Sprinkler activation with porous suspended ceiling

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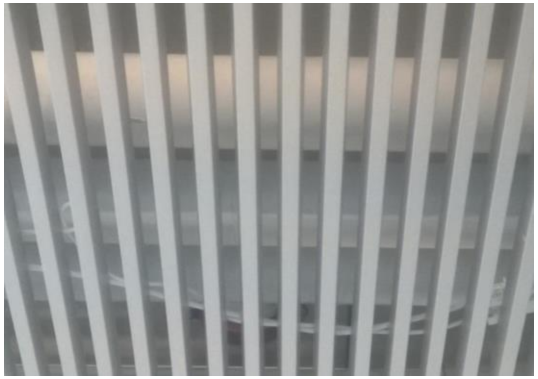
Introduction

False ceilings are:

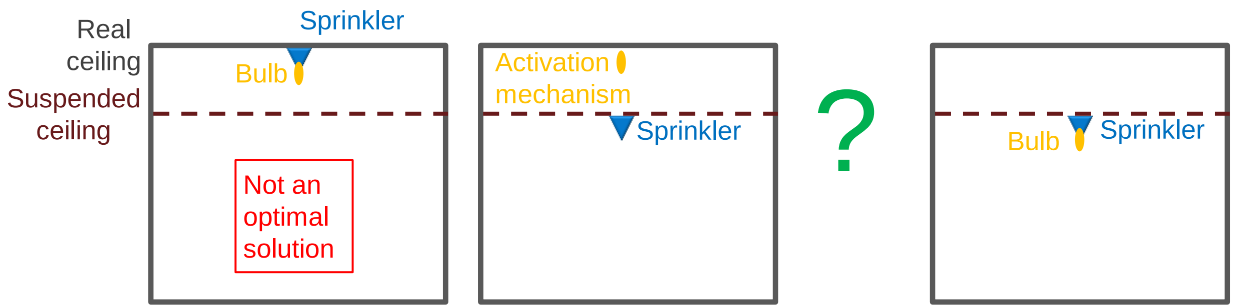
- Commonly installed below a concrete ceiling/floor slab in office, hospital and larger buildings
- Designed to hide HVAC ducts or electric cables
  - The false ceiling material is often quite open – a metal grid or perforated plate
  - Such a porous material partly blocks gas flow
- Affecting both heat spreading and water mist spray
  - Spray penetration is at its best when there is no blockage below the sprinkler
  - The new VdS 3188 standard requires that false ceiling material is shown not to impair the fire protection if the sprinkler is installed above the false ceiling

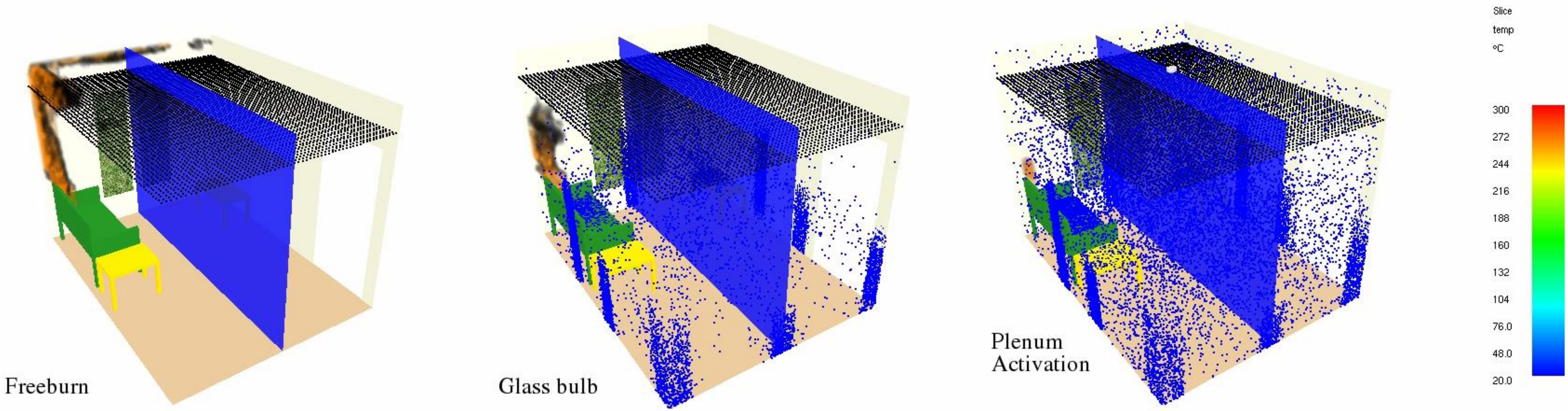
  → *For these reasons, the option of installing water mist sprinklers above a false ceiling was not investigated in this study*



