Experimental characterization and computer modelling of water mist systems

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14th International Water Mist Conference
Istanbul - 22nd & 23rd October 2014
- Technological development and improvement of the components that make the water mist systems of RG Systems for optimum application in Cable Tunnels and Ducts.

- Selection and design of fire protection system components.

- Modeling and Validation (using full-scale tests) of the water mist system.

- Installation and launching of the fire protection system in a pilot Cable Tunnel.
Previous collaboration projects

Small Scale Tests  →  GLOBAL PROJECT  →  Real-Scale Tests

Numerical Analysis
Nozzles:

- **EMM 540856 (K-Factor: 2.04):** Open nozzle for local application protected risks, with a k-factor of 2.04 and 5 micro-nozzles.

- **EMM 20-760-845 (K-Factor: 4.62):** Open nozzle for local application protected risks, with a k-factor of 4.62 and 20 holes.
Types of tests:

Collect data for the characterization of the nozzles and the validation activities in the fire computer model.

- Without ignition source: in order to have data without any element to disturb the droplet distribution, measuring output angles, flow distribution, etc.

- With ignition source: for the verification of the nozzle operation against two different sizes of pool fires.
Without ignition source:

144 pipettes were placed at intervals of 25 cm covering a total area of 3m x 3m.

4 High-definition cameras to estimate angles.
Full Scale Tests

Without ignition source:

EMM 540856
Without ignition source:

**EMM 20-760-845**
With ignition source:

<table>
<thead>
<tr>
<th>Pool fire dimensions</th>
<th>Area (m²)</th>
<th>Fuel</th>
<th>Mass burning rate (kg/m² s)</th>
<th>Heat of combustion (kJ/kg)</th>
<th>Theoretical HRR (kW)</th>
<th>Estimate HRR (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 (84.1 x 59.5 cm)</td>
<td>0.5</td>
<td>Kerosene</td>
<td>0.039</td>
<td>43200</td>
<td>790 kW</td>
<td>480 kW</td>
</tr>
<tr>
<td>A2 (59.4 x 42.0 cm)</td>
<td>0.25</td>
<td>Kerosene</td>
<td>0.039</td>
<td>43200</td>
<td>363 kW</td>
<td>240 kW</td>
</tr>
</tbody>
</table>
Full Scale Tests

With ignition source:
Full Scale Tests

With ignition source: 

**Pool fire – A2**

**Pool fire - A1**

EMM 540856
With ignition source:

**Pool fire – A2**

**Pool fire - A1**
With ignition source:

**Pool fire – A2**

**Pool fire - A1**

EMM 20-760-845
With ignition source:

**Pool fire – A2**

**Pool fire - A1**

EMM 20-760-845
‘Fire Dynamics Simulator (FDS)’ v6:

-Developed by the National Institute of Standards and Technology (USA).

-Solves numerically a form of the Navier-Stokes equations appropriate for low-speed, thermally-driven flow with an emphasis on smoke and heat transport from fires.
Sensitivity analysis:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range of values</th>
<th>Variation in extinction time (s) (HRR=0)</th>
<th>Variation in extinction time (s) (half of HRR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGE</td>
<td>10 - 100 (s)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>DIAMETER</td>
<td>100 – 1000 (μm)</td>
<td>75</td>
<td>86</td>
</tr>
<tr>
<td>HRRPUA</td>
<td>125 - 2000 (kW)</td>
<td>174</td>
<td>162</td>
</tr>
<tr>
<td>OFFSET</td>
<td>0.05 - 0.3 (m)</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>PARTICLES PER SECOND</td>
<td>1000-50000</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>OPERATING PRESSURE</td>
<td>25 - 400 (bar)</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>SAMPLING FACTOR</td>
<td>1 - 51</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>PARTICLES VELOCITY</td>
<td>10 - 160 (m/s)</td>
<td>27</td>
<td>38</td>
</tr>
<tr>
<td>FACTOR K</td>
<td>0.1 - 10 (l/min bar^{1/2})</td>
<td>63</td>
<td>48</td>
</tr>
<tr>
<td>ANGLES</td>
<td>0 – 170 (º)</td>
<td>65</td>
<td>68</td>
</tr>
</tbody>
</table>
Initial parameters:

General Characteristics:

- $K$-Factor ($\text{l/min} \cdot \text{bar}^{1/2}$): 2.04
- Micro-nozzle diameter (mm): 1.14

Specific test data:

- Operation pressure (bar): 100
- Initial velocity (m/s): 66.62

Assumptions:

- Droplet Diameter ($\mu$m): 450
- Offset (m): 0.2
- Age (s): 30
- Sampling factor: 1
- Particles per second: 20000
Results without fire:

EMM 540856
Results without fire:

EMM 20-760-845
Results with fire:

**Pool fire – A2**

Simulation: 580 s
Test 4: 725 s
Mean value Tests 9-10: 264 s

**Pool fire – A1**

Simulation: 612 s
Test 4: 697 s
Mean value Tests 9-10: 317 s

**Extinction time (s)**

<table>
<thead>
<tr>
<th></th>
<th>(No flame)</th>
<th>(Ignition source temp= 40º)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pool fire A2</td>
<td>580 s</td>
<td>612 s</td>
</tr>
<tr>
<td>(240 kW)</td>
<td>Test 4</td>
<td>725 s</td>
</tr>
<tr>
<td>Pool fire A1</td>
<td>Simulation</td>
<td>697 s</td>
</tr>
<tr>
<td>(480 kW)</td>
<td>Test 4</td>
<td>317 s</td>
</tr>
<tr>
<td></td>
<td>Mean value Tests 9-10</td>
<td>293 s</td>
</tr>
<tr>
<td></td>
<td></td>
<td>294 s</td>
</tr>
</tbody>
</table>
Results with fire:

**Pool fire - A2**

**Extinction time (s)**

<table>
<thead>
<tr>
<th></th>
<th>Simulation</th>
<th>Mean value tests 5-6</th>
<th>Mean value tests 11-12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pool fire A2 (240 kW)</td>
<td>591 s</td>
<td>929 s</td>
<td>387 s</td>
</tr>
<tr>
<td></td>
<td>608 s</td>
<td>857 s</td>
<td>310 s</td>
</tr>
</tbody>
</table>

**EMM 20-760-845**

**Pool fire - A1**
Water mist system activated during about 960 s

Ignition source turned off

Water mist system turned on

445 s after activation of water mist system
- It has been sensed a high potential of these techniques for study and development of water mist systems.

- It has developed a methodology for the characterization of water mist systems.

- The use of validated fire computer models will allow to continue with the development of the system, include improvements, and performing an optimized system.
The authors would like to thank CDTI (Spanish Government) for granting the project ‘Development of a new fire protection system for cable ducts based on water mist’, IDI-20130667. Co-funded by The European Union through ERDF (European Regional Development Fund)