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A water mist system evaluation based on real scale fire tests

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INSTITUT CARNOT CSTB

1 Context

2 Test set-up

3 Experimental results
- Temperature
- Transmissivity
- Radiative flux

4 Conclusion

Context

Context
Test set-up
Experimental results
Temperature
Transmissivity
Radiative flux
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

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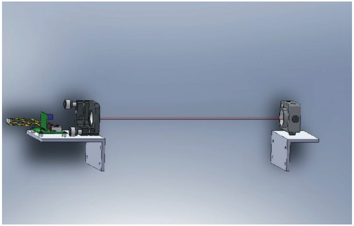
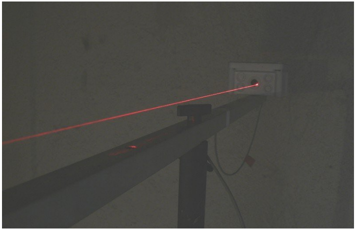
- CSTB building designated for real scale fire test
- Test compartment of 15 m by 15 m with removable ceiling (with a maximum height of 6 m)

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 :

$$Tr = \frac{\textit{Signal during test}}{\textit{Reference signal}}$$

Visibility measurements : data processing

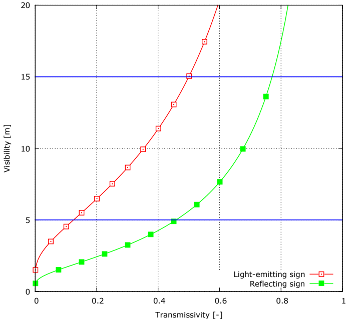
- Transmissivity and extinction coefficient

$$\beta = -\frac{1}{L} \ln Tr$$

- Extinction coefficient and distance of visibility : Jin's relation

$$V = \frac{C}{\beta}$$

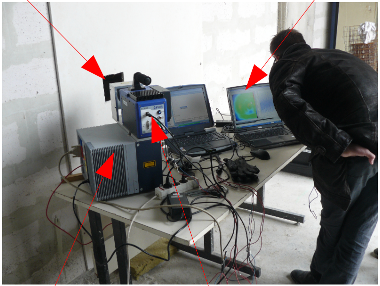
- Distance of visibility



- Levels at 5 m and 15 m : validity domain of Jin's equation
- Under and above these limits : extrapolation of Jin's equation

Radiative flux measurements

- Multi-spectral IR camera and spectrometer (LEMTA)



- Simultaneaous display of the same emission area
- IR camera : 4 pictures at the same time with 4 spectral bands (CO_2, H_2O, soot, infrared radiation between 1,5 μm et 5,5 μm)

Fuel load

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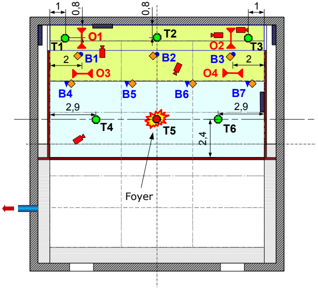
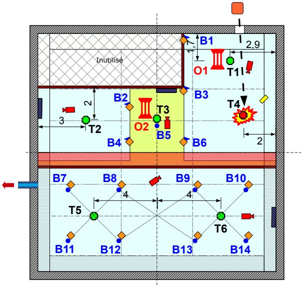
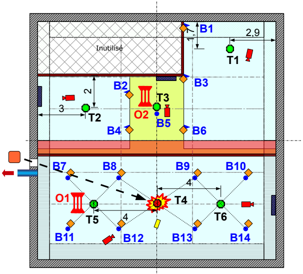
- Office furniture and transfer cases

Metrology plans

- Thermocouple tree
- Thermocouple near spraying nozzle
- Thermocouple shaft above the fire
- Opacimeter
- Camera
- Test pattern
- Fluxmeter
- Spraying nozzle
- Spectrometer and multi-spectral infrared camera







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Evolution of temperature

- Context
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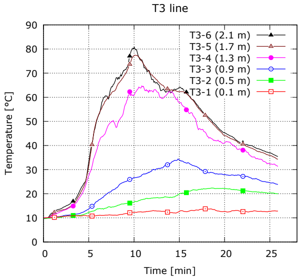
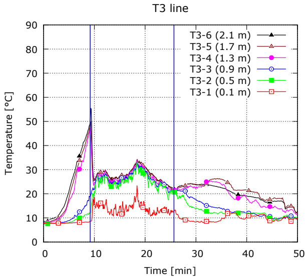


Test without water mist

- 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

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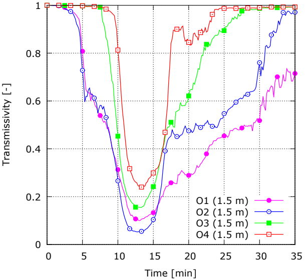
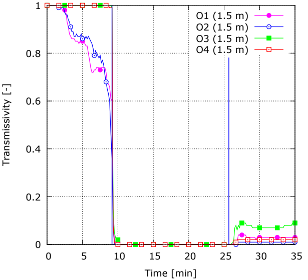
Evolution of transmissivity (1/2)





