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Fire in a naturally ventilated room: a comparison between real-scale tests and FDS simulation

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Safety Problems in small rooms

Credit: J. Stoughton/NIST

- NO extinguishing systems ;
- NO smoke / heat control systems;
- limited ceiling height, quick deterioration of tenability conditions

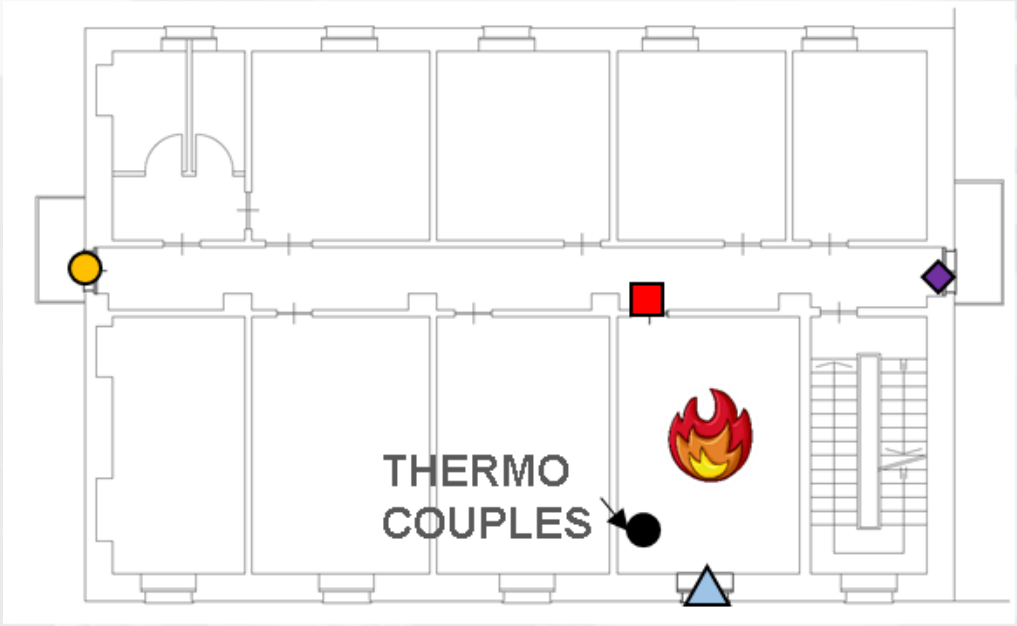
Effort in this work

- **Full-scale experiments**

to observe the effect of different strategies involving the opening of doors and windows, focusing on how this affects the distribution of smoke and tenability conditions.

- **FDS simulations**

to compare results with experimental data



Literature review

- Nist Full Scale Enclosure Experiments (2008)
- Dalmarnock fire tests (2005)

The Brick masonry building

The second floor consists of an 18m long central corridor and 8 office rooms (each one large17-20 m^2) on both sides.

