Topic: Research and Testing

Water Mist Effect on Large Fire Tests, Use of CFD to Investigate Untested Conditions

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Abstract

In September 2010 several large fire tests were conducted by Fogtec in the San Pedro de Anes tunnel tests facility (Spain) to evaluate the efficiency of a high pressure water mist system on a large fire. The fire load was composed of standard wood pallets simulating a severe truck fire under different ventilation conditions.

Few locations offer the possibility to perform real fire tests. Generally, the geometry (cross section) of the test tunnel differs quite substantially from the one of the real tunnel. While reduction of the test tunnel cross section to fit real geometry is conceivable (though difficult and costly), enlargement of the test tunnel is obviously not possible. For this last case, extrapolations of the tests results for larger cross section, using CFD simulations, can provide useful help.

In this study the NIST Fire Dynamics Simulator version 5 (FDS) was used for the simulation of a full-scale fire test with water mist system, conducted in a test tunnel. The aim was first to validate the model by demonstrating a reasonable degree of agreement with the data measured during one of the test. Then the model was used to extrapolate the performance of the water mist system under untested conditions, as for example with a different tunnel's geometry. The objective was to study the impact of the tunnel's geometry on temperatures.

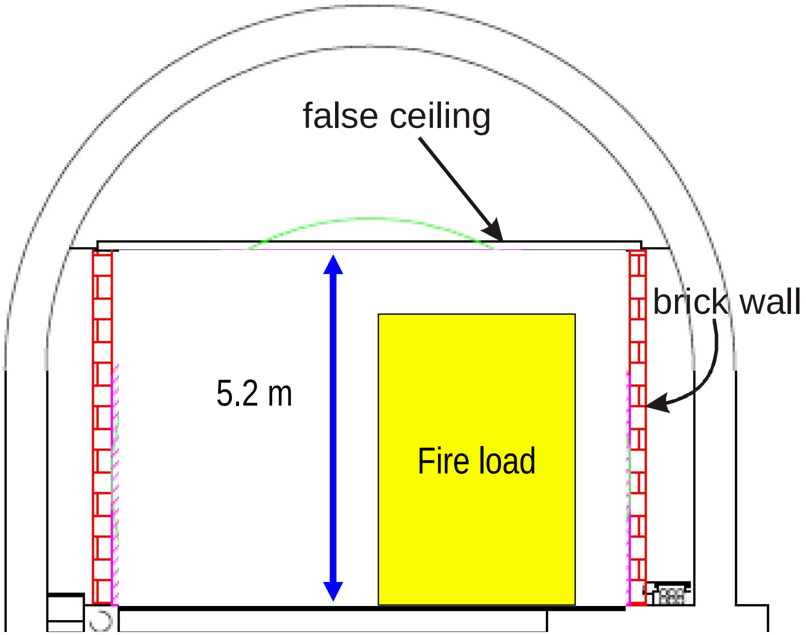
After having described the fire test's set up and the test's results, this article will concentrate on the CFD model and the correspondence between the tests results and the simulations. The impacts of the larger tunnel cross section of the real tunnel will then be discussed in terms of temperature fields.

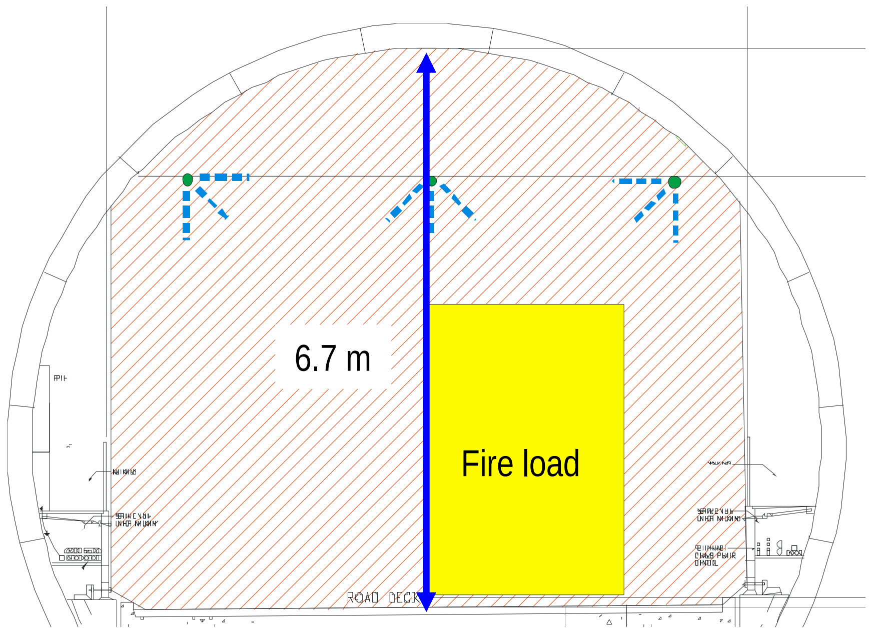
Introduction

When test tunnel geometry differs from "real" tunnel geometry

Test Tunnel

Road Tunnel





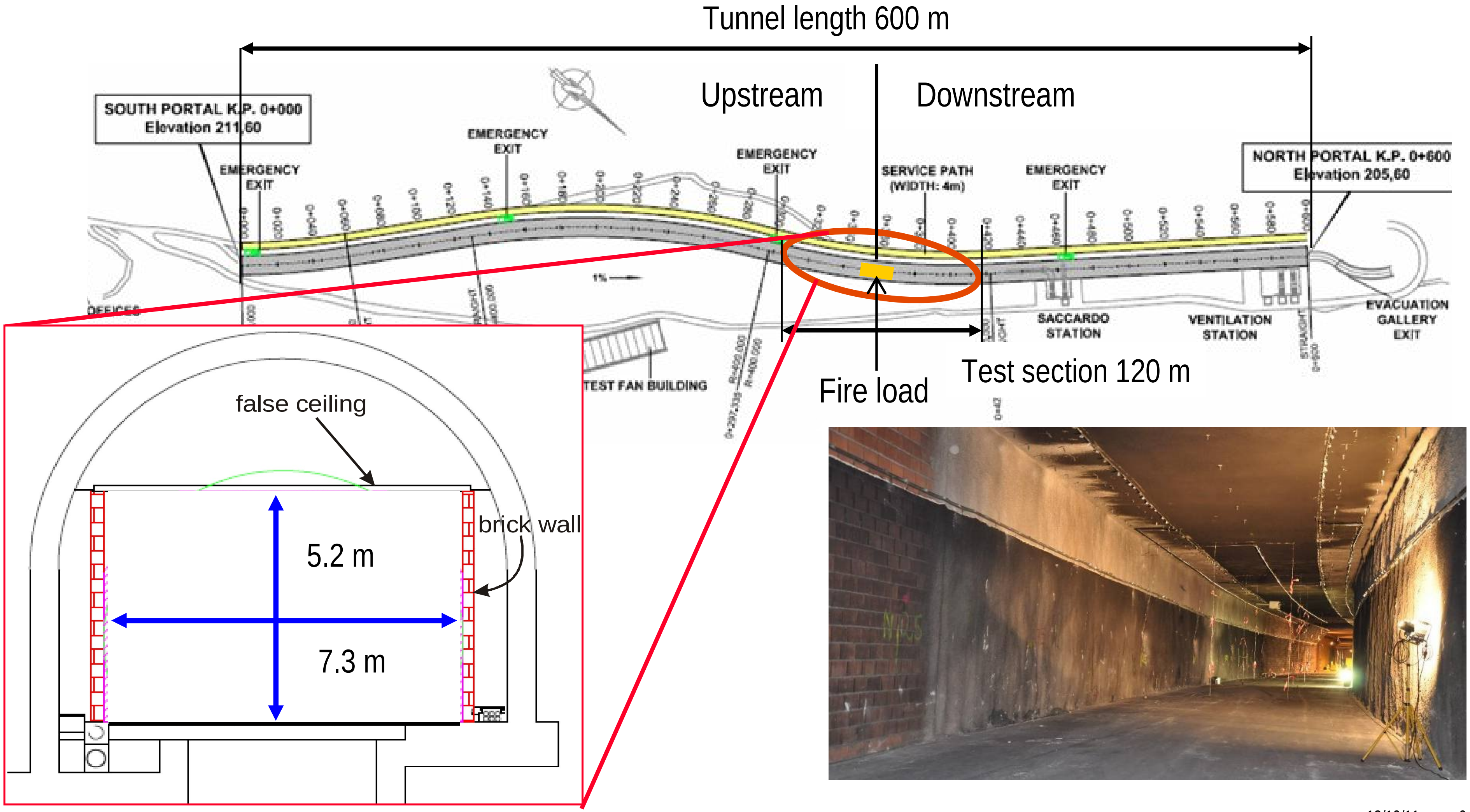
CFD Modelling of Tunnel Fires

- CFD based on real test data is a powerful tool to examine more than is measured during tests
- NIST Fire Dynamic Simulator (FDS) version 5
- Use fire test data to evaluate the model
- Use the model to explore untested scenarios

