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Introducing the New FM Approvals Standard Class 5580 - Hybrid (Water and Inert Gas) Fire Extinguishing Systems

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ABSTRACT

When the FM Approvals Standard Class 5560, "Approval Standard for Water Mist Systems", was originally developed, water mist was the only intended fire extinguishing agent for all the water mist systems available in the market. The function of the pressurized air or inert gases used by the so-called dual-fluid water mist systems was mainly to atomize water into mist. However, as the development of water mist fire protection evolves, some systems now employ a large quantity of inert gas in conjunction with water. As more inert gas is used, the system more and more behaves like a gaseous system. Since the requirements of safety factor and discharge duration for water mist systems and gaseous systems are very different, it is imperative to evaluate the fire extinguishing characteristics of such systems in order to determine whether such systems fall in the water mist, gaseous, or hybrid system category. If the discharged inert gas and water mist can independently extinguish the fire, the combined discharge of inert gas and water mist is expected to shorten the fire extinguishment process. Therefore, such "hybrid systems" require a different safety-factor-and-discharge-duration guideline from those for water mist systems and gaseous systems. Furthermore, to identify such hybrid systems for certification testing, a reasonable criterion based on the test results needs to be established.

This paper presents an investigation conducted recently in FM Global to establish a guideline for bracketing hybrid systems from gaseous and water mist systems, based on fire test results and pertinent suppression/extinguishment modeling. From this investigation, proposed are a test protocol for categorizing systems employing water mist and inert gas, and the corresponding criterion for system categorization. The required system safety factor and discharge duration for hybrid systems will also be addressed in this paper.

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Hybrid (Water and Inert Gas) Fire Extinguishing Systems

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Overview

- Background
- Modeling fire test results
- Hybrid (water mist and inert gas) fire extinguishing system characterization criteria
- Hybrid fire extinguishing system installation requirements

Background – What is a Hybrid System?

- Twin Fluid Water Mist: Depends on water for cooling, vaporization and inerting; gas does not aid in extinguishment and serves only as a means to atomize the water.
- Gaseous: Extinguishment due to inerting
- Hybrid: Water alone is not sufficient enough for extinguishment within the designated time period; gas is also a contributing factor.
- Require a clear and consistent definition to differentiate hybrid systems from twin fluid water mist and gaseous fire extinguishing systems.
- Analysis applies to total flooding applications only.

Background

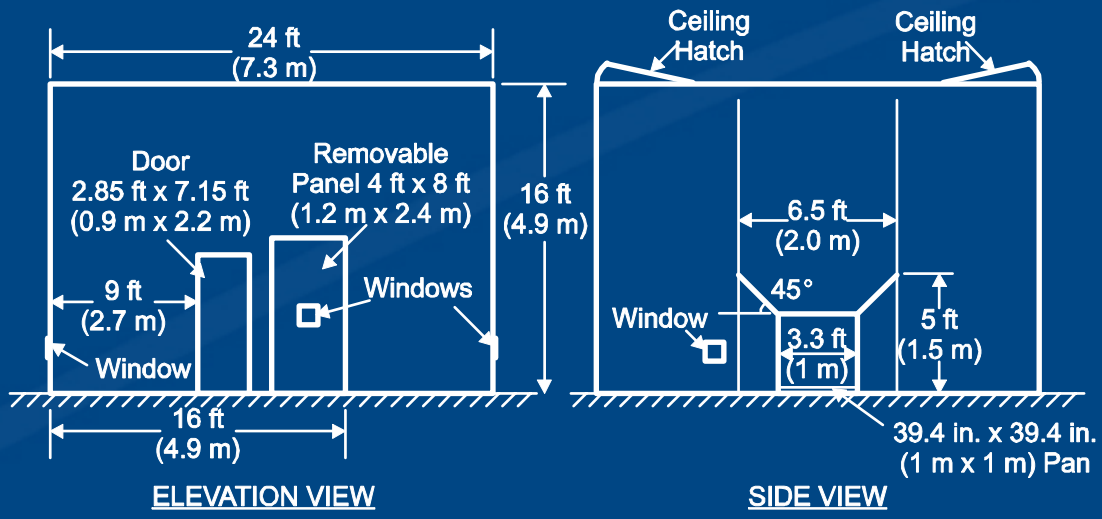
- **2006 – 2008**
  - A (water mist + nitrogen) fire extinguishing system was tested per FM Approval Standard 5560 “Approval Standard for Water Mist Systems” for the protection of turbine, machinery and special hazard enclosures.

