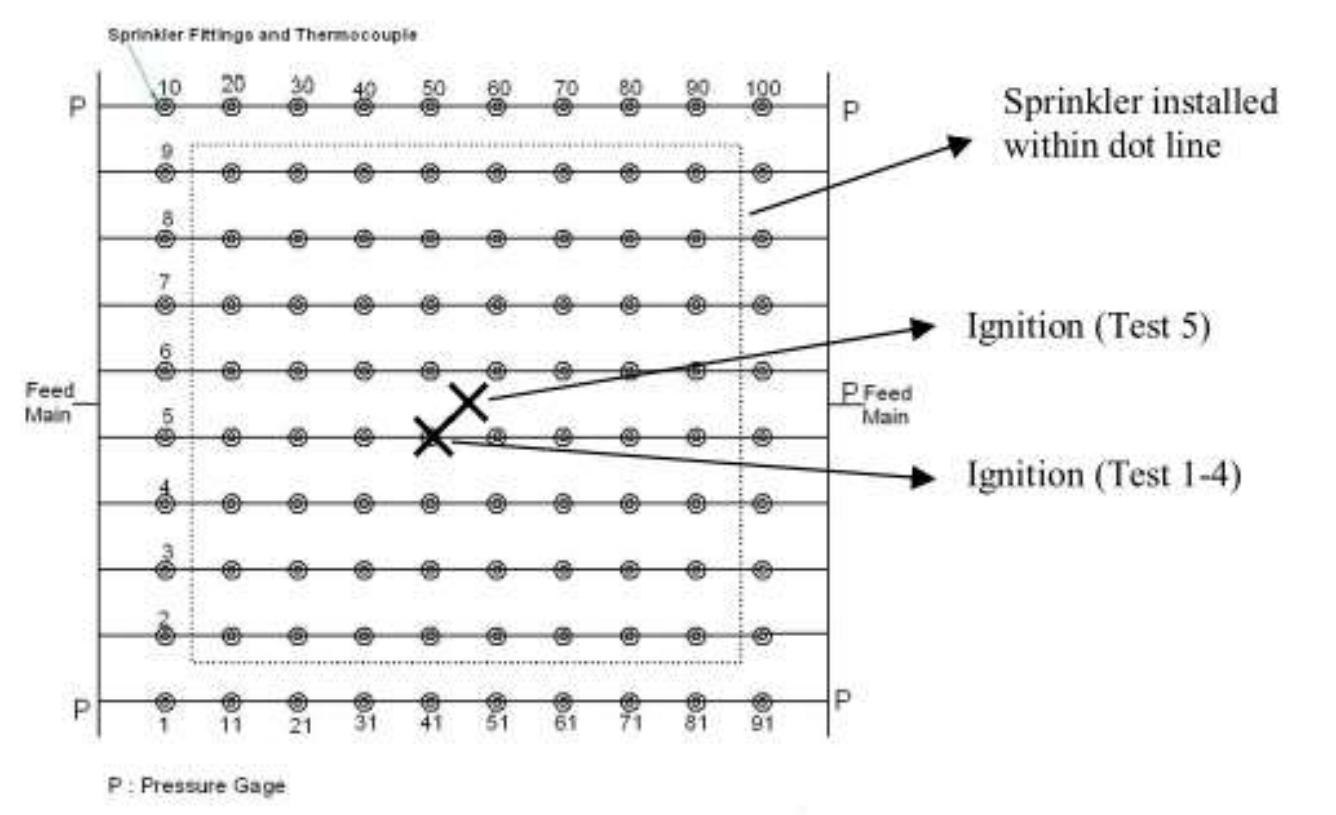
FIRE TEST NUMBER	1	2	3	4	5
DATE	12/8/2008	2/13/2009	2/20/2009	12/3/2009	12/8/2009
PARAMETERS					
Initial ambient temperature, (°C)	15.0	14.8	13.4	14.3	15.0
Relative humidity, (%)	N/A	N/A	N/A	45	40
Stack height, (m)	1.63	1.63/1.13*	1.63/1.13*	1.63	1.63
Main array in term of pallet loads (L × W)	8 × 2	8 × 2	8 × 2	6 × 2	6 × 2
Target array in term of pallet loads (L ×W)	6 × 1	6 × 1	6 × 1	4 × 1	4 × 1
Cardboard moisture content (%)	N/A	N/A	N/A	5.2	5.5
Ceiling height, (m)	12	16	16	18	18
Ceiling clearance, (m)	10.4	14.4	14.4	16.4	16.4
Deflector to ceiling, (mm)	290	290	290	308	308
Aisle width, (m)	1.5	1.5	1.5	1.5	1.5
Ignition location	Under 1	Under 1	Under 1	Under 1	between 4
Temperature rating, (°C)	68	68	74	72	72
Sprinkler sensitivity (RTI), $(m \cdot s)^{1/2}$	105	35	138	130	130
Sprinkler spacing, (m × m)	3 × 3	3 × 3	3 × 3	3 × 3	3 × 3
Nominal sprinkler K factor, $L/min/(bar)^{1/2}$	115	115	161	363	363
Discharge pressure, (MPa)	0.15	0.25	0.15	0.10	0.10
Sprinkler Discharge Rate, (L/min)	141	182	209	363	363
Estimated Relative Drop Diameter	1.00	0.84	1.13	1.69	1.69

