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Evaluation of a Hybrid System of High Pressure Water Mist and Aerosol Fire Suppression Systems

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Acknowledgement

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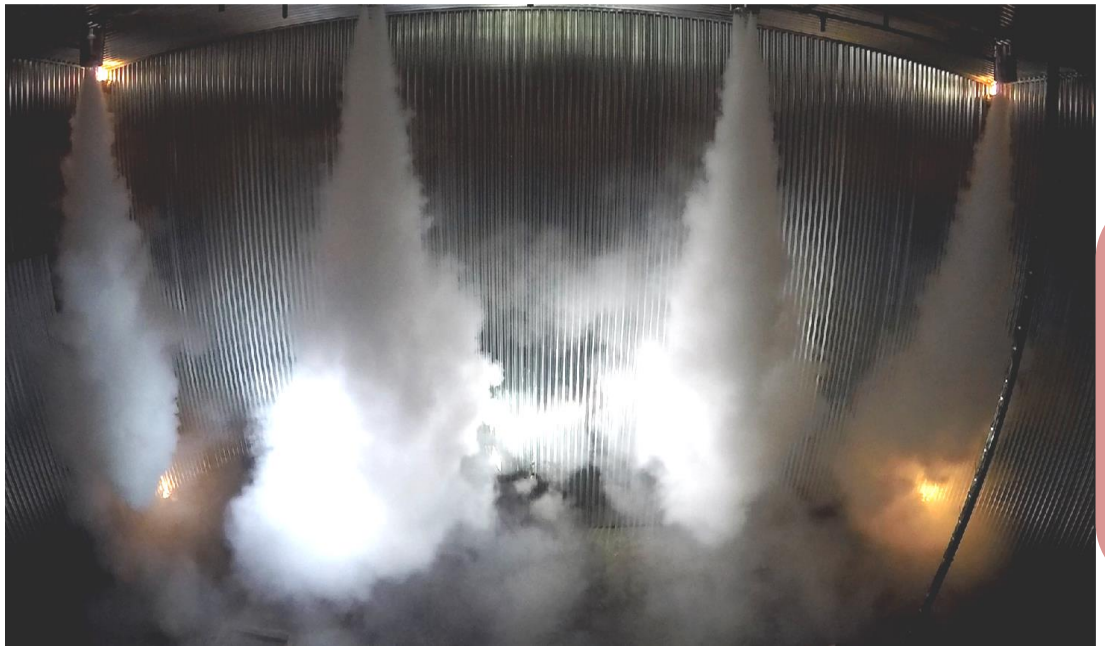
Overview

- Hybrid system combining HPWM and aerosol fire suppression system
  - Phase 3 of NRC investigations of the performance of aerosol system
  - In continued effort to find effective solutions for marine engine rooms protection
  - Numerous aerosol fire suppression tests – room tests, IMO tests
  - Performance comparisons with other fire suppression systems – LPWM
  - Evaluation tests of a combined system of HPWM and aerosol fire suppression system

Fire Suppression Systems



- Actuator at top energizes proprietary compound
- creating aerosol agent by exothermic oxidation
- Discharge fills protected area with ultra fine (≤2 µm) potassium ions
- inhibiting the fire chain reaction

Aerosol System		
• Total flooding fire suppression system • Environmentally friendly • Ultra-fine potassium based aerosol • Interfere the flame's free radicals-terminating propagation of the fire • Quick fire extinguishment • Simple for installation and maintenance	• Air tightness of enclosures	• IMO Circ. 1270 Guidelines for the approval of Fixed aerosol fire extinguishing systems equivalent to fixed gas fire extinguishing systems, as referred to in SOLAS 74 for machinery spaces.

Fire Suppression Systems

High Pressure Water Mist System		
• Ultra-fine water droplets • Fast evaporation • Effective cooling, displacing oxygen, fuel surface wetting, radiation attenuation	• Enough times required for flame suffocations • Less effective on small fires • Require pumps and water delivery system	• MSC/Circ. 728, "Amendments to the Test Method for Equivalent Water-Based Fire Extinguishing Systems for Machinery Spaces of Category A and Cargo Pump Rooms Contained in MSC/Cir. 668, Appendix B," International Maritime Organization, London, England: 1996 • IMO MSC/Circ.1165 Revised guidelines for the approval of equivalent water-based fire extinguishing systems for machinery spaces and cargo pump rooms

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Hybrid System

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Hybrid System

? Interactions of ultra-fine water mist and aerosol particulates
? Water mist scrubbing aerosol
? To what extend the scrubbing would affect the fire suppression performance of aerosol
? If no direct interaction, would the hybrid system provide the benefits of both systems
? Activation sequences

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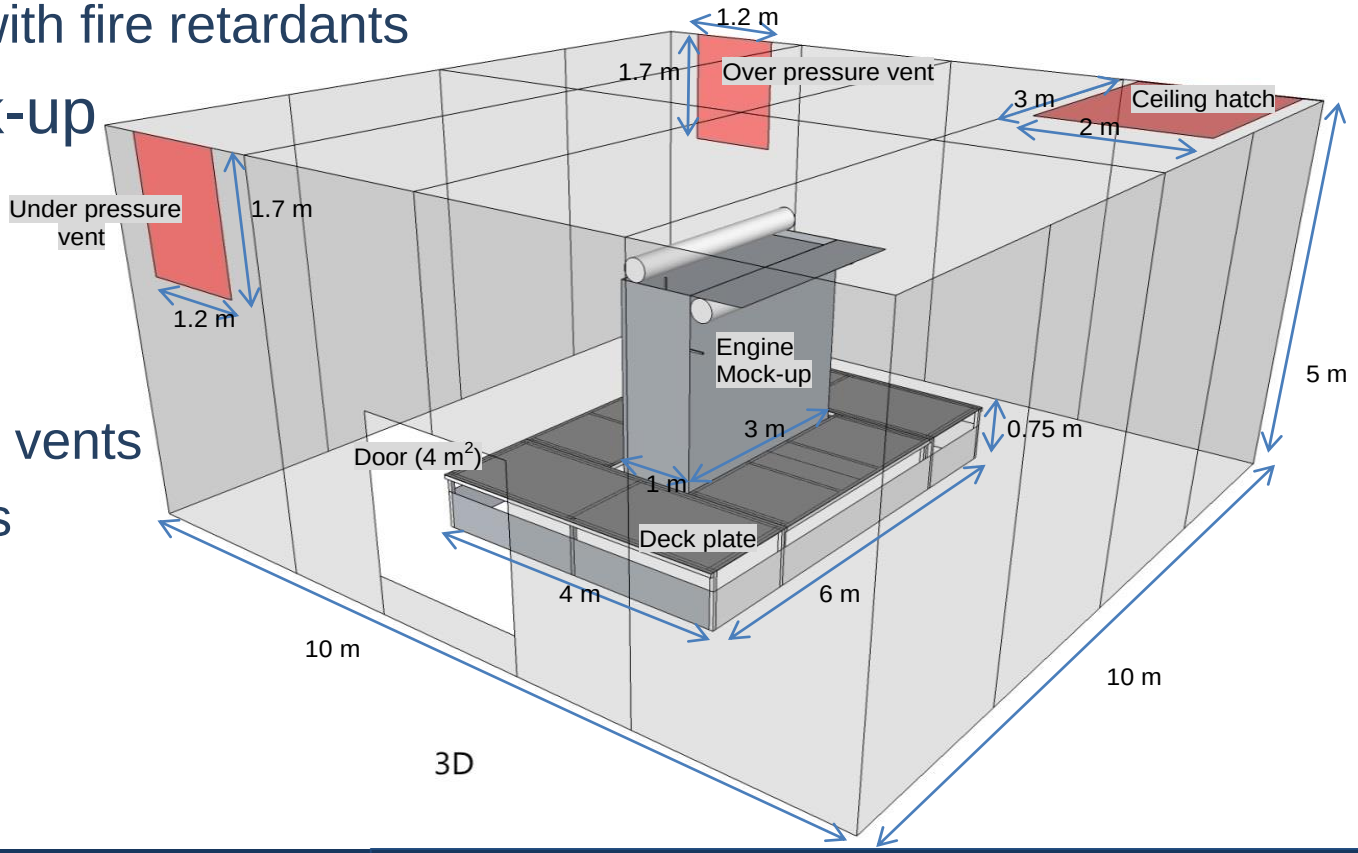
Test Room