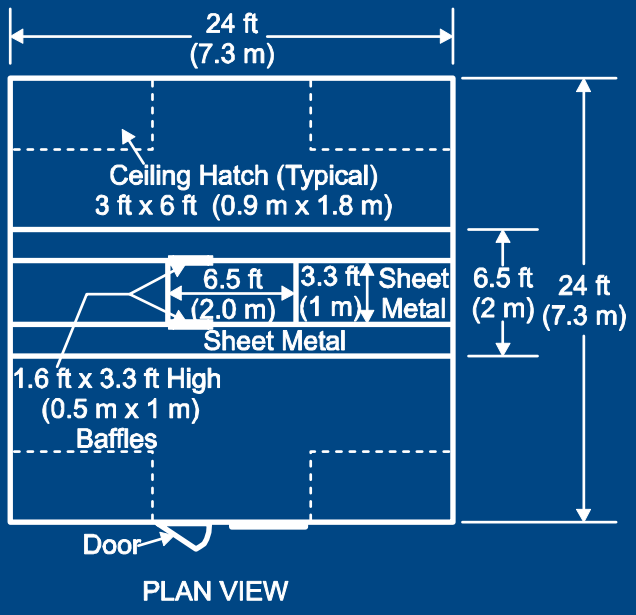
- **Discharge rates per nozzle**
  - Water – 3.78 liters/min
  - Nitrogen – 4.25 m^3/min

Background

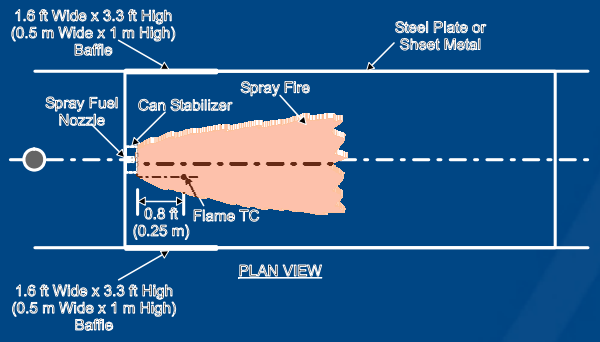
- **Establish a definition and classification test for hybrid fire extinguishing systems.**
  - Analysis of experimental test data
  - Theoretical analysis and modeling

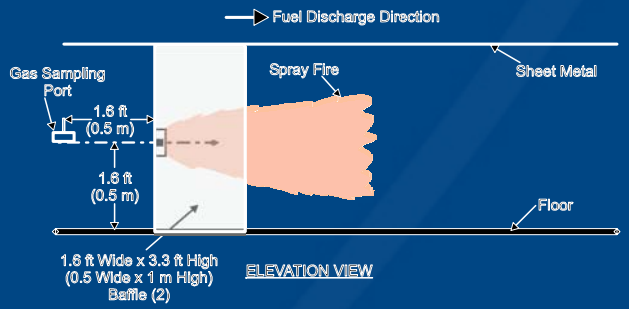
260 m³ Test Enclosure for System Characterization





Note: Door may be Built within Removable Panel





Fire Tests for System Characterization

Test	Spray Fire HRR (MW)	Fuel	Is the 0.9x2.2-m High Door Opened?	System Discharge Time After Ignition [Pre-burn] (seconds)	Fire Extinction Time After Ignition (seconds)
D3.2	1	Diesel	No	18	125
D3.4	2	Diesel	Yes	21	65
E3.2	1	Heptane	No	20	173
E3.4	2	Heptane	Yes	21	86

A Well-Stirred Reactor Model – Assumptions (1)

- The gas temperature and concentrations of gases and droplets are uniformly distributed in the enclosure.
- The mist is heated to the wet bulb temperature instantly.
- The fire is shielded in such a fashion that it is not subject to the disturbances by water mist sprays and gas current.
- The fire heat release rate is constant until extinguishment.
- The poly-disperse water mist spray is represented with an equivalent mono-disperse spray using the volumetric median drop diameter as the characteristic droplet size.