Test Fuel and Fuel Array Arrangement





Sprinkler System



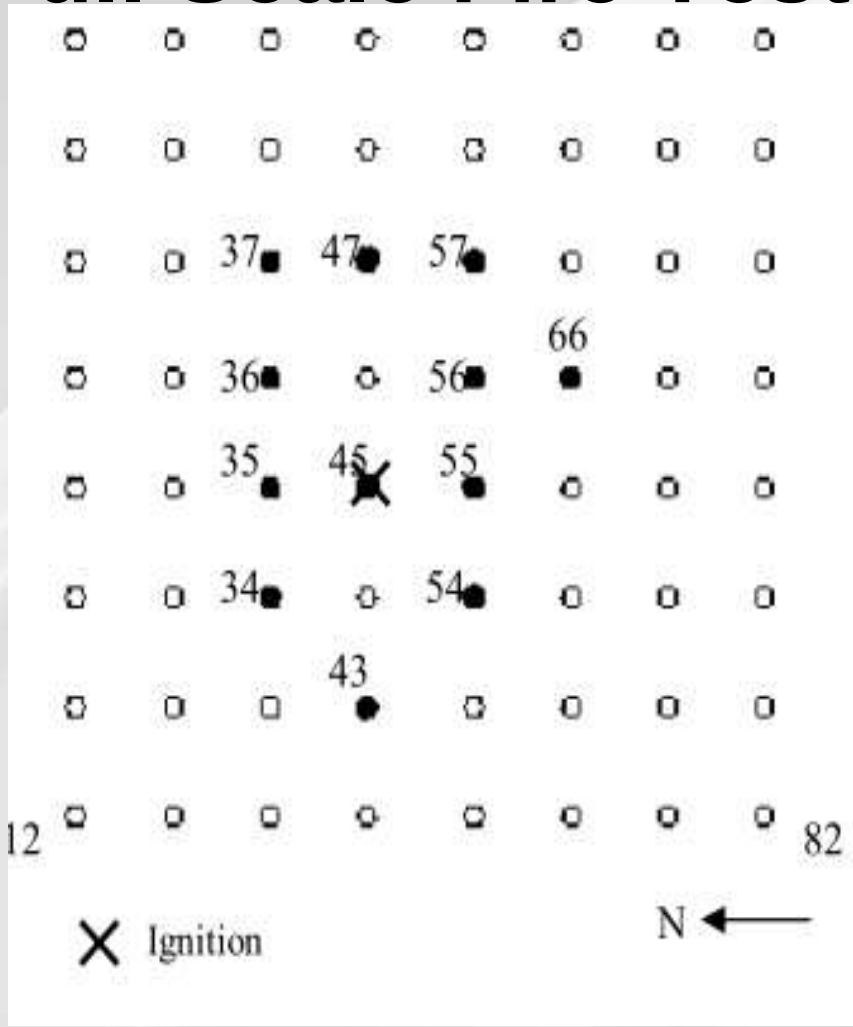
Full Scale Fire Test 1

- Fuel Arrangement: Group A Plastics
- Ceiling height: 12 m
- Fuel Height: 1.63 m
- Clearance to ceiling: 10.4 m
- Arrangement of fuel package: 8 by 2, solid pile
- Ignition Location: Under 1 sprinkler
- Density: 15 mm/min (0.37 gpm/sq ft)
- Sprinklers: K115, RTI 105 $(m\text{-}s)^{1/2}$ Standard Response, Pendent
- Spacing: 3.0 m x 3.0 m