- 500 m^3 test compartment
  - 10 m (W) by 10 m (L), with a ceiling height of 5 m
  - assembled with metal panels
  - Gaps sealed with fire retardants
- Engine mock-up
- Openings
  - Door
  - Ceiling hatch
  - Pressure relief vents
  - Leakage levels

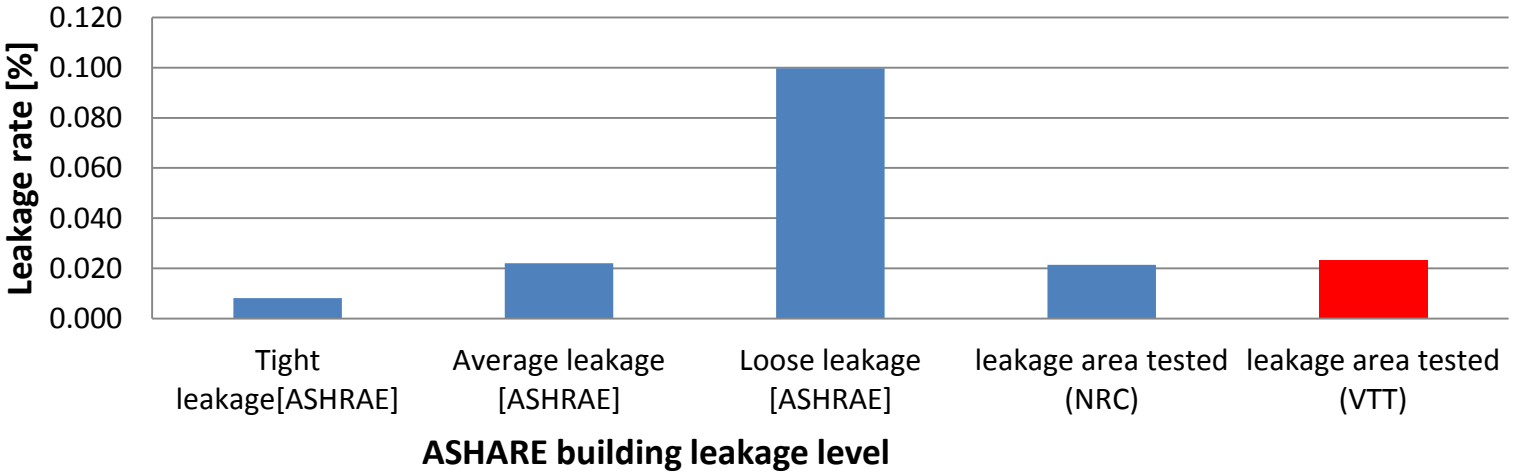


Test Room
Leakage Test

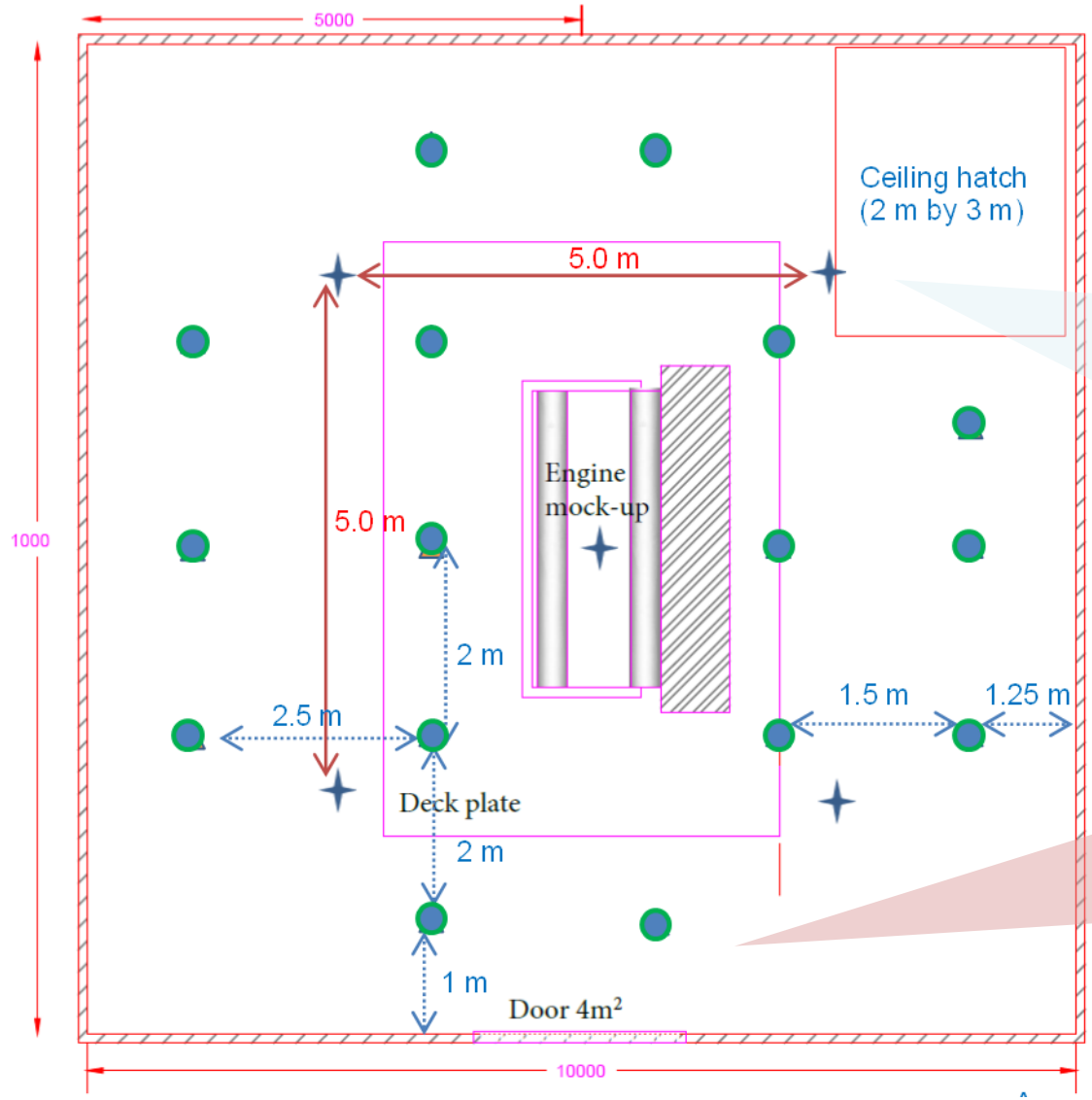
- Blow fan test according to ASTM E 1827
  - Conducted prior to fire tests to evaluate the level of leakage in the test room
  - IMO 1270 requires the test enclosure be nominally leak tight
  - The measured leak level about 0.02%

