Water Mist Simulations in the Marine Sector

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Outline of talk

1. What is water mist.
2. Use of water mist as a replacement for Halon
3. Testing of water mist systems.
4. Applications for the use of water mist in the marine sector
5. Simulations of water mist system on ships
Why use water mist

- Ban of Halon (Montreal Protocol in 1987)
- Protection of passenger ferries ("Scandinavian Star" incident in 1990)
- Environmentally friendly
Water mist is one of several alternatives to Halon, other alternatives are

- $\text{CO}_2$
- $\text{N}_2$ mixtures (trade names are Inergen & Argonite)
- Chemical reaction producing powder (used on Mir)
- Other chemicals (Novec 1230 ($\text{C}_6\text{F}_{12}\text{O}$), FM 200)
What is water mist

- Fine water droplets
- NFPA 750 (US)
  - The first standard on water mist
  - 99% of the droplets should be below 1 mm
  - Typically droplets are 200 – 500 µm

- European standard
  - CEN/TS 14972:2011
How does water mist work

Primary mechanism

- Cooling of gasses
  - Droplets evaporate
  - Flame temperature lowers
  - Reactions are slowed down

Gas temperature ↓
Reaction rate ↓
Heat release rate ↓
Water mist also has its limitations

- The water are small droplets and not a gas
  - Difficult for droplets to go pass an obstacle

- Limits visibility when released

- Ventilation conditions can affect the performance
Two different high pressure nozzles at 100 bar

Hollow cone, 0.38 l/min
Danfoss 1910

Full cone, 0.13 l/min
Lehler 212.085
Measurement method I
Particle Image Velocimetry (Velocity)
Measurement method II
Phase Doppler Anemometry (Vel. & Droplet size)
Obstacle for a more wide spread use of water mist

• Lack of engineering methods for designing water mist systems

• Full scale tests are very expensive
  – but currently this is the only option for approving water mist systems
Standards for water mist systems on ships

Deep fat fryers and ducts  
ISO 15371

Ro-Ro and special category spaces  
MSC.1/Circ.1340

Cabin balconies  
MSC.1/Circ1268

Accomodation  
Resolution A.800(19)

Public spaces  
Resolution A.800(19)

Machinery space total flooding  
MSC/Circ.1165

Machinery space local application  
MSC/Circ.1387

Service areas  
Resolution A.800(19)

Source: www.marioff.com/media/brochures/en_GB/brochures/
Water mist in machinery space, total flooding
IMO MSC/Circ. 1165
### Combinations of pool fires and spray fires, 8 tests

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Fire Scenario</th>
<th>Test Fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Low pressure horizontal spray on top of simulated engine between agent nozzles.</td>
<td>Commercial fuel oil or light diesel oil</td>
</tr>
<tr>
<td>2</td>
<td>Low pressure spray in top of simulated engine centred with nozzle angled upward at a 45° angle to strike a 12-15 mm diameter rod 1 m away.</td>
<td>Commercial fuel oil or light diesel oil</td>
</tr>
<tr>
<td>3</td>
<td>High pressure horizontal spray on top of the simulated engine.</td>
<td>Commercial fuel oil or light diesel oil</td>
</tr>
<tr>
<td>4</td>
<td>Low pressure concealed horizontal spray fire on the side of simulated engine with oil spray nozzle positioned 0.1 m in from the end of the engine and 0.1 m² tray positioned on top of the bilge plate 1.4 m in from the engine end at the edge of the bilge plate closest to the engine.</td>
<td>Commercial fuel oil or light diesel oil</td>
</tr>
<tr>
<td>5</td>
<td>Concealed 0.7 m × 3.0 m fire tray on top of bilge plate centred under exhaust plate.</td>
<td>Heptane</td>
</tr>
<tr>
<td>6</td>
<td>Flowing fire 0.25 kg/s from top of mock-up (see figure 3).</td>
<td>Heptane</td>
</tr>
<tr>
<td>7</td>
<td>Class A fires wood crib (see Note) in 2 m² pool fire with 30 s preburn. The test tray should be positioned 0.75 m above the floor as shown in figure 1.</td>
<td>Heptane</td>
</tr>
<tr>
<td>8</td>
<td>A steel plate (30 cm × 60 cm × 5 cm) offset 20° to the spray is heated to 350°C by the top low pressure spray nozzle positioned horizontally 0.5 m from the front edge of the plate. When the plate reaches 350°C, the system is activated. Following system shutoff, no reignition of spray is permitted.</td>
<td>Heptane</td>
</tr>
</tbody>
</table>
Test are preformed by fire laboratories