Full Scale Fire Test 1

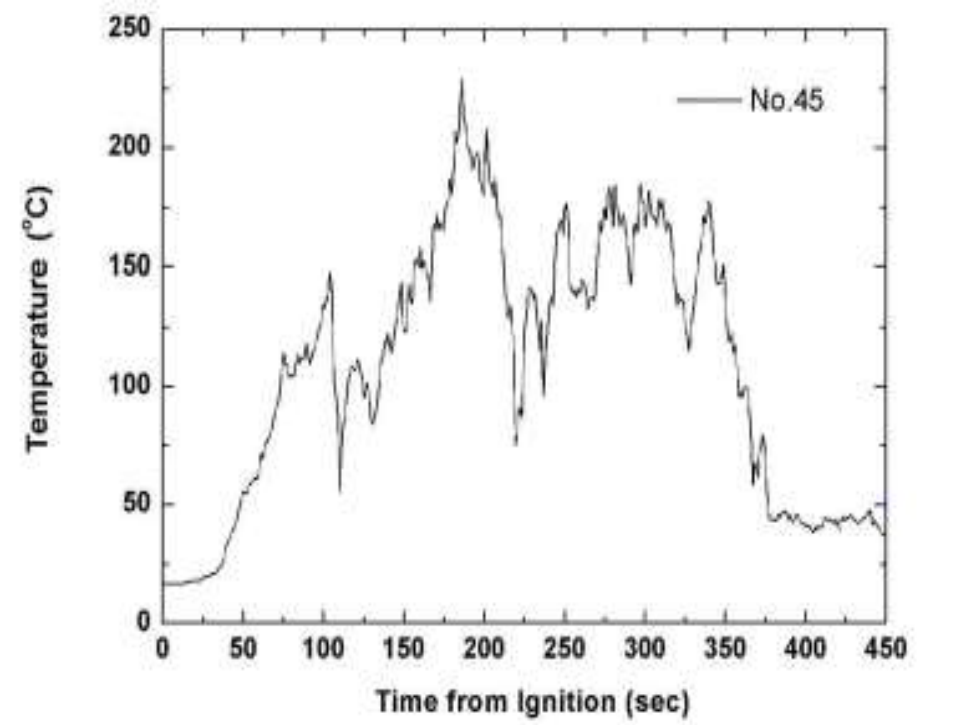
Length of test, (min)	7.5
First sprinkler operation, (min:s)	1:53
Last sprinkler operation, (min:s)	6:01
Number of operated sprinklers	12
Time of ignition across aisle, (min:s)	N/A
Peak gas temperature at ceiling above Ignition, (°C)	228.7
Maximum 1 minute average gas temperature at ceiling above ignition, (°C)	163.3
Maximum steel temperature, (° C)	62.6
Fire travel to end of main array	N/A
Fire spread across aisles	Yes