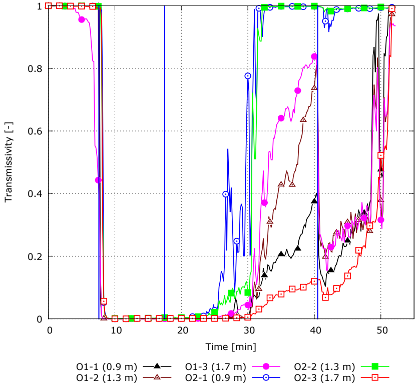
Test without water mist

- Significant fall of transmissivity
- Lowest value : between 5 % and 25 %
- Gradual increase due to the decline of the fire activity

Test with water mist

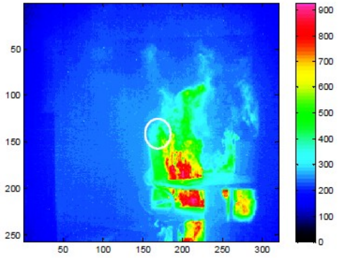
- Decrease of transmissivity before mist activation (between 40 % and 60 %)
- Sudden fall at mist activation explained by smoke destratification
- Weak increase after mist stop (at few percents)

Evolution of transmissivity (2/2)



- 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

Characterization of radiative flux



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).

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Characterization of radiative flux

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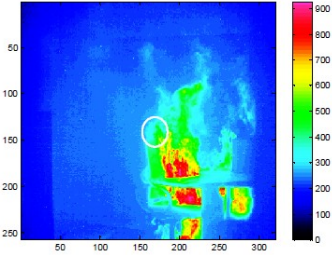

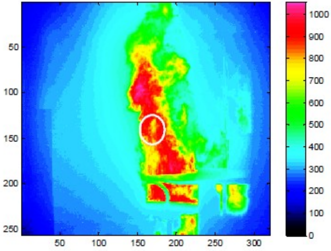

At time to peak HRR

- Fire has propagated at the chair back
- Fast fire propagation fire
- Maximum value : 1000°C

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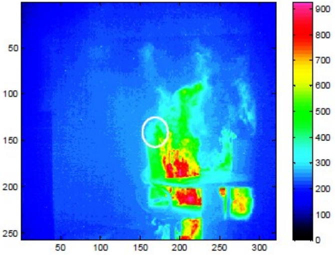
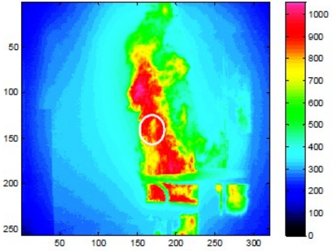
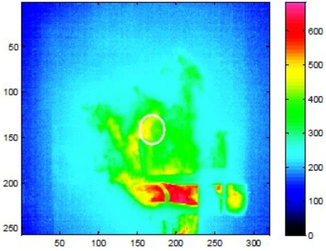
Characterization of radiative flux





At water mist activation

- Sudden fall of received radiative flux
- Maximum emission on the hiding area under the office
- Maximum value : 600°C



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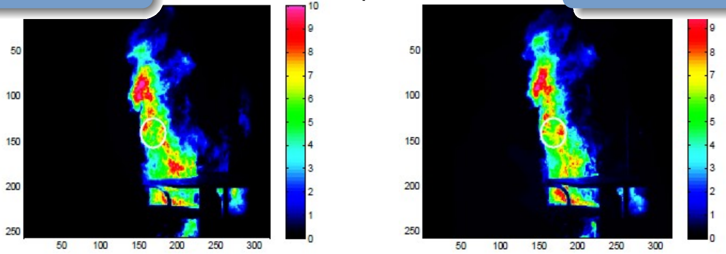
Radiative flux emitted by combustion gases
(in terms of spectral intensity [$W.m^{-2}.sr.cm^{-1}$])

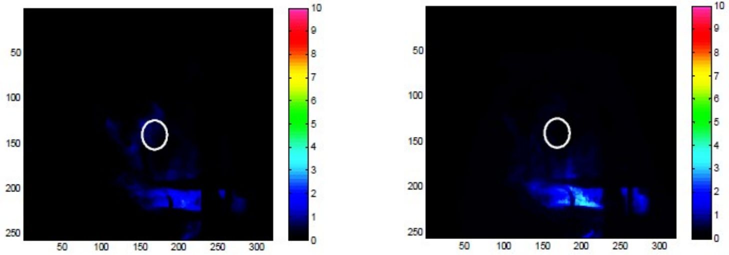
$(H_2O)_v$ ($\approx$ 2,9 μm)

Suie ($\approx$ 3,9 μm)

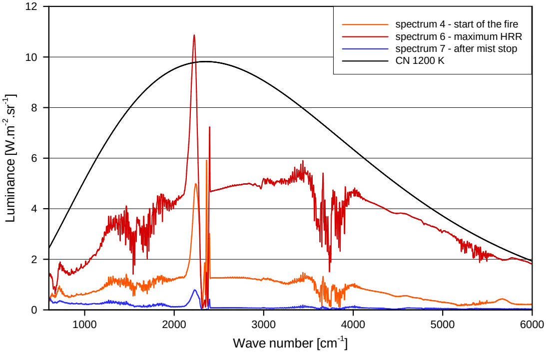
At time to peak HRR



After mist activation



Emission spectrum (in terms of intensity [$W.m^{-2}.sr.cm^{-1}$])



- Fine peaks due to emission of combustion gases (CO, CO_2 et H_2O)
- 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

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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

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  - Weakly rise after mist stop
- 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