



Use of SMART Sprinkler to Reduce Water Demand for Occupancies with Low-piled Storage of Plastics

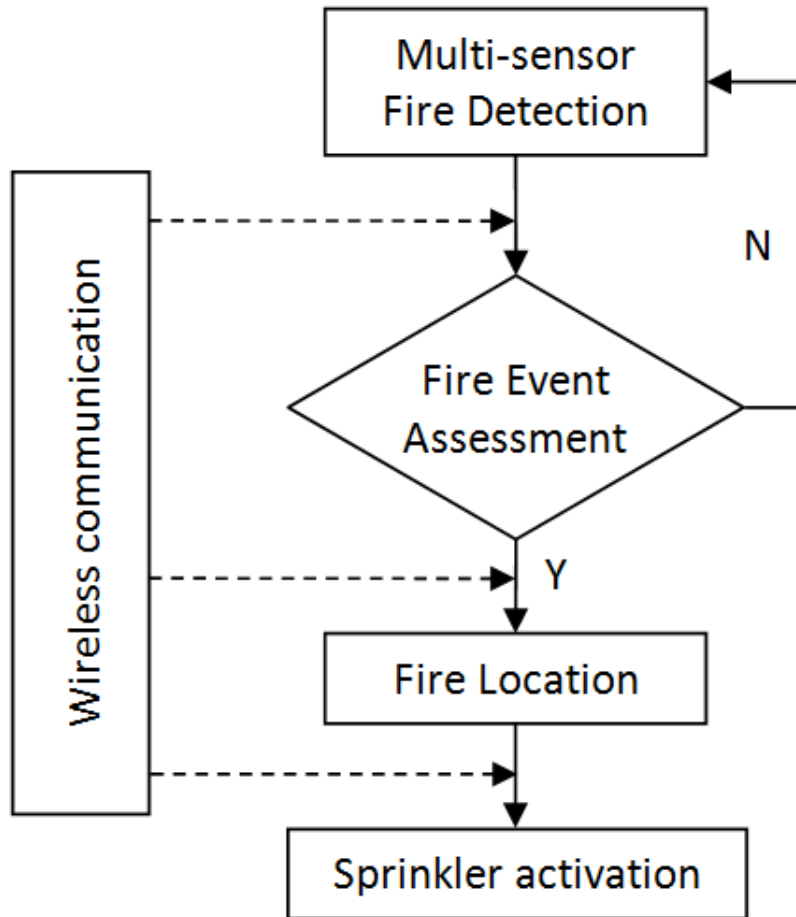
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SMART sprinkler

- A sprinkler system that utilizes
 - Simultaneous
 - Monitoring,
 - Assessment &
 - Response
 - Technology
- Detect fire very early
- Activate multiple sprinklers simultaneously
 - Surround the fire
 - Avoid skipping
- Lower water demand

