A water mist system evaluation based on real scale fire tests

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1 Context

2 Test set-up

3 Experimental results
   - Temperature
   - Transmissivity
   - Radiative flux

4 Conclusion
As part of rehabilitation of an office building, a project manager planned the installation of a fixed fire fighting system

Objective is to rise the maximum value of heat potential defined in French regulation

Project manager also charged CSTB to realize an experimental study with real scale fire tests

Evaluate the impact of water mist on conditions of people evacuation and firefighters intervention
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Test compartment of CSTB

- CSTB building designated for real scale fire test
- Test compartment of 15 m by 15 m with removable ceiling (with a maximum height of 6 m)
Test metrology

- Temperature measurements
  - Thermocouple tree
  - Thermocouple near spraying nozzles
- Radiative flux measurements
- Smoke opacity measurements
  - Agress conditions
- Measurements of spectral radiative flux
  - Radiative shield effect of water mist
- Characterization of water mist system
  - Time of activation of water mist system
  - Operating pressure
- Evaluation of test conditions by video camera
Visibility measurements with opacimeters

Laser diode with an emitting radiation at 635 nm

Photodiode for the detection

Distance between source and detector: 1.3 m

Transmissivity:

\[ Tr = \frac{\text{Signal during test}}{\text{Reference signal}} \]
Visibility measurements: data processing

- Transmissivity and extinction coefficient
  \[ \beta = \frac{1}{L} \ln Tr \]

- Extinction coefficient and distance of visibility: Jin’s relation
  \[ V = \frac{C}{\beta} \]

- Distance of visibility

  - Levels at 5 m and 15 m: validity domain of Jin’s equation
  - Under and above these limits: extrapolation of Jin’s equation
Multi-spectral IR camera and spectrometer (LEMTA)

- Simultaneous display of the same emission area
- IR camera: 4 pictures at the same time with 4 spectral bands (CO$_2$, H$_2$O, soot, infrared radiation between 1.5 $\mu$m et 5.5 $\mu$m)
- Office furniture and transfer cases
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Evolution of temperature

Test without water mist
- Thermal stratification
- Highest value : 80°C

Test with water mist
- Thermal stratification before mist activation
- Sudden fall of temperature at mist activation
- Highest value after mist activation : 30°C
Evolution of transmissivity (1/2)

Test without water mist
- Significant fall of transmissivity
- Lowest value: between 5% and 25%
- Gradual increase due to the decline of the fire activity

Test with water mist
- Decrease of transmissivity before mist activation (between 40% and 60%)
- Sudden fall at mist activation explained by smoke destratification
- Weak increase after mist stop (at few percents)
Decrease of transmissivity at 1.70 m high before mist activation (Tr ≈ 50 %)
Sudden fall of visibility after mist activation
Test without smoke (40 min) : 20 % < Tr < 30 %
⇒ opaque mixing between water droplets, water vapor and smoke
After the fire ignition
- Fire mainly concerns transfer cases
- Then, fire propagates to the office chair
- Maximum value: 900°C

_Infrared pictures converted to an equivalent temperature of blackbody (ie which radiates at the same power)._
Characterization of radiative flux

At time to peak HRR
- Fire has propagated at the chair back
- Fast fire propagation fire
- Maximum value: 1000°C
Characterization of radiative flux

At water mist activation
- Sudden fall of received radiative flux
- Maximum emission on the hiding area under the office
- Maximum value: 600°C
Radiative flux emitted by combustion gases (in terms of spectral intensity [W.m$^{-2}$.sr.cm$^{-1}$])

At time to peak HRR

$$(\text{H}_2\text{O})_v \ (\approx 2,9 \ \mu\text{m})$$

Suie ($\approx 3,9 \ \mu\text{m}$)

After mist activation
Fine peaks due to emission of combustion gases (CO, CO₂ et H₂O)
Continuous emission of soot particles
In the large wave numbers, the level of emission is similar to that of a high temperature flame
Sudden fall of received signal due to mist activation
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Remarked trends during the tests

- Sudden fall of temperature due to the effect of water mist
  - Strong absorbed heat due to the strong evaporation of water droplets
  - Direct injection on the fire ⇒ HRR decrease
  - Temperature becomes more uniform in the test compartment due to smoke destratification
  - Compartment environment is becoming thermally stratified again when mist is stopped
Remarked trends during the tests

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  - Compartment environment is becoming thermally stratified again when mist is stopped

- Decrease of the visibility due to the effect of water mist and slowly rises after mist stop
  - Absorbing and scattering mixing between water droplets, water vapor and smoke
  - Decrease of the visibility without water mist
  - Weakly rise after mist stop
Remarked trends during the tests

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- Sudden fall of thermal radiation due to water mist
  - Effect of radiative shield
  - Decrease of thermal radiation production considering the direct spraying of the fire
  - Control of the fire propagation
Perspectives

- Experimental and numerical research in building configurations (within corridor for example)
- Characterization of fires (several types of fire: pool, wood crib, furniture and impact of ventilation)
- Characterization of smoke (composition and optical properties)
- Interaction fire-spray, smoke-spray with water mist and sprinkler (relative to the water droplet size)
- Transmissivity through a water mist (without smoke) and a sprinkler: visibility analysis