

Ceiling Height Limits for Effective Water Mist Protection of FM Global HC-2 and HC-3 Fire Hazards in Open Environment

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Factors Affecting Efficiency of Water Mist Suppression of Solid Combustible Fires in Open Environment

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Vienna, Austria**

Background

Class 2 Commodity (EUR Commodity Category I)



**FM Global HC-2 Fire Hazard:
Class 2 commodity storage
up to 3.05 m high**

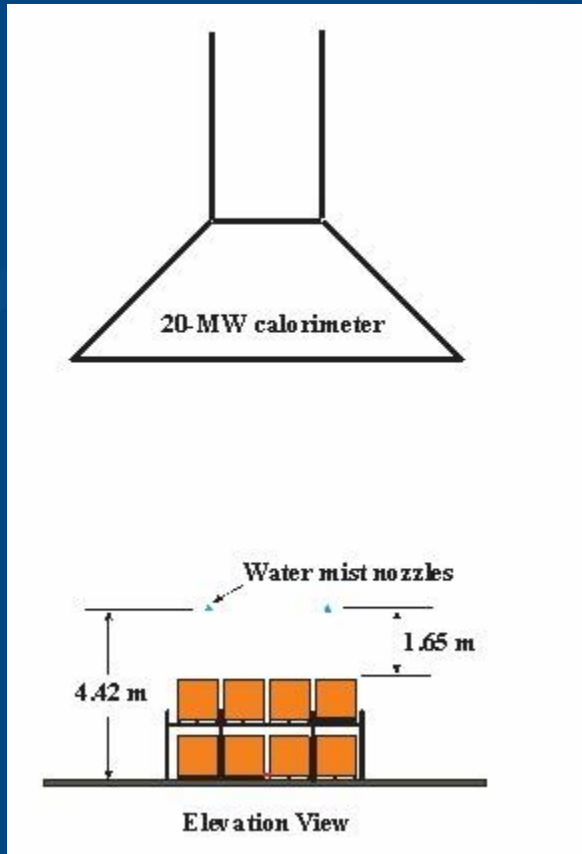
Cartoned Expanded Polystyrene (CEP) (EUR Commodity Category IV)



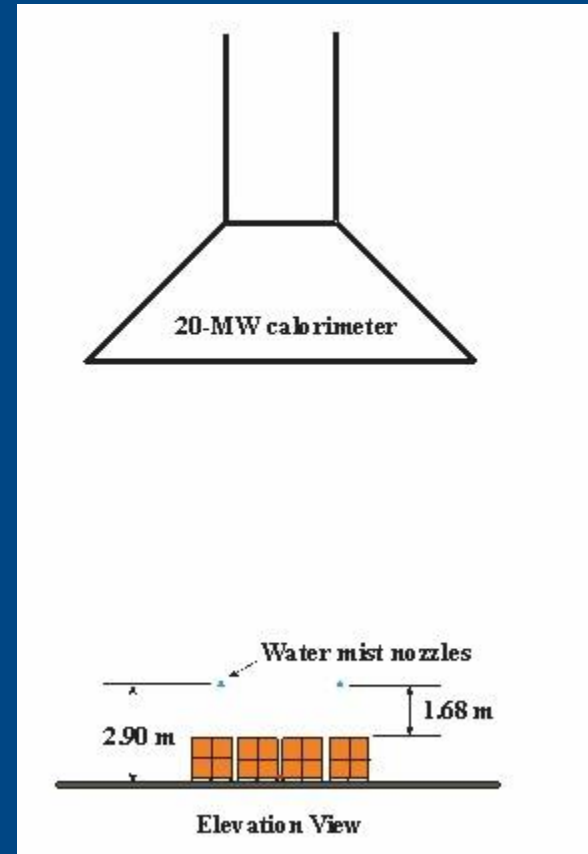
**FM Global HC-3 Fire Hazard:
CEP commodity storage up to
1.52 m high**

Background: 20-MW Calorimeter Fire Tests

HC-2 Fire Tests



HC-3 Fire Tests



- Water application density: 6.1 mm/min for HC-2; 8.1 mm/min for HC-3.
- Nozzle clearance above storage: ~ 1.65 m
- Water discharge started when fire convective heat flow rate reached 1000 kW.

Background: Key Conclusions from the Calorimeter Tests



- Fire suppression was affected by application density and droplet size, not by nozzle configuration and operating pressure.
- With the applied densities of 6.1 and 8.1 mm/min, fire suppression in open environment could not be achieved if the sprays' volume median droplet diameter was not sufficiently large for the fire challenge.
- Fire suppression in open environment with water mist required water densities comparable to those of sprinkler protection.

Follow-up Work

- **Determine the ceiling height limits for water mist suppression of HC-2 and HC-3 fires in open environment**
 - **Deluge protection**
 - **Automatic nozzle protection**