Full Scale Fire Test 1



Sprinkler	Time(min:s)
45	1:53
55	3:22
35	3:27
36	3:29
37	3:32
56	3:34
54	3:37
43	4:05
34	4:21
57	4:46
66	5:47
47	6:01

Full Scale Fire Test 1



Test 1 - Ceiling gas temperature at Sprinkler 45

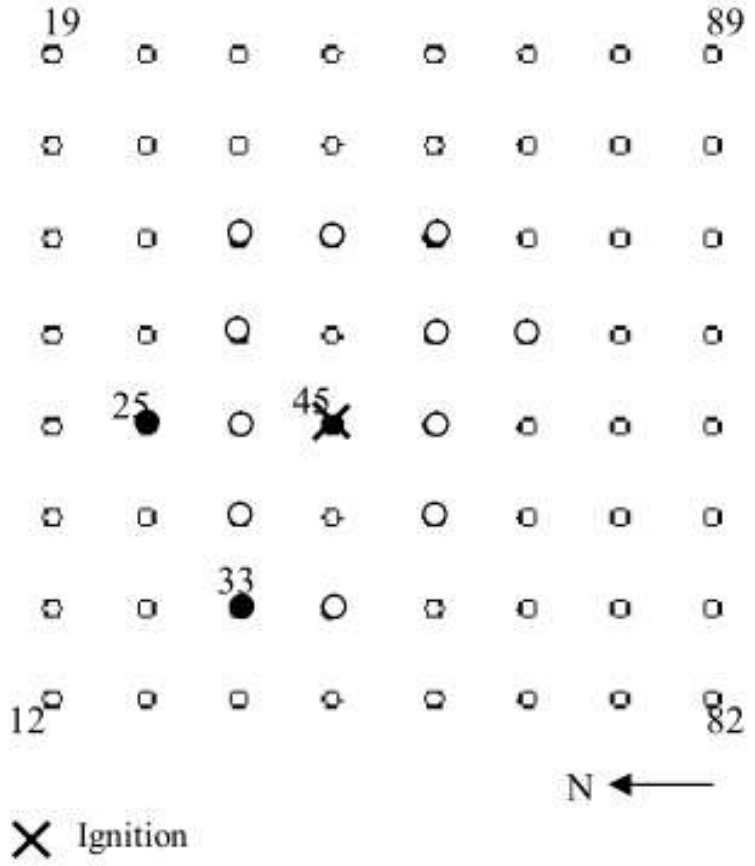
Full Scale Fire Test 2

- Fuel Arrangement: Group A Plastics
- Ceiling Height: 16 m
- Fuel Height: 1.63 / 1.13 m
- Clearance to ceiling: 14.4 m
- Arrangement of fuel package: 8 by 2, solid pile
- Ignition Location: Under 1 sprinkler
- Density: 20 mm/min (0.50 gpm/ sq ft)
- Sprinklers: K115, RTI 35 $(m\text{-}s)^{1/2}$ Quick Response, Pendent
- Spacing: 3.0 m x 3.0 m

Full Scale Fire Test 2

Length of test, (min)	7.5
First sprinkler operation, (min:s)	2:00
Last sprinkler operation, (min:s)	5:44
Number of operated sprinklers	3
Time of ignition across aisle, (min:s)	N/A
Peak gas temperature at ceiling above Ignition, (°C)	99.5
Maximum 1 minute average gas temperature at ceiling above ignition, (°C)	62.9
Maximum steel temperature, (° C)	60.9
Fire travel to end of main array	N/A
Fire spread across aisles	Yes

Full Scale Fire Test 2



Sprinkler	Time(min:s)
45	2:00
33	5:39
25	5:44

Figure 7. Sprinkler opening sequence of Test 2.

