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Predicting Smoke Layer Temperature in an Adjacent Room

A correlation derived from multiple CFD simulations

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Johansson, N. and van Hees, P.
Department of Fire Safety Engineering and Systems Safety
Lund University, Sweden

OBJECTIVE

A correlation for predicting gas temperatures in a room adjacent to a room involved in a pre-flashover fire is discussed in this poster. A correlation has been derived from computer simulation results and validated with data from fire experiments.

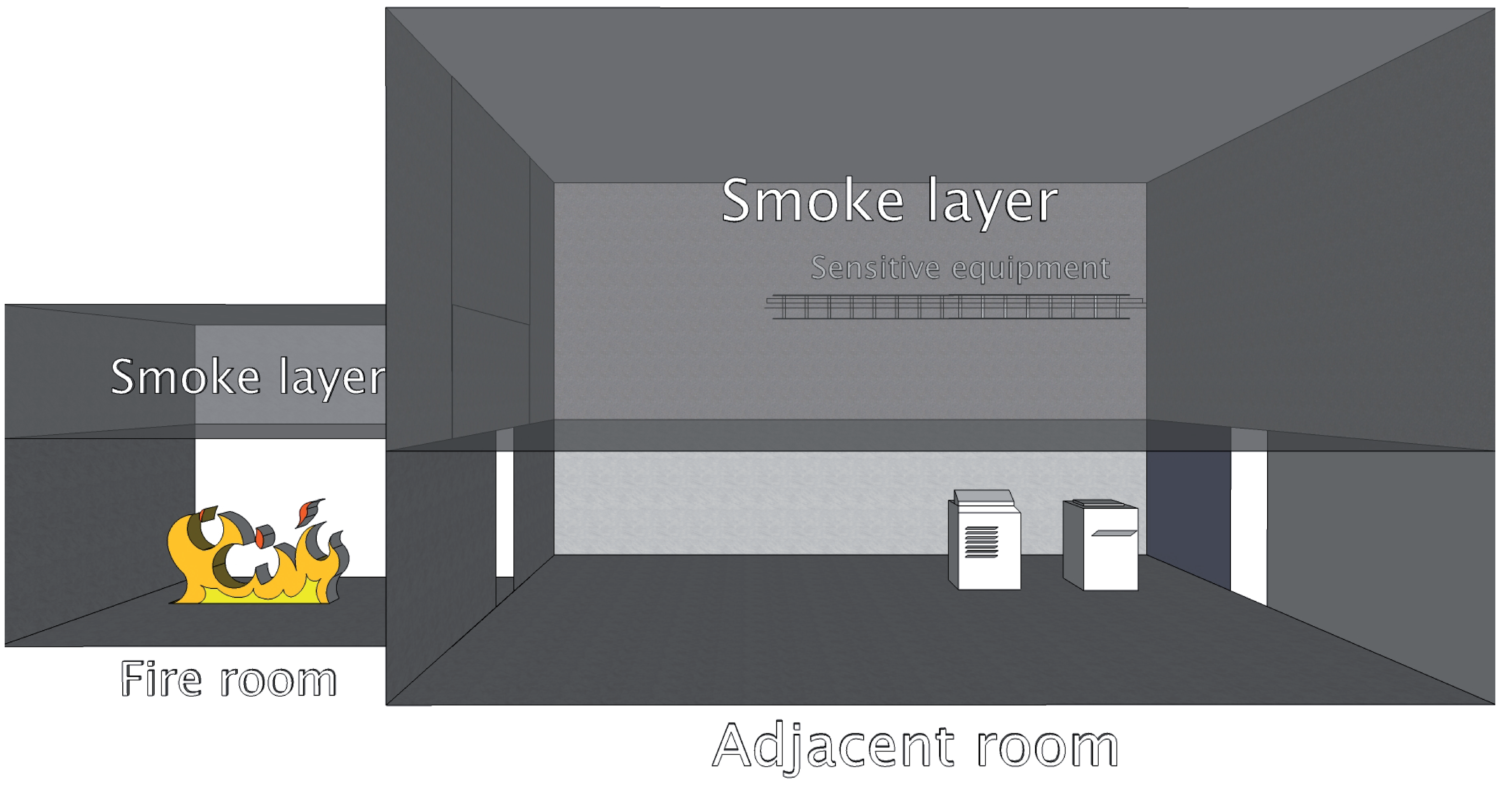

Figure 1: A fire occurs in a room and smoke spreads to a adjacent compartment. There is an opening between the fire room and the adjcent room and between the adjaccent room and the outside.