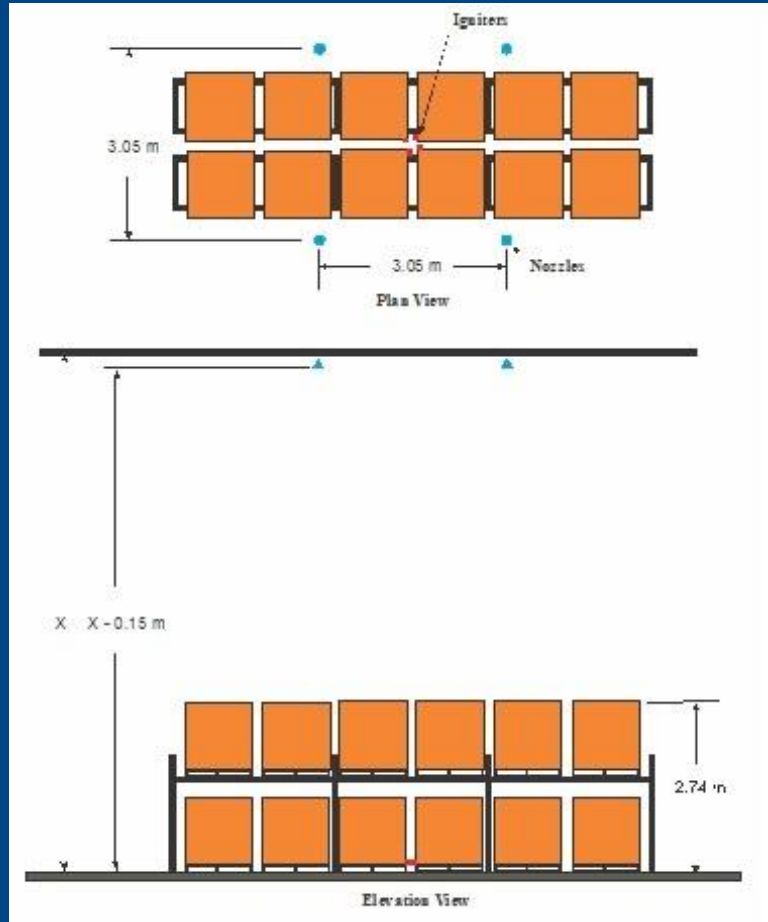
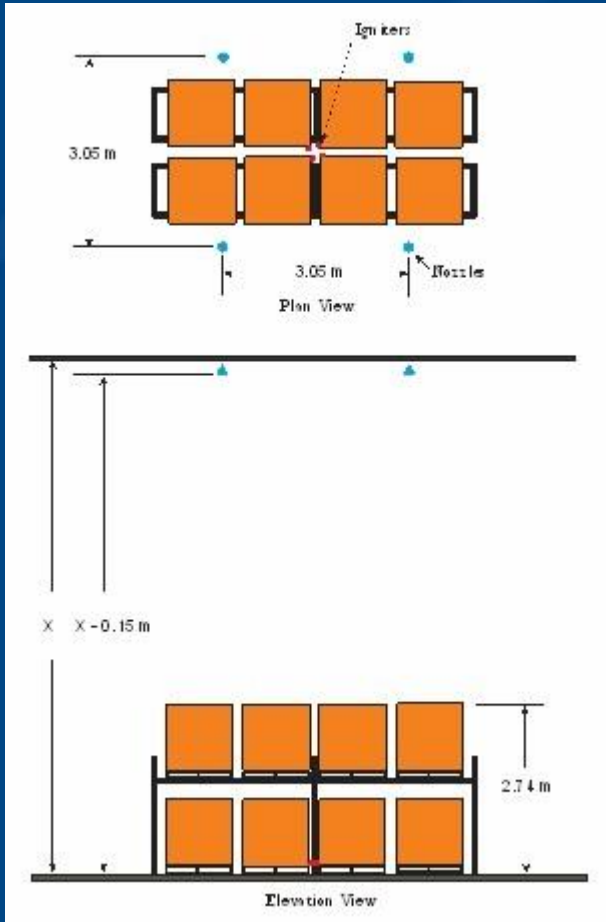
Water Mist Protection Conditions



- **Nozzle discharge parameters**
 - Operating pressure: 16.5 bar
 - Nozzle discharge rate: 76 liter/min
 - Volume median droplet diameter: ~220 μm
 - Nozzle spray thrust force: 40 N
 - Nozzle spray angle: 110°
- **Nozzle/thermal sensor spacing: 3.05 x 3.05 m**
- **Thermal sensor RTI: 27.6 (m-s)^{1/2}**
- **Activation temperature for nozzle discharge: 74°C**
- **Nominal application density: 8.1 mm/min**

