

# Simulation of Smoke Spread Through Small Openings



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## Use of small-scale experiments to validate FDS for smoke spread to attics

An on-going research project at Lund University is presented in this poster. In the first stage of the project it will be investigated if the Fire Dynamics Simulator (FDS) can be used to predict vertical smoke spread through a small ventilation openings.

### BACKGROUND

Deliberately lit fires are a large societal problem in Sweden, 10 to 15% of all fires occurring are caused by arson. In school buildings it is more than 40% of the fires (figure 1). The cost of fires in school buildings are around 500 million Swedish crowns (50 million Euros) yearly which are more than 10% of the total cost of fires in Sweden.

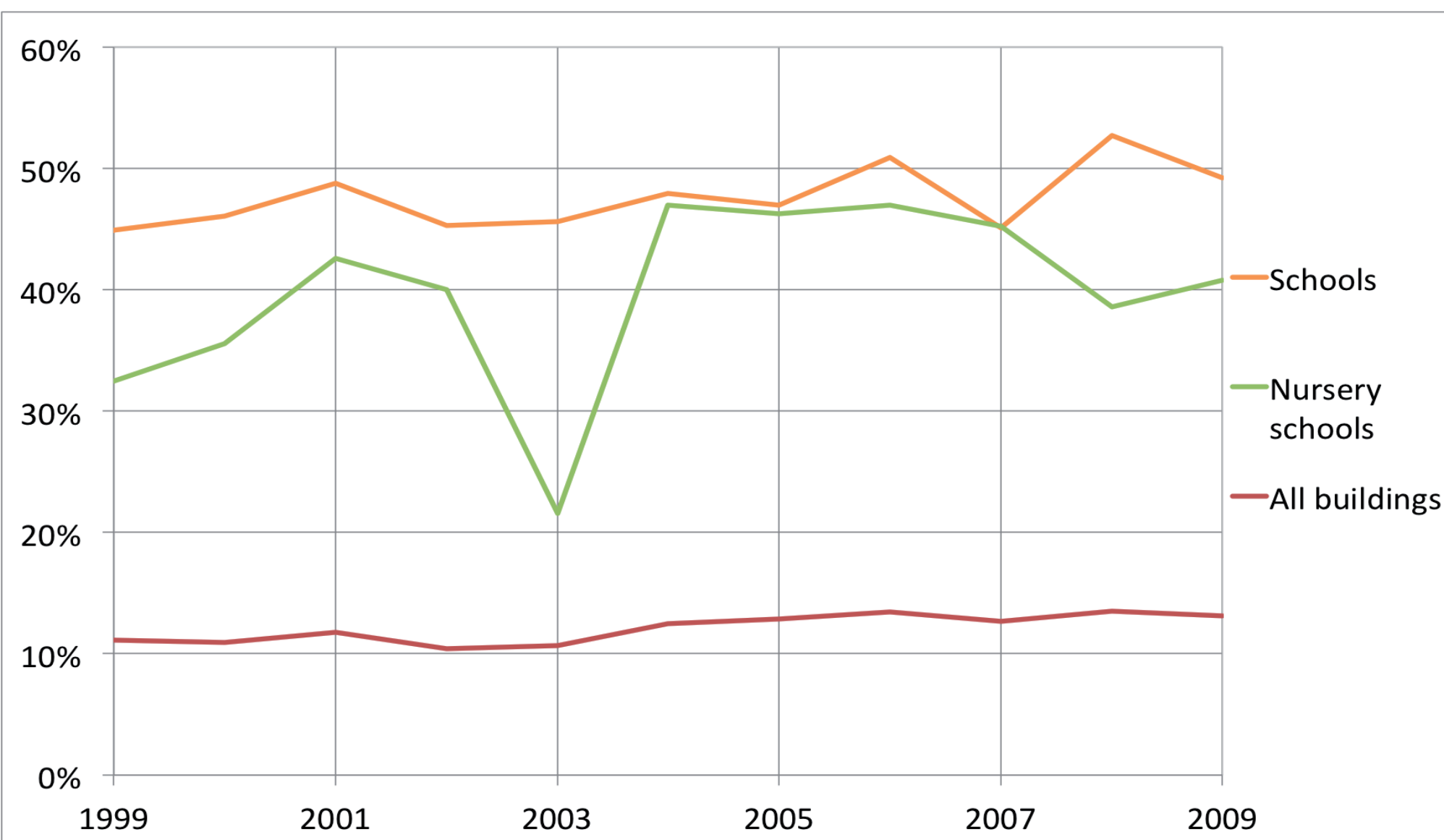


Figure 1: The diagram illustrates the percentage of deliberately lit fires for "schools", "nursery schools" and "all buildings". It is clear that deliberately lit fires are a problem in school buildings.