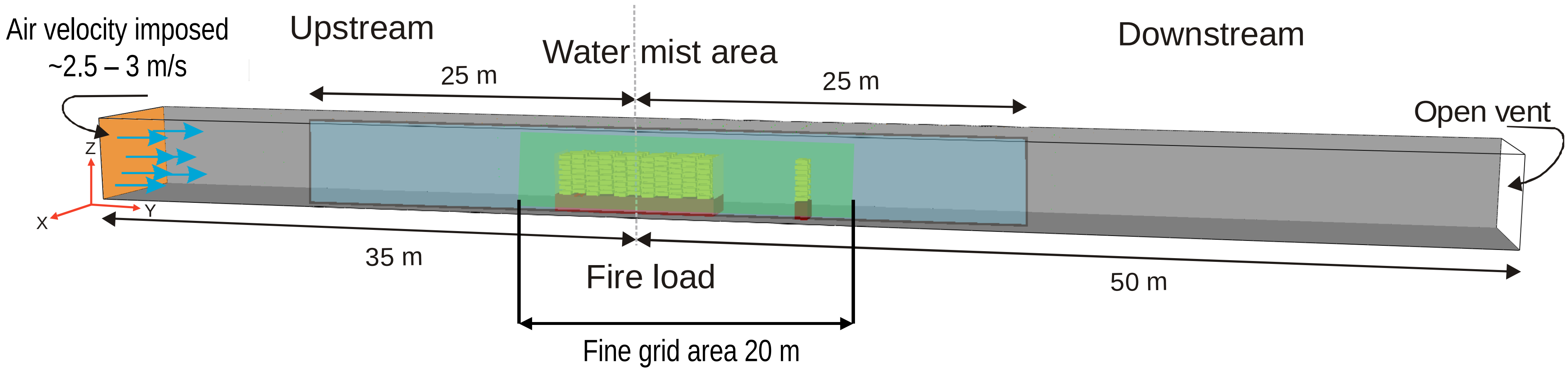
- Chaotic behavior of large fires

Test Tunnel

TST Test Facility at San Pedro des Anes (Spain)



Simulated Tunnel



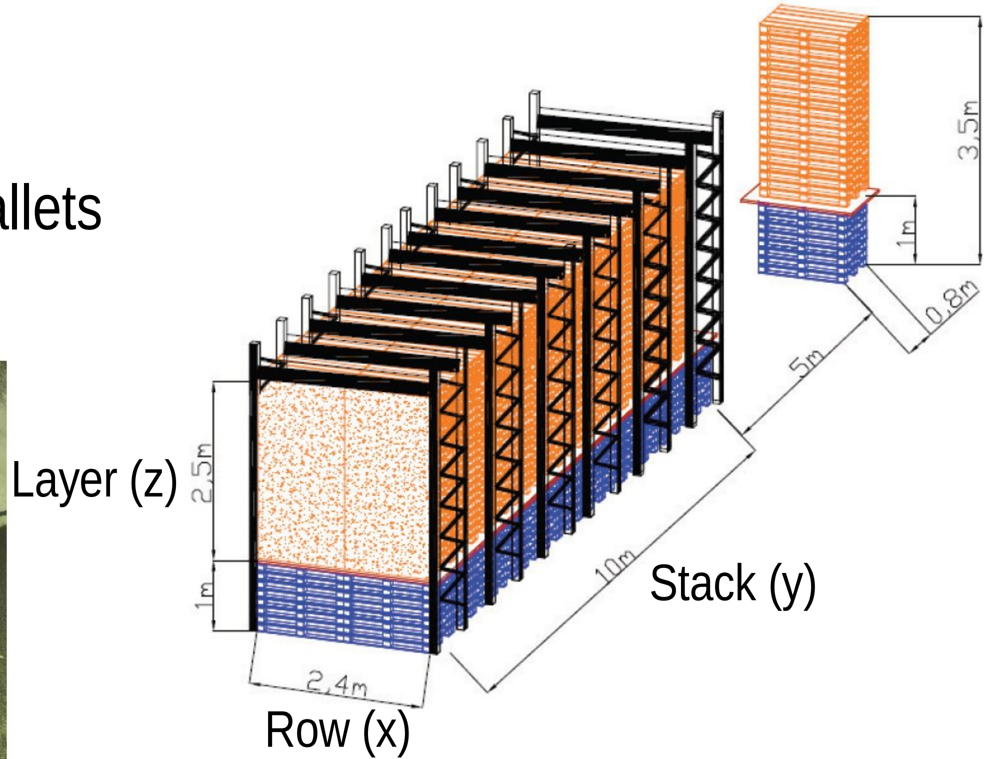
	Test Tunnel	FDS Model
Height (max)	5.2 m	5.2 m
Height below nozzles	5.2 m	5.2 m
Width	7.3 m	7.3 m
Cross section	35.9 m^2	36.1 m^2
Distance ceiling - fire load (top)	1.7 m	1.7 m

	Computational Domain	Grid size
X Axis (width)	7.3 m	0.10 m
Y Axis (length)	85 m	0.125 m / 0.25 m
Z Axis (high)	5.2 m	0.10 m