BACKGROUND

Advanced computer modelling software, that can predict smoke spread and compartment temperatures, has been developed during the last decays. With zone models and computational fluid dynamics (CFD) it is possible to e.g. calculate smoke layer heights, species and temperatures in a multi-room geometry. The programs are generally good tools for fire engineering purposes, but they do not remove the need for simple engineering correlations. Simple correlations can be used for hand-calculations to get a first estimate of e.g. smoke layer temperatures in performance based design of a building and help the fire engineer to determine if it is necessary to perform a detailed CFD calculation. Simple correlations can also be a useful tool to use in sensitivity analysis or in fire risk analysis.

Correlations that predict compartment temperatures for single room enclosures date back to the early eighties [1, 2] and are still used for different purposes by fire engineers. These correlations are rough and less accurate compared to computer simulations but they have the benefit of being simple and giving a good description of the hazard. The method that McCaffrey et al presented [1] (MQH-correlation) is based on an simple conservation of energy expression. The MQH correlation gives the gas temperature as a function of the heat release rate, ventilation conditions, enclosure geometry and thermal properties of the enclosure. The MQH correlation has a set of limitations, which the user must be aware of, but it has been shown to give good predictions of room fire temperatures [3]. The correlation has even been developed further and modified [2, 3]. Lately new models for predicting compartment fire temperatures have been presented [4, 5].

However there are few correlations that can predict temperatures outside the room of fire origin. Thus such predictions have to be done with the help of zone or CFD models. A simple correlation that would predict temperatures outside a compartment is something that could be useful to get a first estimate when for example evaluating conditions for evacuees in a room next to the room of fire origin.

METHOD

The work presented in this poster has been performed in three steps.

In the first step numerous CFD simulations with the computer software FDS 5 [6] have been conducted. Input files to FDS, with randomly sized two-room configurations, were created with a Matlab script. Approximately 140 FDS files were simulations with different, geometries, openings, wall materials, fuels and heat release rates on the Lund cluster. In all simulations the fire was placed in the center of the fire room as illustrated in figure 1. The various inputs are presented in table 1 and 2. The mesh size near the fire was determined by following the recommendations of characteristic fire diameter D*, which varied between 0.61 and 1.27 m.

Table 1: Geometrical variables in meters.

	Width (min/max)	Length (min/max)	Height (min/max)
Compartment 1	2.4/12	2.4/12	2.4/4.5
Compartment 2	2.4/12	2.4/12	2.4/4.5
Opening size 1-2	0.5/2.2	.	1/3.7
Opening size 2-out	0.5/2.2	-	1/3.7

Table 2: Wall and fuel variables

Variable	Values
Wall material	Concrete/Brick/Light weight concrete
Fuel	Heptane/Methanol/Polystyrene
Wall thickness	0.01/0.1/0.2 [m]
Heat release rate	320 to 2000 [kW]

In the second step a statistical analysis has been conducted with the statistical software package SPSS (Statistical Package for the Social Sciences) [7]. The smoke layer temperature in the adjacent room was retrieved from the FDS simulations and was used as dependent variable in the statistical analysis. The heat release rate, area of boundary surfaces of both enclosures, ventilation factors for both openings and heat transfer coefficient were used as independent variables. A multiple linear regression analysis of the logarithmic values of the variables were conducted in SPSS.

In the third step the correlation was tested and validated against results from full-scale experiments both found in literature and conducted within the project.

SUMMARY OF RESULTS

All included variables were statistical significant and the correlation had a correlations coefficient, R2-value, of approximately 0.9 with respect to the data from the simulations (figure 2). The most important variable was the heat release rate.

A validity check was preformed by studying data from real fire tests [8,9]. Three sets of experimental data were studied and a the result of the validity check can be found in figure 3. It is considered to be a good agreement between the calculated and measured temperatures since the maximum difference is less than 20%.