A Well-Stirred Reactor Model – Assumptions (2)

- When the enclosure door is open, the loss of droplets in the enclosure is by convection out of the enclosure opening and settling to the enclosure floor.
- When the enclosure door is closed, the gas exchange between ambient and the enclosure interior is estimated by assuming that the enclosure pressure is always equal to the ambient pressure.
- The flame temperature is calculated by assuming that the fuel is burned completely in the vitiated environment and the fire gases are cooled by the water mist contained in the air involved in the combustion.
- The flame extinction temperature is taken to be 1600±100 K for propane used in the tests.

Results – Scenario E3.2

Enclosure: 7.3x7.3x5 m high

Door opening: No

Fuel: heptane

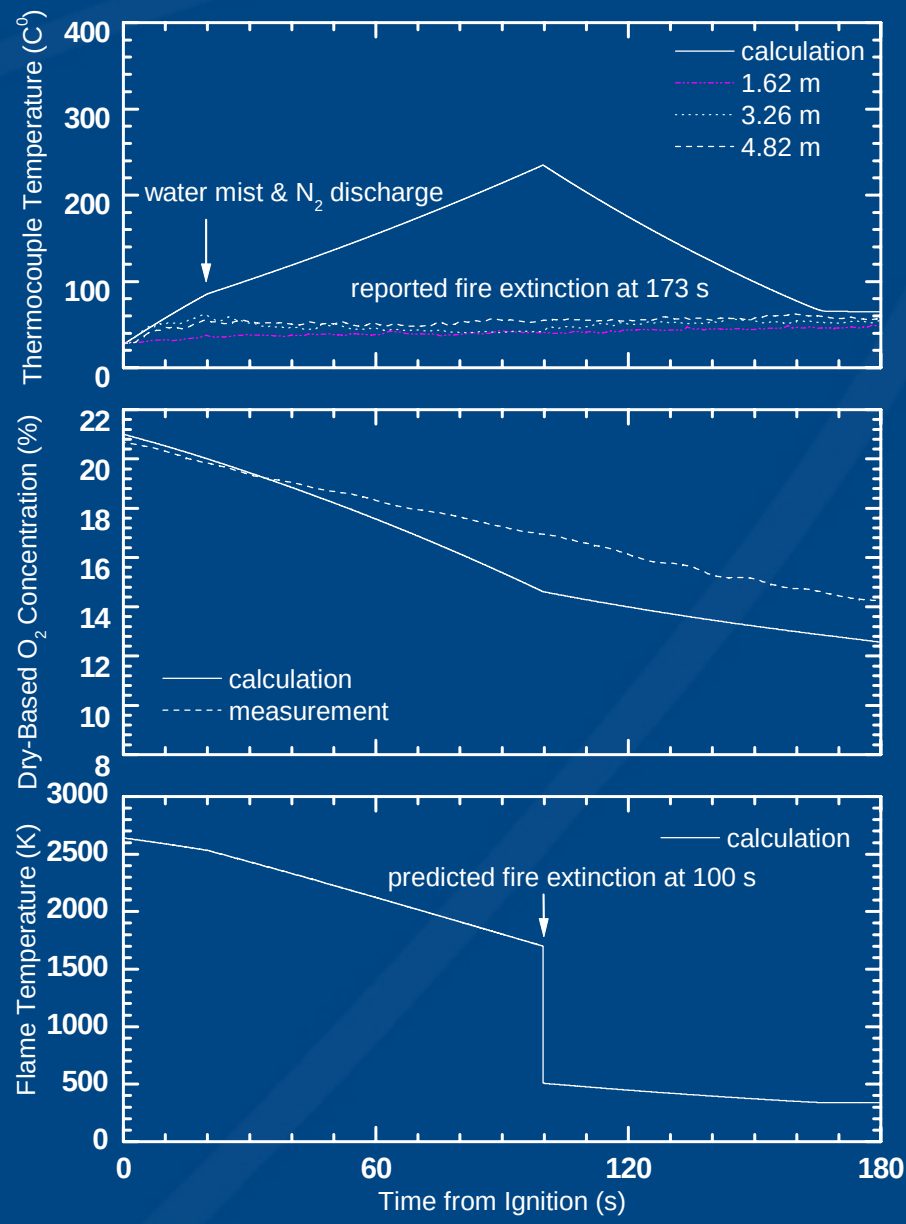
Heat release rate: 1 MW

Mist: 15.1 lpm

Nitrogen: 600 cfm

Time of system discharge after ignition: 20 s

Fire extinction time: 173 s



Results – Scenario E3.4

Enclosure: 7.3x7.3x5 m high

Door opening: 0.9 x 2.2 m high

Fuel: heptane

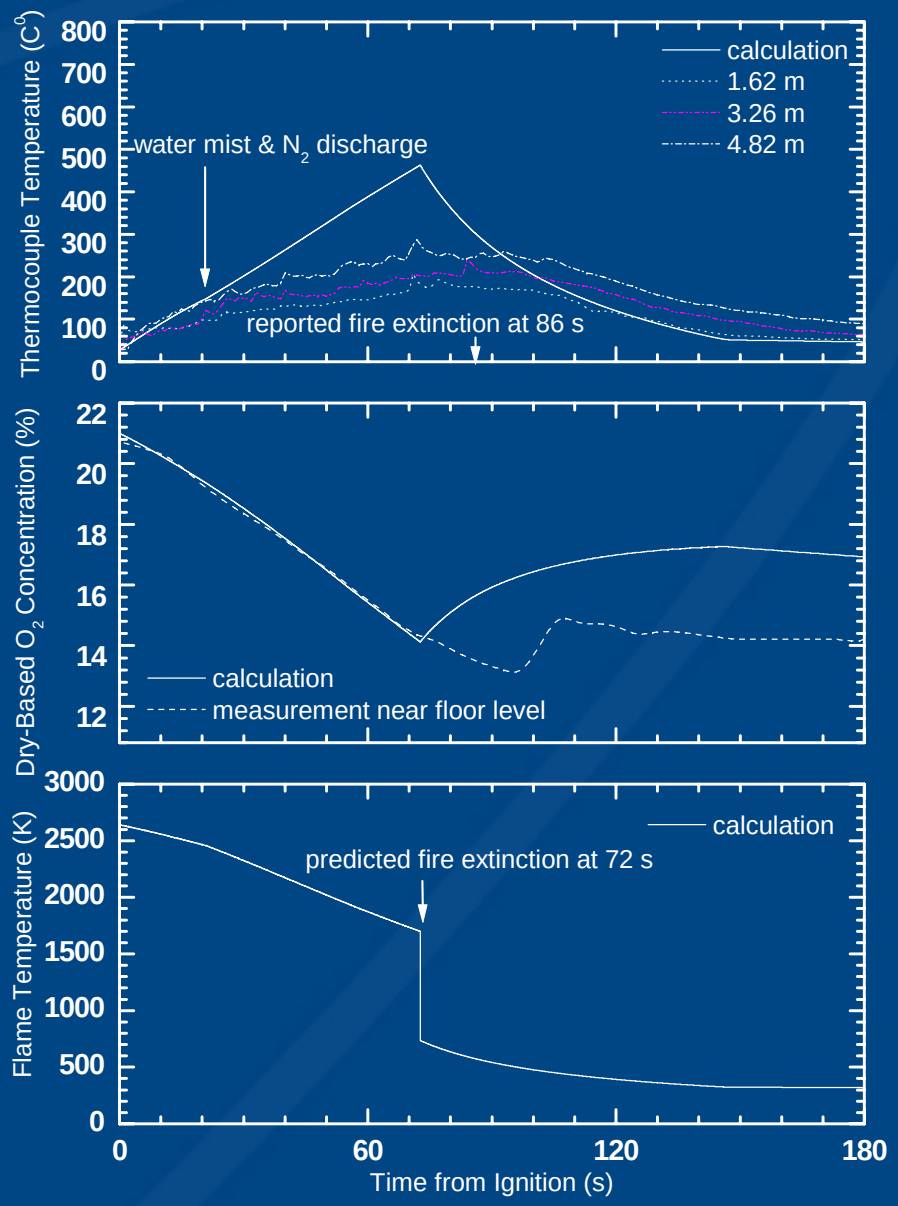
Heat release rate: 2 MW

Mist: 15.1 lpm