Fire Load

- Composed of 456 standart Euro pallets simulating a severe truck fire

mock up in the test tunnel

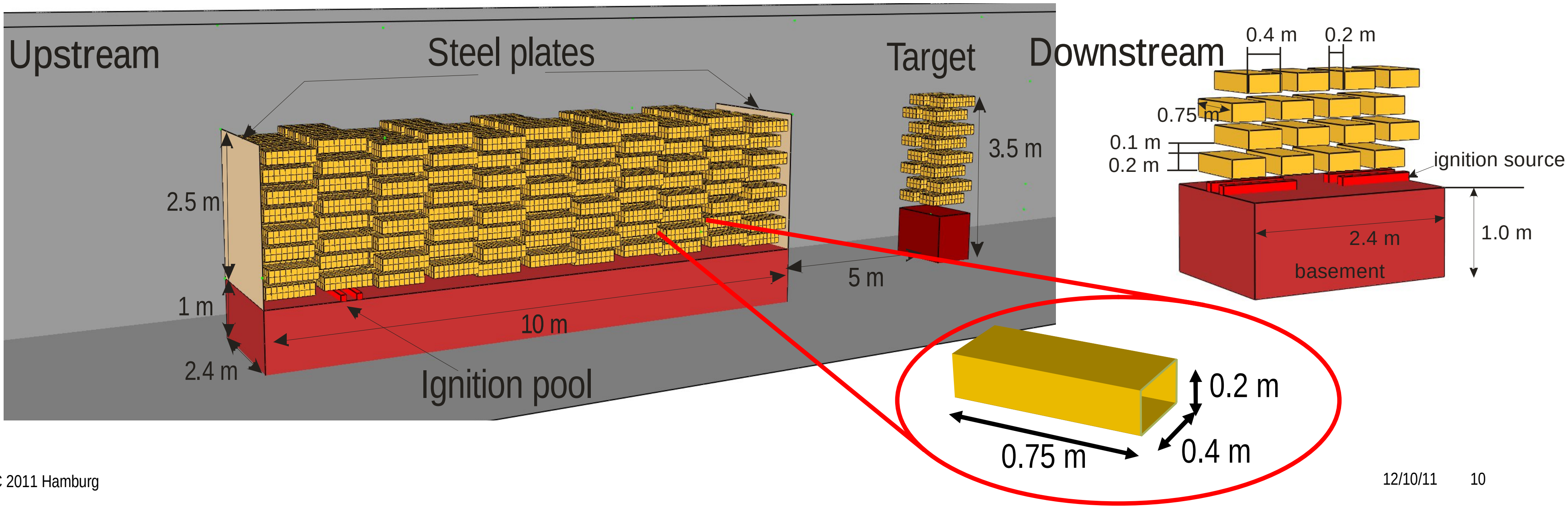


Fire Load

- § Ignition with 4 pools filled with gazoline

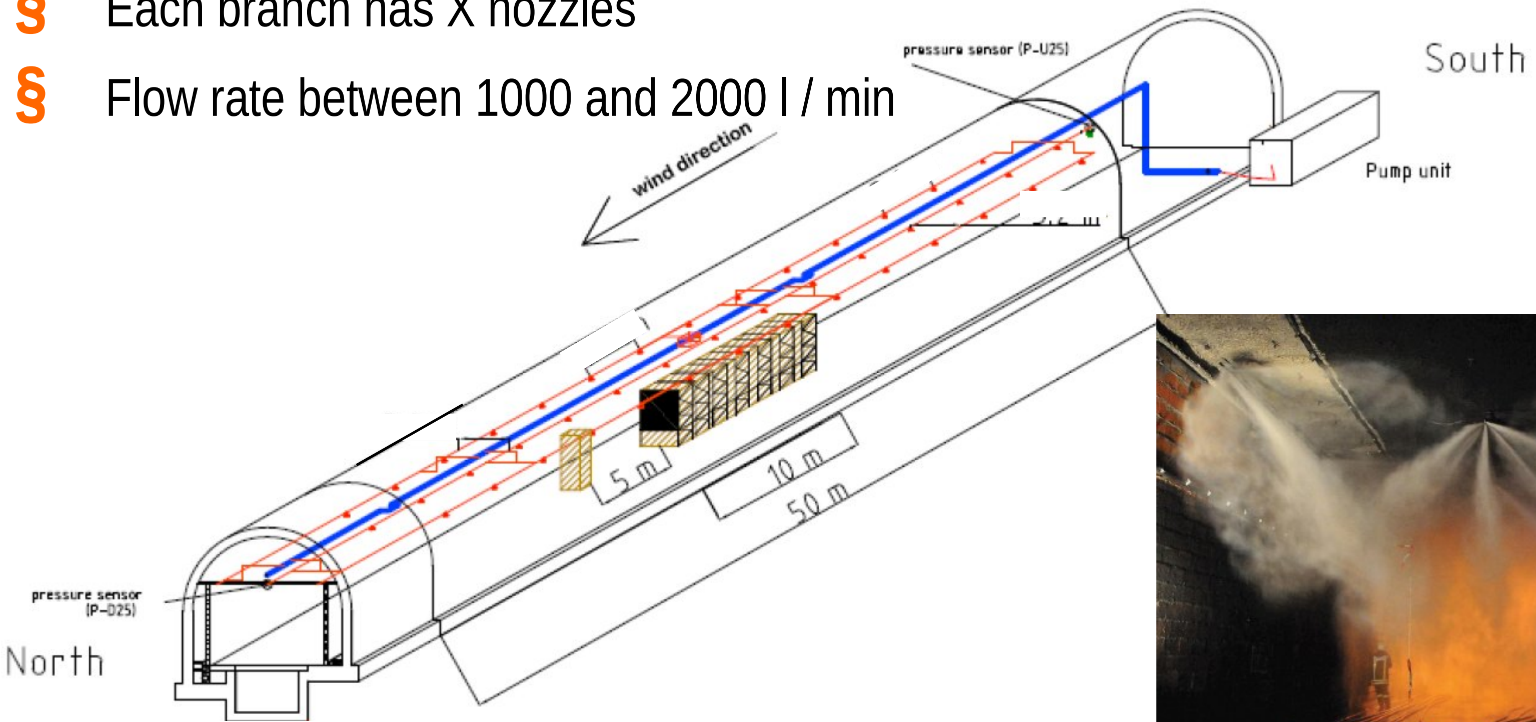
Modelling the Fire Load

- Composed of 352 wood blocks distributed in:
  - 4 rows (x axis)
  - 11 stacks (y axis)
  - 8 layers (z axis)
- Porous fuel package to allow air movement



Water Mist System

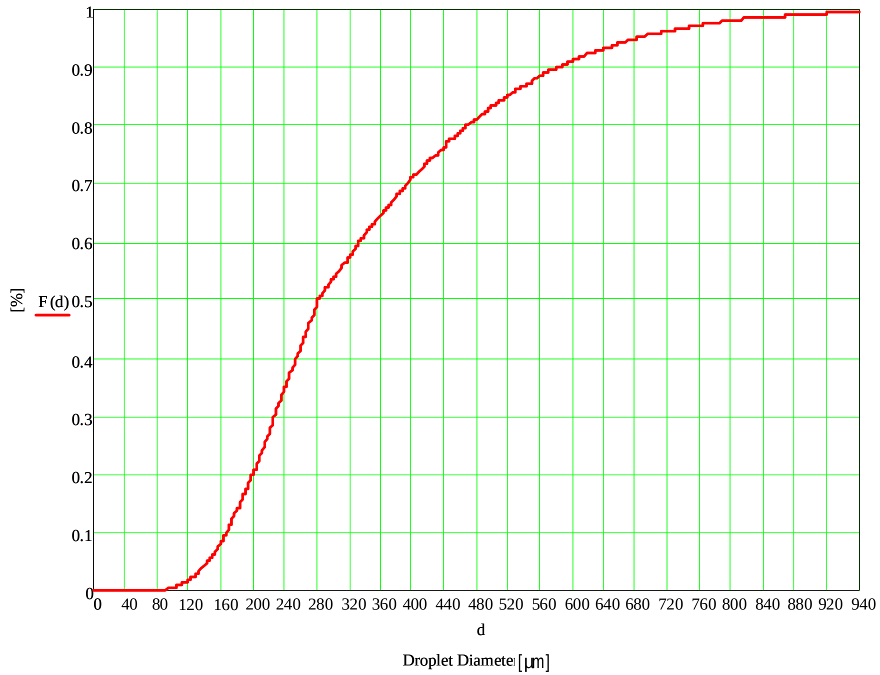
- Installed on a 50 m long section
- Composed of 3 rows of nozzles, 2 side branches, 1 middle branch
- Each branch has X nozzles
- Flow rate between 1000 and 2000 l / min



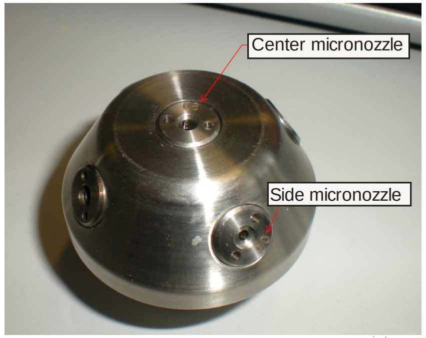
Water Mist

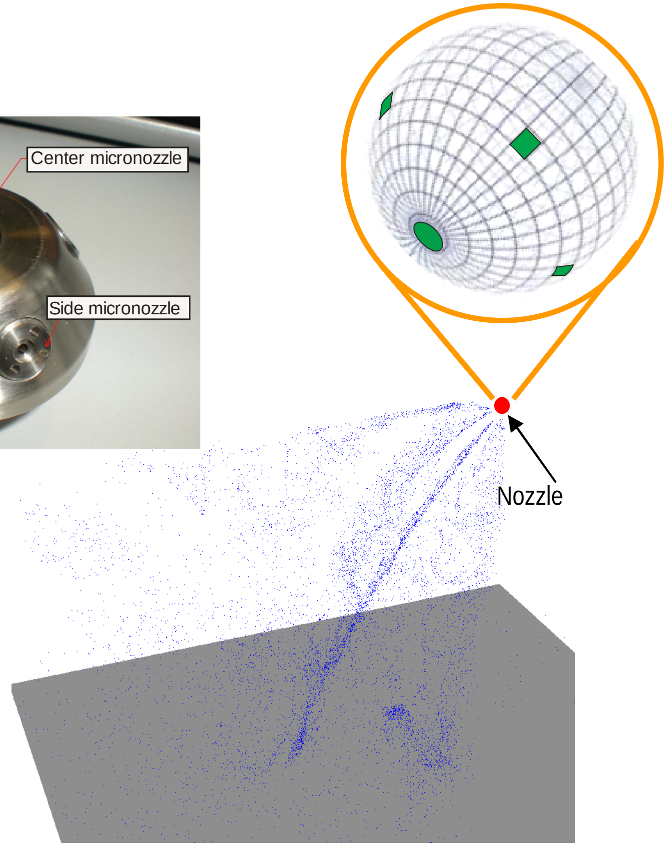
- Droplet Size distribution
  - Based on measured values Dv10, Dv50, Dv90

$$F(d)=\begin{cases}\frac{1}{2}\left[1+erf\left(\frac{\ln[d/d_m]}{\sqrt{2}s}\right)\right] & if \quad d\le d_m \quad (Log-Normal)\\ 1-e^{-\ln 2\left(\frac{d}{dm}\right)^g} & if \quad d_m>d \quad (Rosin-Rammler)\end{cases}$$



- Spray nozzle characterization
  - Spherical model
  - 2 types: side and middle nozzles