    → close to the average leakage for a building with the same surface area

    → comparable leakage levels for both NRC (used in ph1 ph2) and VTT (used in ph3)



Test Room
Fire Suppression Systems

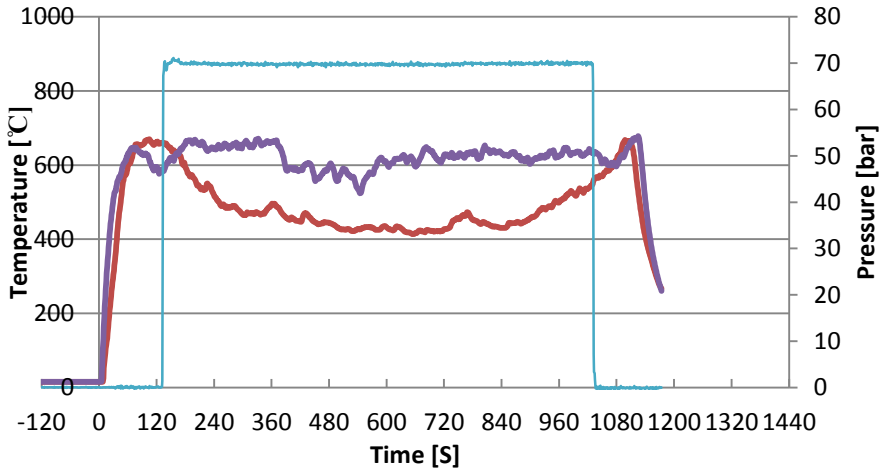


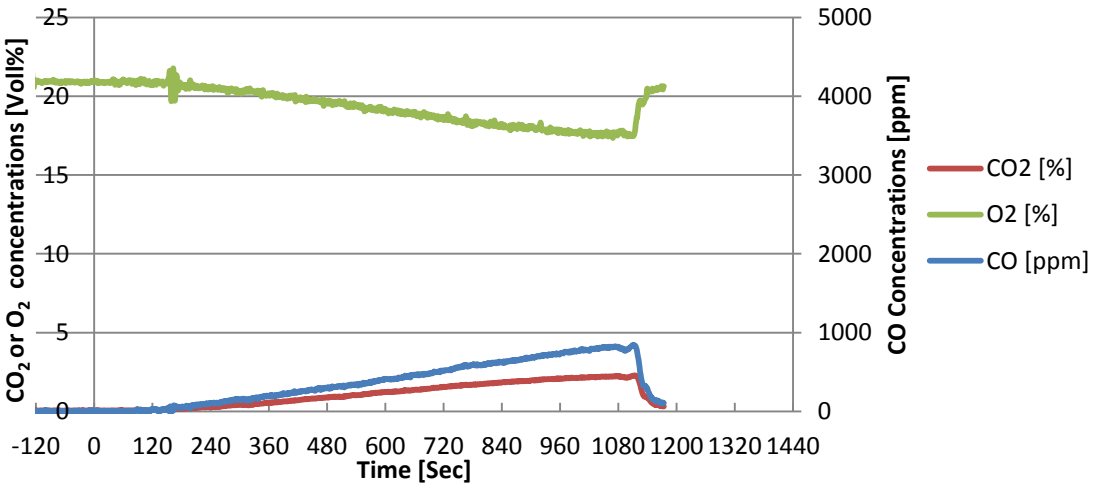
- 5 high pressure water mist heads
- at a 5 m spacing
- K factor 1.9 l/min/bar$^{0.5}$
- Operating pressure 70 bar (1015 psi)
- the total water flow rate 60 l/min with the operating pressure of 70 bar

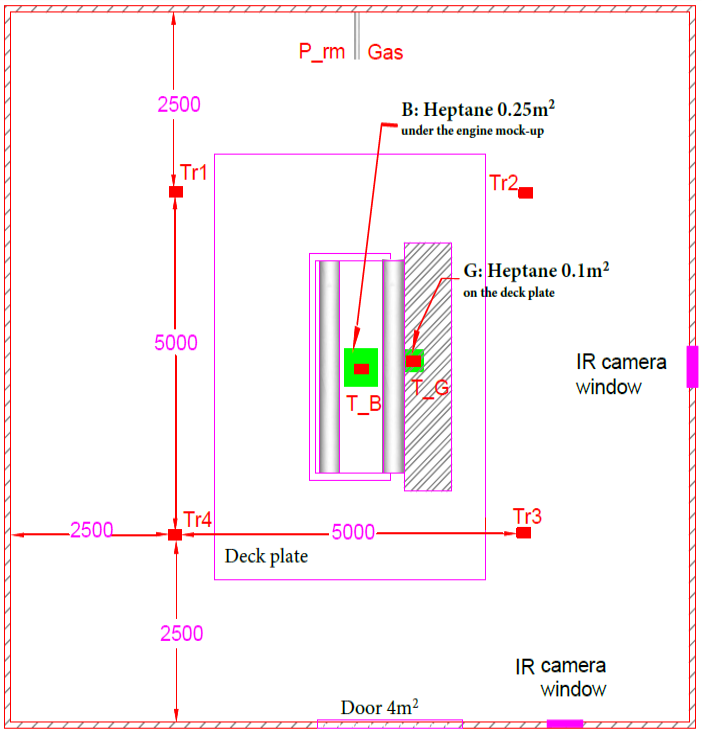
- 16 Aerosol Generators
- Aerosol density 80 g/m^3 (the target concentrations in the range of 52 g/m^3 to 80 g/m^3)

Fire Test Results
High Pressure Water Mist System

Test #	IMO setup	Aerosol	High pressure water mist	
H1	IMO 2	N/A	70 bar (1015 psi) 60 l/min	Two smal