Nitrogen: 600 cfm

Time of system discharge after ignition: 21 s

Fire extinction time: 86 s



Results – Scenario E3.4

Enclosure: 7.3x7.3x5 m high

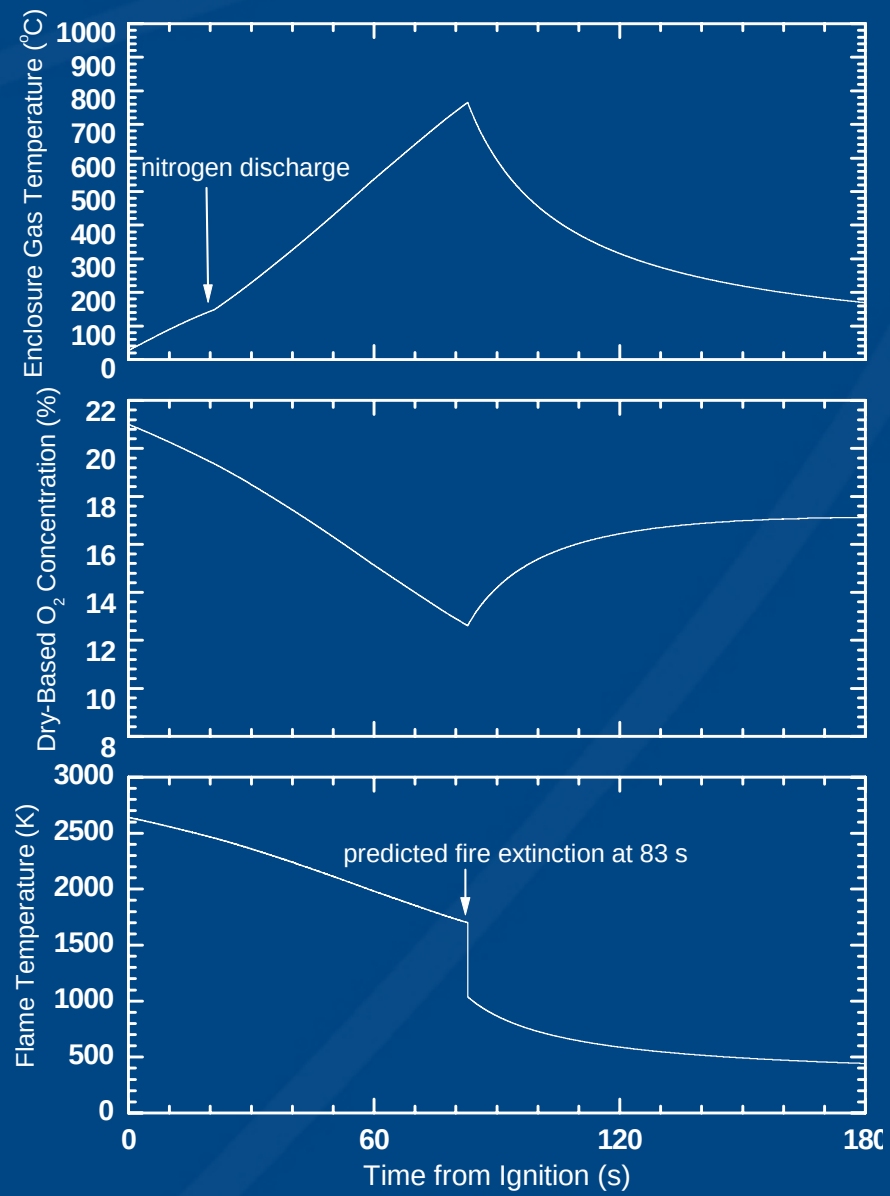
Door opening: 0.9 x 2.2 m high

Fuel: heptane

Heat release rate: 2 MW

Mist: 0 lpm

Nitrogen: 600 cfm



Results – Scenario E3.4

Enclosure: 7.3x7.3x5 m high

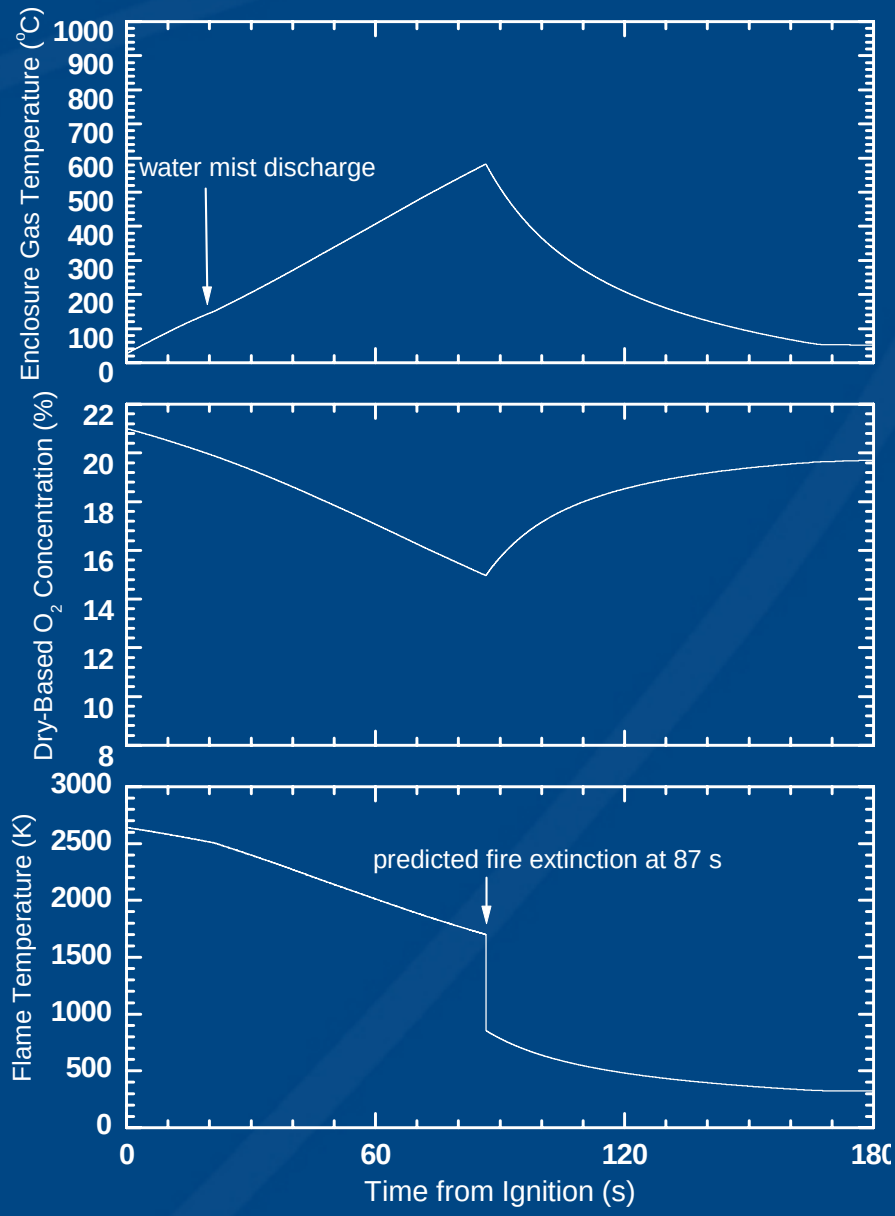
Door opening: 0.9 x 2.2 m high

Fuel: heptane

Heat release rate: 2 MW

Mist: 15.1 lpm

Nitrogen: 0 cfm



Results – Scenario E3.4

Enclosure: 7.3x7.3x5 m high