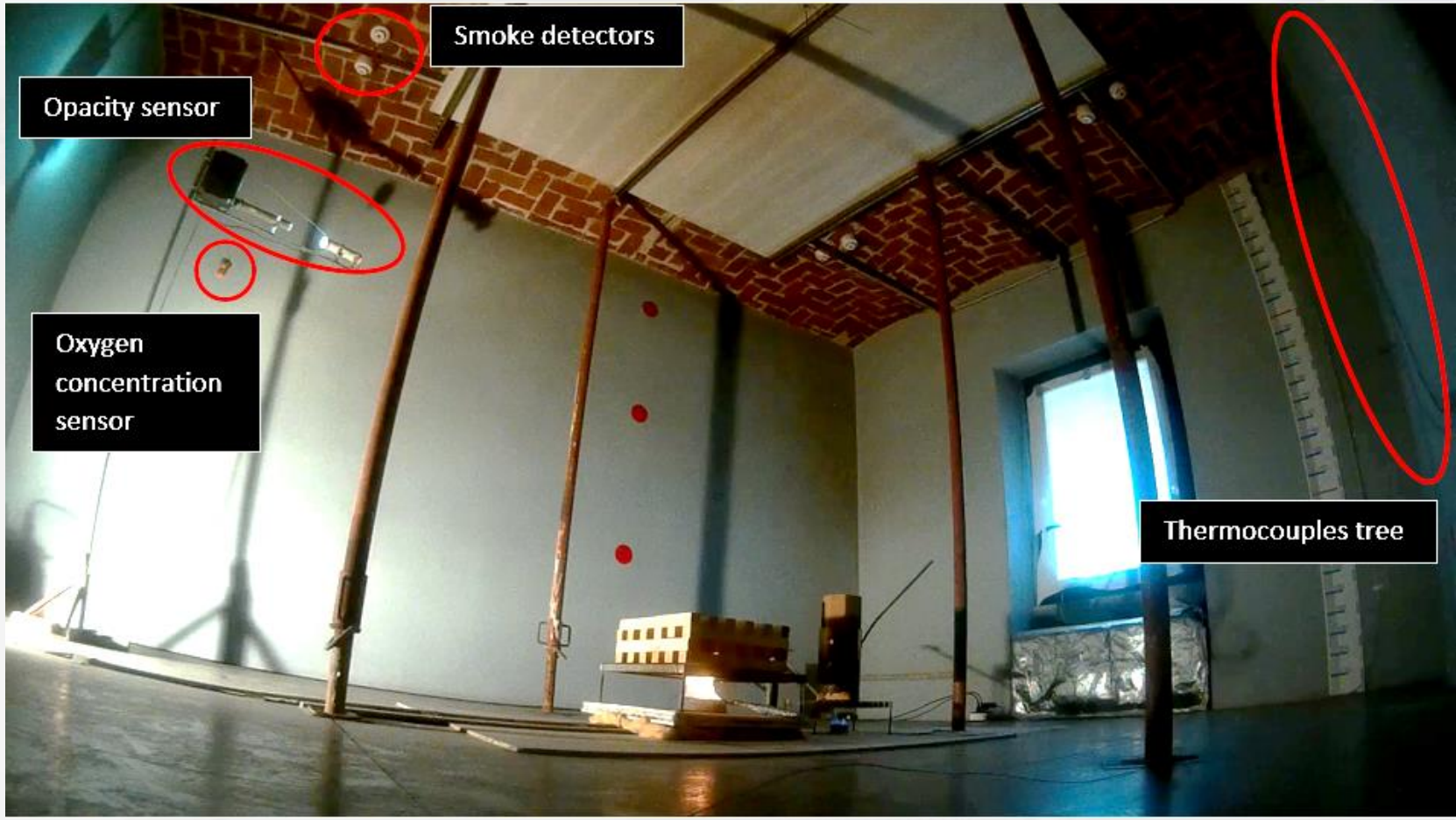
Fire Room, is 5.55mx3.90m, with average height 2.95m, has an entrance door of 1.00mx2.05m and a window of 1.00mx1.50m.

The fire room


The corridor

Instrumentation

- Thermocouples trees;
- Oxygen concentration sensors;
- Opacity sensors;
- Smoke detectors;
- Video-cameras;



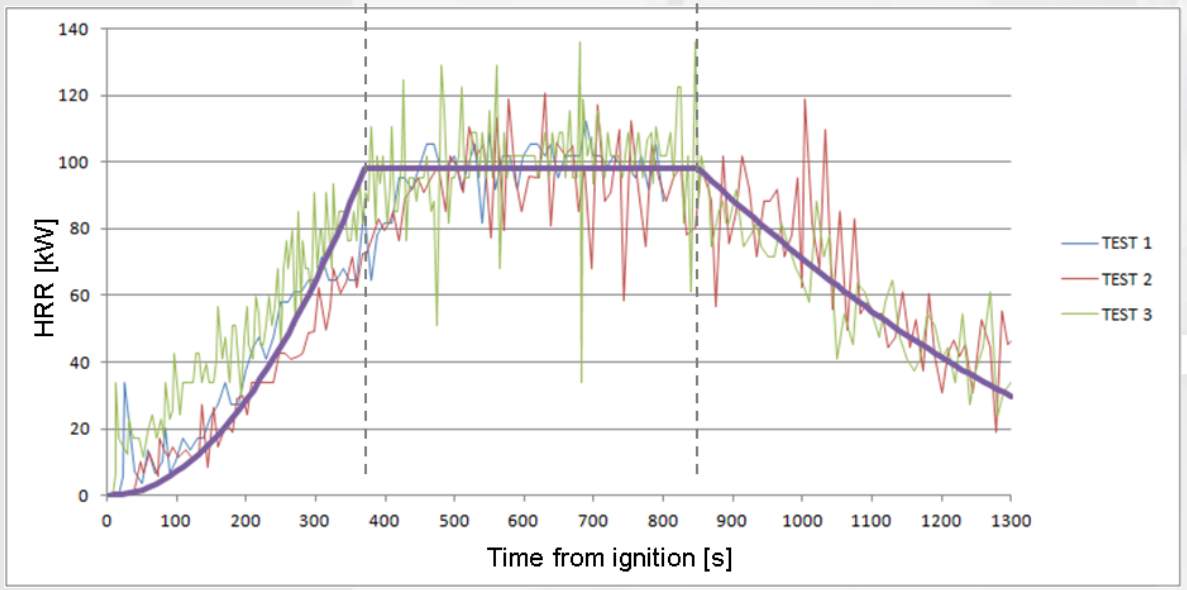
Output datas:

smoke layer height, gas temperature and oxygen concentration

The fire

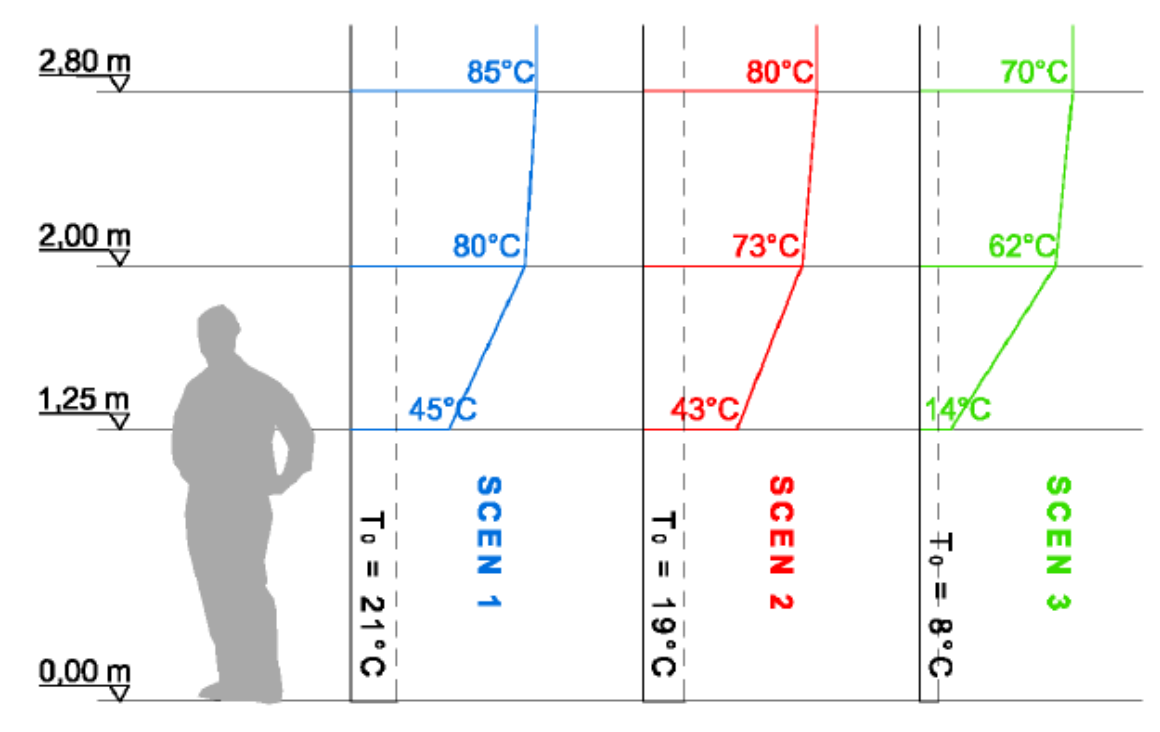
6kg **pine wood crib** with a pan filled of ethyl alcohol as ignition source → 100kW HRR peak

Smoke generator made by a rolled cardboard sheet to produce light gray smoke



Fire Scenarios - Temperature

- **SCEN1**: sudden propagation of smoke in corridor, after an initial accumulation in the *Fire Room;*
- **SCEN2**: slow propagation of smoke in the corridor;
- **SCEN3**: presence of automatic natural evacuation system.