Basic system design



Smoke/Heat/Optical Detectors at the ceiling

Smoke: $(\Delta I/I) > (\Delta I/I)_{\min}$

Heat: $(\Delta T) > (\Delta T)_{\min}$

Thermal Centroid

$$x_i = \sum_i x_i T_i^* / \sum_i T_i^* ,$$

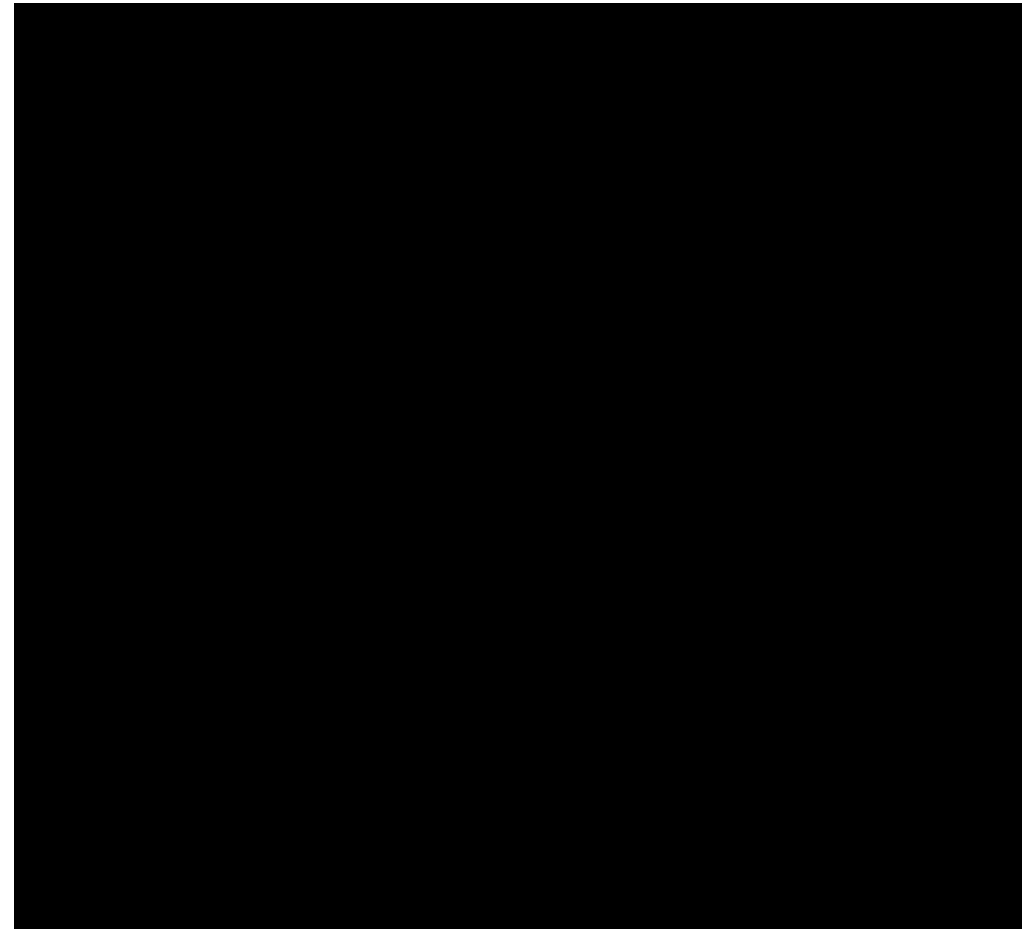
$$y_i = \sum_i y_i T_i^* / \sum_i T_i^*$$

Activate six sprinklers closest to thermal centroid using solenoids

7-tier rack storage test

- Test conditions

- 2x4, 7-tier CUP
- Ignition between 2 offset
- Smoke alarm & $\Delta T=5K$
- SMART: K25, 6@0.90 gpm/ft²
- AS QR: K25, 12@1.8 gpm/ft²