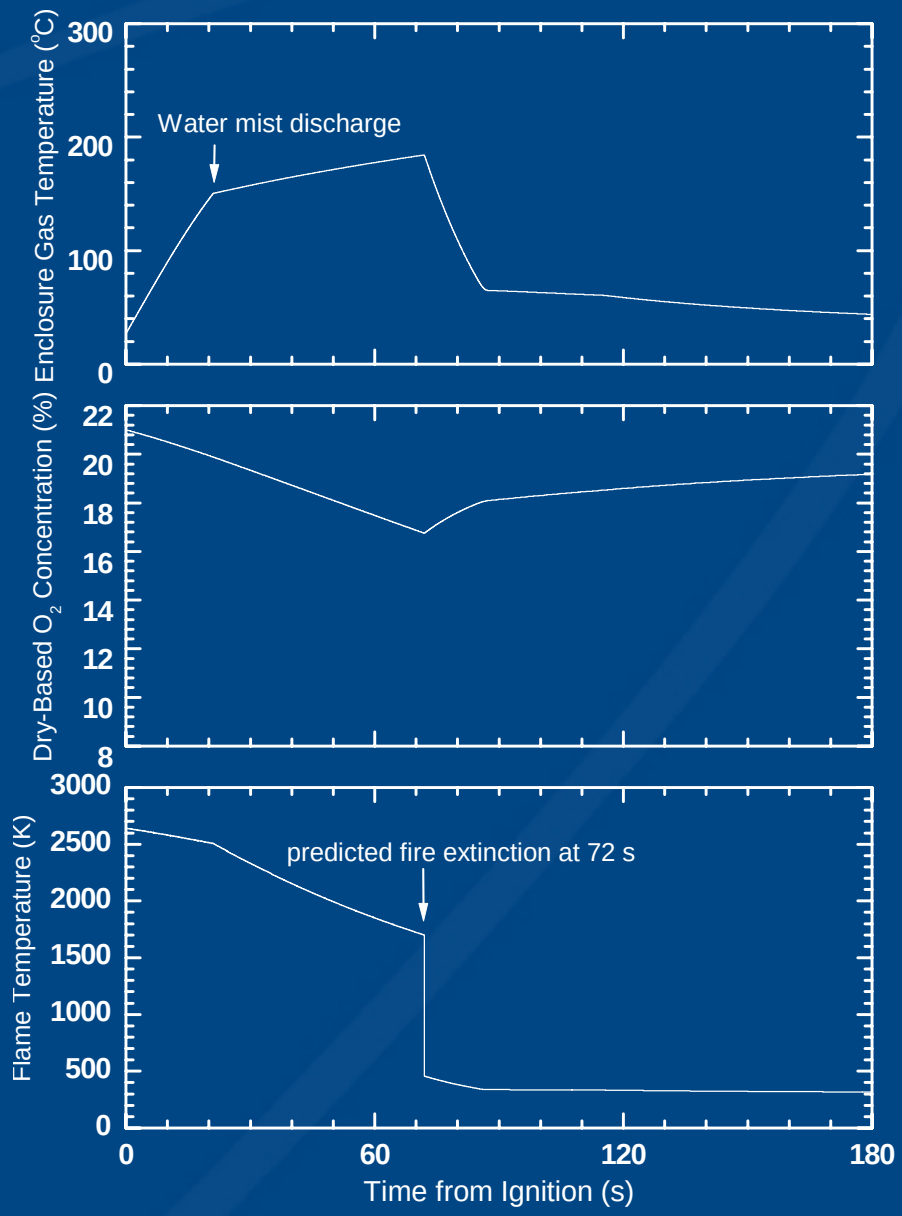
Door opening: 0.9 x 2.2 m high

Fuel: heptane

Heat release rate: 2 MW

Mist: 45 lpm

Nitrogen: 0 cfm



Result Summary

	Mist & Nitrogen 15.1 lpm+600 cfm				Hypothetical Case Nitrogen Only 600 cfm		Hypothetical Case Mist Only 15.1 lpm	
Test Scenario	Reported Fire Extinction Time (s)	Predicted Fire Extinction Time (s)	Measured O2 Concentration at Fire Extinction (%)	Predicted O2 Concentration at Fire Extinction (%)	Predicted Fire Extinction Time (s)	Predicted O2 Concentration at Fire Extinction (%)	Predicted Fire Extinction Time (s)	Predicted O2 Concentration at Fire Extinction (%)
D3.2	125	101	No data	14.6 (dry based) 12.3 (wet based)	113	12.3 (dry based) 12.0 (wet based)	124	16.1 (dry based) 12.5 (wet based)
D3.4	65	73	No data	14.0 (dry based) 12.2 (wet based)	84	12.5 (dry based) 12.0 (wet based)	88	14.9 (dry based) 12.4 (wet based)
E3.2	173	100	14.4 (dry based)	14.6 (dry based) 12.3 (wet based)	112	12.4 (dry based) 12.0 (wet based)	122	16.2 (dry based) 12.6 (wet based)
E3.4	86	72	13.5 (dry based)	14.1 (dry based) 12.3 (wet based)	83	12.6 (dry based) 12.1 (wet based)	87	14.9 (dry based) 12.4 (wet based)