Introduction

- Hot fire gases penetrate a porous ceiling and plenum may heat up faster than rest of the room
- When should the solution with a mechanism in plenum activating the sprinkler below the false ceiling be used?





Computer simulations

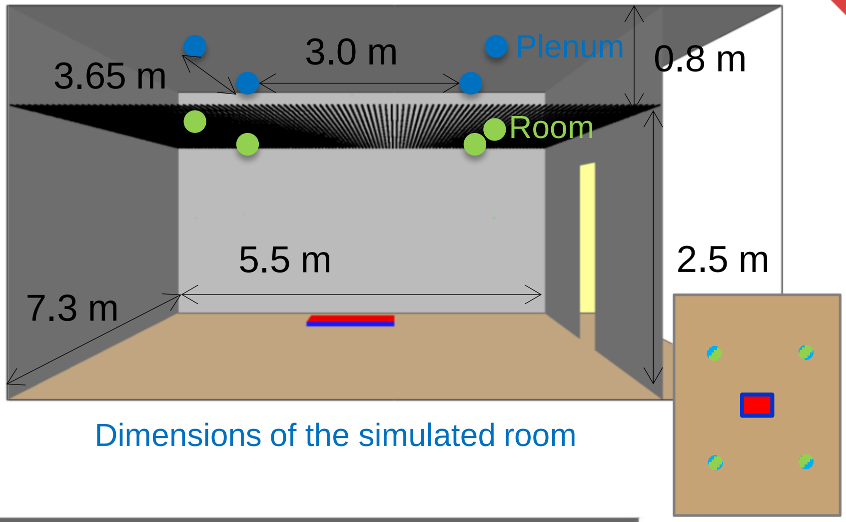
A number of cases were simulated with FDS (Fire Dynamics Simulator), a 3D CFD code, to determine the trends of sprinkler activation with suspended ceilings

- Simulations were conducted at Marioff during 2014-2015 with FDS versions 6.0 and 6.1 by the author

Room	Conditions
40 m^2 room with 0.8 m plenum	Fully open/closed and half open ceiling materials with different fire growth rates
	A range of ceiling material loss coefficients
	Heat collectors
40 m^2 room with 0.3 m plenum	Two ceiling material loss coefficients
12 m^2 room with 0.8 m plenum	Three ceiling material loss coefficients
12 m^2 room with 0.3 m plenum	Three ceiling material loss coefficients

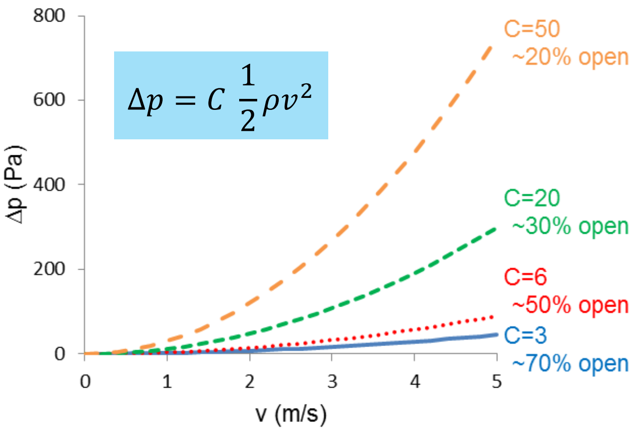
Simulation setup

- Several dummy sprinklers (RTI 20) were placed in plenum and room
  - Simulation continued until one of them reached 57°C
- Porous ceiling material was modeled with static particles forming a plane