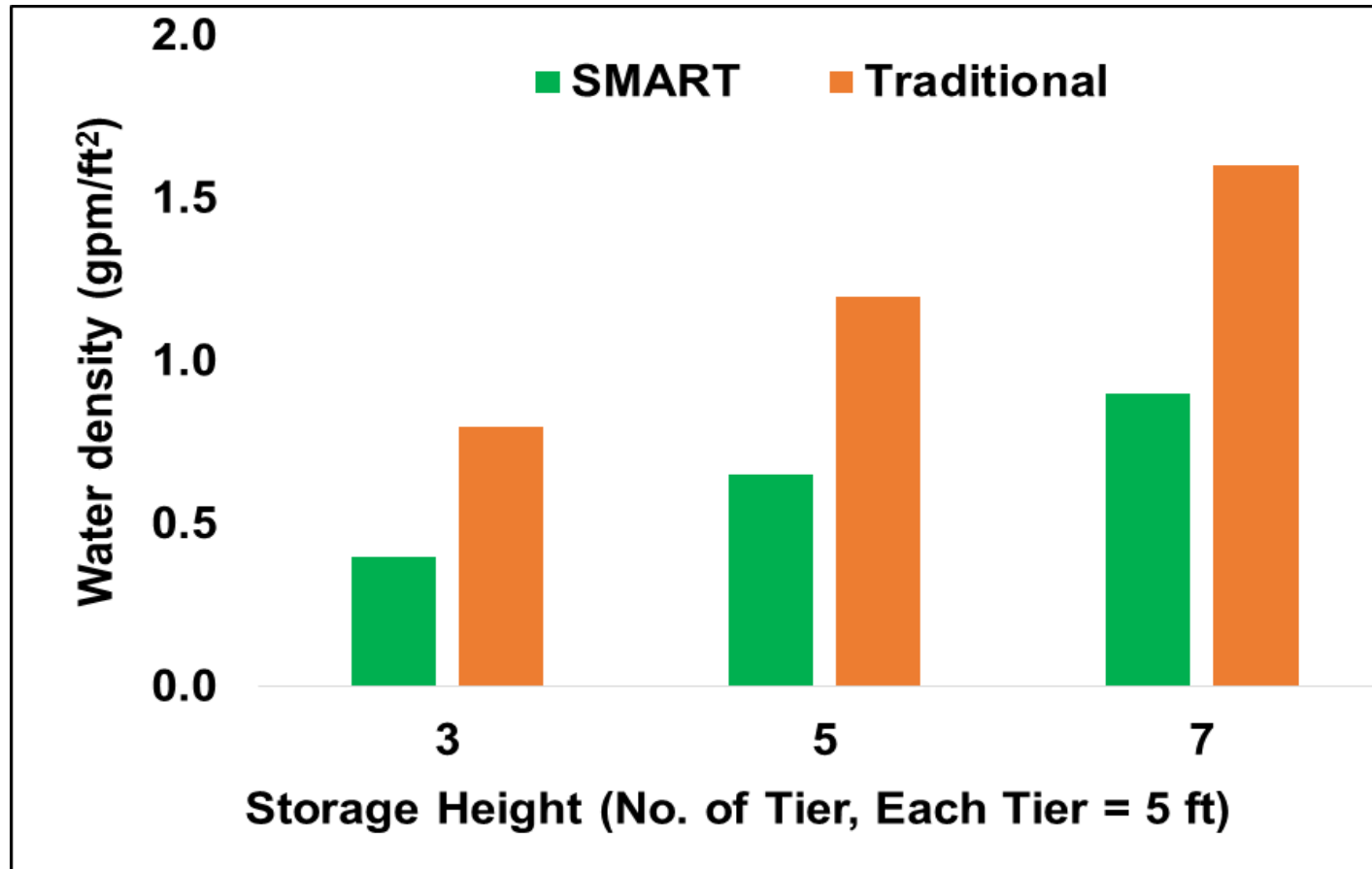
Fire size @ sprinkler activation



← Traditional sprinkler activation
↓ SMART sprinkler activation



Rack Storage of CUP – Required Density



Examples of Low-piled Storage of Plastics



Low-piled Storage of Plastics

FM Global OS 3-26

- Hazard Category 3
 - 0.3 gpm/ft² over 2500 ft²
 - 750 gpm
- Low-piled storage of uncartoned unexpanded plastics
 - 0.8 gpm/ft² over 2500 ft²
 - 2000 gpm

NFPA 13

- Extra Hazard Group 1
 - 0.3 gpm/ft² over 2500 ft²
 - 750 gpm
- Extra Hazard Group 2
 - 0.4 gpm/ft² over 2500 ft²
 - 1000 gpm