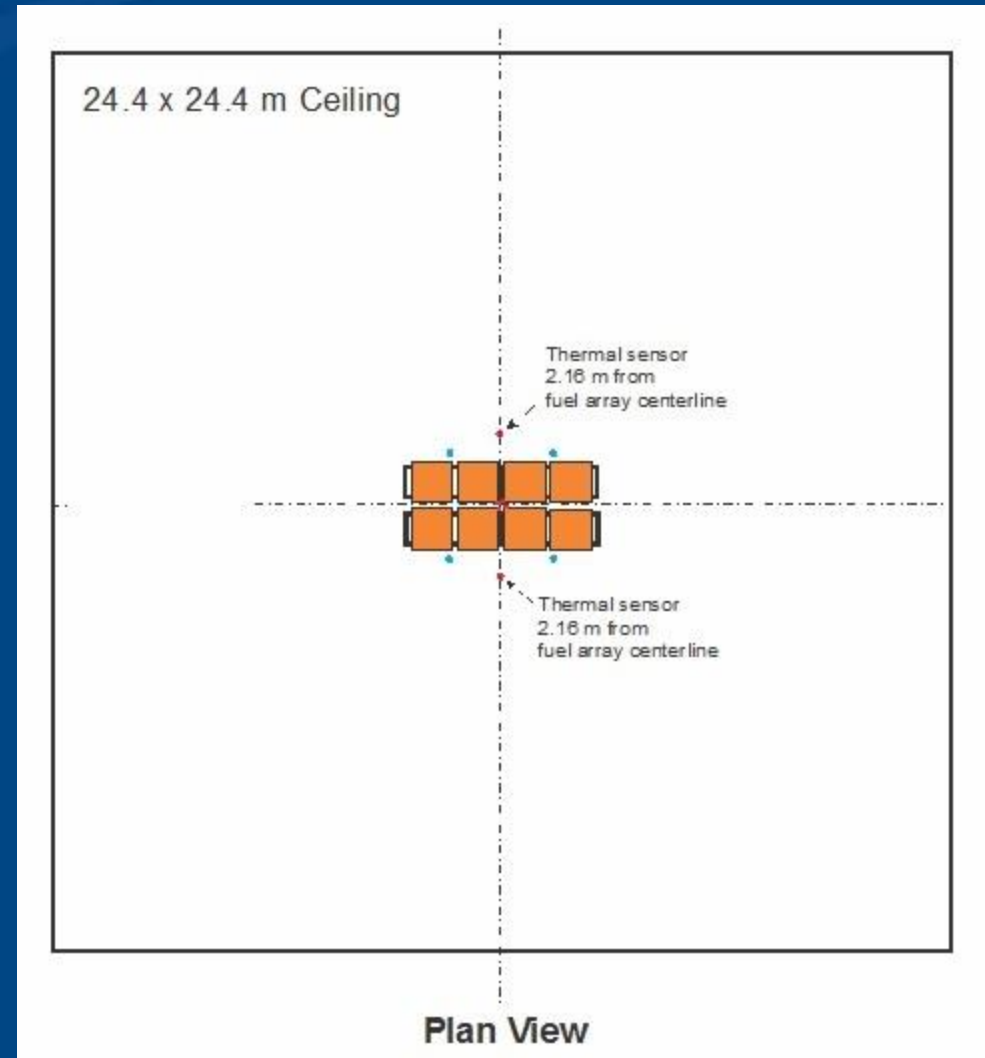
Deluge Protection: HC-2 Fuel Arrays

X: 7.6 – 10.7 m



Thermal Sensors for Initiating the Discharge of Open Nozzles

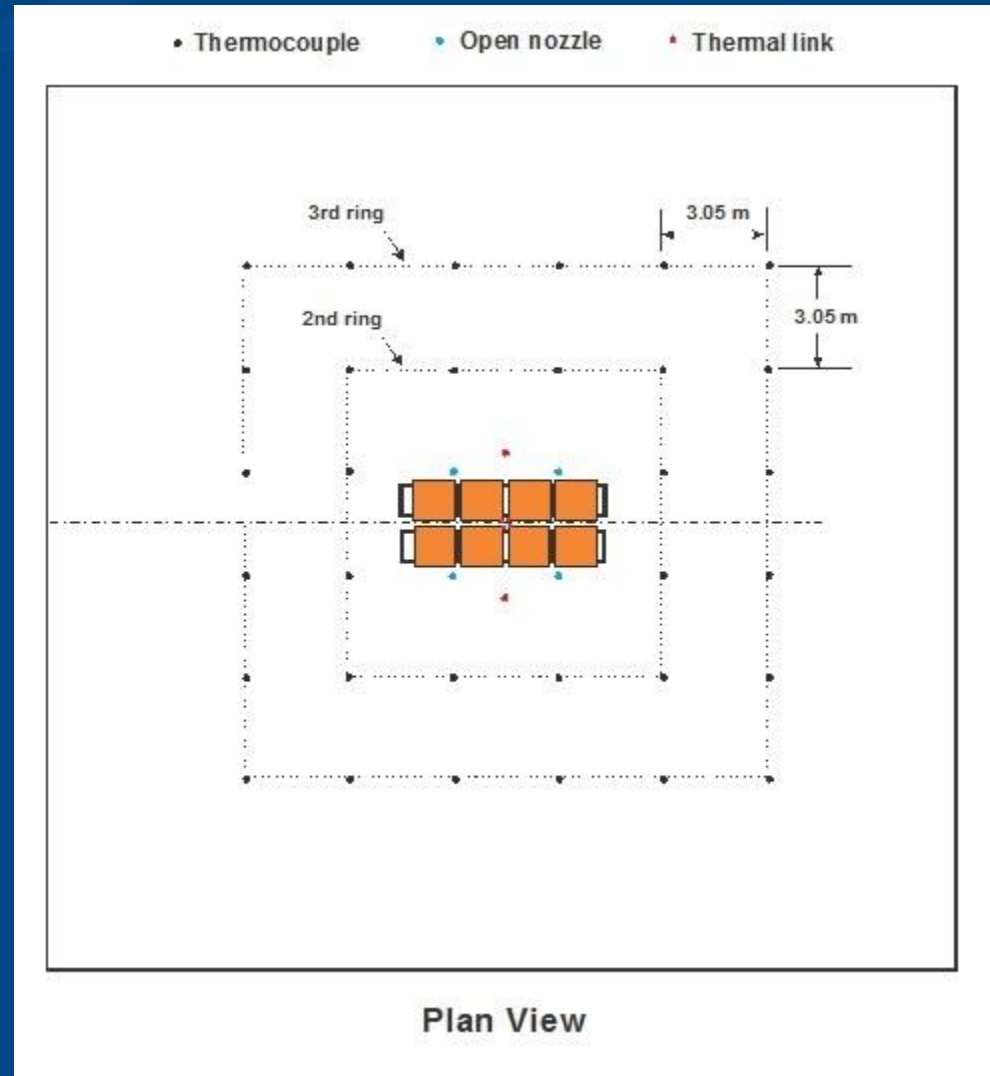
- Thermal sensor location:
 - 2.16 m radially from the fuel array centerline
 - 0.15 m below ceiling
- Temperature rating: 74°C
- RTI: 27.6 (m-s)^{1/2}