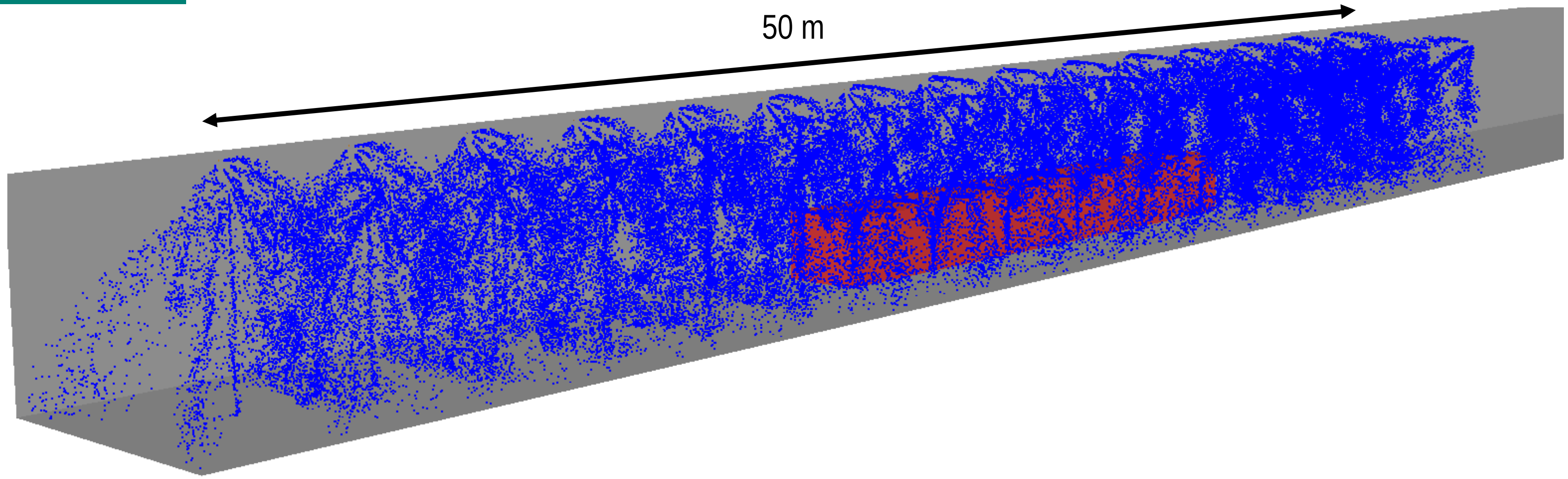




Test Sequence

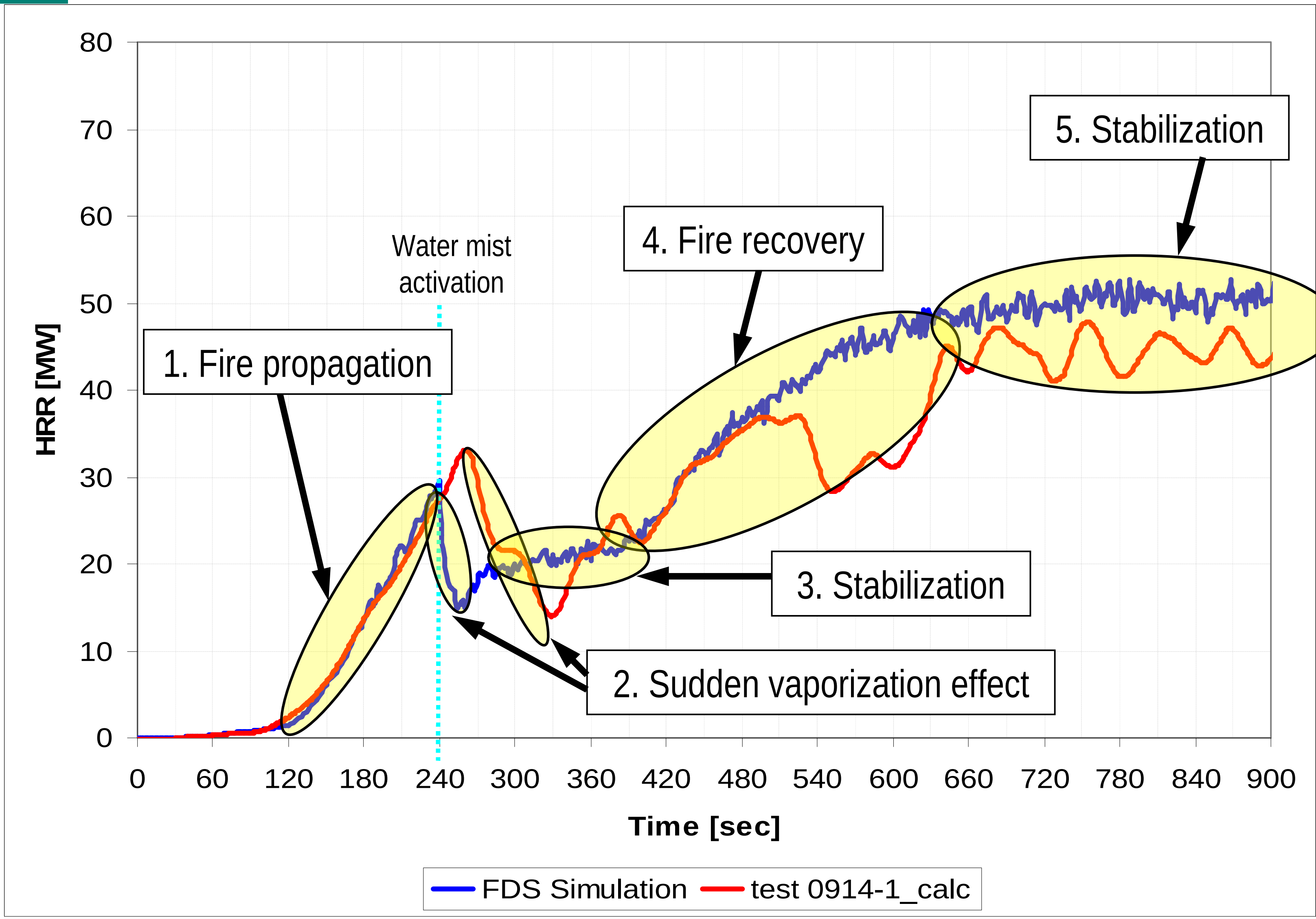
Event	Fire Test [mm:ss]	Simulation [mm:ss]
Ventilation stable (S to N) ~2.7 m/s	00:00	00:00
Ignition of the pools	00:00	00:00
HRR 20 MW	03:32	03:32
HPWM activation in tunnel	03:58	03:58
Ventilation ~2 m/s	04:20	04:20
Ventilation ~2.0 m/s -> 3.0 m/s	06:00	05:50
Ventilation ~ 3 m/s	08:00	08:00

Modelling the Water Mist

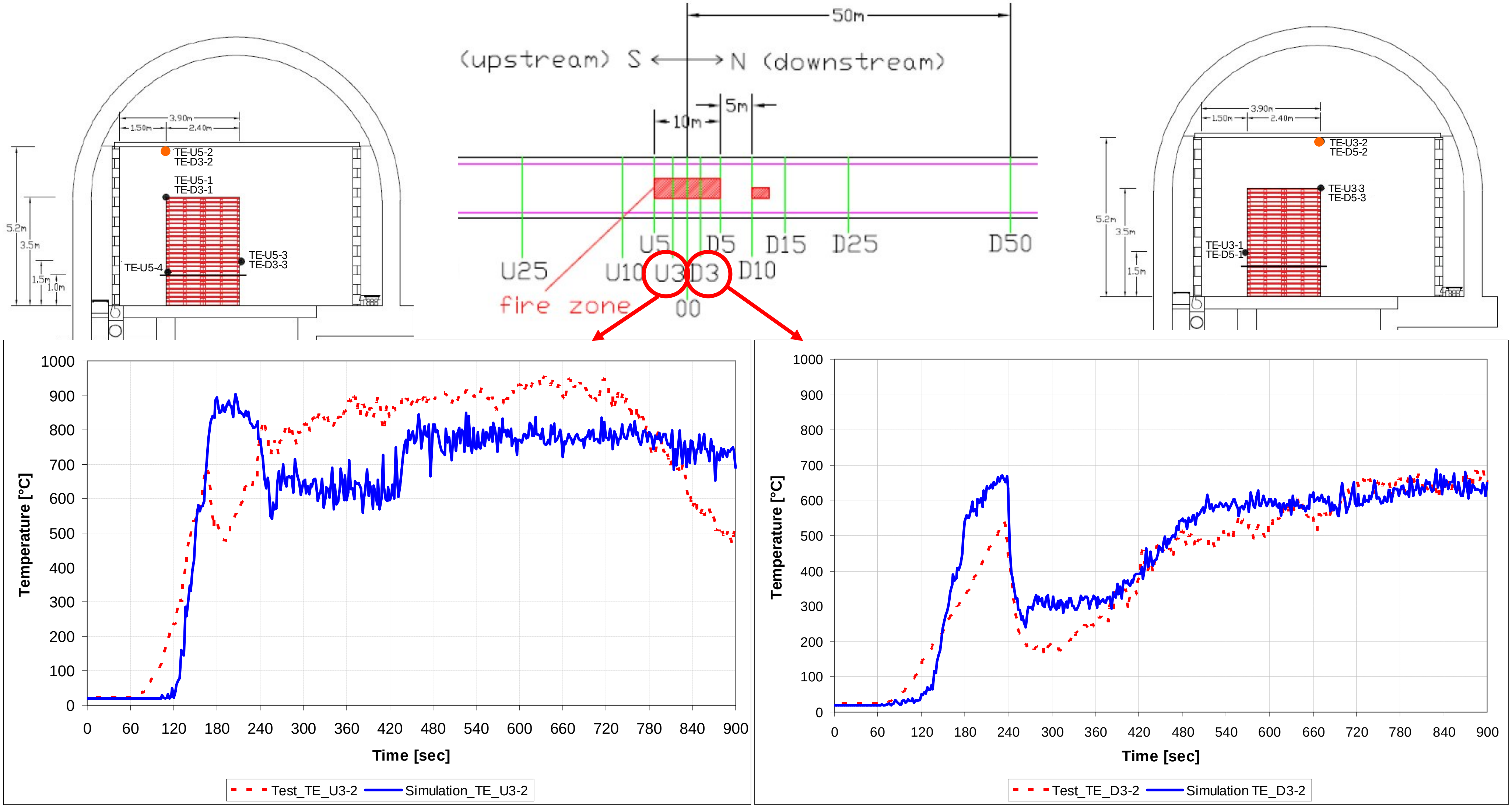


ITEM	Nozzle Specifications
Sauter mean diameter (D_{32})	< 500 **m**m
Average operating pressure	50-100 bar
K-factor	3 - 8
Flow rate	20 - 80 l/min
Activation parameter	time

