# Experimental and numerical studies to assess the benefits of water mist system in Mont-Blanc tunnel

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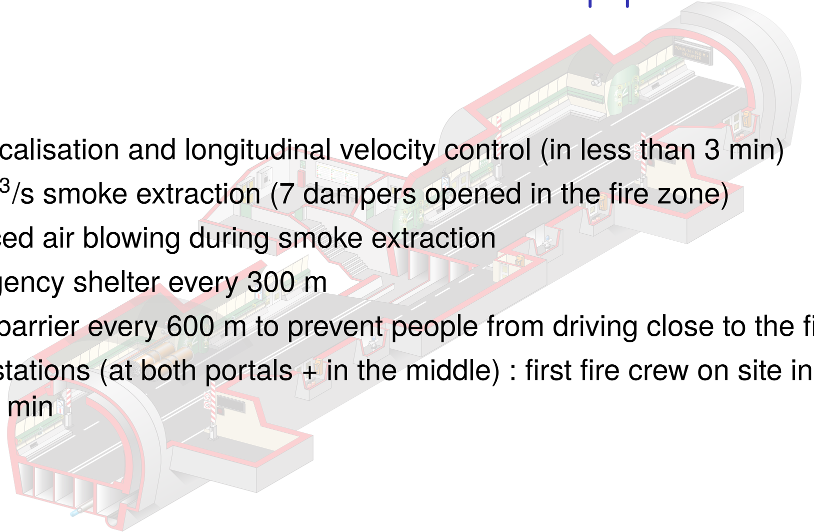
# Presentation outline

# Use of water mist in Mont-Blanc tunnel

- Bibliographic review of existing fixed fire-fighting systems (FFS)
- Experimental performance assessment of several types of FFS at scale 0.8
- Numerical simulations to evaluate the interaction of water mist system with existing safety equipment and procedures

**What are the benefits of using water mist in the Mont-Blanc tunnel in its existing state ?**

# Mont-Blanc tunnel current high-end safety equipments



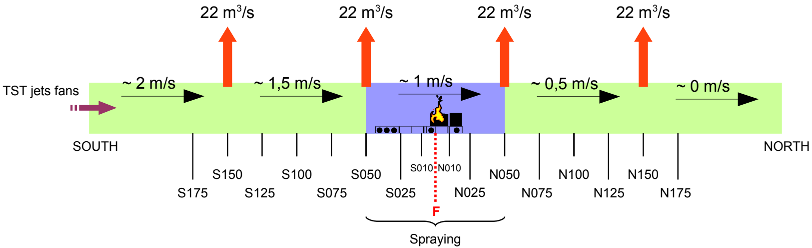
- Fire localisation and longitudinal velocity control (in less than 3 min)
- 156 m$^3$/s smoke extraction (7 dampers opened in the fire zone)
- Reduced air blowing during smoke extraction
- Emergency shelter every 300 m
- Road barrier every 600 m to prevent people from driving close to the fire
- 3 fire stations (at both portals + in the middle) : first fire crew on site in less than 7 min

# Experimental campaign

15 fire tests carried out in the TST tunnel tests facility (San Pedro, Spain)

# Experimental campaign

- 3 FFS technologies : SPK, low-pressure & high-pressure water mist
- 2 fire load compositions (using electric cables, tyres, hidden surfaces)
    - 30 MW wood
    - 50 MW wood and gasoil
- Generate steady longitudinal flow (with extraction) then start the fire
- 2 activation strategies
    - At fire detection (heat sensor cable)
    - At t = 7 min (firefighters arrival)
- Monitoring of temperature, velocity, gas composition, heat flux, etc.



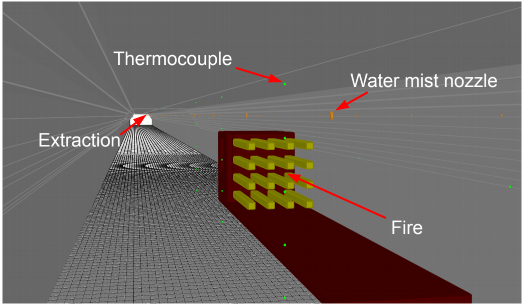
# Experimental campaign main findings

- High-pressure water mist system provides the global best performance (gas cooling and fire suppression), especially when activated at 7 min
- High-pressure water mist and sprinkler give similar results when activated early (at fire detection)
- Significant reduction of visibility has been observed in the flooding zone with water mist (smoke de-stratification and water droplets)
- Carbon monoxyde yield is clearly affected by water flooding on the fire, but at the same time HRR is reduced