Thermocouple Layout for Assessing Nozzle Activation Area

Elevation: 0.15 m below ceiling

RTI: $8 \text{ (m-s)}^{1/2}$



Deluge Protection: HC-2, 9.1-m High Ceiling



1:48



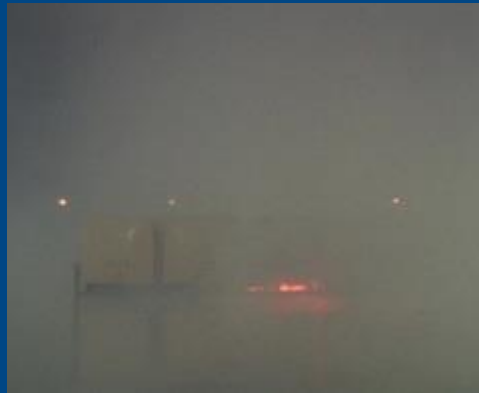
2:56



3:56



4:37



8:46



Post test
(20 min)

Projected nozzle activations: Up to 2nd Ring

Deluge Protection: HC-2, 10.7-m High Ceiling



0:50



1:00



2:45



5:00

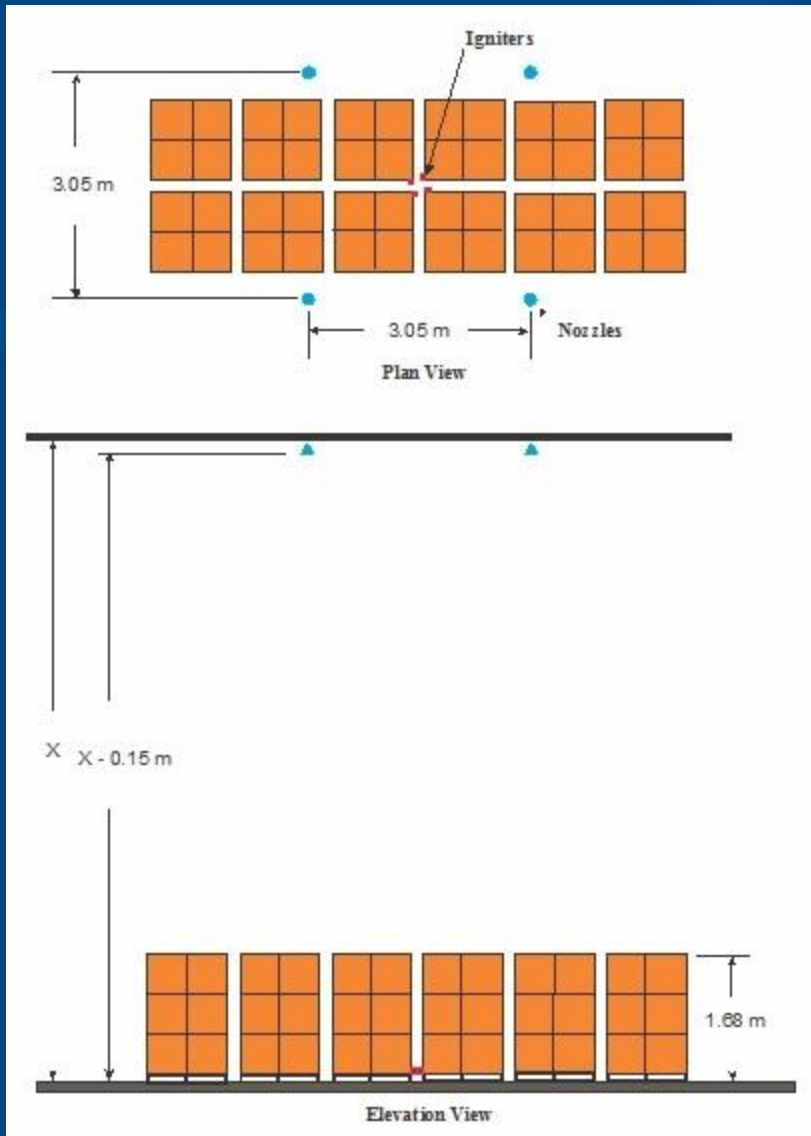


7:00



9:30

Deluge Protection: HC-3 Fuel Array



X: 7.6 – 10.7 m

Deluge Protection: HC-3, 9.1-m High Ceiling



0:44



1:03



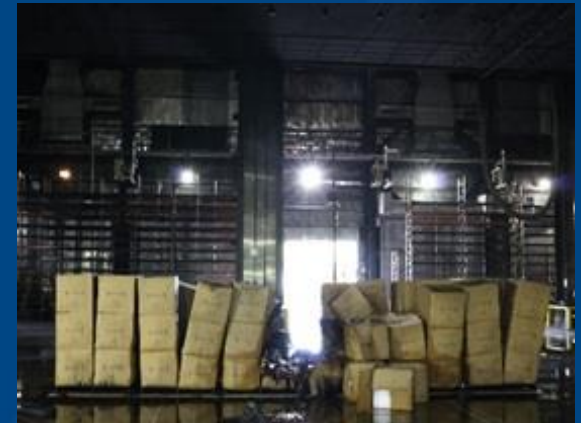
1:58



3:38



13:28



post test
(25 min)