Full Scale Fire Test 2

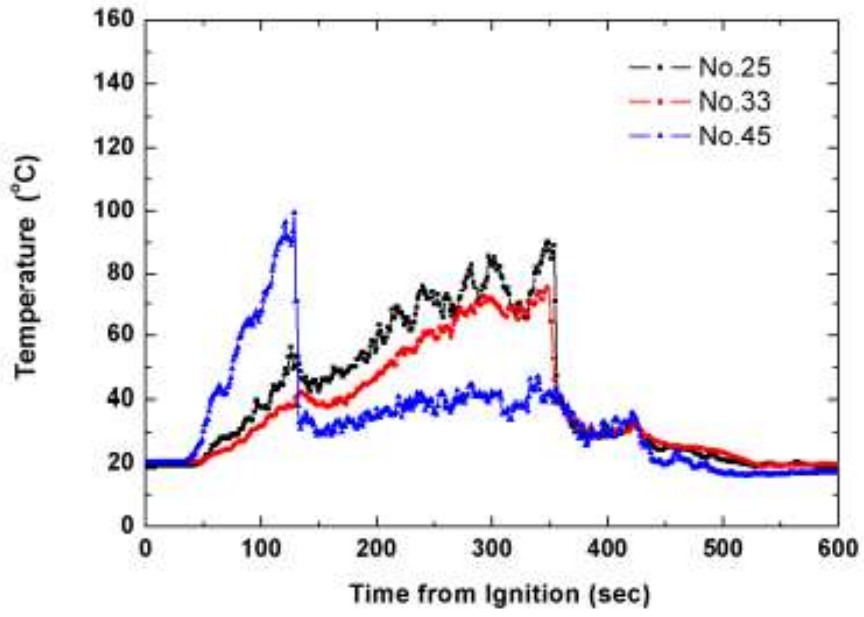


Figure 6, Test 2 – Ceiling gas temperatures at Sprinklers 25, 33 and 45.

Full Scale Fire Test 3

- Fuel Arrangement: Group A Plastics
- Ceiling Height: 16 m
- Fuel Height: 1.63 / 1.13 m
- Clearance to ceiling: 14.4 m
- Arrangement of fuel package: 8 by 2, solid pile
- Ignition Location: Under 1 sprinkler
- Density: 23 mm/min (0.58 gpm/sq ft)
- Sprinklers: K161, RTI 138 $(m\text{-}s)^{1/2}$ Standard Response, Pendent
- Spacing: 3.0 m x 3.0 m

Full Scale Fire Test 3

Length of test, (min)	10
First sprinkler operation, (min:s)	2:44
Last sprinkler operation, (min:s)	/
Number of operated sprinklers	1
Time of ignition across aisle, (min:s)	5:47
Peak gas temperature at ceiling above Ignition, (°C)	158.7
Maximum 1 minute average gas temperature at ceiling above ignition, (°C)	103.3
Maximum steel temperature, (° C)	92.1
Fire travel to end of main array	No
Fire spread across aisles	Yes