A reliability check was preformed by looking at the grid sensitivity of six of the preformed simulations, when decreasing the grid size from 0.1 to 0.05 m (figure 4).

The presented work is based on FDS simulations of wellventilated pre-flashover fires thus is the results only valid for such conditions. Further analysis of the validity of the correlation, by comparing it to more experimental data, is needed.

The method used to find a simple correlation could possibly be applied to other areas in fire science to be able to find other simple correlations that can be used by engineers in an initial stage of their design.

ACKNOWLEDGMENTS

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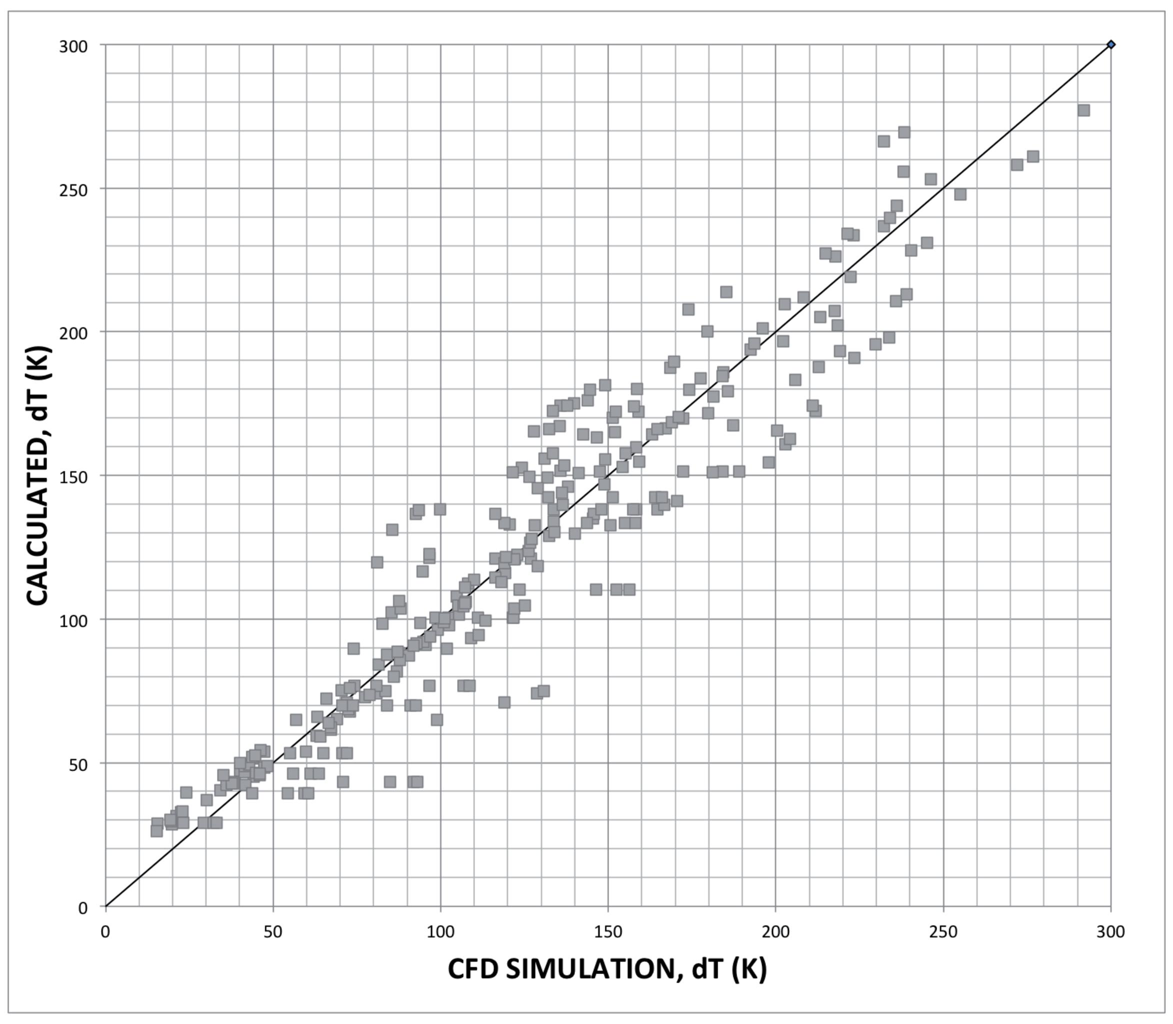

Figure 2: A trend is obvious when comparing the results from the CFD calculations with temperatures calculated with the correlation.