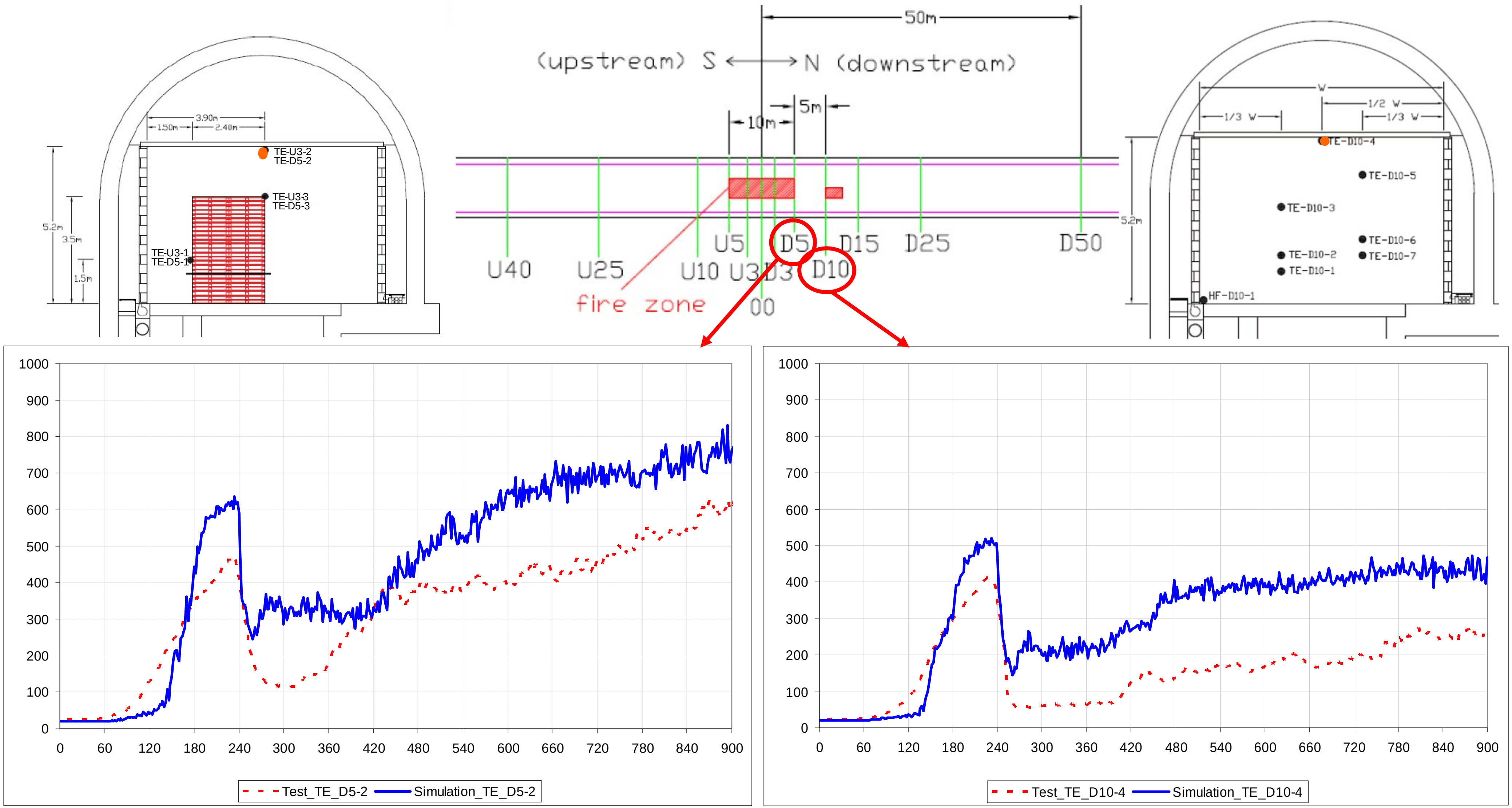
Heat Release Rate



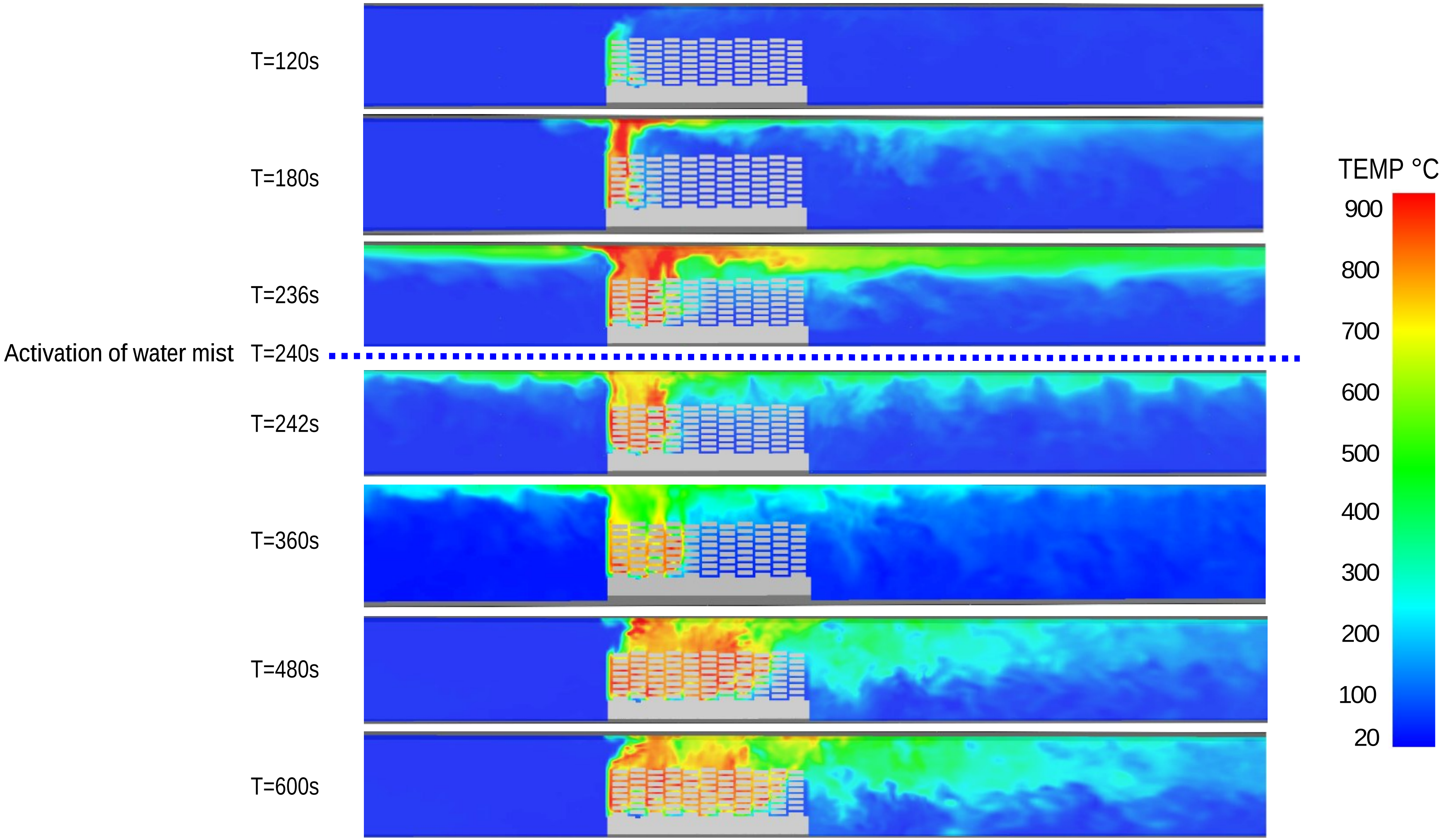
Temperatures



Temperatures

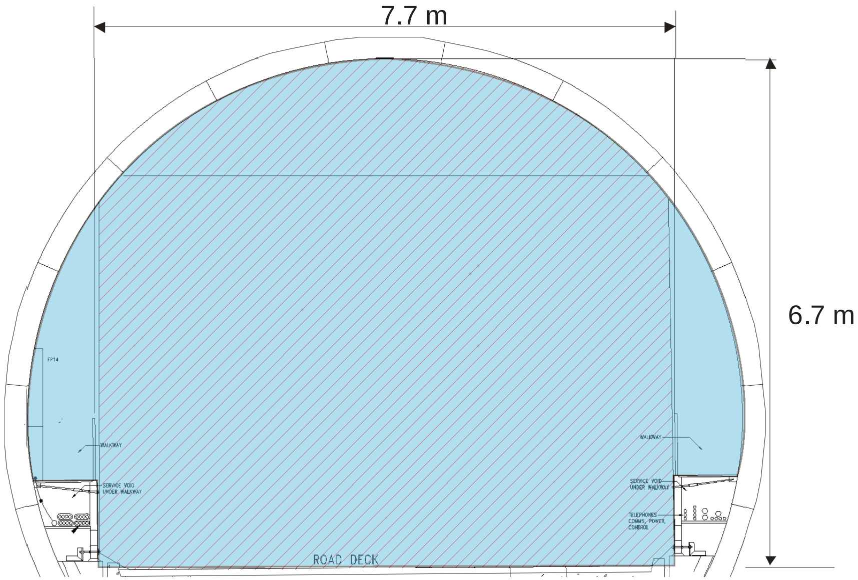


Fire Propagation

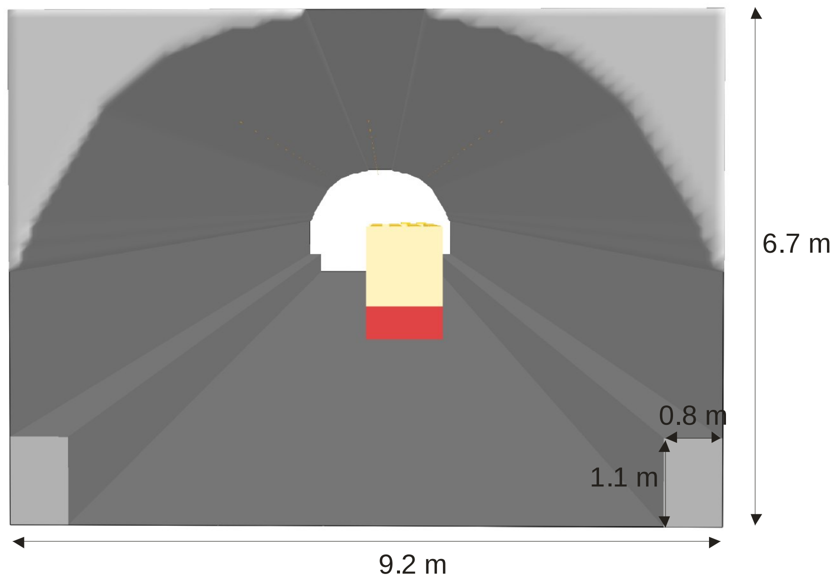


Modified Tunnel Geometry

Modified Tunnel Geometry



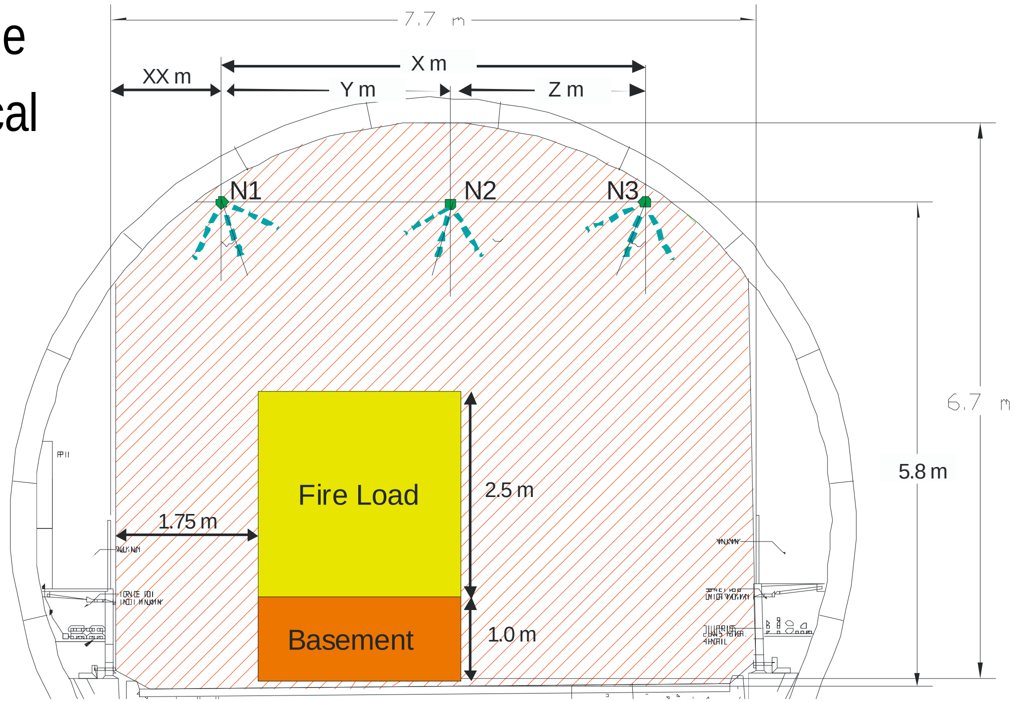
FDS Model



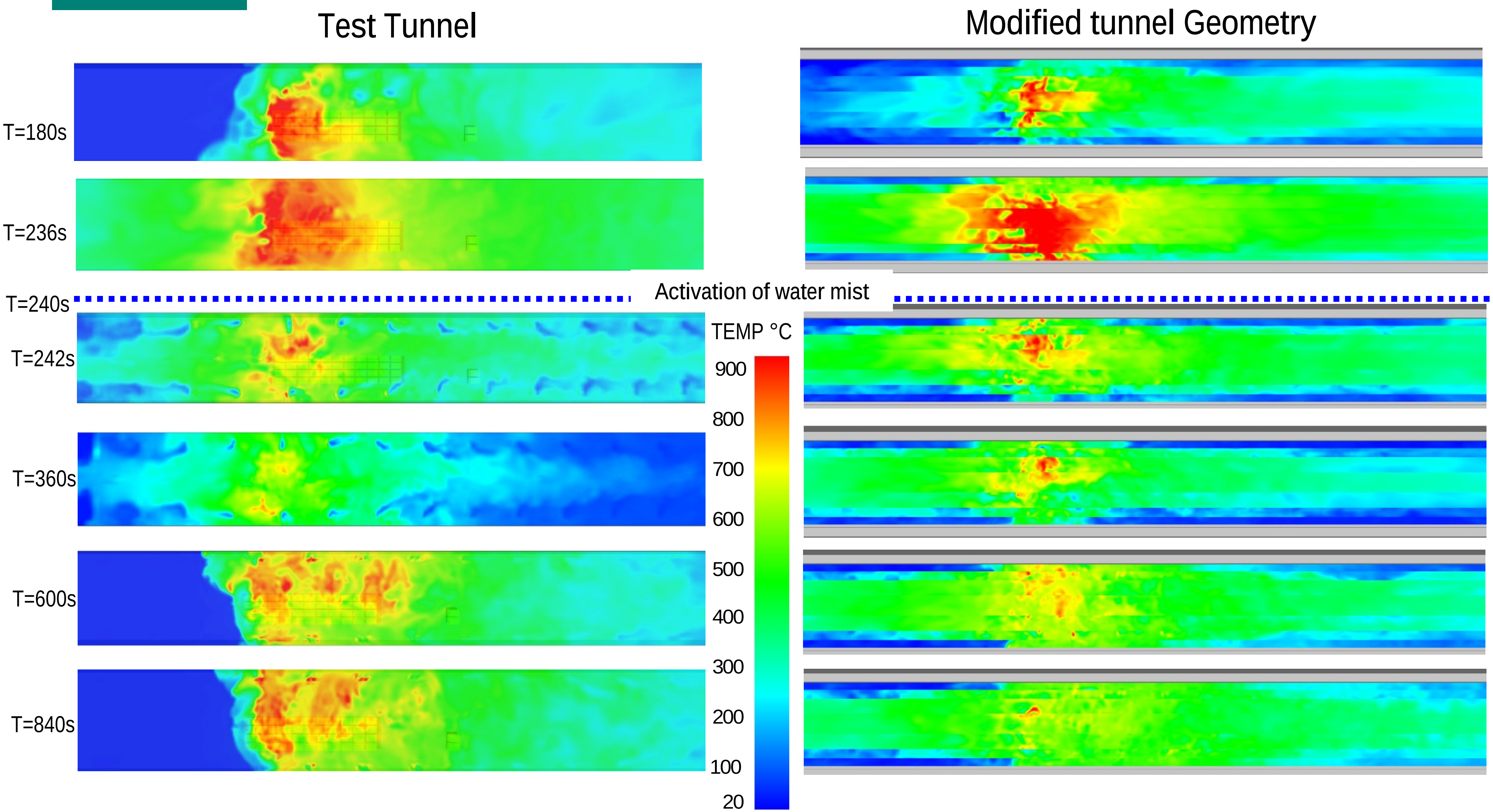
	Modified Tunnel	FDS Modified Tunnel	Test Tunnel	FDS Test Tunnel
Height (max)	6.7 m	6.7 m	5.2 m	5.2 m