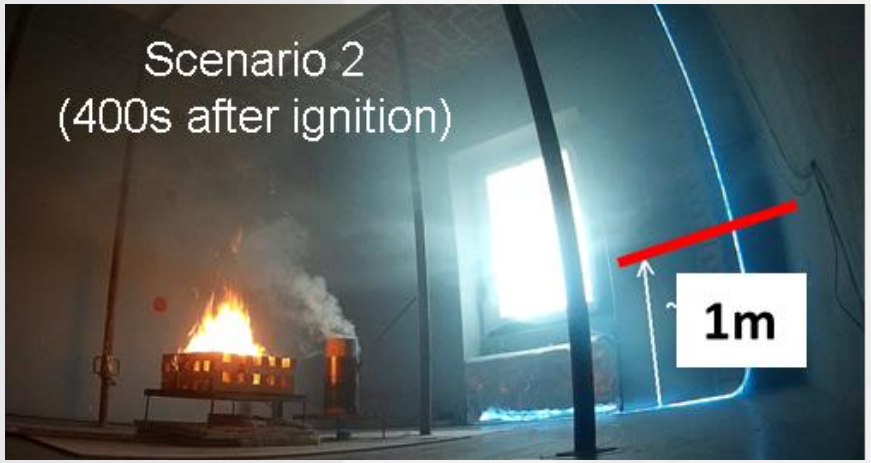


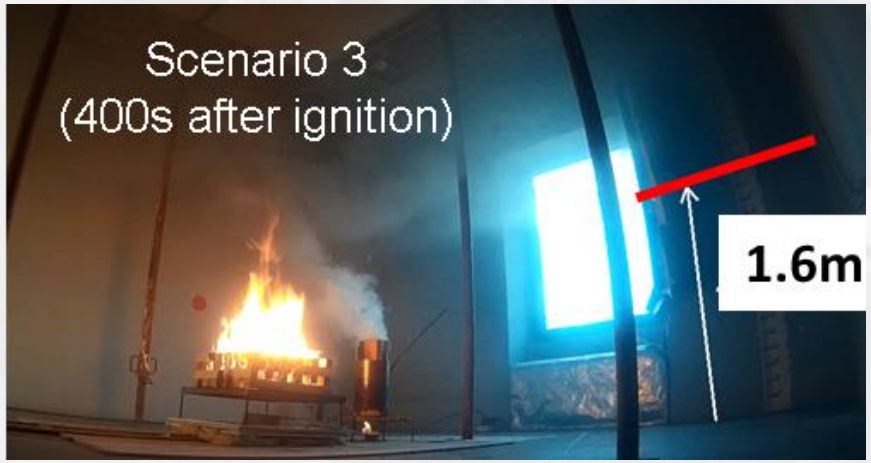
Temperature safety threshold (60°C at 2 meters) exceeded in all scenarios in 8-14 minutes from ignition.

Fire Scenarios – Smoke Layer

Free-smoke height threshold (no smoke at 2 meters) in corridor exceeded in all scenarios after 5 minutes from ignition.

The *Fire Room* was rapidly filled with smoke during scenario 1 (door and window closed), while in scenario 3 the opening of the window produced a smoke layer higher than in scenario 2, when the window was initially closed.