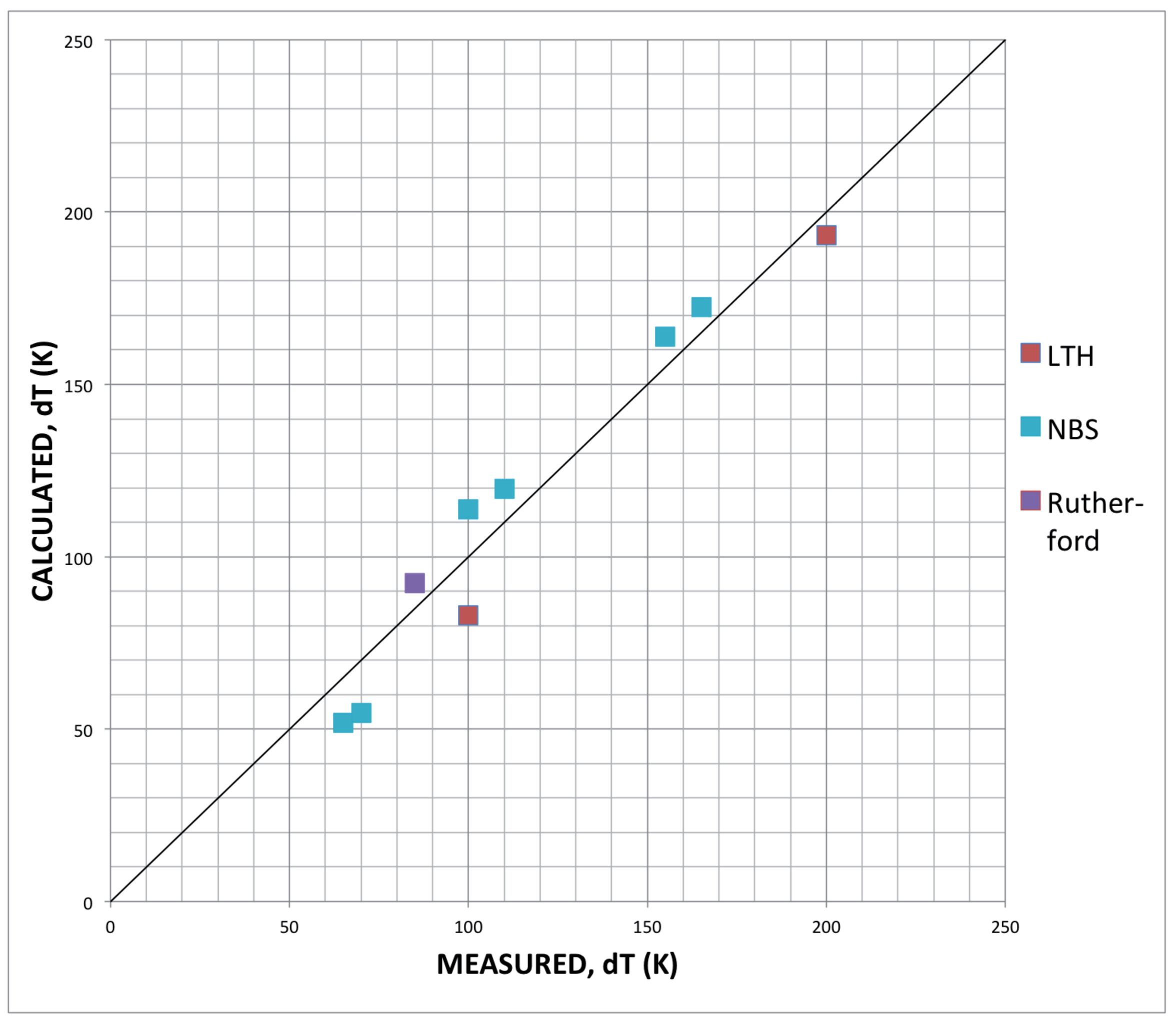

Figure 3: In the graph the results from real fire experiments are compared to temperatures calculated with the found correlation.