Full Scale Fire Test 3

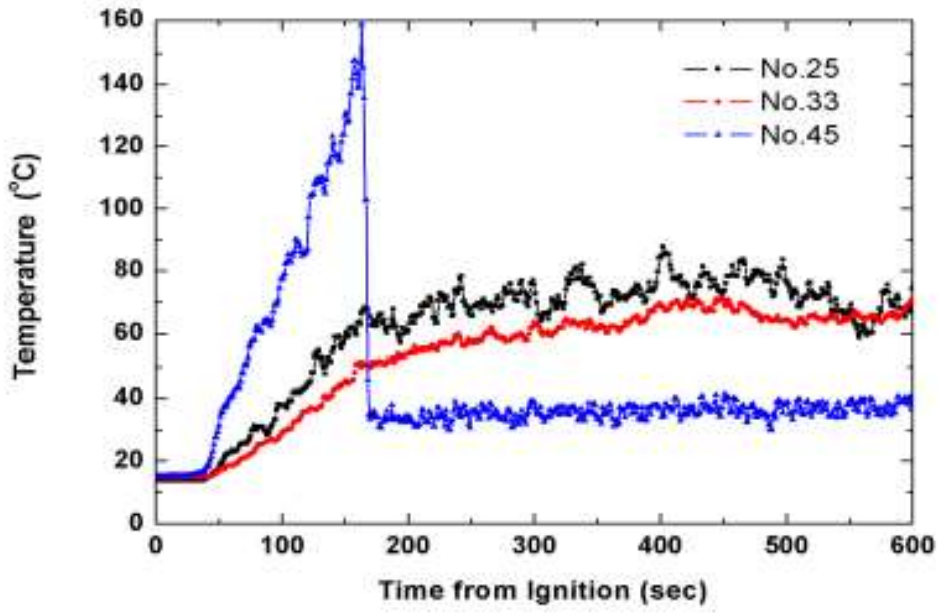


Figure 8, Test 3 – Ceiling gas temperatures at Sprinklers 25, 33 and 45.

Full Scale Fire Test 4

- Fuel Arrangement: Group A Plastics
- Ceiling Height: 18 m
- Fuel Height: 1.63 m
- Clearance to ceiling: 16.4 m
- Arrangement of Fuel Package: 6 by 2, solid pile
- Ignition Location: Under 1 sprinkler
- Density: 40 mm/min (1.0 gpm / sq ft)
- Sprinklers: K363, RTI 130 $(m\text{-}s)^{1/2}$ Standard Response, Pendent
- Spacing: 3.0 m x 3.0 m

Full Scale Fire Test 4

Length of test, (min)	30
First sprinkler operation, (min:s)	3:34
Last sprinkler operation, (min:s)	/
Number of operated sprinklers	1
Time of ignition across aisle, (min:s)	5:17
Peak gas temperature at ceiling above Ignition, (°C)	120.7
Maximum 1 minute average gas temperature at ceiling above ignition, (°C)	94.9
Maximum steel temperature, (° C)	42.2
Fire travel to end of main array	No
Fire spread across aisles	Yes

Full Scale Fire Test 4

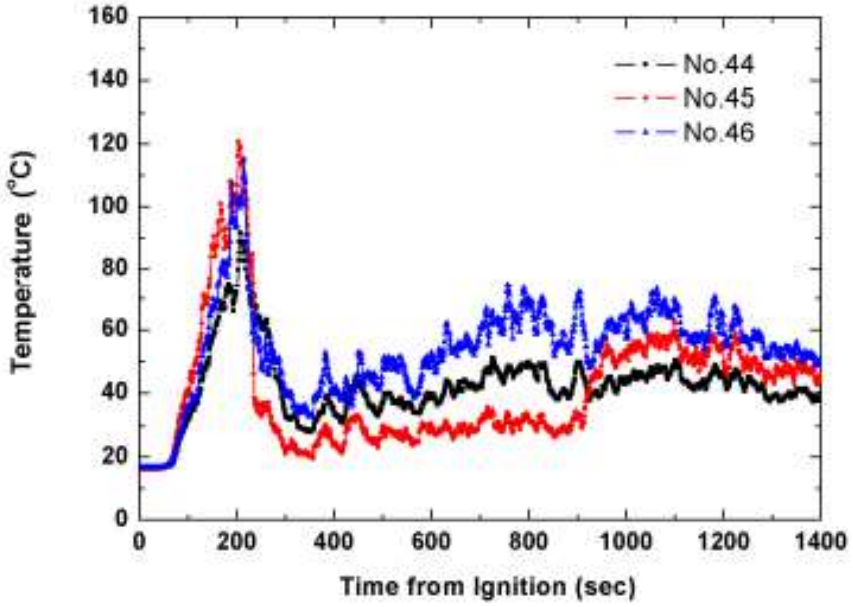


Figure 9, Test 4 – Ceiling gas temperatures at Sprinklers 44, 45, and 46.