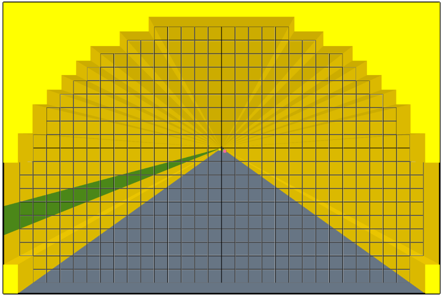
# Numerical study : overview

## Working approach

- CFD modeling using FDS (NIST, USA)
- Numerical parameters tuning by simulating 6 experimental tests
- Extensive use of FDS to simulate realistic fire scenarios




*Experimental campaign*

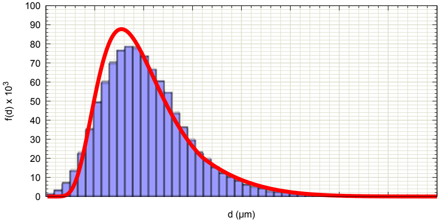


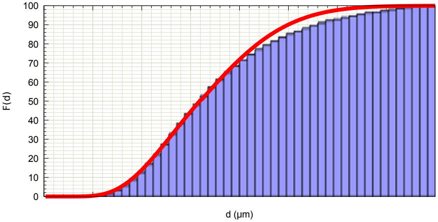
*Mont-Blanc tunnel*

# Numerical study : parameters tuning

## Fitting the Rosin-Rammler/log-normal droplets size distribution

$$F(D) = \begin{cases} \frac{1}{\sqrt{2\pi}} \int_0^d \frac{1}{\sigma d'} \exp\left(-\frac{[\ln(d'/d_m)]^2}{2\sigma^2}\right) dd' & (d \leq d_m) \\ 1 - \exp\left(-0.693 \left(\frac{d}{d_m}\right)^\gamma\right) & (d > d_m) \end{cases}$$



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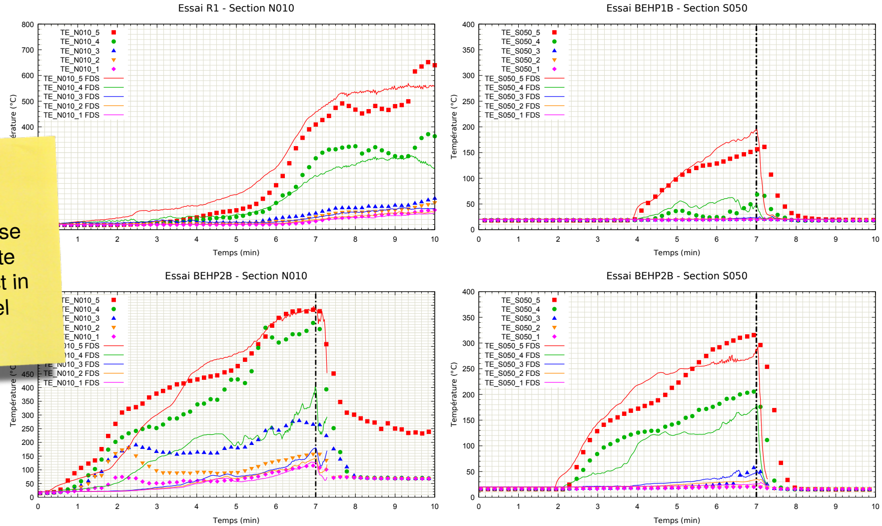
# Numerical study : validation