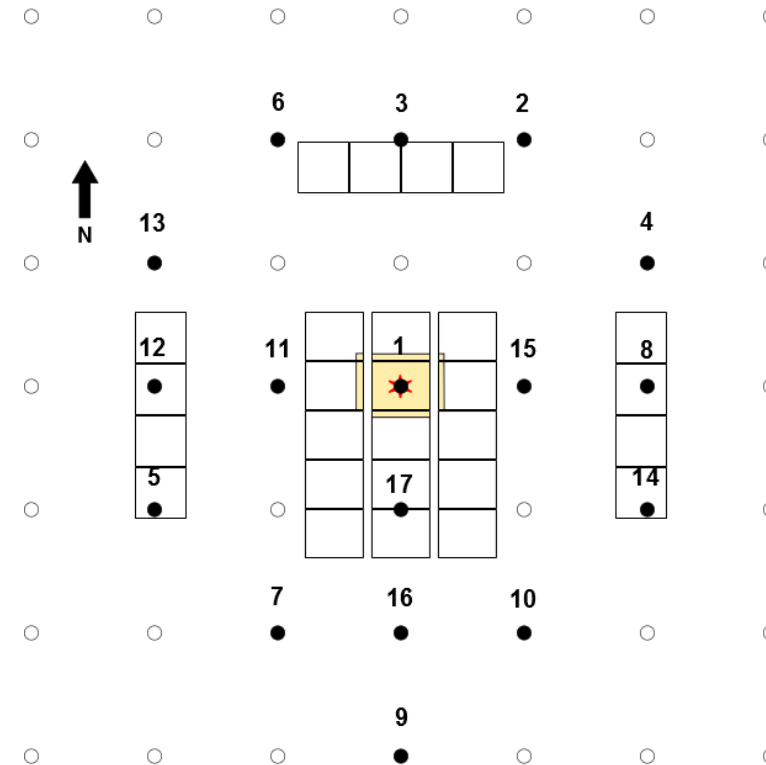
Low-piled Storage of UUP – Test Setup

- Uncartoned Unexpanded Plastic Commodity (HDPE pallets)
- Piled Storage
- Height: 5 ft
- Storage Area: 19 m² (200 ft²)
- Target arrays of Class 2 commodity with 2.4 m (8 ft) aisles



Low-piled Storage of UUP

Ceiling Height (ft)	30
Sprinkler	Upright K11.2 165 °F SR
Density (gpm/ft ²)	0.8
Fire Controlled?	Yes
# of Sprinklers	17
Perimeter Sprinklers	1
Energy Released (MJ)	5,100 ± 500



Sprinkler Sequence	
#	Time (m:s)
1	4:20
2	12:22
3	12:28
4	12:32
5	12:36
6	12:40
7	13:43
8	13:49
9	13:52
10	14:00
11	14:02
12	14:03
13	14:06
14	14:17
15	14:25
16	14:51
17	14:52

- Sprinkler Location
- Activated Sprinklers
- ★ Location of Ignition
- Fire Damage

Sprinkler skipping leads to increased water demand

Options to Reduce Water Demand

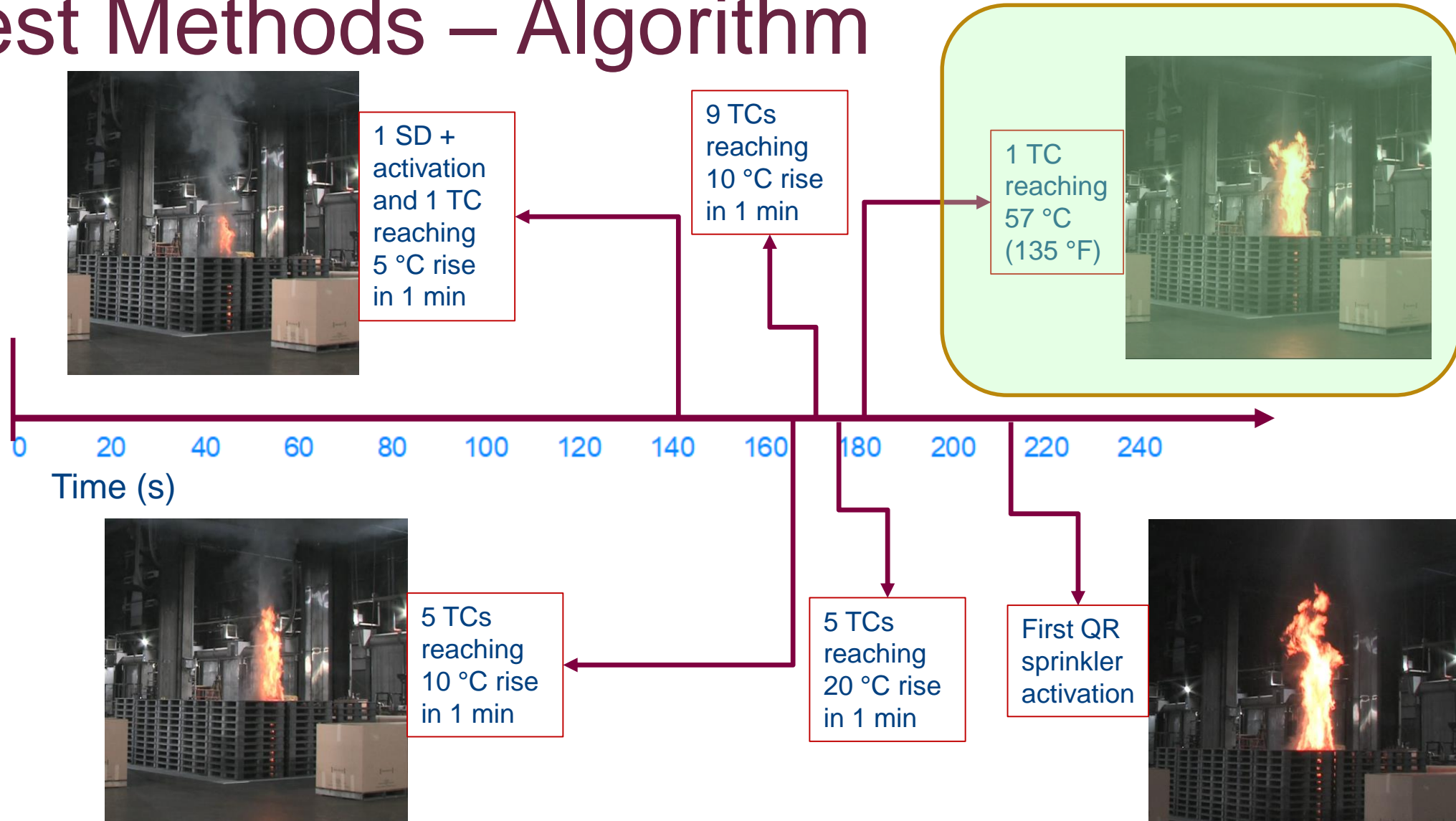
- Quick Response (QR) sprinklers operating at a high density
 - First few sprinklers to activate suppresses the fire
 - Fire is suppressed before farther sprinklers can open
- Automatic water cannon
- SMART sprinklers
 - Avoids sprinkler skipping
 - Early activation