The most severe fires generally start outside the building and spreads up along the façade and in to the attic through ventilation openings in the eaves [1], see figure 2. Smoke detectors can be placed in the attic to detect smoke that flows into the attic from the outside through the ventilation openings in the eave.

A couple of full-scale experiments have been conducted in Sweden, [2, 3] which demonstrates that smoke detectors in attic spaces can give a shorter detection time than heat detection cables placed on the façade. Few tools are however available to design these types of smoke detection systems. Computational fluid dynamics (CFD) might be used for this purpose.



Figure 2: A typical fire scenario that causes great monetary loss. A fire is deliberately lit outside the school building and has spread to the roof and attic of the school. The fire was devastating and 2/3 of the school was destroyed in the fire.

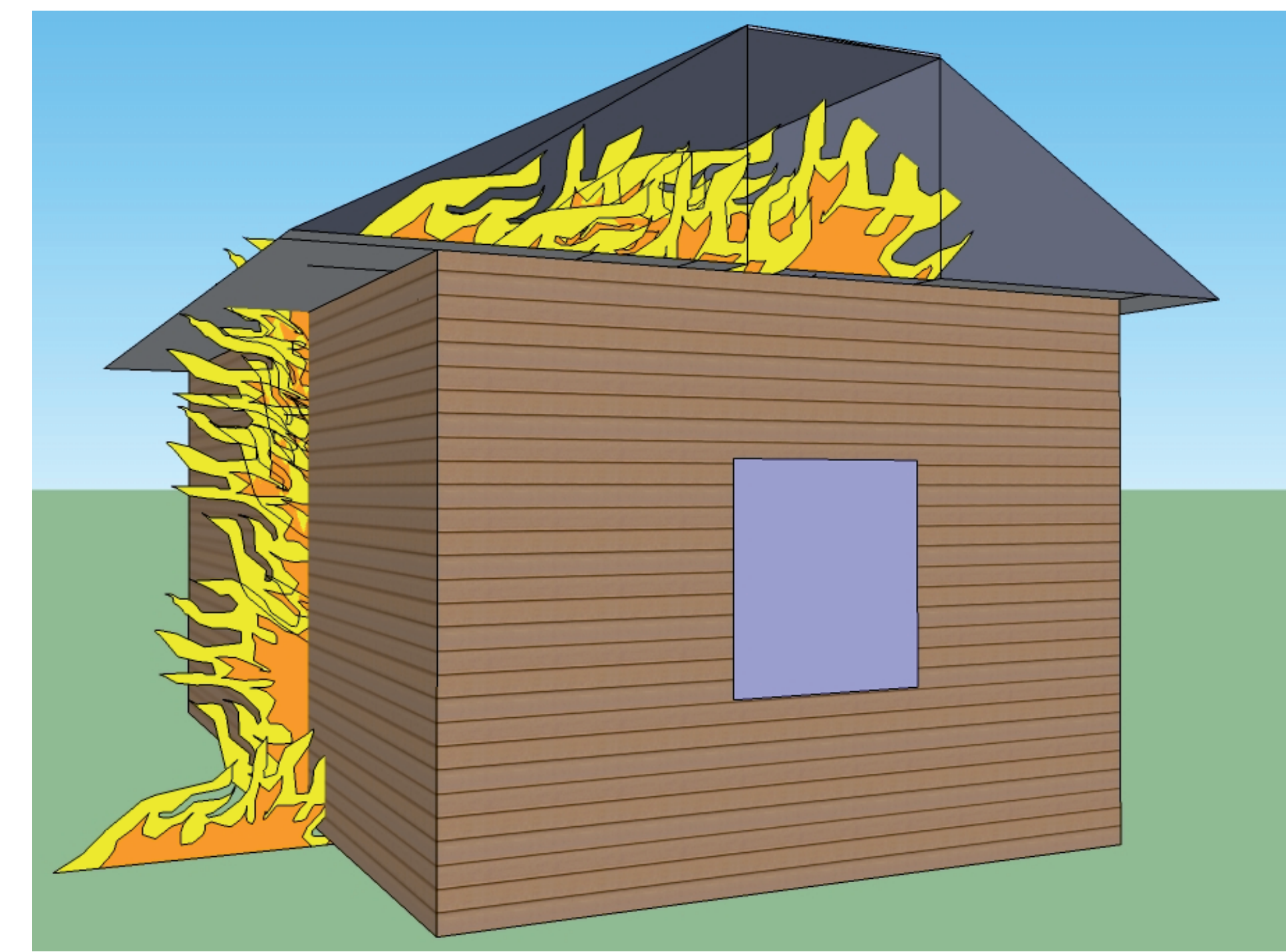


Figure 3 An illustration of the most severe type of fire. The fire is lit close to the facade and spread up along the building to the attic where it develops rapidly.

If a CFD model is found to be valid for the described purpose it can be used as a tool when evaluating different technical systems for mitigating and reducing the consequences of deliberately lit fires in school buildings.

### METHOD

A set of experiments in 2/5-scale has been conducted at Lund University. Smoke entrainment to a small space has been studied in these experiments. A 1.15 meter high wall was constructed and a box was placed on top of the wall. A ventilation slot was made on the 120 mm eave. The slot was supposed to represent the commonly used openings for natural ventilation of un-insulated attics in Sweden. Two sizes of slots were used 10 mm and 20 mm. Two sets of experiments were conducted. In the first set a 10 and 15 kW methane burner was used as fire source. In the second set a circular pan (with a diameter 120 mm) filled with heptane was used as fire source. The size of the fires corresponded to the design fire for exterior fires that has been presented in a previous paper [4].

The experiments were repeated on another day to test the repeatability. The obscuration was measured in the box with a