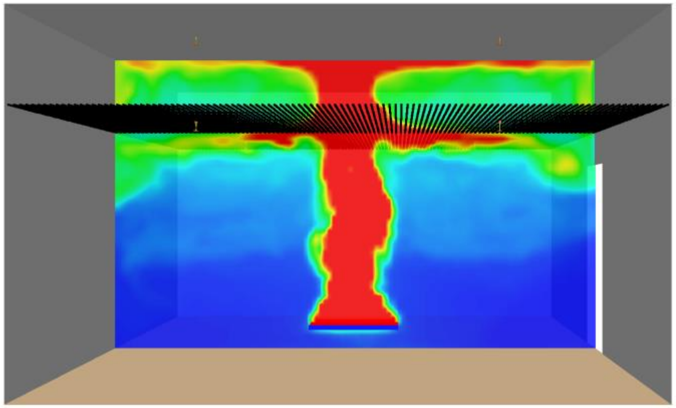


Dimensions of the simulated room

Any device in flow field, like a grill, a sprinkler, a valve, pipe, a car, airplane, a building in wind, also water droplet or particle, exchanges momentum with the flow field, i.e. causes a resisting force to the flow, i.e. causes pressure loss. With relatively high Reynolds numbers this **force is proportional to the square of the flow speed** as shown below.



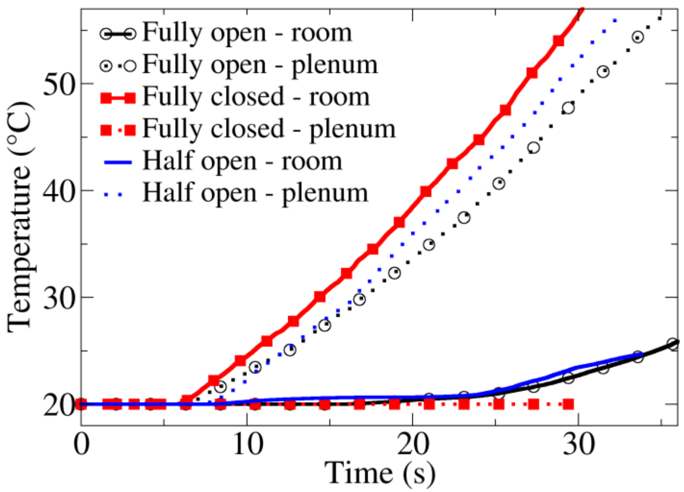
Proportionality coefficient C depends on porous material geometry in a non-trivial way. Open area fraction is only directional.



Fire heat spread with porous suspended ceiling

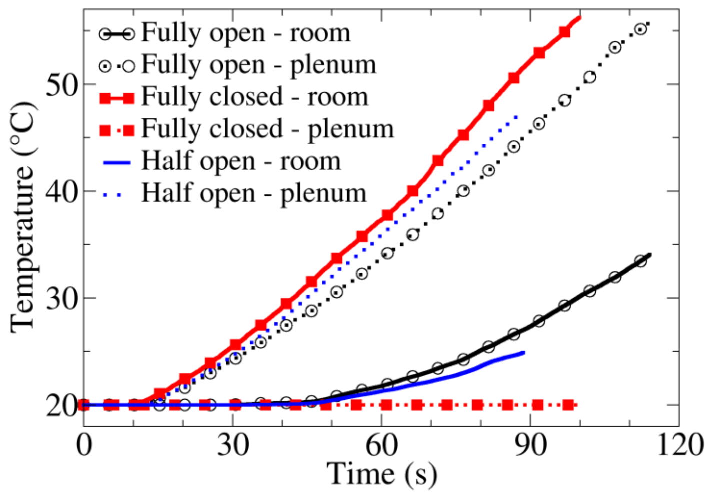
Fully open, closed or half open false ceiling