Low-piled Storage of CUP – Test Setup

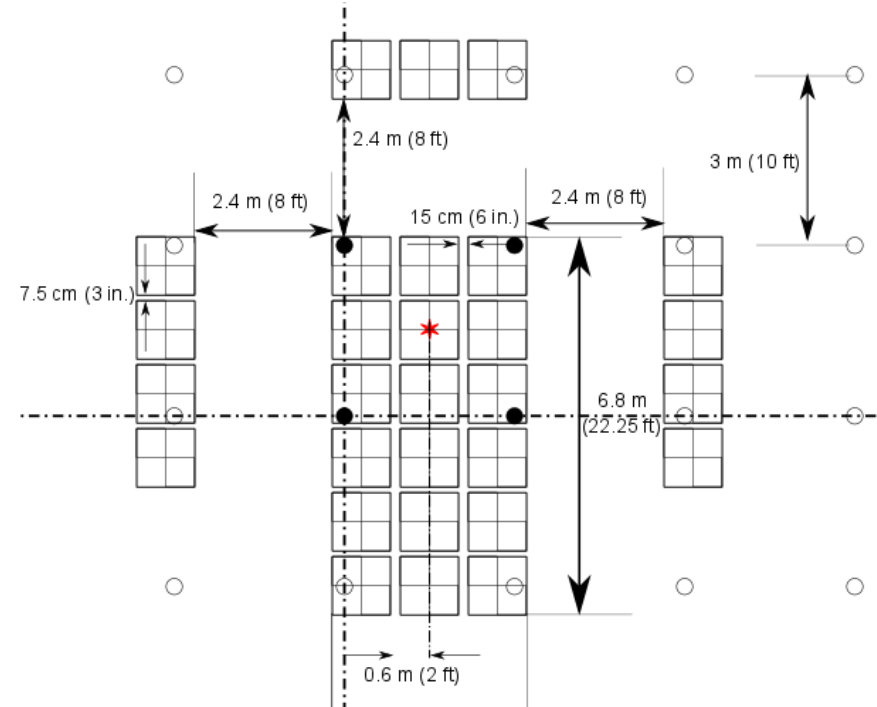
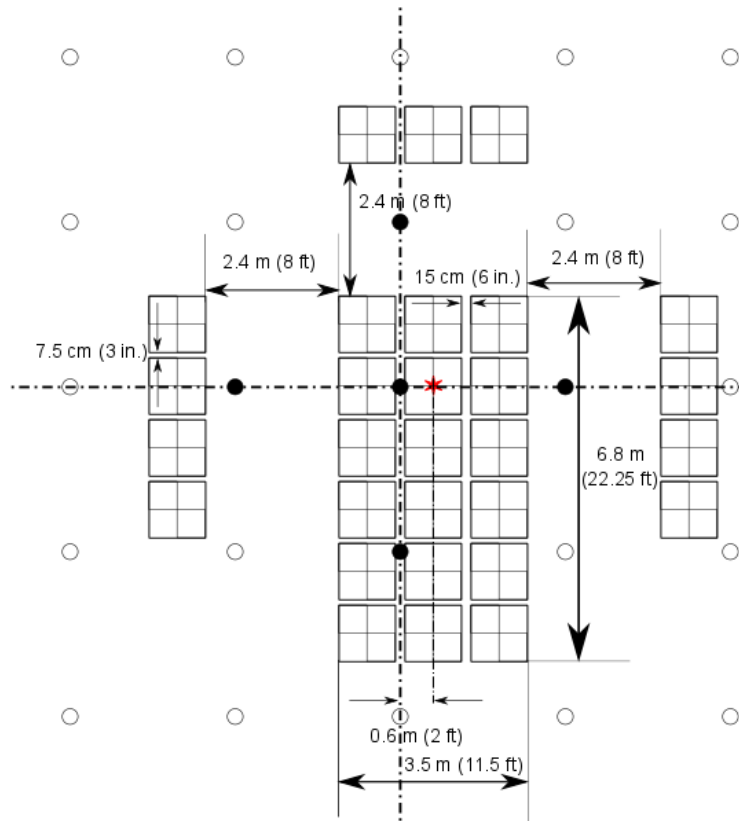
- Cartoned Unexpanded Plastic Commodity
- Piled Storage
- Height: 6 ft
- Storage Area: 19 m² (200 ft²)
- Target arrays of CUP commodity with 2.4 m (8 ft) aisles