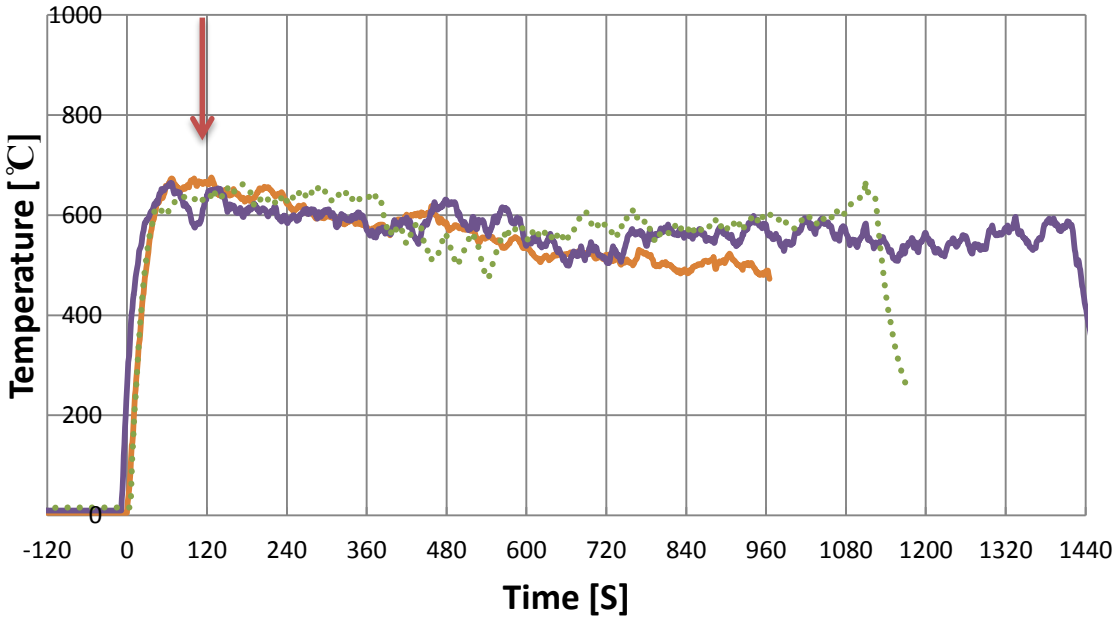


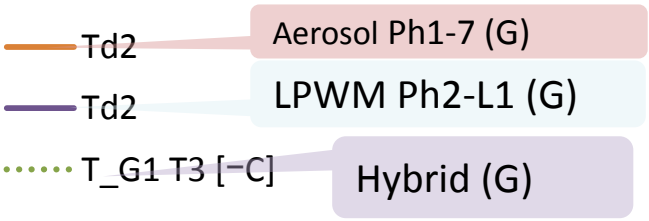


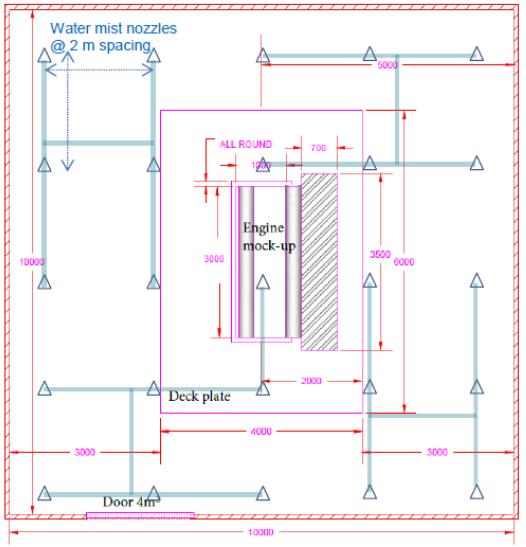


Fire Test Results
High Pressure Water Mist System

Test #	IMO setup	Aerosol	High pressure water mist	Note
H1	IMO 2	N/A	70 bar (1015 psi) 60 l/min	Two small heptane pool fires, HPWM
Ph1-7	IMO 2	68 g/m^3	N/A	Two small heptane pool fires, Aerosol
Ph2-L1	IMO 2	N/A	7 bar (110 psi) 510 l/min	Two small heptane pool fires, LPWM

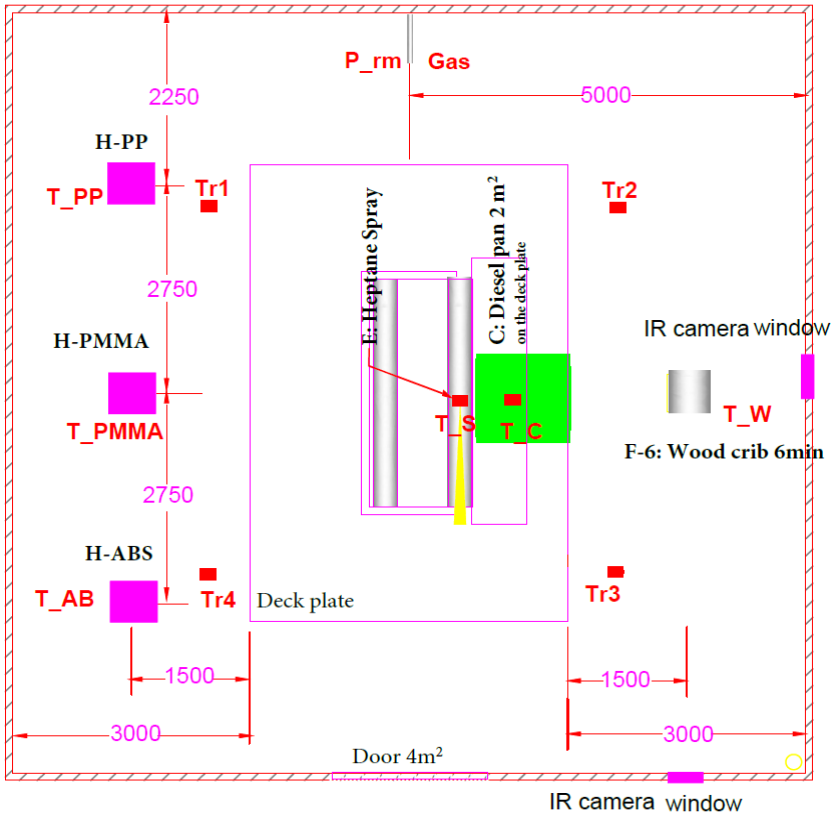






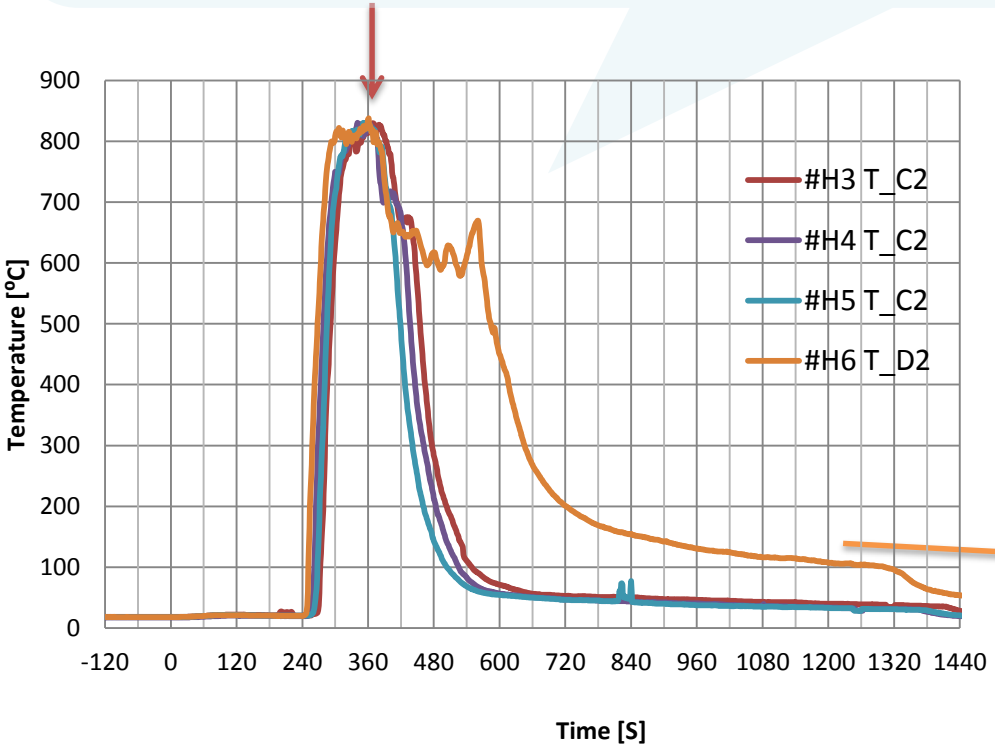
Fire Test Results
Hybrid System

Test #	IMO setup	Aerosol	High pressure water mist	Note
H3	IMO 3	80 g/m^3	70 bar (1015 psi) 60 l/min	Activate aerosol system first
H4	IMO 3	80 g/m^3		High pressure water mist system first
H5	IMO 3	80 g/m^3		Activate both systems at the same time
H6	IMO 3	80 g/m^3	N/A	