Projected nozzle activations: Up to 2nd Ring

Deluge Protection: HC-3, 10.7-m High Ceiling



0:58



1:10



1:52



3:05

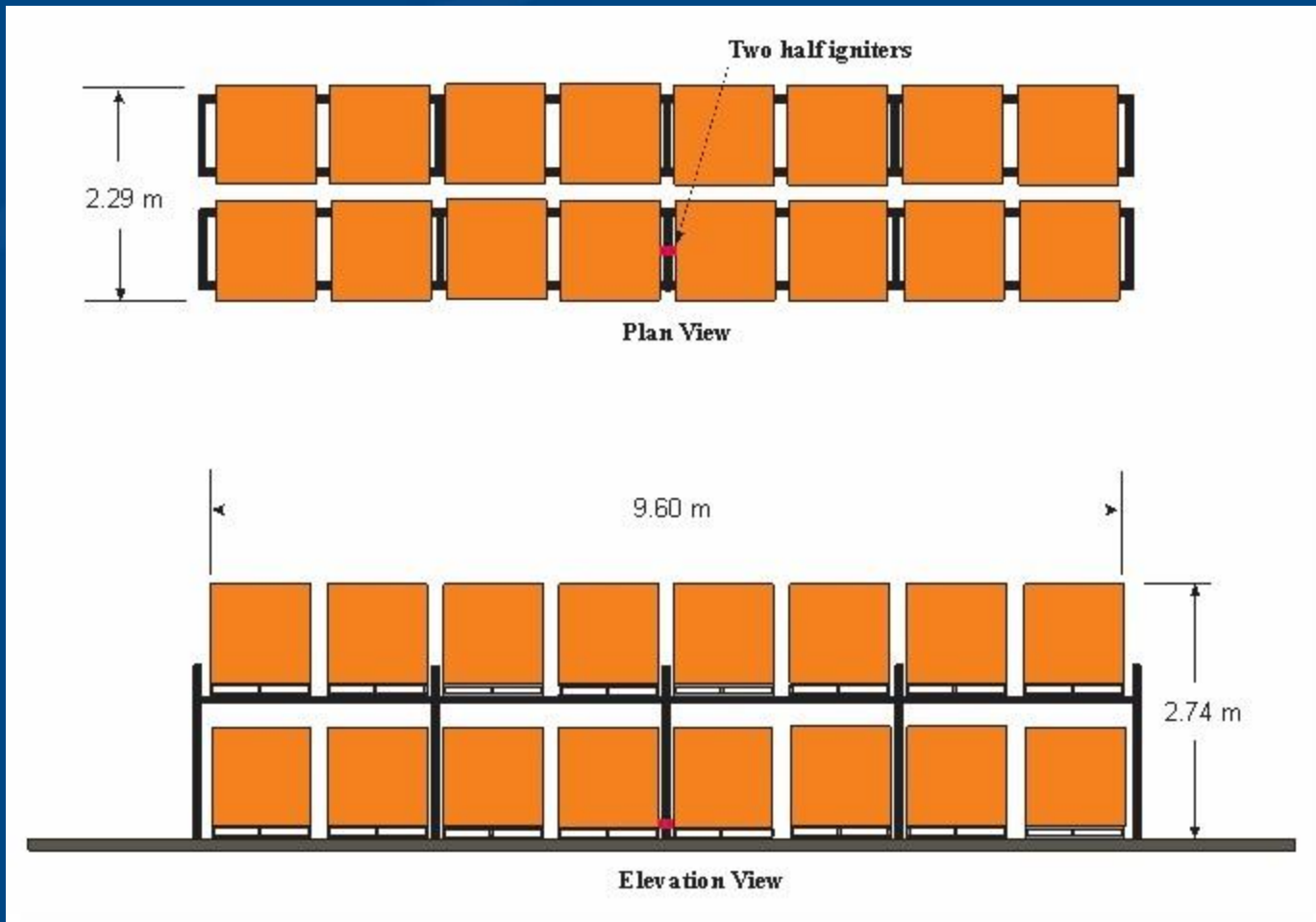