Test Methods – Algorithm

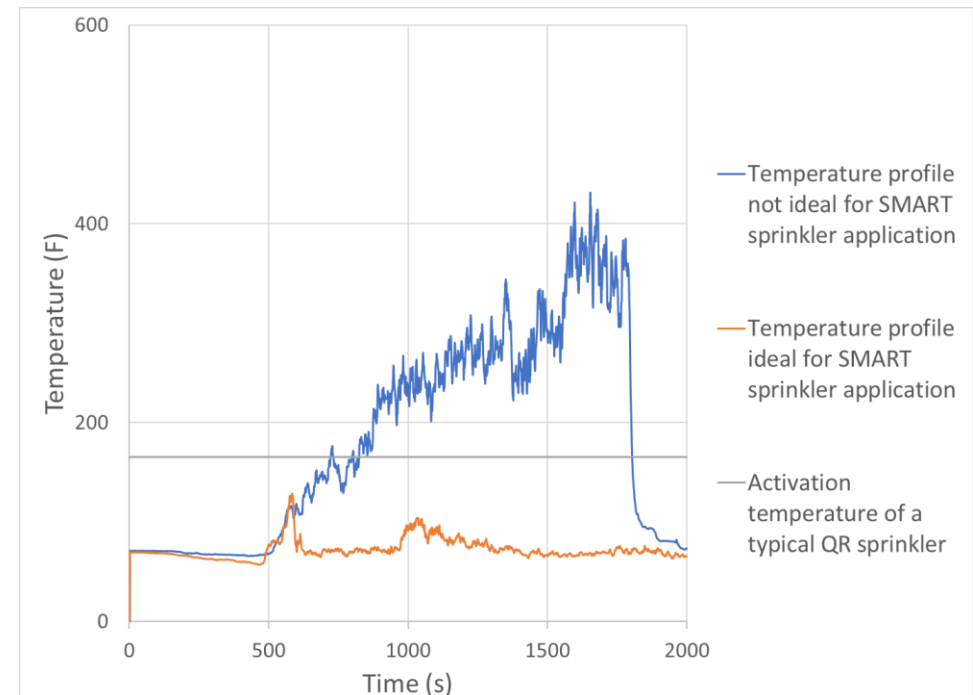
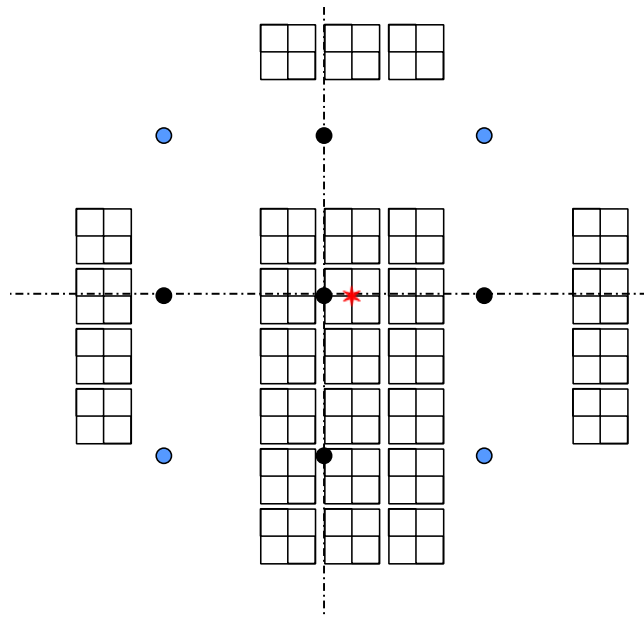