Height below nozzles	5.78 m	5.8 m	5.2 m	5.2 m
Width	9.2 m	8.2 m	7.3 m	7.3 m
Cross section	53 m^2 (blue)	52.94 m^2	35.9 m^2	36.1 m^2
Distance ceiling - fire load (top)	3.2 m	3.2 m	1.7 m	1.7 m

Water Mist
in the Modified Tunnel geometry

- Nozzles disposition modified
- Longitudinal spacing remain identical
- Characteristic of the nozzles, droplet size distribution, spray pattern remain identical



Temperature comparison
at ceiling level

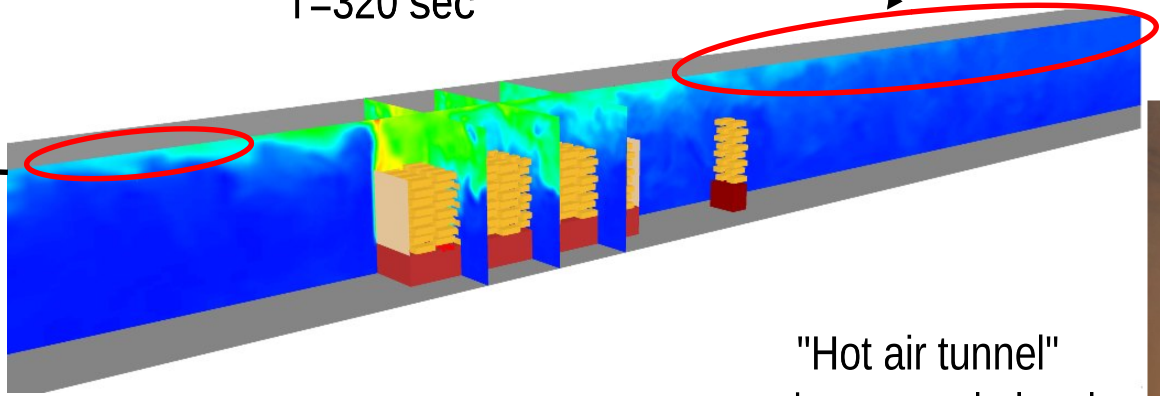


"Hot Air Tunnel"