2d: Test 4

Full Scale Fire Test 5

- Fuel Arrangement: Group A Plastics
- Ceiling Height: 18 m
- Fuel Height: 1.63
- Clearance to Ceiling: 16.4 m
- Arrangement of Fuel package: 6 by 2, solid pile
- Ignition Location: Between 4 sprinklers
- Density: 40 mm/min (1.0 gpm/ sq ft)
- Sprinklers: K363, RTI 130 $(m\text{-}s)^{1/2}$ Standard Response, Pendent
- Spacing: 3.0 m x 3.0 m

Full Scale Fire Test 5

Length of test, (min)	15
First sprinkler operation, (min:s)	3:11
Last sprinkler operation, (min:s)	3:15
Number of operated sprinklers	3
Time of ignition across aisle, (min:s)	No
Peak gas temperature at ceiling above Ignition, (°C)	98.4**
Maximum 1 minute average gas temperature at ceiling above ignition, (°C)	70.0
Maximum steel temperature, (° C)	31.5
Fire travel to end of main array	No
Fire spread across aisles	No

Full Scale Fire Test 5

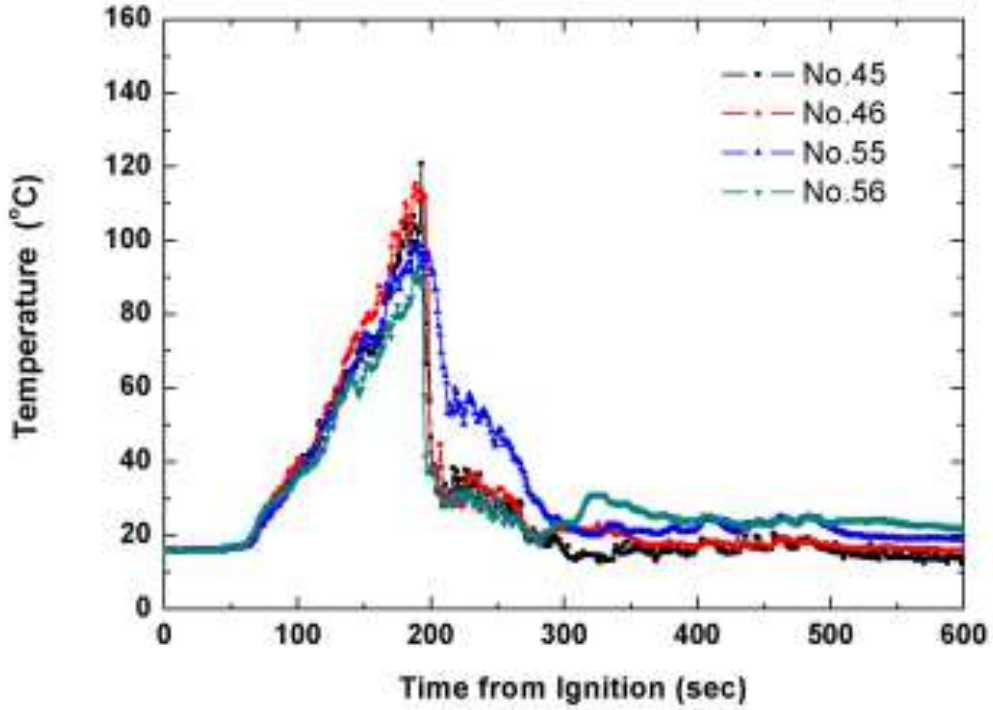


Figure 10, Test 5 – Ceiling gas temperatures at Sprinklers 45, 46, 55, and 56.

Conclusion

- **Effectiveness of sprinkler to control depends on delivered density**
- **Under 12 m ceiling, K 115 sprinkler at 1.5 bar did not control the fire.**
- **Under 16 m ceiling, K115 sprinkler at 2.5 bar did not control the fire. A K160 sprinkler marginally controlled the fire at discharge pressure of 1.5 bar.**
- **Under 18 m ceiling, K363 sprinkler at 1.0 bar generates significantly larger drops and effectively controlled the fire.**