FDS simulations

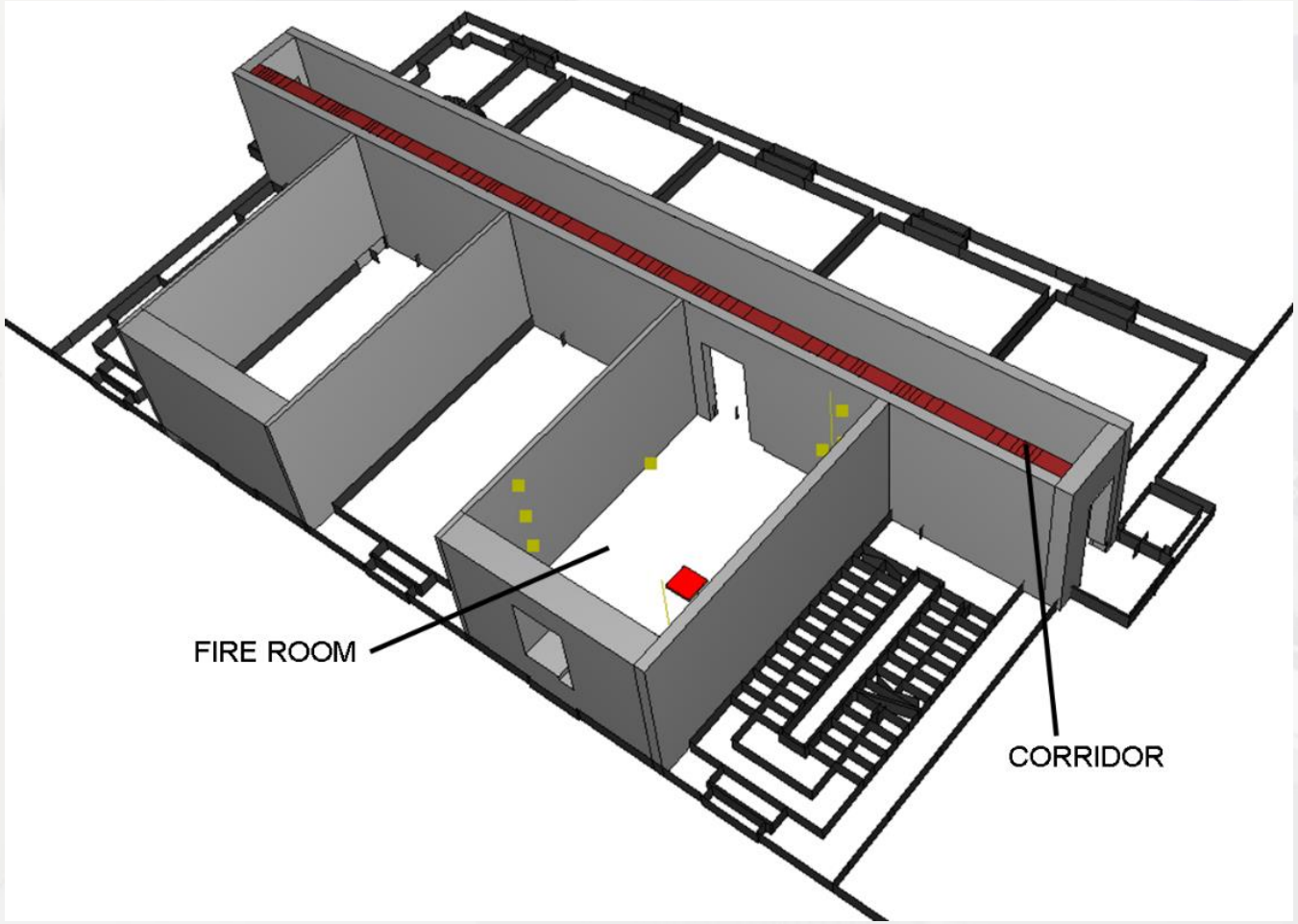
The FDS model includes the *Fire Room* and the corridor.

Mesh 0.1mx0.1mx0.1m

Combustible $CH_{1.7}O_{0.83}$

CO yield 0.005

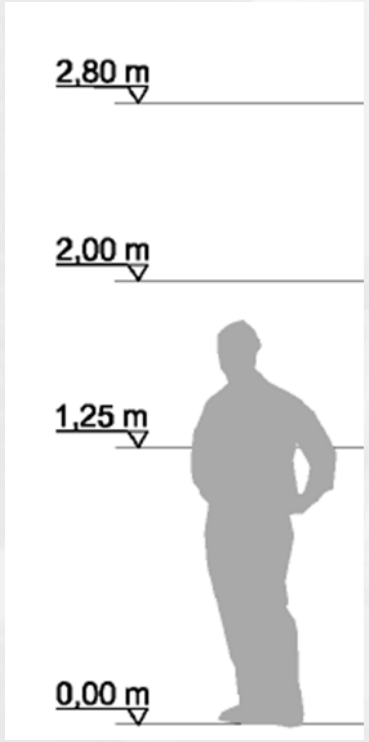
Soot yield, wall properties, thermocouples features defined by means of sensitivity analysis based on empirical results



Temperature comparison

Numerical simulations tended to over-predict the gas temperature. In particular for the lower layer.