- Comparisons with no suspended ceiling, with fully closed suspended ceiling, and half open suspended ceiling, with two fire growth rates
  - With a closed suspended ceiling, the room sprinkler temperature rises quickly, plenum sprinklers remain at initial temperature
  - With no suspended ceiling, plenum sprinklers heat up much faster
  - With a porous suspended ceiling, the plenum sprinklers seem to heat up even faster than without the suspended ceiling, but the effect is not significant
- Temperature differences between plenum and room sprinklers are larger with the faster fire growth rate



Fast fire growth (up to 1 MW in 100 s)

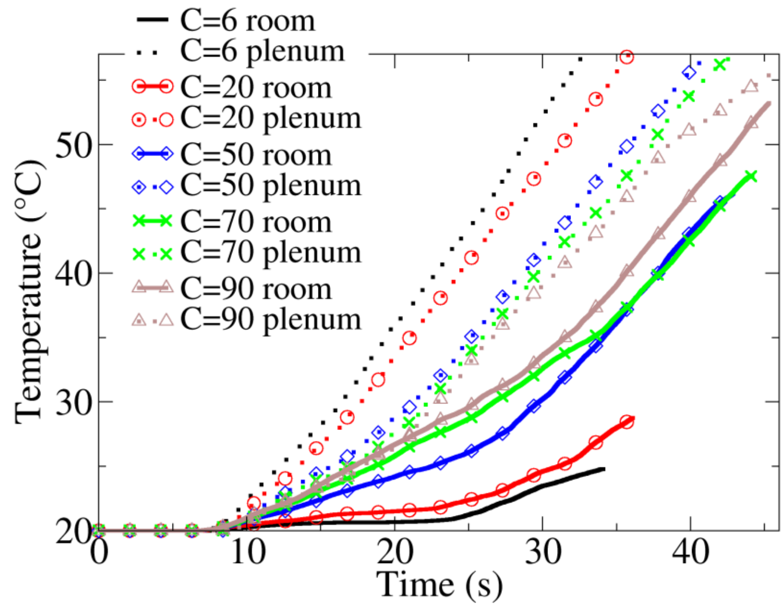
Averages of the four bulb temperatures, plenum or room



Slow fire growth (up to 94 kW in two min)

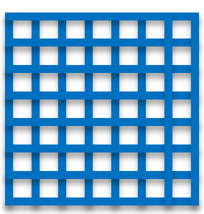
Different loss coefficients

- Simulations with different loss coefficients show that with increasing loss coefficient (less open material) the activation time in plenum tends to increase
- Even though room and plenum bulb temperatures get closer to each other with rising loss coefficient, the room ones do not get quicker than the plenum ones with the used loss coefficients
  - Loss coefficient 90 is already quite high – ceiling grids probably are not that closed
- It is a matter of fire safety considerations to decide whether the delay of using room temperature is significant