14:50

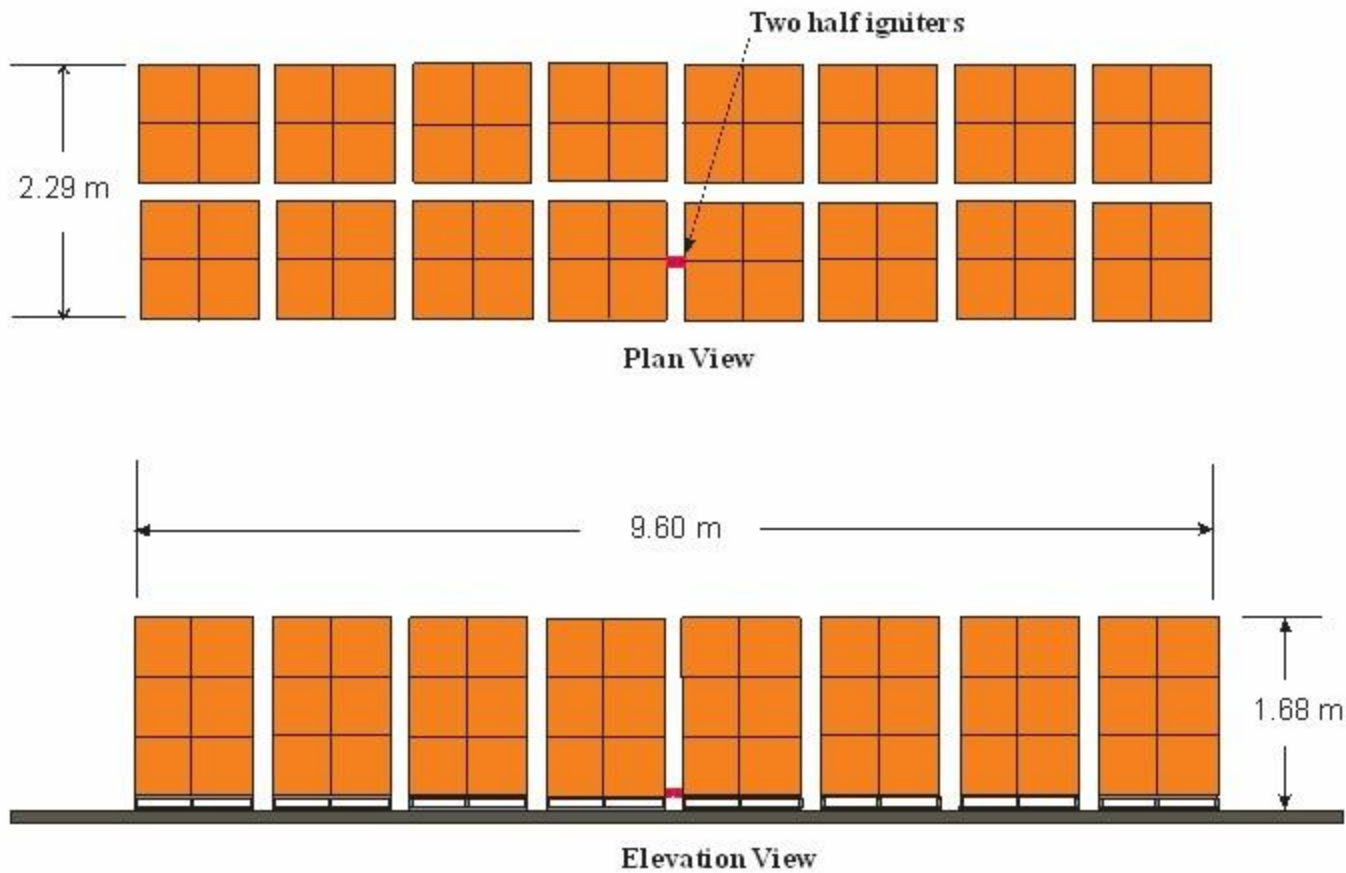


post test
(30 min)

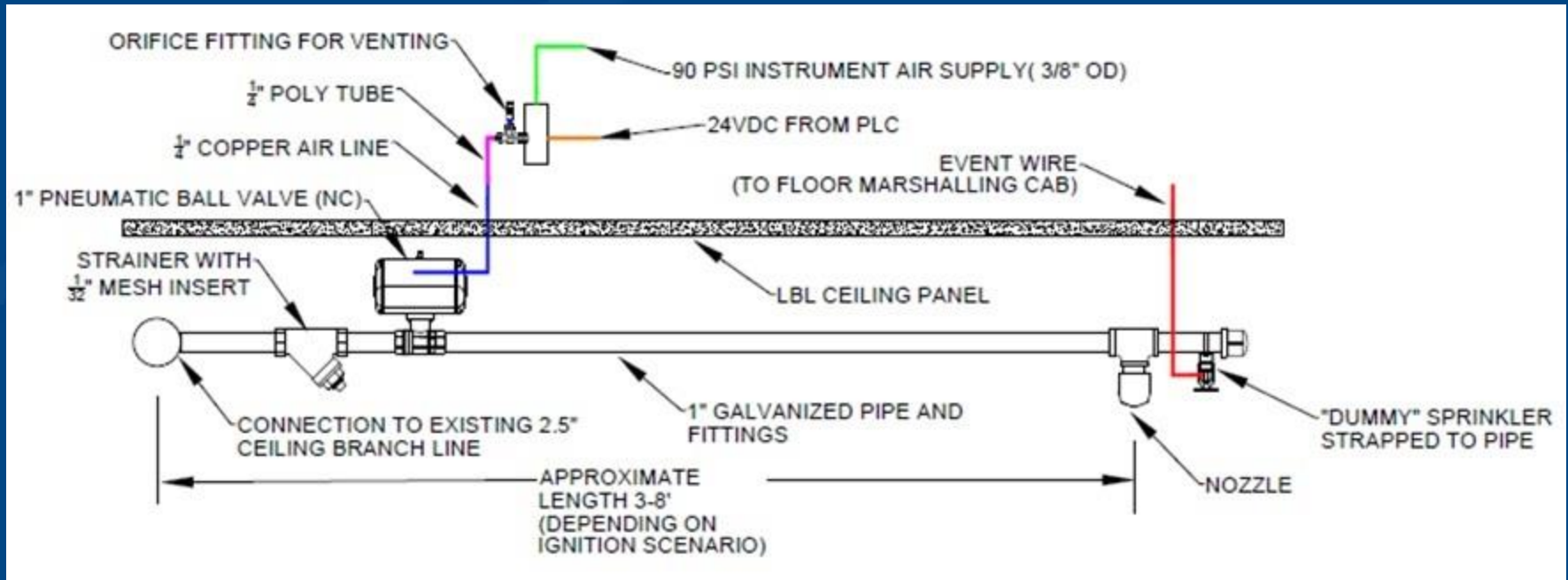
Automatic Nozzle Protection: HC-2 Fuel Array