## Comparison with experimental data




Acceptable agreement to use FDS to simulate water mist effect in the real tunnel

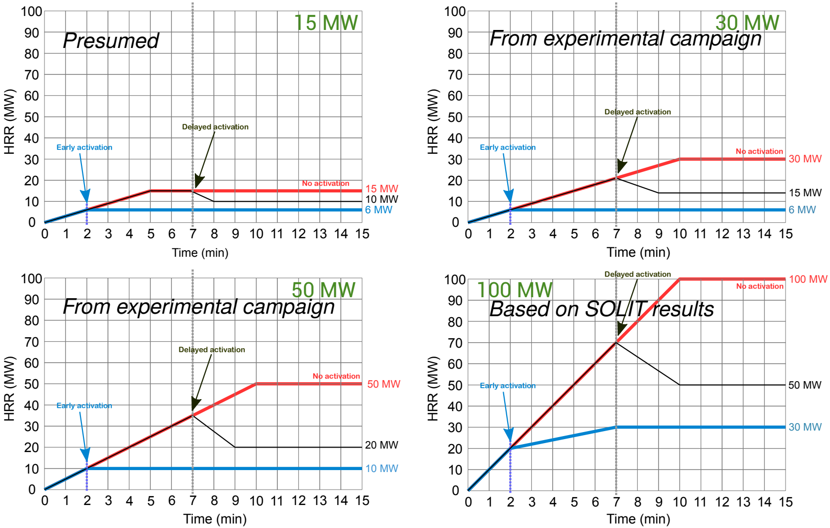
# Numerical study : fire scenarios

**Numercical simulation of 36 fire scenarios (3’000 hours of calculation)**

- 4 fire intensities
  - 15 MW (big light vehicle fire, common serious fire case)
  - 30 MW (design HGV fire for ventilation system)
  - 50 MW (big HGV fire)
  - 100 MW (huge HGV fire - dangerous goods are forbidden)
- 3 initial natural draught conditions due to meteorological effects (quickly vanished thanks to longitudinal velocity control system)
  - $\Delta p = 100$ Pa $\Rightarrow$ initial 1.9 m/s
  - $\Delta p = 300$ Pa $\Rightarrow$ initial 3.4 m/s
  - $\Delta p = 500$ Pa $\Rightarrow$ initial 4.3 m/s
- 3 FFS activation strategies
  - no activation (current configuration)
  - activation at 2 min (as fire is detected)
  - activation at 7 min (firemen arrival on site)

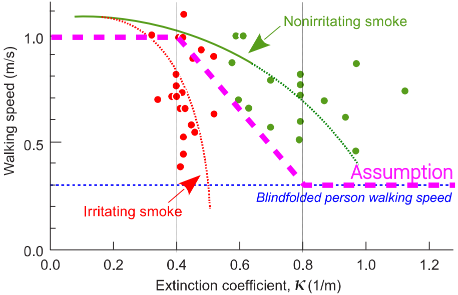
# Numerical study : assumptions

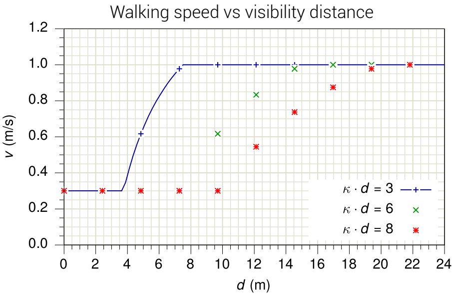
## Simplified HRR curves



# Results analysis methodology

- Tenability conditions for people : FED calculation (heat and toxicity)
- Walking speed affected by visibility

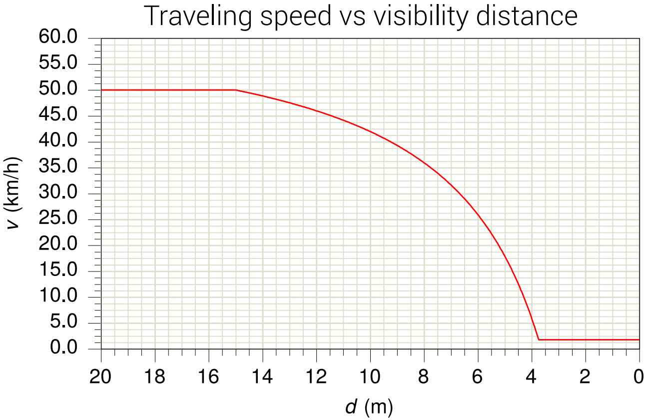



- Reduced visibility within water mist taken into account

# Results analysis methodology

- Firemen intervention conditions (temperature and radiative heat fluxes)
- Firemen traveling speed affected by visibility