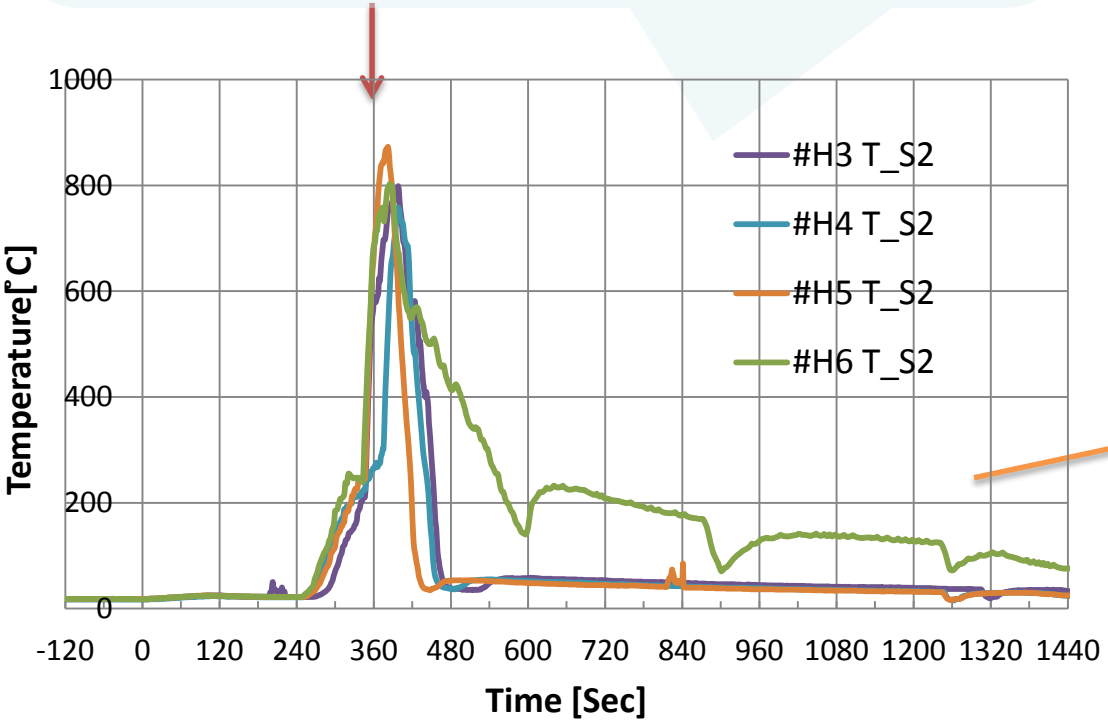
IMO#3 Test Results
Diesel Pan Fire (2 m²)

- Diesel pan fire (2 m²)
- On the deck around the mock-up
- Free burn 2 min
- With hybrid system, the diesel fire - extinguished within 2 min
- With aerosol system, the diesel fire - extinguished with a delay of about 4 minutes

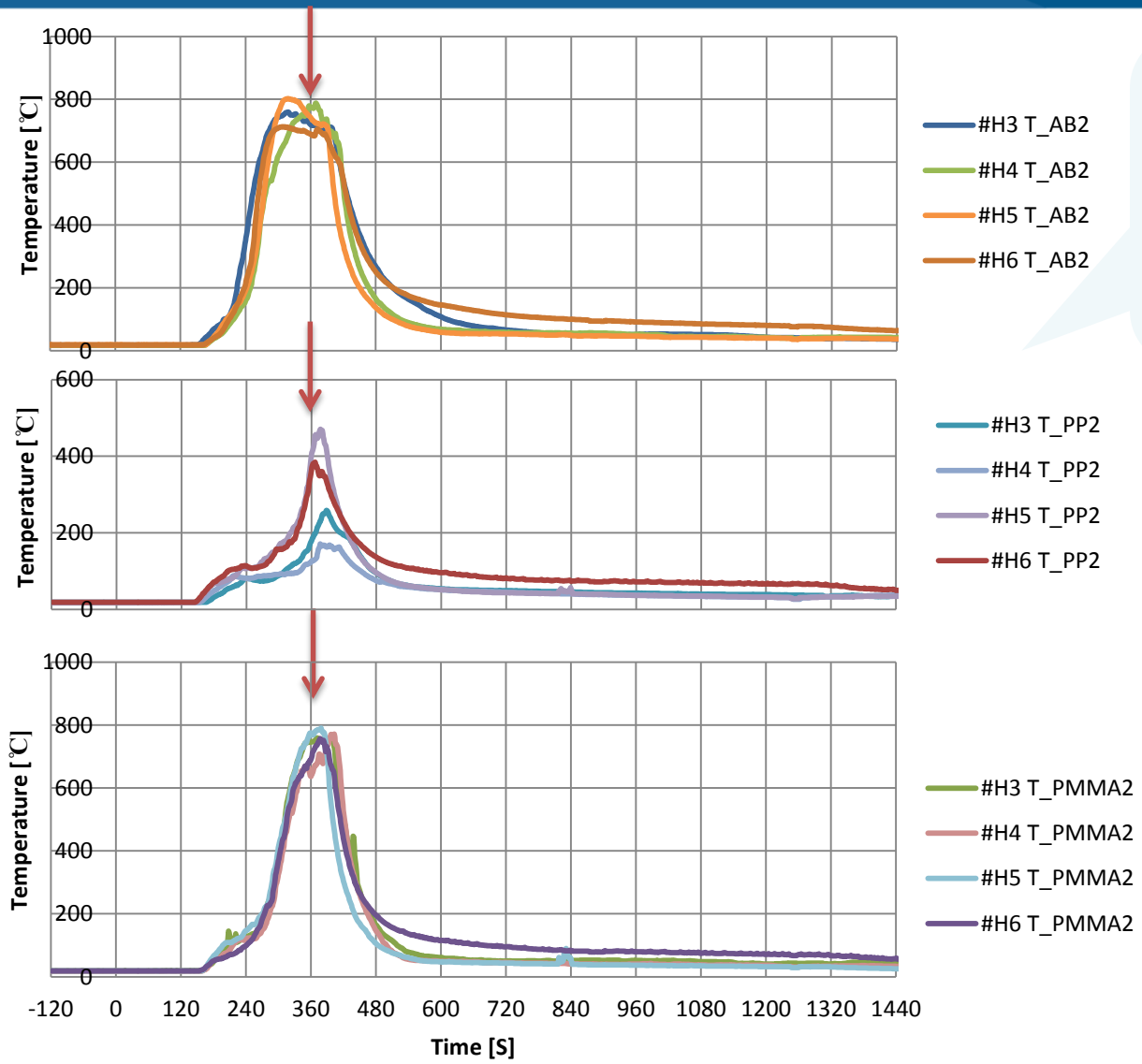


IMO#3 Test Results
Heptane Spray Fire

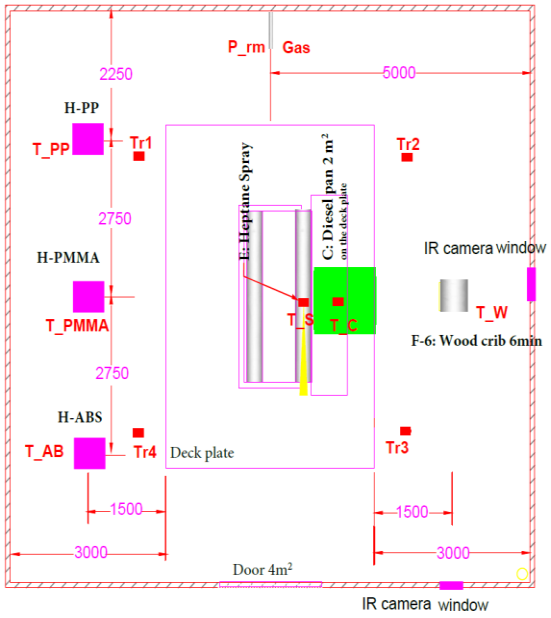
- Heptane spray fire
- On the engine mock-up at h= 2.35 m
- Free burn 15 seconds
- Temperatures of the spray fire started to decrease within 20-30 sec in all tests
- Hybrid system, aerosol system extinguished the spray fire