white light system and the flow out of the box was measured with bi-directional probes. Thermocouples were used to measure temperature on the wall, inside the box and by the bi-directional probes. The heat release rate was measured with the oxygen depletion method [5].

### THE NEXT STEP

The experiments will be simulated in the next step of the project. For each experiment two FDS simulations will be performed, the first with a uniform mesh around the fire and slot and the second with local grid refinement around the ventilation opening as described by Li et al [6]. The major objective is to see how well FDS can predict temperatures and obscuration in the box. The mesh size will be determined by following the recommendations of characteristic fire diameter  $D^*$ .

The experiments and simulations will hopefully yield in recommendations on how to simulate entrainment of smoke through small openings. These recommendations will later be used to look at the previous described problem with smoke detection on attics using a real-scale experimental setup.

### ACKNOWLEDGMENTS

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### REFERENCES

- van Hees, P., Johansson, N., "Use of Case Studies to Determine Technical Deficiencies with Respect to Fire Spread in School Buildings Subjected to Arson Fires", Interflam 2010 Proceedings of the Twelfth International Symposium, Nottingham, UK, 2010, pp 1811-1816.
- Hammarström, R., "Jämförelse mellan termokabel och rökdetektor", SP report, SP Fire Technology, Borås, Sweden, 2004. In Swedish.
- Andersson, P., "Undersökning av detektionsproblem vid Torslandaskolan", SP report, SP Fire Technology, Borås, Sweden, 2010. In Swedish.
- Klason, L-G., Johansson, N., Andersson, P. and van Hees, P., "Design Fires for Fire Protection Engineering of Swedish School Buildings", Fire and Materials, San Francisco, USA, 2011.
- Hugget, C., "Estimation of Rate of Heat Release by Means of Oxygen Consumption Measurements", Fire and Material, Vol. 4, 1980, pp. 61-65.
- Li, Y., Holmberg, S., Paprocki, A., Tang, Y.Q., "Simulation of room flows with small ventilation openings by local grid-refinement technique", Building Services Engineering Research & Technology, Vol. 15, 1994, pp. 1-10.