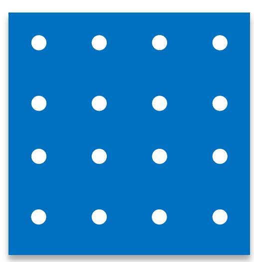


Averages of the four bulb temperatures, plenum or room

Grid with C≈3

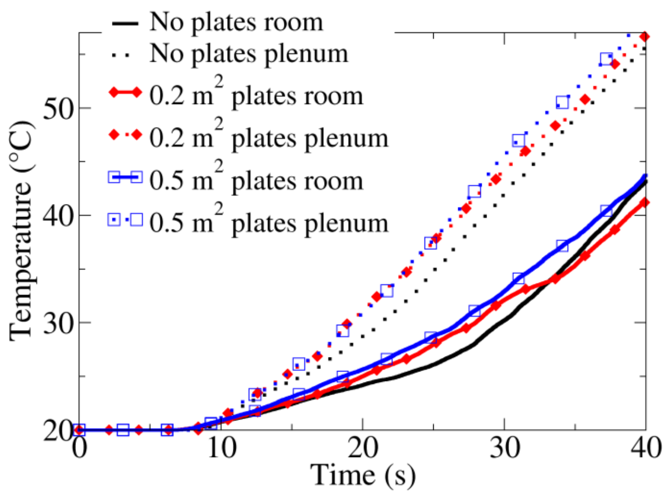


Perforated plate with C≈50

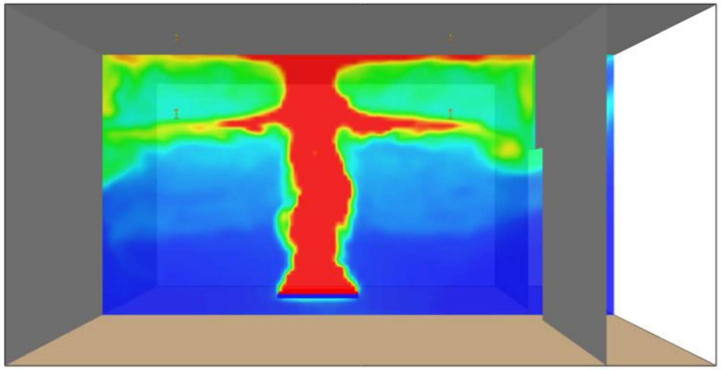


Using heat collectors

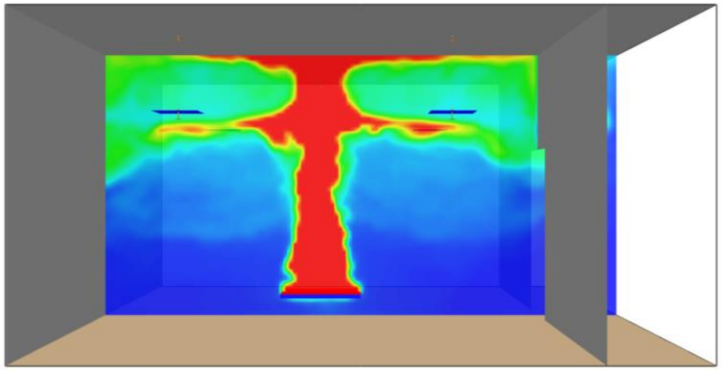
- Heat collectors, i.e. metal plates above the room sprinklers have been a common practice to assist sprinkler activation
  - Not allowed by NFPA 13
- Tried two sizes of plates: 0.2 m x 0.2 m, and 0.5 m x 0.5 m with loss coefficient 50
  - Also loss coefficient 6 tried with same conclusions
- No significant effect on sprinkler temperatures