IMO#3 Test Results
Plastic Crib Fire

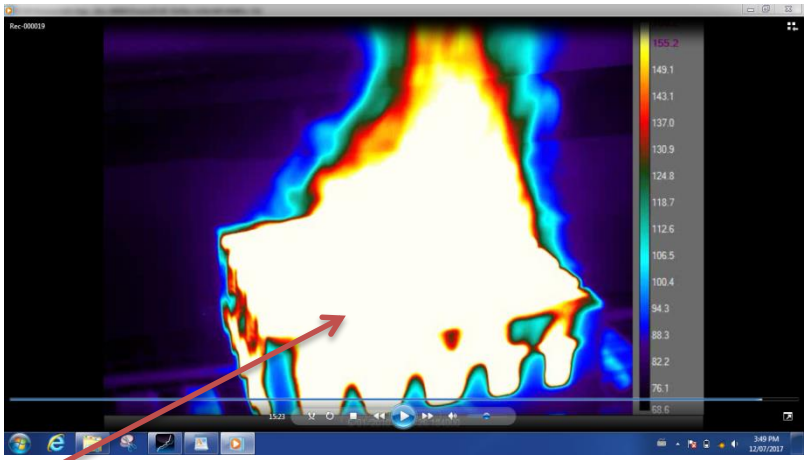


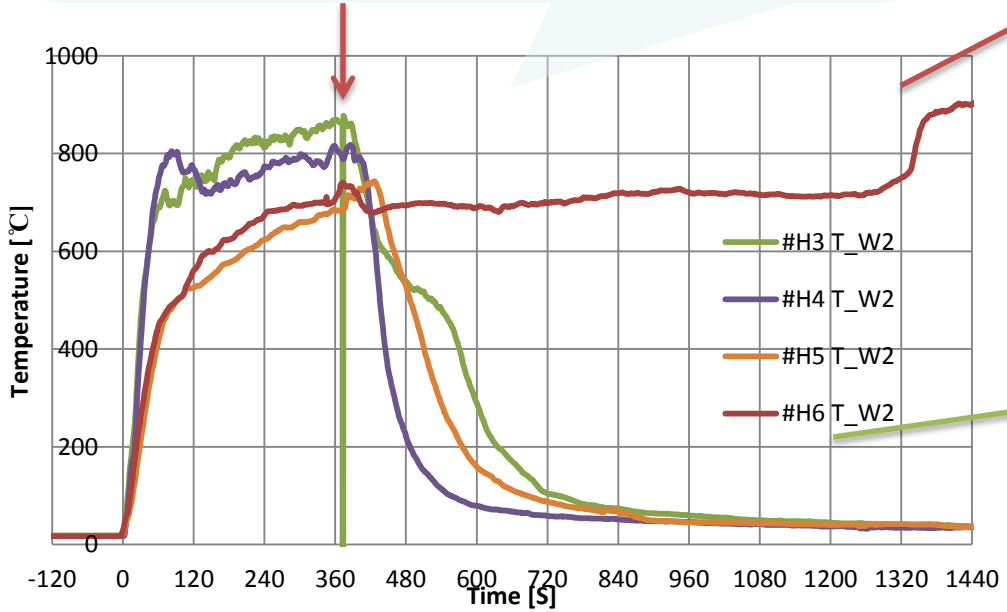
- Plastic crib fires
- ABS, PP and PMMA
- Free burn 3.5 minutes
- Hybrid system, aerosol system extinguished the fires within 60 seconds form the activation