Automatic Nozzle Protection: HC-3 Fuel Array



Automatic Nozzle Discharge Setup

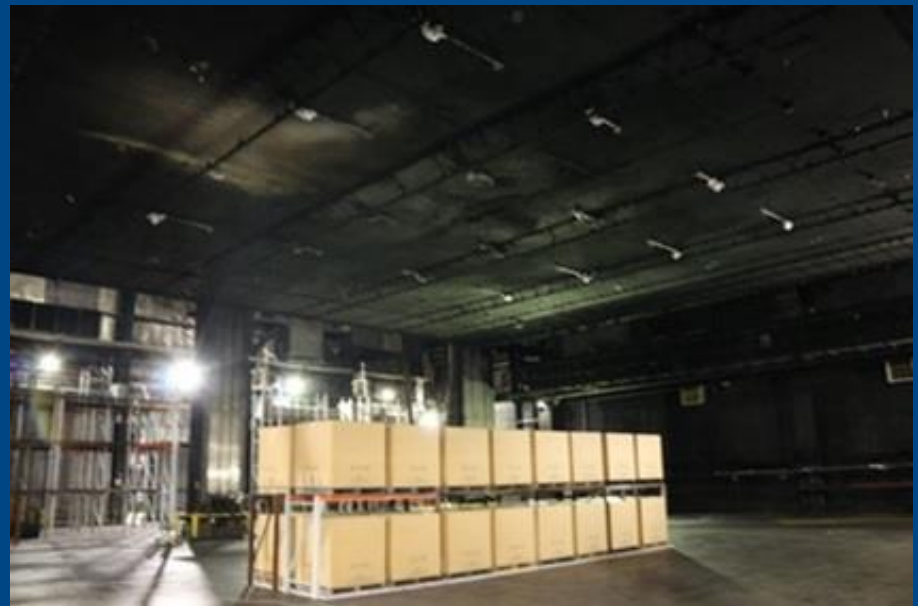
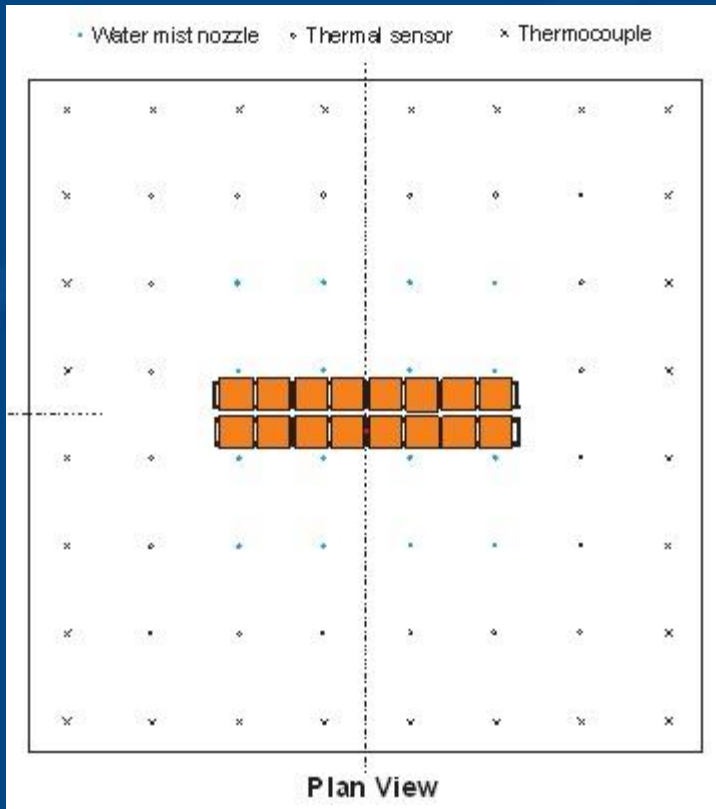


Dummy sprinkler:

- Temperature rating: 74°C
- RTI: 27.6 (m-s)^{1/2}

Layout of Nozzles, Thermal Sensors and Thermocouples for Fuel Array Centered below Four Nozzles

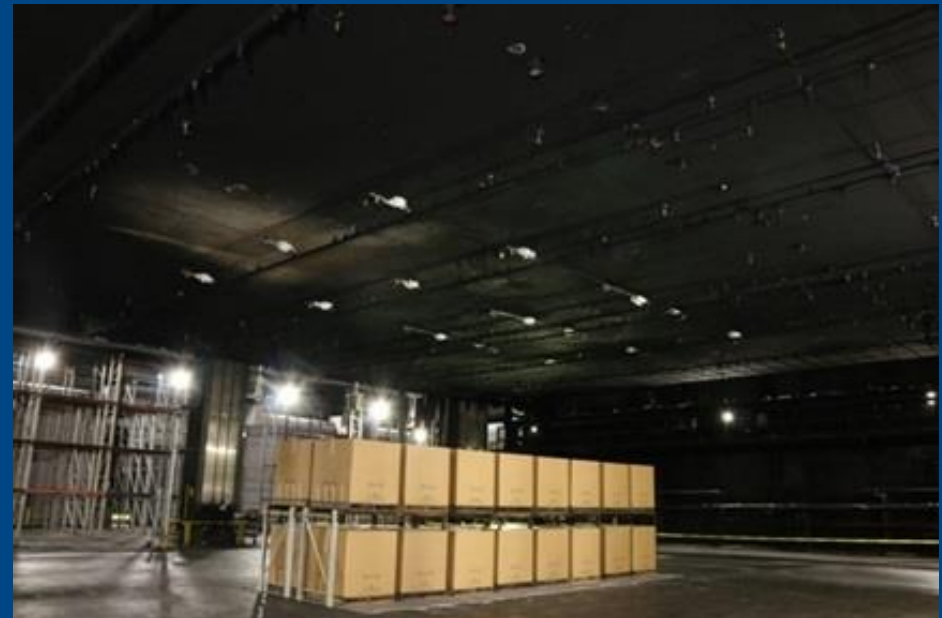
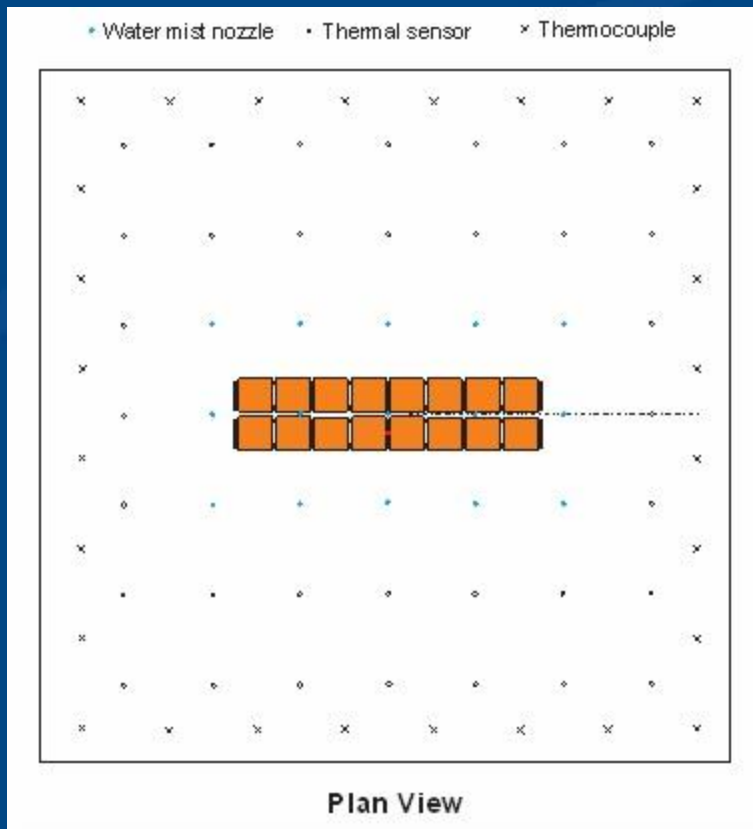
Spacing: 3.05 x 3.05 m