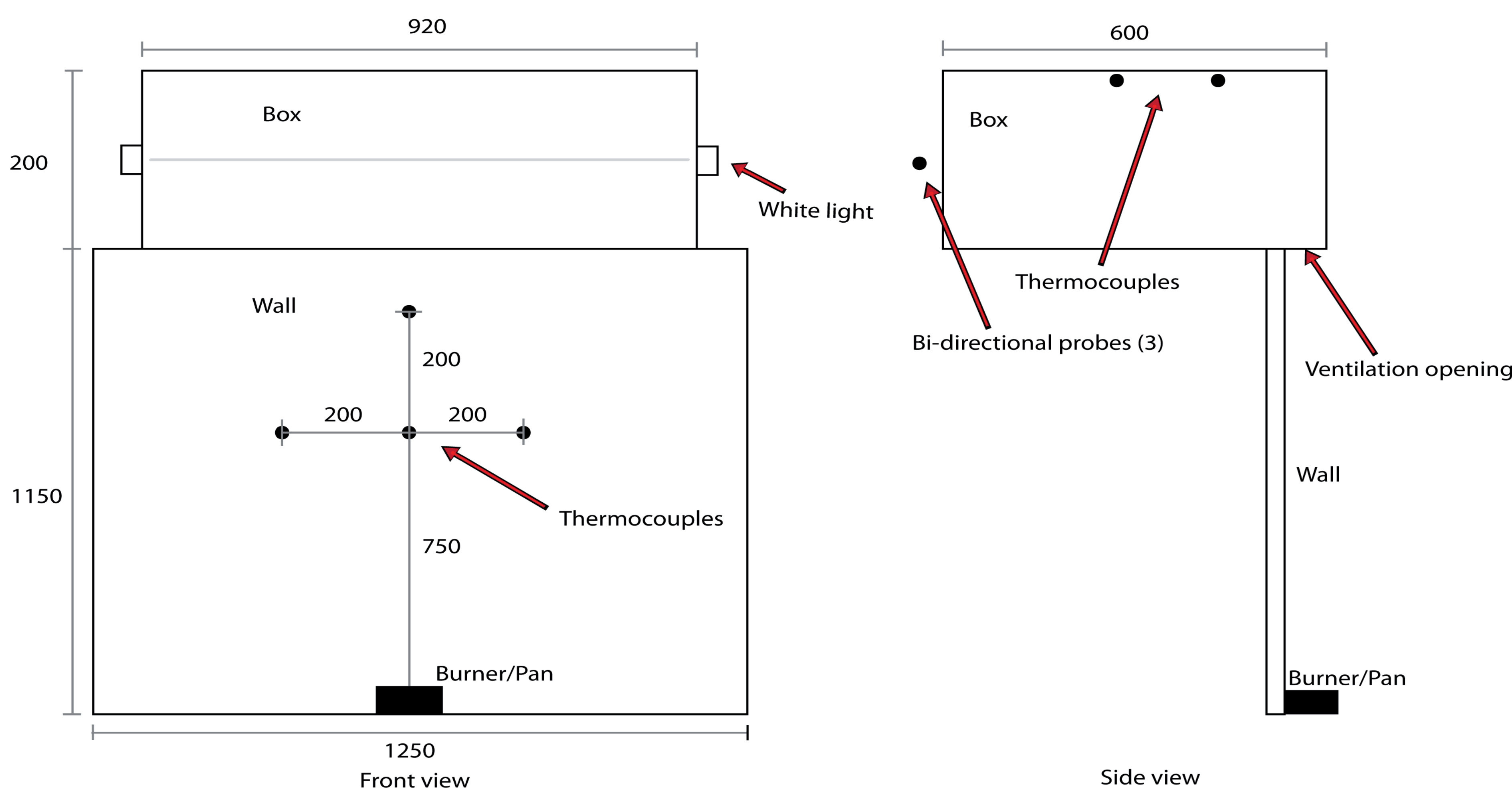


Figure 4: This illustration shows the experimental setup that was placed under the smoke exhaust hood. The picture to the left is a view from in front of the setup and the picture to the right is from the side.