• As an example of test
  – SINTEF NBL in Norway
  – The largest IMO approved machinery space on board ship is now
    • 3348 m³ with 10,1 m headroom

• Other laboratories testing water mist systems
  – DBI in Denmark
  – SP in Sweden
Simulating fires on ships

• Simulating smoke spread
  – Geometry can be imported from CAD program
  – Important to define leakage of compartments
  – Can be used to check detection systems
  – Can be combined with evacuation modelling

• Advanced topics
  – Simulate fire spread
  – Simulate extinguishment
    • An example will be shown
The geometry is split into small control volumes

- Structured grid (FDS)
- Unstructured grid (Comsol, FireFOAM)
Additional models in order to model fire
Example with engine room and water mist Experiments and Simulation

• Experiment carried out by the US navy (from FDS Validation Guide)

• Simulation (input file from FDS validation guide)
  – Large Eddy Simulation, Fire Dynamic Simulator version 6
  – Lagrangian particle tracking
  – For the simulations, the extinguishment time is taken to be when the Heat Release Rate drops to half of its specified value
Recorded extinguishment times for the USCG/HAI water mist suppression tests in a small shipboard machinery space

<table>
<thead>
<tr>
<th>System</th>
<th>Navy</th>
<th>Grinnell</th>
<th>Fogtec</th>
<th>Chemetron</th>
<th>Fike</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Nozzles</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>15</td>
<td>6</td>
</tr>
<tr>
<td>Operating Pressure (bar)</td>
<td>70</td>
<td>13</td>
<td>100</td>
<td>12</td>
<td>21</td>
</tr>
<tr>
<td>Flow Rate (L/min)</td>
<td>68</td>
<td>75</td>
<td>22</td>
<td>70</td>
<td>48</td>
</tr>
<tr>
<td>Assumed Median Drop Size (μm)</td>
<td>175</td>
<td>225</td>
<td>100</td>
<td></td>
<td>200</td>
</tr>
<tr>
<td>Assumed Initial Velocity (m/s)</td>
<td>75</td>
<td>32</td>
<td>90</td>
<td></td>
<td>41</td>
</tr>
<tr>
<td>Assumed Spray Angle (deg.)</td>
<td>120</td>
<td>90</td>
<td>120</td>
<td></td>
<td>90</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fire Scenario</th>
<th>Ventilation</th>
<th>Navy</th>
<th>Grinnell</th>
<th>Fogtec</th>
<th>Chemetron</th>
<th>Fike</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 MW Spray</td>
<td>Closed</td>
<td>15</td>
<td>26</td>
<td>21</td>
<td>27</td>
<td>21</td>
</tr>
<tr>
<td>1.0 MW Spray</td>
<td>Natural</td>
<td>15</td>
<td>40</td>
<td>32</td>
<td>43</td>
<td>35</td>
</tr>
<tr>
<td>1.0 MW Spray</td>
<td>Forced</td>
<td>17</td>
<td>55</td>
<td>76</td>
<td>357</td>
<td>133</td>
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<tr>
<td>0.5 MW Spray</td>
<td>Closed</td>
<td>34</td>
<td>70</td>
<td>39</td>
<td>53</td>
<td>56</td>
</tr>
<tr>
<td>0.5 MW Spray</td>
<td>Natural</td>
<td>41</td>
<td>117</td>
<td>67</td>
<td>158</td>
<td>140</td>
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<tr>
<td>0.5 MW Spray</td>
<td>Forced</td>
<td>124</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>0.25 MW Spray</td>
<td>Closed</td>
<td>157</td>
<td>360</td>
<td>169</td>
<td>314</td>
<td>277</td>
</tr>
<tr>
<td>0.25 MW Spray</td>
<td>Natural</td>
<td>206</td>
<td>No</td>
<td>290</td>
<td>525</td>
<td>566</td>
</tr>
<tr>
<td>0.25 MW Spray</td>
<td>Forced</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
Time = 0 s

Smokeview 5.6 – Oct 29 2010

Frame: 91
Time: 0.1
Time = 10 s

Smokeview 5.6 – Oct 29 2010

Frame: 106
Time: 10.0
Time = 20 s

Smokeview 5.6 – Oct 29 2010

Frame: 122
Time: 20.5
Time = 30 s

Smokeview 5.6 – Oct 29 2010
Time = 35 s

Smokeview 5.6 – Oct 29 2010

Frame: 144
Time: 35.0
Results of simulation

Water mist in closed engine room

- HRR [kW]
- Pressure [hPa]

Extinguishment of fire in simulation
Extinguishment of fire in test
Water spray started
Other work, references


Thank you