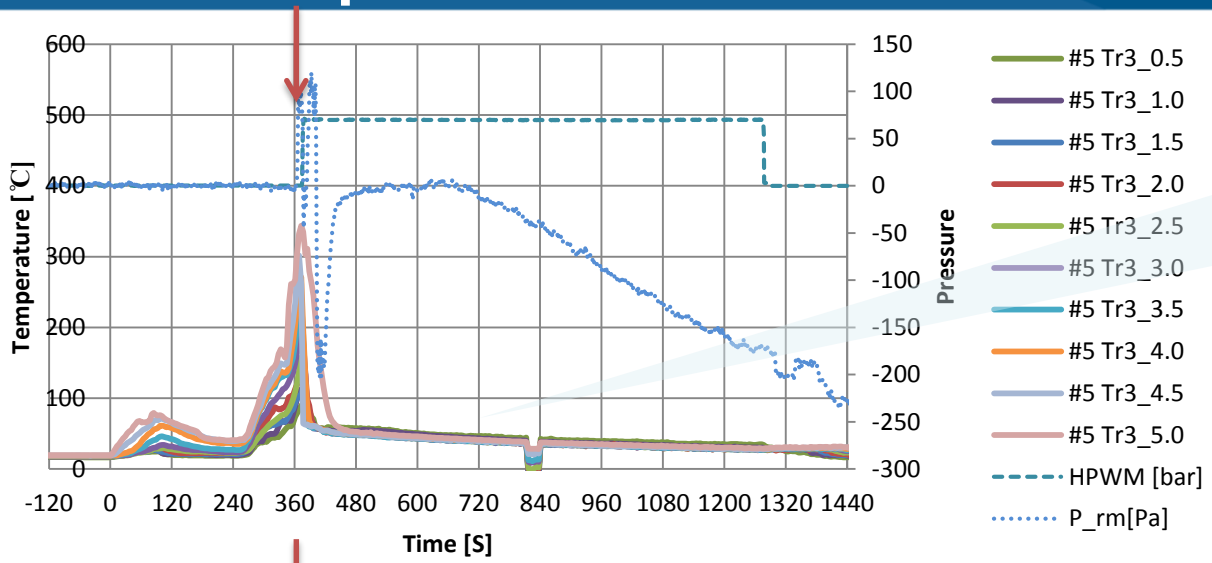
IMO#3 Test Results
Wood Crib Fire

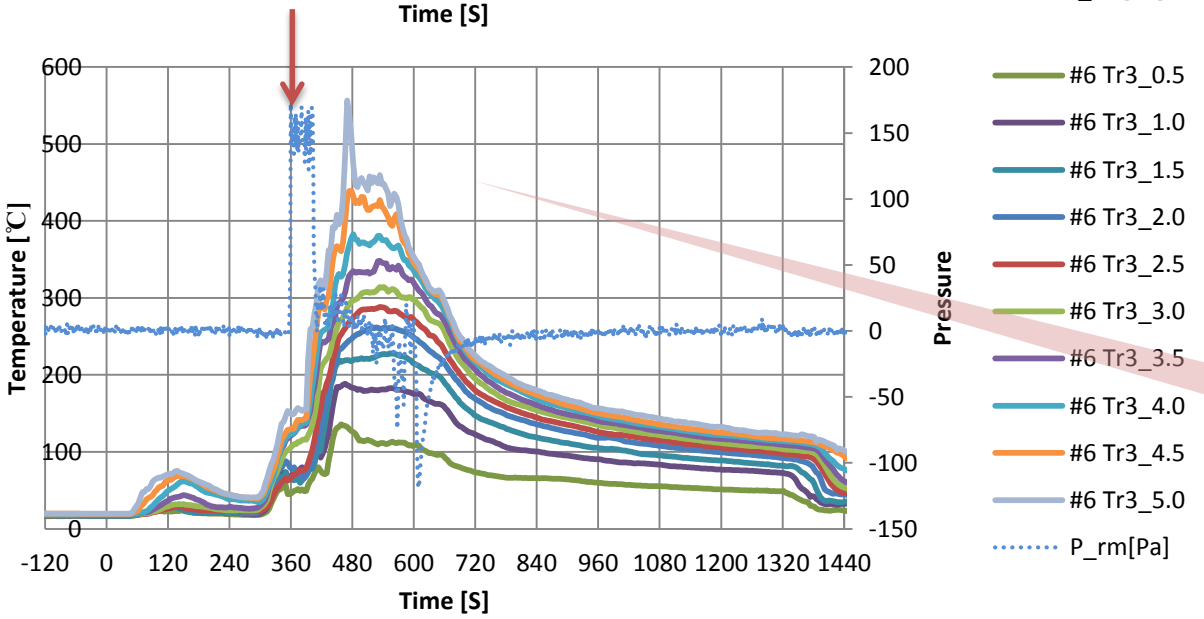
- Wood crib fire
- Free burn 6 minutes
- Hybrid system extinguished the wood crib fires at 2, 3.5 and 5 min., for H4, H5 and H3
- Aerosol system did not extinguish the wood crib fire during the hold time of 15 minutes



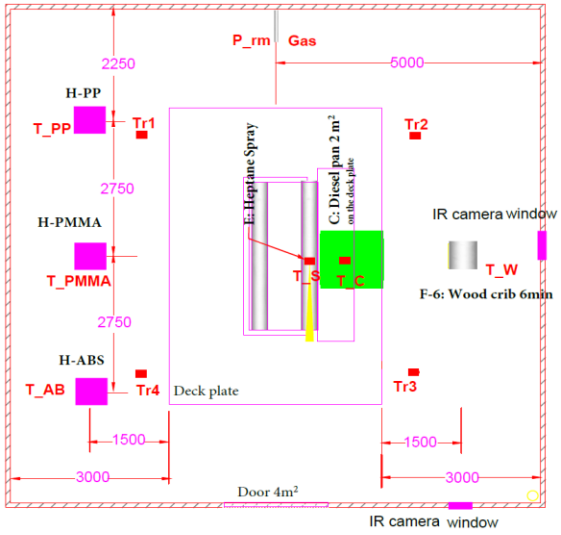


IMO#3 Test Results
Room Temperatures



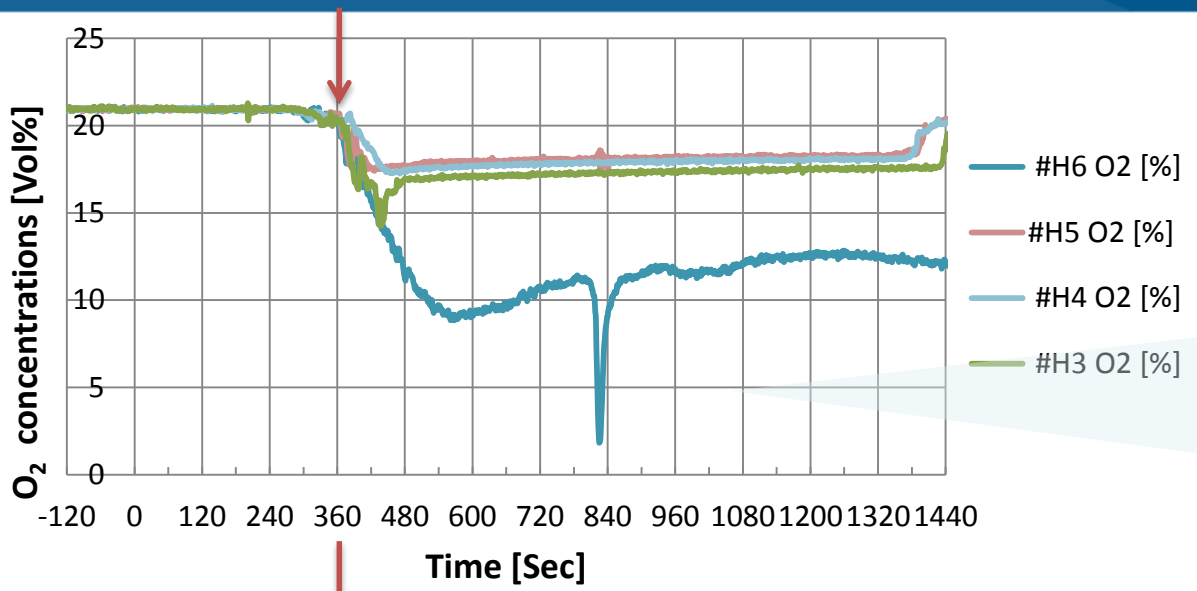


- Hybrid system
- activated at 6 min
- due to water mist, room temperatures decreased
- Due to mixing by HPWM, uniform room temperature