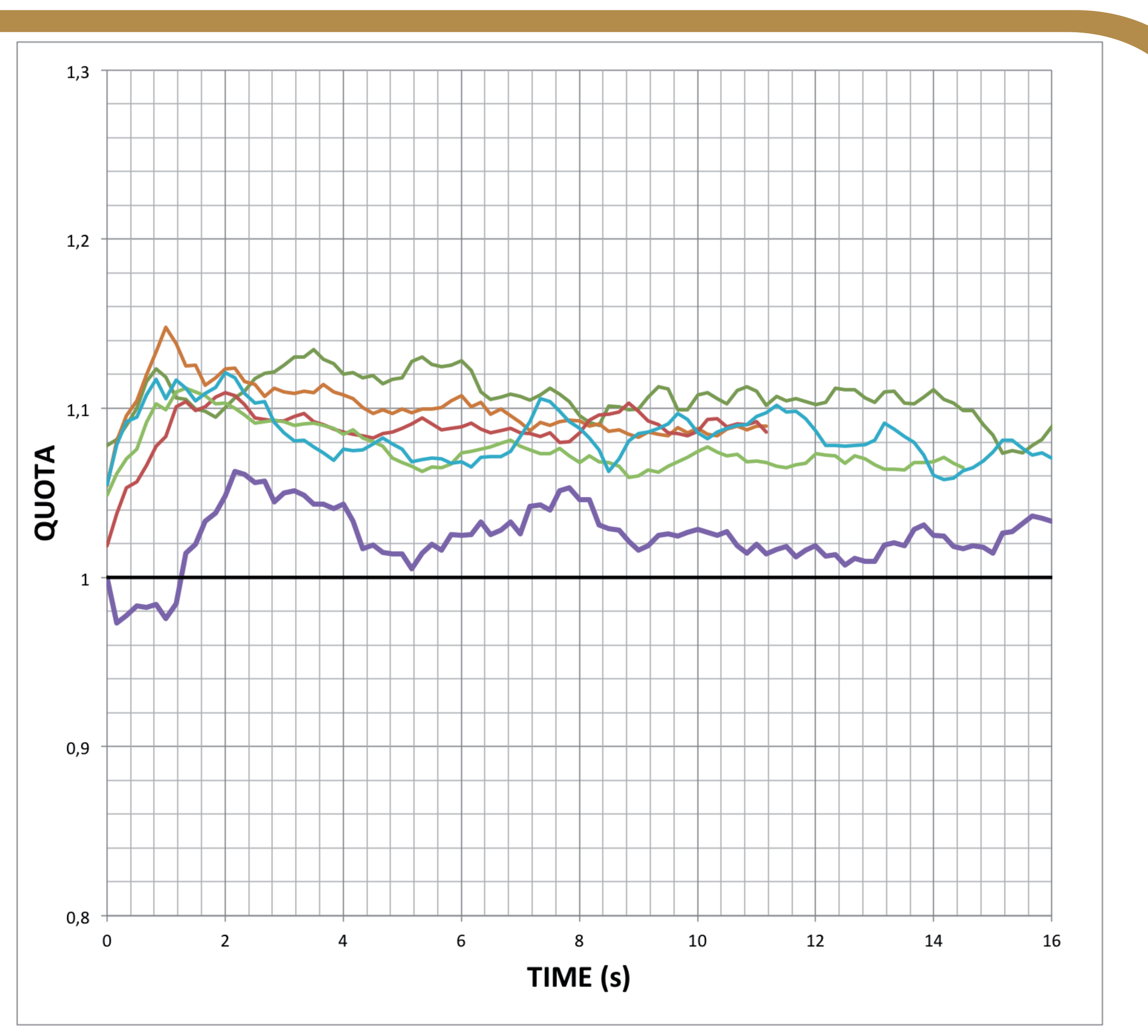

Figure 4: Illustration of the grid sensitivity. The quota is smoke layer temperature in the coarse grid divided by the smoke layer temperature finer grid. A coarser grid give a slighlty higher temperature.