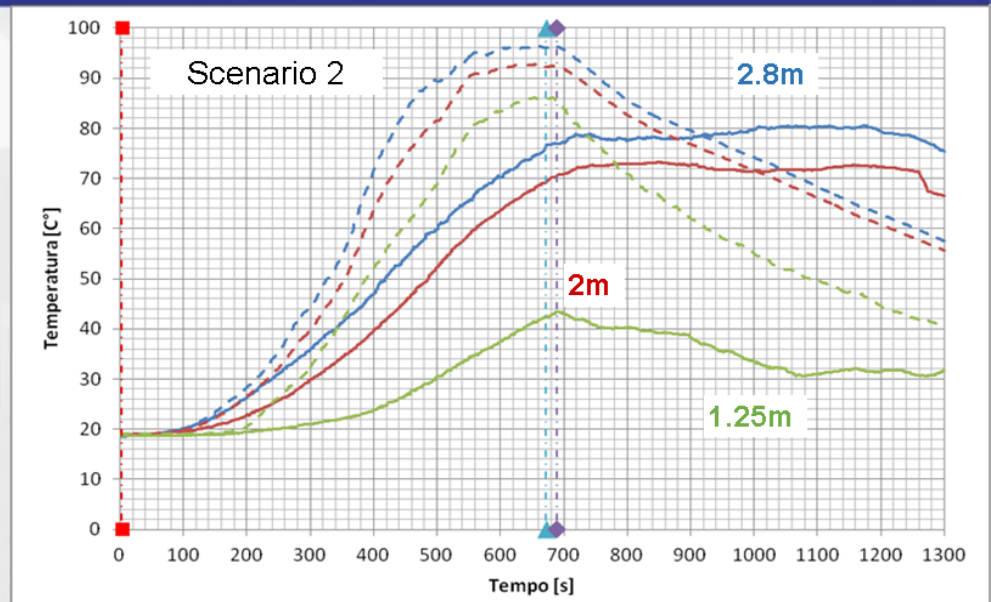
Scenario 3 (high ventilated) is the one in which the simulation prediction of gas temperature was more similar to the empirical values

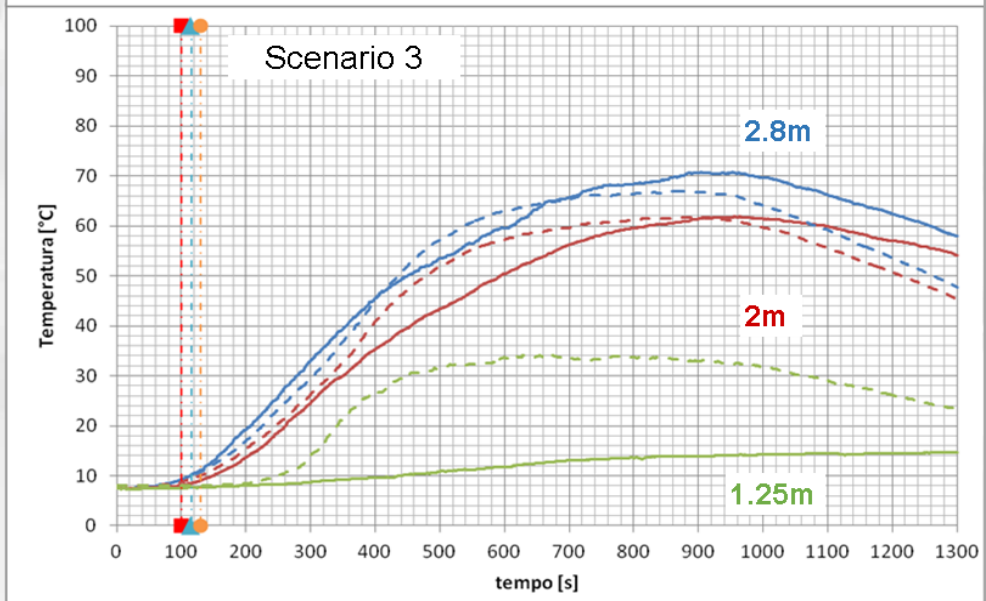


Temperature comparison

In SCEN2, the predicted temperature in the simulation showed higher peaks than the test. In the simulation, the window opening cause a stronger decrease of temperature respect to the test.

The difference between simulation and tests was smaller in SCEN3, where the fresh airflow was established since the first phase of experiment.