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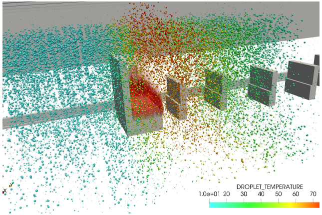
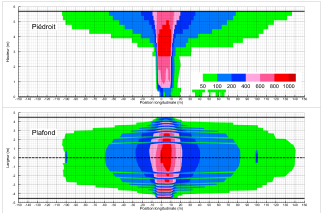
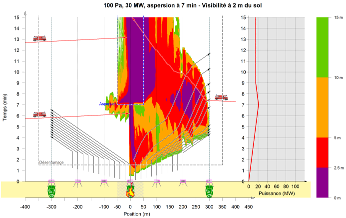
# Results analysis : types of representation

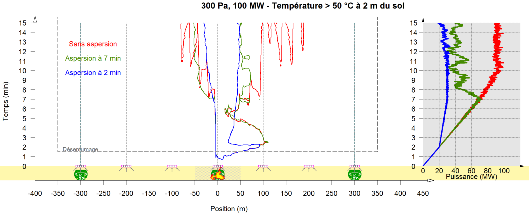
- Water mist interaction with fire and damages to the structure




- Evacuation conditions



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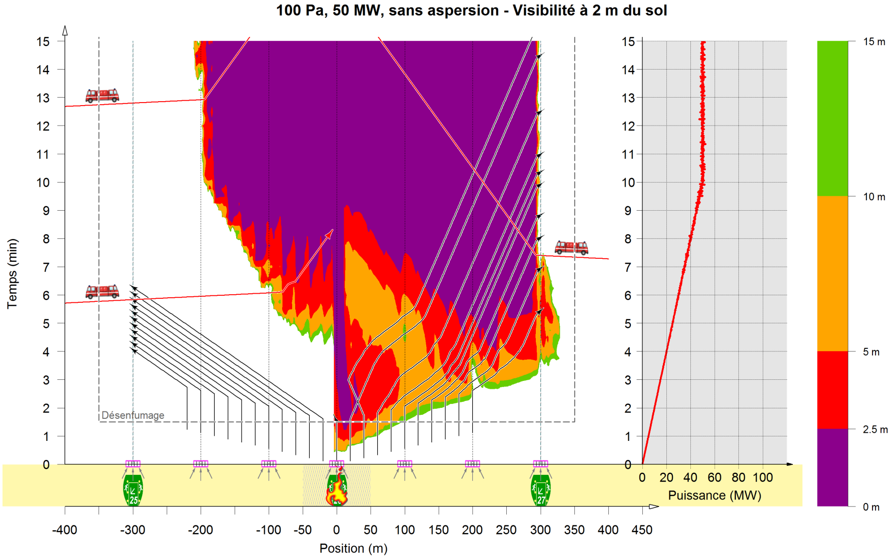
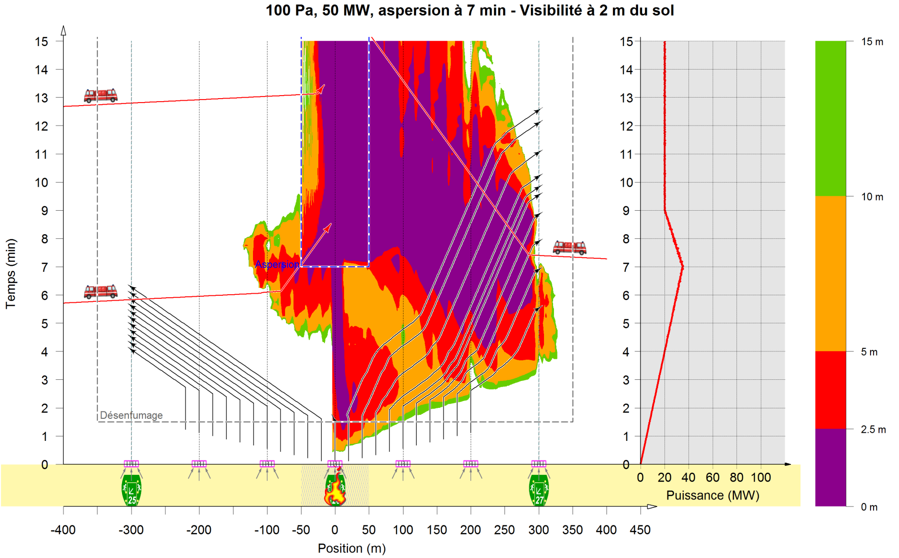
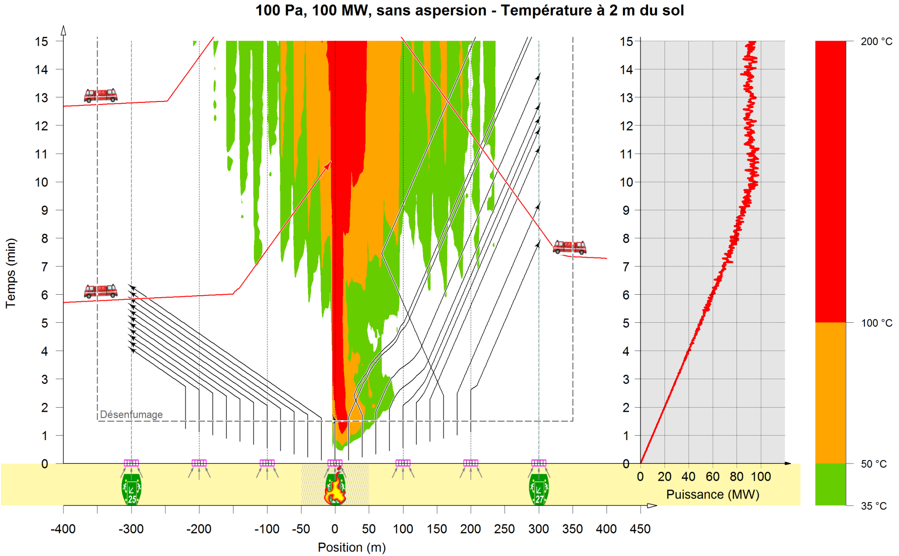
# Results analysis : effect on visibility