Test Methods – Sprinkler Locations



Test Evaluation Criteria

- Fire should be controlled
- No ignition on target arrays
- $T_{\text{ceiling}} < T_{\text{AS}}$ for non-activated sprinklers



UUP under 9.1 m (30 ft) Ceiling

- Video

Results - UUP

Commodity	Ceiling Height [m (ft)]	Ignition Location	Water Design Density [mm/min (gpm/ft ²)]	Results
UUP	9.1 (30)	Under 1	18 (0.44)	Fire not controlled
UUP	9.1 (30)	Under 1	33 (0.8)	All criteria satisfied
		Among 4		
UUP	9.1 (30)	Under 1	24 (0.6)	Fire controlled but peak ceiling temperatures beyond 74 °C (165 °F)
UUP	18.3 (60)	Under 1 – K200 (K14)	41 (1.0)	All criteria satisfied
		Under 1 – K360(K25.2)		

Results - CUP

Commodity	Ceiling Height [m (ft)]	Ignition Location	Water Design Density [mm/min (gpm/ft ²)]	Results
CUP	9.1 (30)	Under 1	12 (0.3)	All criteria satisfied
		Among 4		
CUP	9.1 (30)	Among 4	8 (0.2)	Fire controlled but peak ceiling temperatures beyond 74 °C (165 °F)
CUP	18.3 (60)	Under 1	20 (0.5)	All criteria satisfied
CUP	18.3 (60)	Under 1	15 (0.37)	All criteria satisfied
		Among 4		

Results – Sprinkler Water Demand

Cartoned Unexpanded Plastics (CUP)

Ceiling Height [m (ft)]	FM Global Current Recommendation	SMART Sprinkler Protection	Reduction in Water Demand with 5 sprinklers	Reduction in Water Demand with 9 sprinklers
9.1 (30)	0.3 gpm/ft ² for 2500 ft ²	0.3 gpm/ft ²	80 %	64 %
18.3 (60)	0.5 gpm/ft ² for 2500 ft ²	0.37 gpm/ft ²	88 %	78 %

Uncartoned Unexpanded Plastics (UUP)

Ceiling Height [m (ft)]	FM Global Current Recommendation	SMART Sprinkler Protection	Reduction in Water Demand with 5 sprinklers	Reduction in Water Demand with 9 sprinklers
9.1 (30)	0.8 gpm/ft ² for 2500 ft ²	0.8 gpm/ft ²	80 %	64 %
18.3 (60)	1.6 gpm/ft ² for 1000 ft ²	1.0 gpm/ft ²	69 %	44 %

Cost

- SMART systems are more expensive
 - Control unit, detectors, actuators
 - Increased ITM
- Benefits for locations where
 - Water is scarce
 - Water storage expensive or impractical
 - Lower water demand eliminates storage

Conclusions

- Traditional sprinkler protection for low-piled storage
 - Prominent skipping
 - High water demand
- SMART sprinkler protection
 - Avoid sprinkler skipping
 - Achieve early activation
 - Reduce water demand by 50–90%