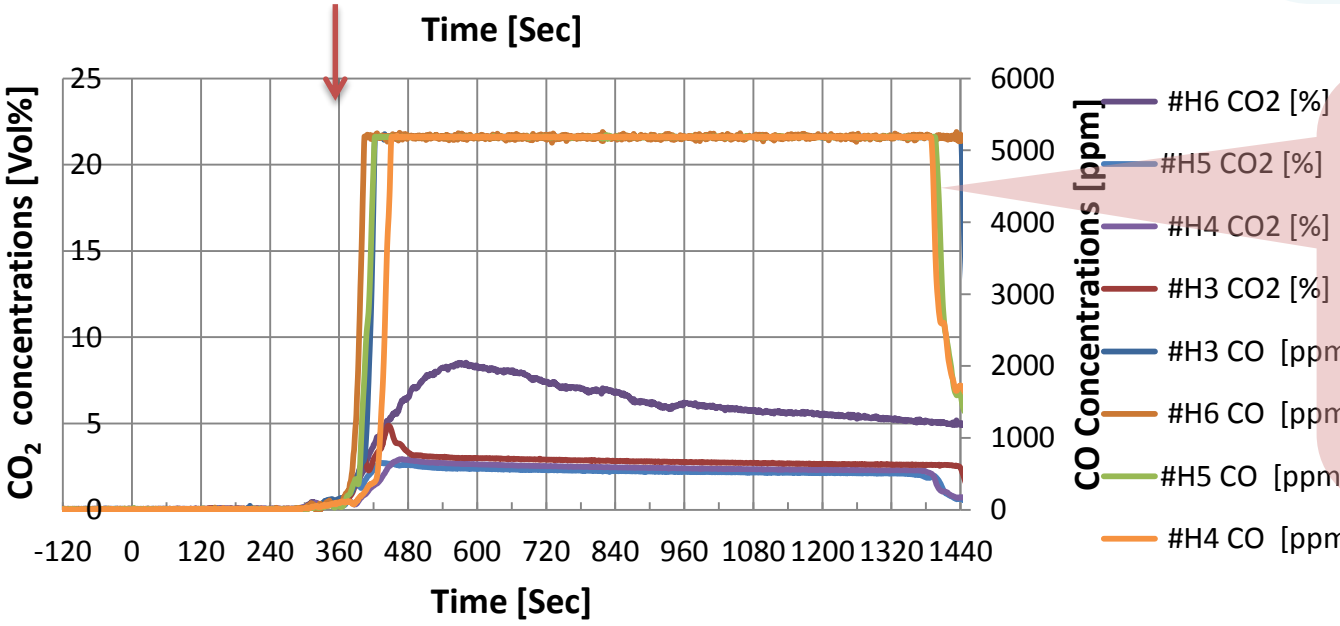


- Aerosol system
- activated at 6 min
- room temperatures increased

IMO#3 Test Results
Room Gas Concentrations



- Oxygen concentrations
- Sampled at mid-height
- Low oxygen in H6
- In part, because of smoke layer in the upper part of the room



- CO concentrations reached the maximum measurement range (5000 ppm) when aerosol system activated
- 4000 ppm measured at a previous cold discharge test

Discussions
Hybrid System Vs. Aerosol System

- Overall fire suppression performance
  - Better performance of the hybrid system in particular for the wood crib fire and diesel pan fire
  - Consistent fire suppression performance of the aerosol system for the plastic crib fires and heptane spray fire, regardless of the presence of the HPWM
  - Indicating the fine water mists did not interfere with the fine aerosol particles scavenging radicals
  - Why better with plastic fires? A reason could be that the polymers of PP, ABS and PMMA have slightly higher limiting oxygen index than the heptane and gasoline.
- Wood crib fire
  - Hybrid : Effective flame cooling and surface wetting by HPWM
  - Aerosol : a lack of mixing of aerosol in the room

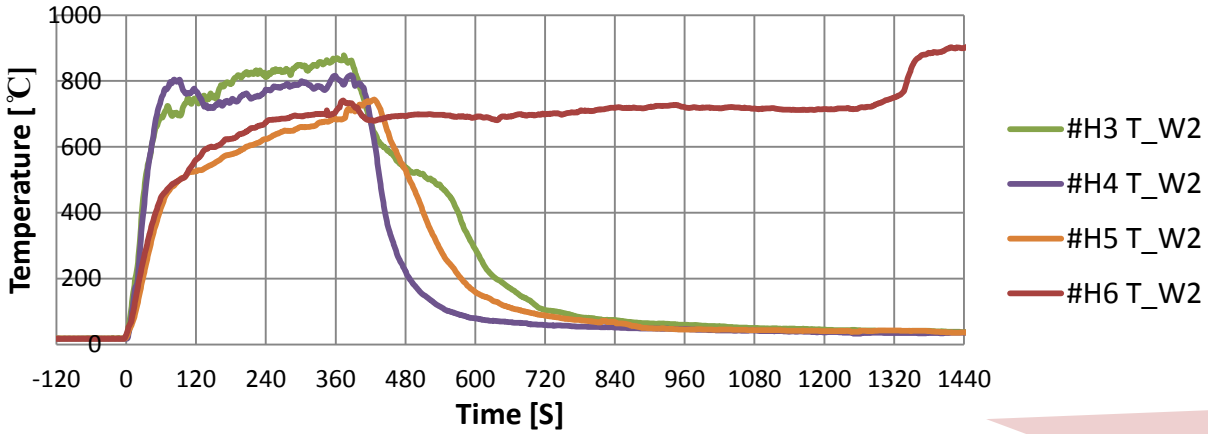
    Discharged from the ceiling to the floor, but momentarily moved upward and hanging above the height of the wood crib
- **Improvements**
  - Effective mixing in the room

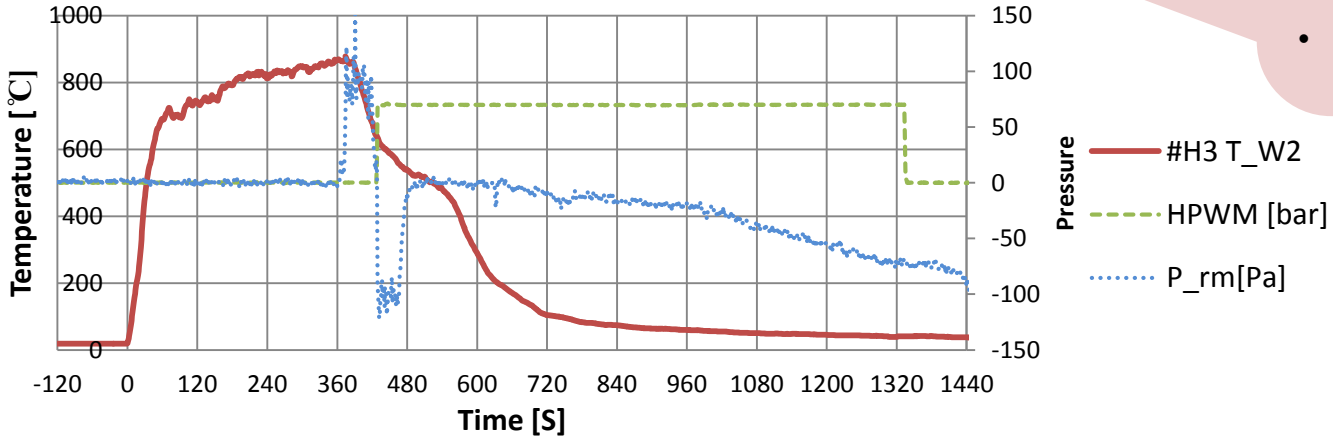
Discussions

- Aerosol Scrubbing by the HPWM
  - pH level was measured for the water sampled from the test room after each fire test
  - The Aerosol system generates Potassium nitrate (KNO3) which is moderately soluble in water and the aqueous solution in pH 7.
  - The pH level of water from the main line was about 10. After each test, the sampled water from the test room showed a pH level in the range of 9.5-10 for all tests. This indicated that there was no significant scrubbing by the water mist.
- Advantages of the hybrid system
  - provide the benefits of both the high pressure water mist and aerosol systems.
  - The water mists provide quick control of the fire and rapid cooling of the protected space, while the aerosol provides quick fire extinguishment.

Discussions

❑ Activation sequences in the Hybrid system





- Wood crib fire: the extinguishment times varied with different activation sequences
- The earliest fire extinguishment in H4 (with HPWM activated first)
- Further research!

Future Studies

- Improvements needed for the aerosol system
- Like the water mist system, the aerosol system also requires strong mixing of the fine particles in the enclosure so that the aerosol can reach close to the flame area.
- While the HPWM system showed efficient mixing, which resulted in uniform temperature in the room, the room temperature profiles from the aerosol only tests showed substantial temperature gradients.
- Further studies are necessary to identify the uniformity of the aerosol concentration in the enclosure.
- The aerosol system could potentially provide rapid fire extinguishment of all the fire types tested in the project, when the HPWM system was complemented.
- This study showed that the hybrid system is feasible and effective. However, the use of the two systems with different design requirements demands detailed system designs, some of which are air tightness of the enclosure and peak pressure relief of the enclosure. Therefore, further study is necessary with the focus on realistic settings of an actual machinery room.

Questions?

Thank you

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