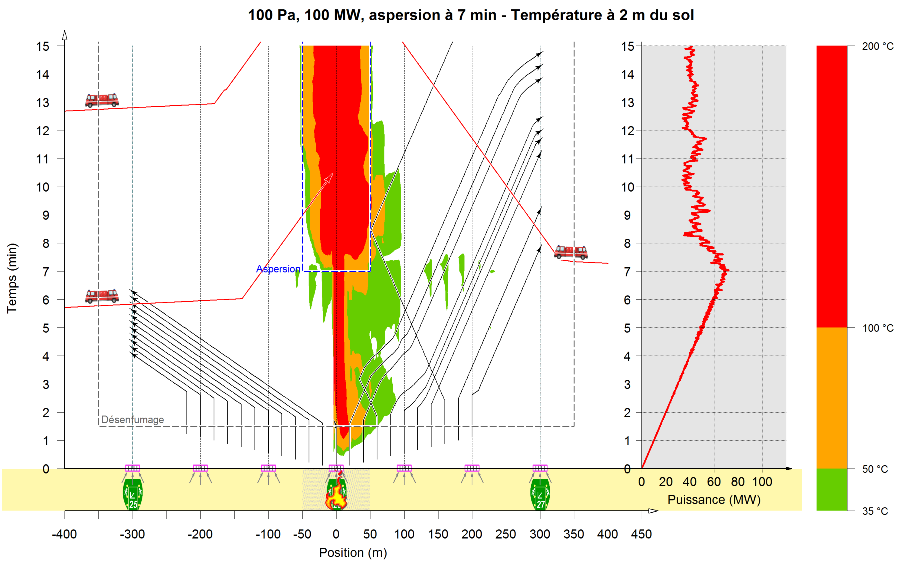
# Results analysis : effect on visibility



# Results analysis : effect on temperature



# Results analysis : effect on temperature



# Conclusion

- Early activation leads to significant degradation of visibility and temperature in the flooding area, that may disturb evacuation
- No significant asset for safety of users up to medium fires (15 MW, 30 MW) because the existing smoke management system is very effective in Mont-Blanc tunnel
- Aspersion can help firemen with their progression to the fire, by reducing smoke generation
- But firemen operating conditions can be deteriorated (reduced visibility near the fire and temperature increase with water vapor)
- Very good results to protect structure and equipments when facing big fires (50 MW, 100 MW)
- The technical feasibility has not been studied here

# Thank you for your attention