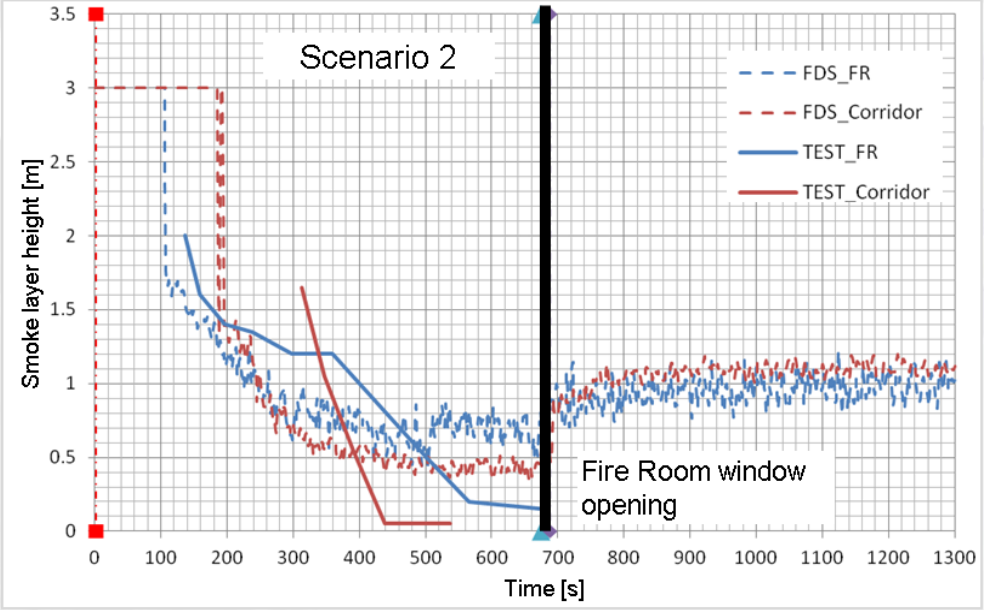
Test
Numerical simulation

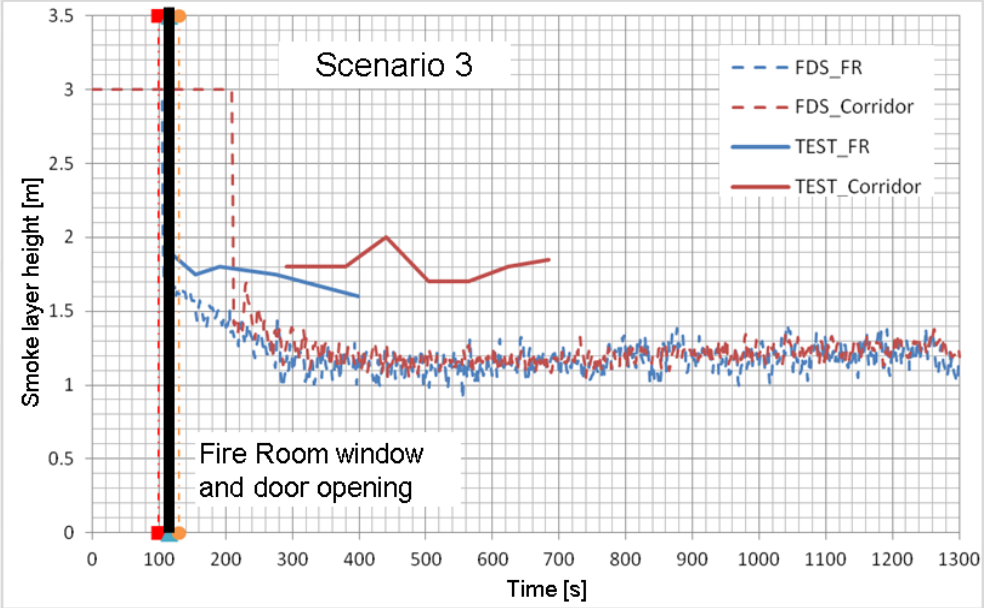
Smoke layer comparison

SCEN2 showed a good agreement between test and simulations.

In SCEN3, the simulation prediction was worse than empirical observations.

In general, there was low correspondence between experimental data and simulation results, related to the difficulties in empirical measurements during the tests (visual estimation became difficult when fresh air mixed with smoke)





Conclusions

- Tenability conditions in the fire room and corridor were quickly compromised, despite the low HRR fire;
- Smoke layer height (and visibility) deteriorated first;
- Positive effect of natural ventilation, as demonstrated in SCEN3;

Conclusions

Regarding the agreement between experiments and numerical simulations, in accordance with Dalmarnock Fire Tests results:

- a better agreement in gas temperature detected in the hot smoke layer than in the lower layer;
- a divergence between experimental and numerical results in correspondence of the window opening instant;
- the importance of sensitivity analysis on some parameters, such as soot yield, which are difficult to evaluate during experimental tests;
- numerical simulations generally gives more conservative outcomes than experimental test

Thank you for your attention

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