No hot air

Simulation Test Tunnel
T=320 sec

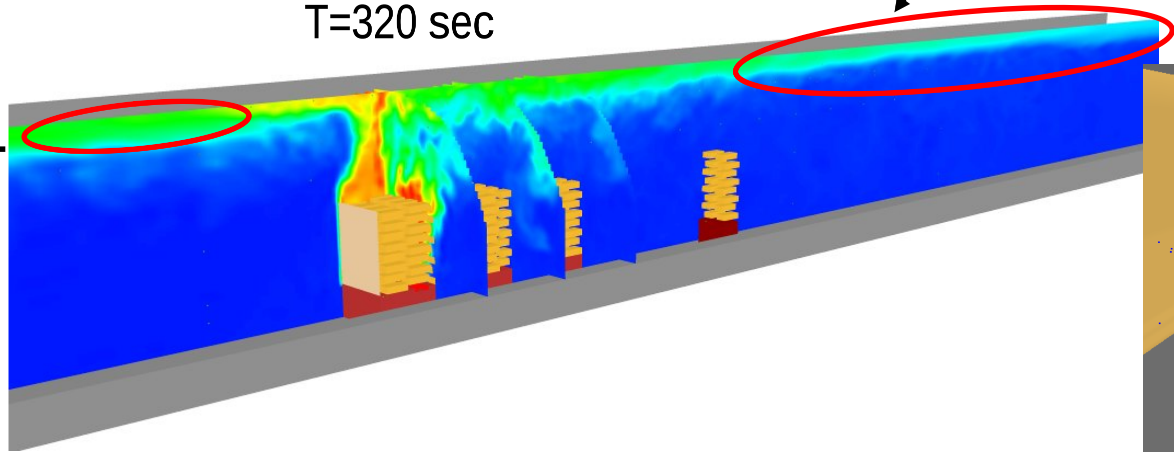
Nozzles
Level (5.2 m)

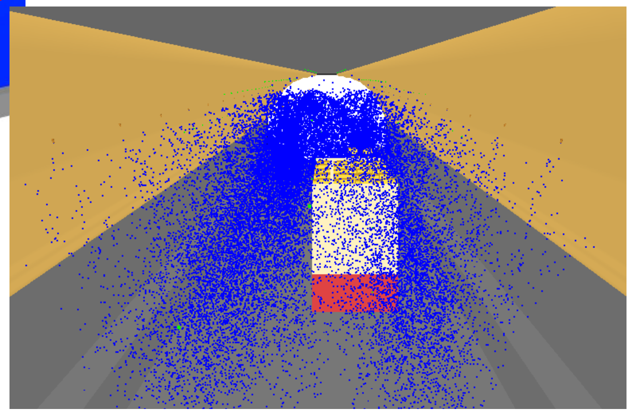


"Hot air tunnel"
above nozzle level

Simulation Modified Tunnel Geometry
T=320 sec

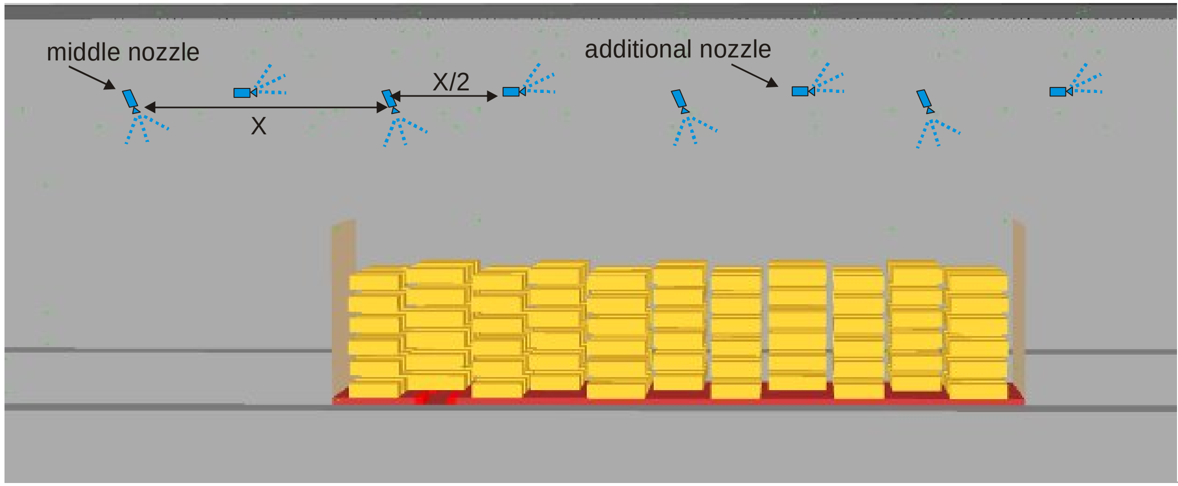
Nozzles
Level (5.8 m)