Oxygen Concentration Limits for Mist Protection

Mist & Nitrogen 15.1 lpm + 600 cfm		Hypothetical Case Mist Only 15.1 lpm	Hypothetical Case Mist Only to match fire extinction time of (Mist & Nitrogen)	
Test Scenario	Measured O2 Concentration at Fire Extinction (%)	Predicted O2 Concentration at Fire Extinction (%)	Required Water Discharge Rate (lpm)	Predicted O2 Concentration at Fire Extinction (%)
D3.2	No data	16.1 (dry based)	35	18.0 (dry based)
D3.4	No data	14.9 (dry based)	45	16.7 (dry based)
E3.2	14.4 (dry based)	16.2 (dry based)	35	18.0 (dry based)
E3.4	13.5 (dry based)	14.9 (dry based)	45	16.8 (dry based)

(Water Mist + Inert Gas) System Characterization and FM Approval Testing

- Characterization Conditions
  - 260 m3 enclosure
  - 1 MW (closed door) and 2 MW (open door) spray fires
  - Diesel or heptane

- Suggested Criteria
  - Dry-based oxygen concentration at fire extinction < 12.5 percent for 1MW and 2 MW spray fires → Gaseous extinguishing system.
  - Dry-based oxygen concentration at fire extinction > 16 percent for either 1 MW or 2 MW spray fire → Twin-fluid water mist system.
  - Dry-based oxygen concentration at fire extinction 12.5 – 16 percent → Hybrid extinguishing system.

Hybrid System Requirements

- Classification testing.
- The fire tests and component tests for listing in the designated occupancy prescribed in the Approval Standard for Hybrid Systems (Class 5580) shall be conducted in full.
- Design and installation requirements.
  - Discharge time
  - Agent quantity safety factor

Water Mist vs. Gaseous System Requirements

Agent	Extinguishment Time	Agent Safety Factor	Discharge/Hold Time
CO2	60 seconds	20 %	10 minutes
Inert Gas	60 seconds	20 – 30 %	10 minutes
Water Mist	No requirement	No requirement	2X extinguishment time or 10 minutes

Hybrid System Requirements

- Discharge duration: 10 minutes minimum
- Agent safety factor
  - 20 percent
  - Safety factor would not apply to systems with extinguishment times less than 5 minutes for all the required tests.
- Extinguishment times must not exceed 8 minutes for all the required tests.

Hybrid System Requirements

Extinguishment Time	Discharge Time	Agent Safety Factor
0 to 5 minutes	10 minutes	Not required
5 to 8 minutes	10 minutes	20 percent
Greater than 8 minutes	Not permitted	

Example 1

	Water Mist	Hybrid
Water	3.8 Lpm	3.8 Lpm
Nitrogen	-	4.25 m^3/min
Number of Test Nozzles	4	4
Longest Extinguishment Time	4 minutes	4 minutes
Required Discharge Duration	10 minutes	10 minutes
Number of Installed Nozzles [1]	4	4

[1] Due to required safety factor

Example 2

	Water Mist	Hybrid
Water	3.8 Lpm	3.8 Lpm
Nitrogen	-	4.25 m^3/min
Number of Test Nozzles	4	4
Longest Extinguishment Time	7 minutes	7 minutes
Required Discharge Duration	14 minutes	10 minutes
Number of Installed Nozzles [1]	4	5 [2]

[1] Due to required safety factor

[2] Could also reduce allowable protected area

Example 3

	Water Mist	Hybrid
Water	3.8 Lpm	3.8 Lpm
Nitrogen	-	4.25 m^3/min
Number of Test Nozzles	4	4
Longest Extinguishment Time	9 minutes	9 minutes
Required Discharge Duration	18 minutes	Not permitted / Test failure
Number of Installed Nozzles [1]	4	Not permitted / Test failure

[1] Due to required safety factor

Other Hybrid System Considerations

- **Pressure effects**
  - Structural strength and integrity
  - Enclosure venting
- **Life safety considerations**
  - Low oxygen concentrations
  - Pre-discharge alarms
  - Time delays
  - Warning signs

Questions?