- Thermal sensors: 74°C rating, 27.6 (m-s)^{1/2} RTI
- Thermocouples: 8 (m-s)^{1/2} RTI

Layout of Nozzles, Thermal Sensors and Thermocouples for Fuel Array Centered under One Nozzle

Spacing: 3.05 x 3.05 m



- Thermal sensors: 74°C rating, 27.6 (m-s)^{1/2} RTI
- Thermocouples: 8 (m-s)^{1/2} RTI

Automatic Nozzle Protection: HC-2, 7.6-m High Ceiling, Fuel Array Centered below Four Nozzles



1:13



3:38



7:33



11:02



15:18



23:32

Automatic Nozzle Protection: HC-2, 6.1-m High Ceiling, Fuel Array Centered below Four Nozzles



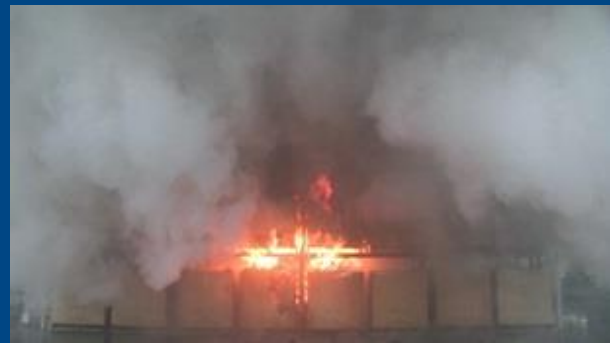
1:28



2:25



4:54



9:10



15:03



post test
(25 min)

Number of nozzle activations: 4

Automatic Nozzle Protection: HC-2, 6.1-m High Ceiling, Fuel Array Centered under One Nozzle



1:24



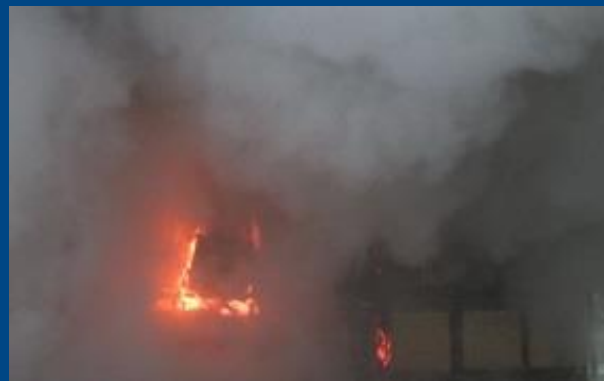
2:26



7:09



13:42



23:06



post test

Number of nozzle activations: 13

Automatic Nozzle Protection: HC-3, 6.1-m High Ceiling, Fuel Array Centered below Four Nozzles



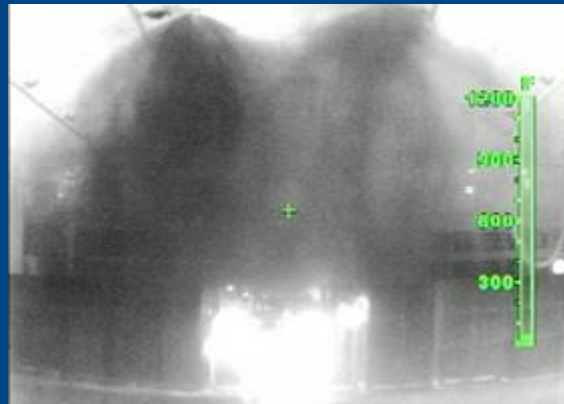
0:52



1:53



2:43



10:38



14:50



post test

Number of nozzle activations: 3

Automatic Nozzle Protection: HC-3, 6.1-m High Ceiling, Fuel Array Centered under One Nozzle



0:54



2:32



5:01



14:43



18:51



post test

Number of nozzle activations: 11

Summary



- **A series of fire tests was conducted with the following water mist conditions for protecting the FM Global HC-2 and HC-3 fire hazards:**
 - **Nozzle operating pressure: 16.5 bar**
 - **Nozzle discharge rate: 76 liter/min**
 - **Volume median droplet diameter: ~220 μm**
 - **Nozzle spray thrust force: 40 N**
 - **Spray angle: 110°**
 - **Nozzle spacing: 3.05 x 3.05 m**
 - **Thermal sensor RTI: 27.6 (m-s)^{1/2}**
 - **Thermal sensor temperature rating: 74°C**
 - **Water mist application density: 8.1 mm/min**
- **With deluge protection, the FM Global HC-2 and HC-3 fire hazards can be protected with ceiling heights up to 9.1 m.**
- **With automatic nozzle protection, the FM Global HC-2 and HC-3 fire hazard can be protected with ceiling heights up to 6.1 m, with a water demand of 20 nozzle operations for a safety factor of 50%.**

Thank you for your attention!