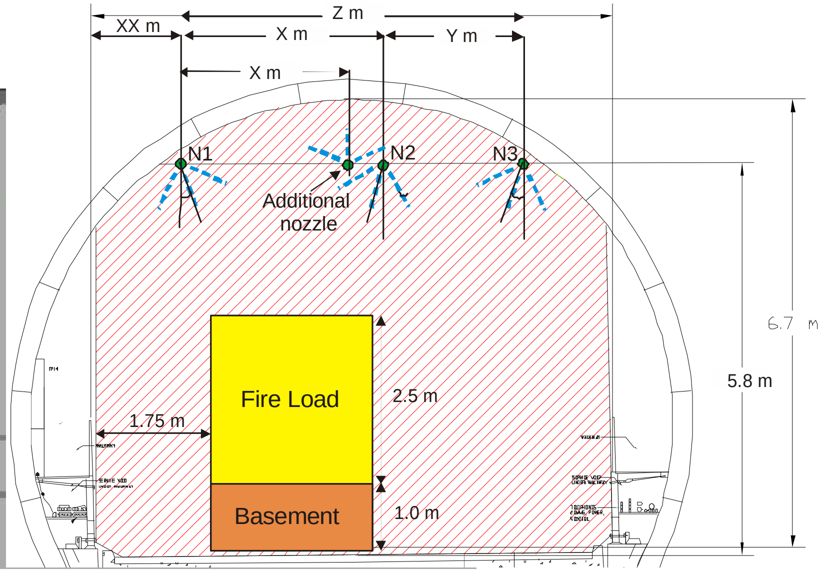




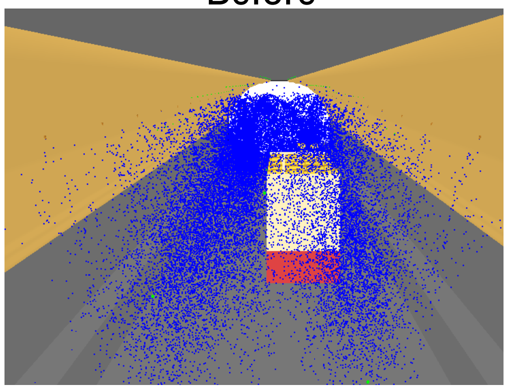
Solution

§ Add additional nozzles reproducing water

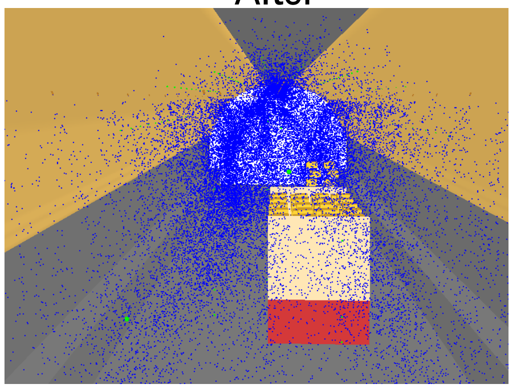




Before

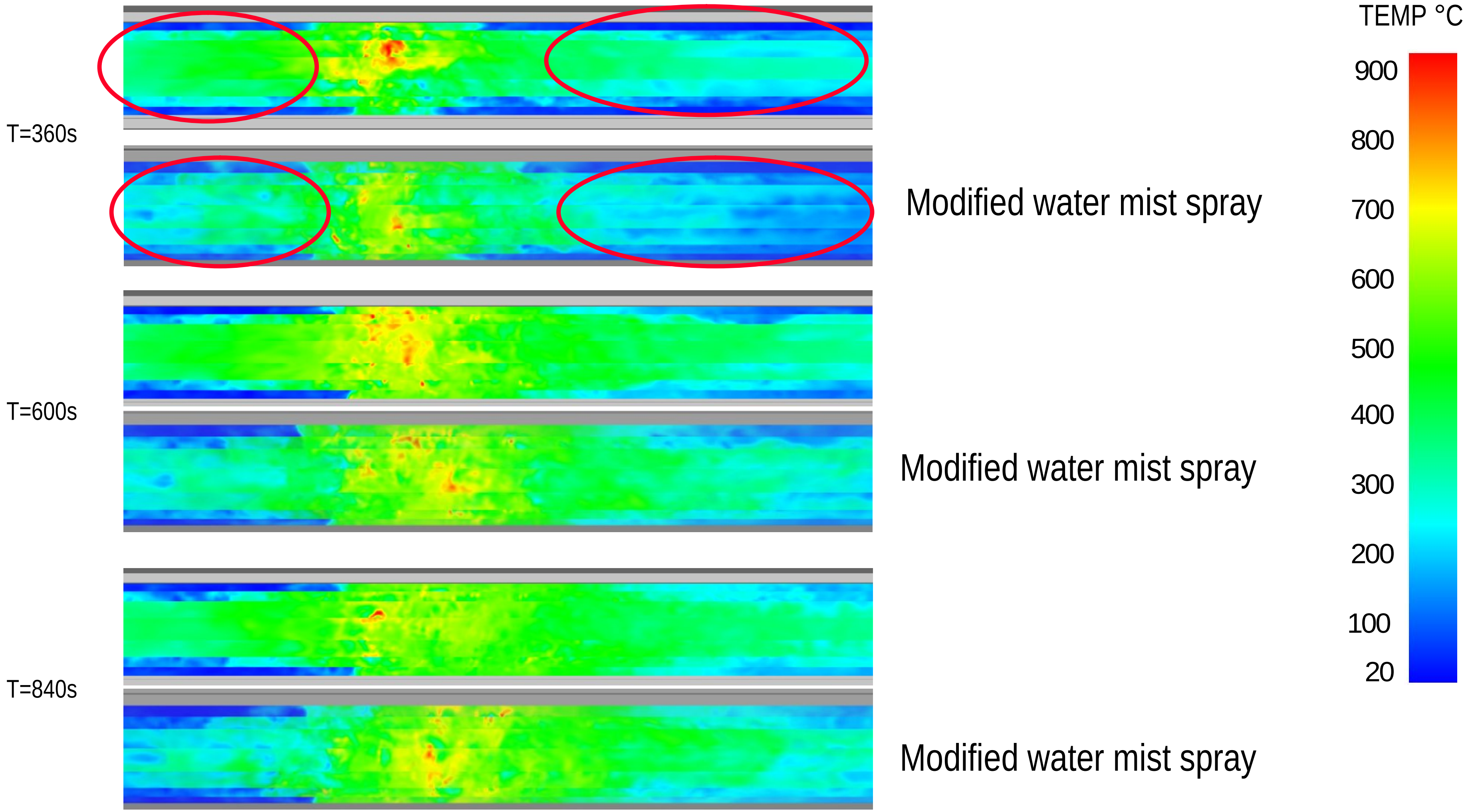


After



Temperature comparison

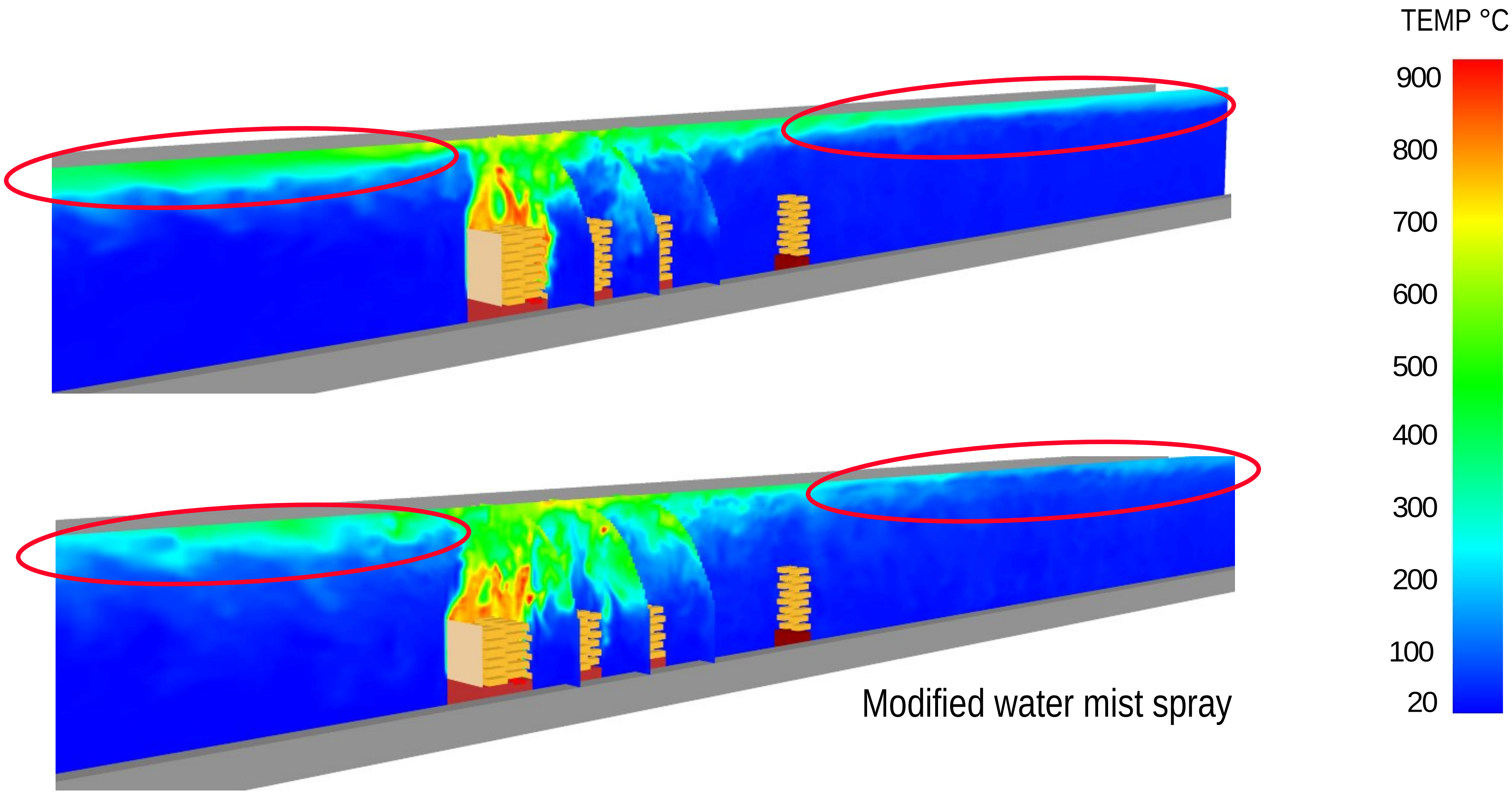
Modified Tunnel Geometry



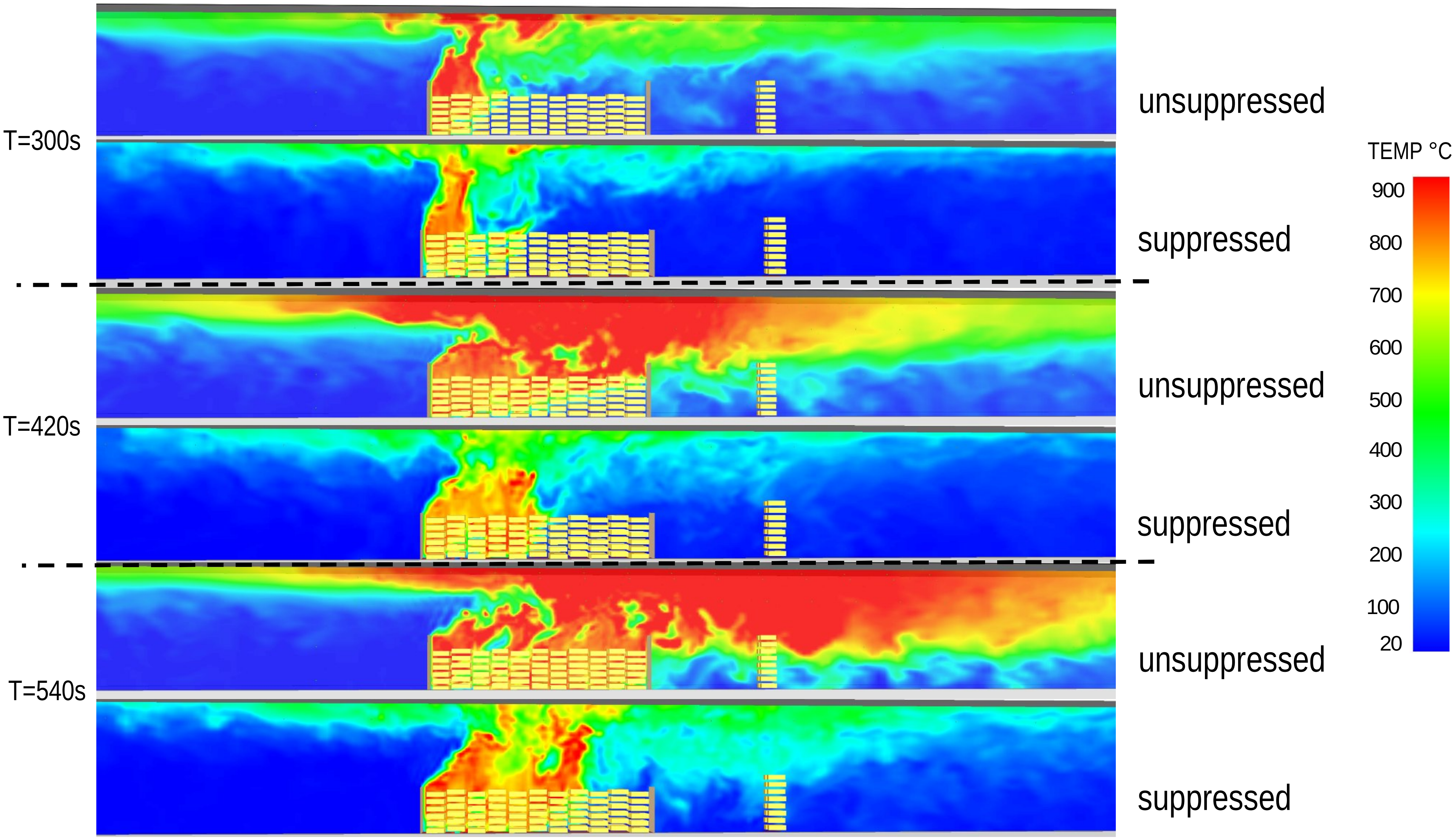
Results comparison

Modified Tunnel Geometry

T=360s



Suppressed versus Unsuppressed



Conclusion

- *Very large fires in tunnels are complex, chaotic and barely reproducible*
- *A global analysis is required to evaluate the benefits of the suppression system*
- *High cost of fire tests*
- *CFD modelling, validated by test data, allow to investigate untested conditions and to better understand the complex fire dynamic*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