Averages of the four bulb temperatures, plenum or room



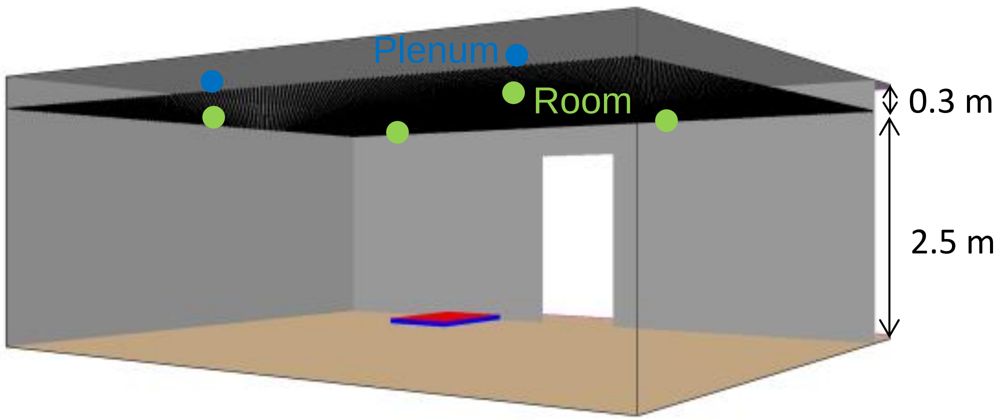
C = 50 without plates



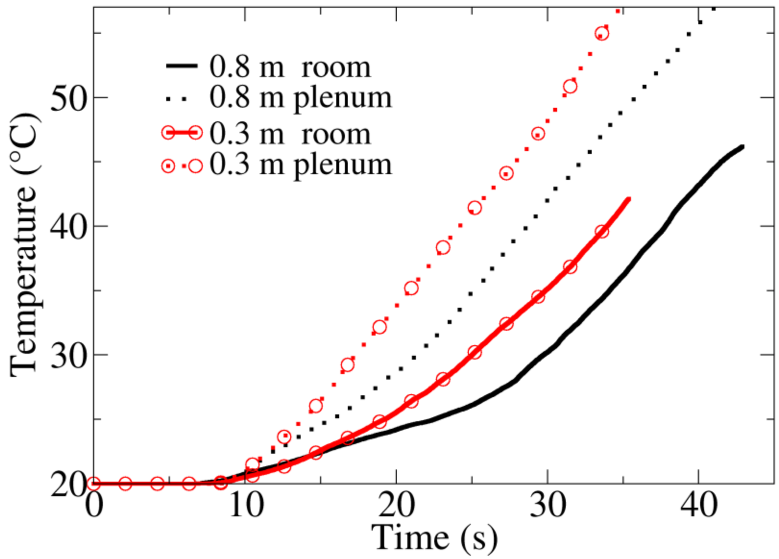
C = 50 with 0.5 m x 0.5 m plates

Shallow plenum

- A different plenum height might change the results
  - Two loss coefficients, 50 and 70, tested but showing results for C = 50
- Overall heating of the sprinklers was faster, but the difference between room and plenum remained about the same



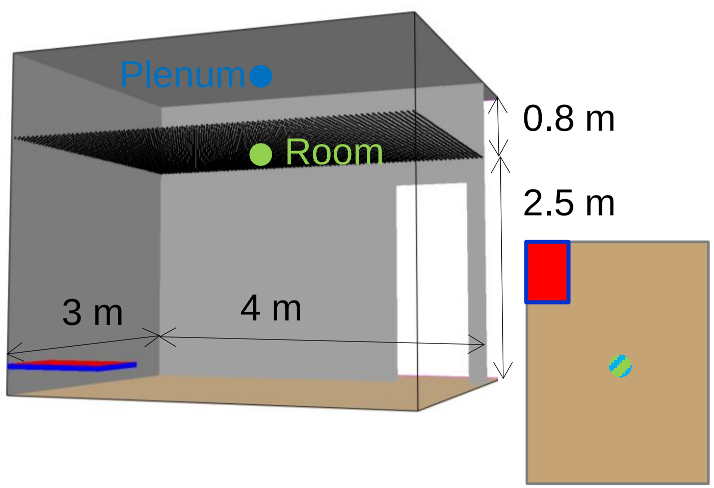
Dimensions of the simulated room



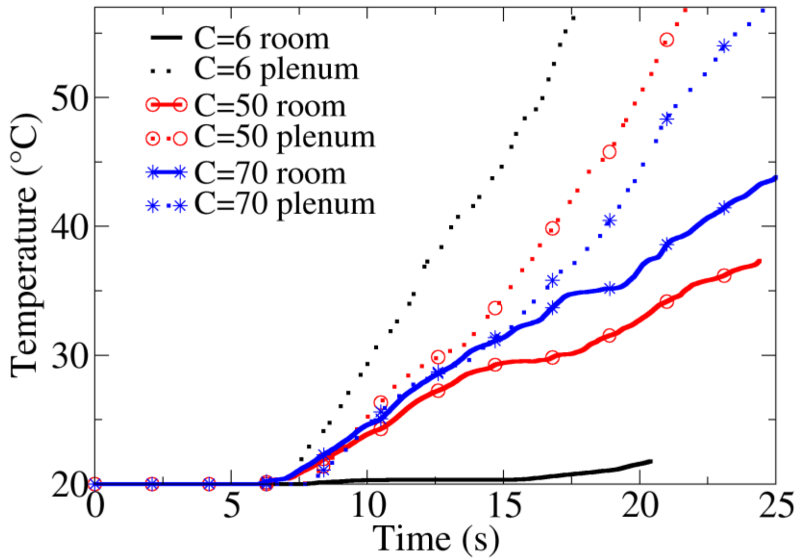
Averages of the four bulb temperatures, plenum or room

Small room

- The effect of room size was studied by simulating a small 3 m x 4 m room, with one sprinkler, fire in the corner of the room and 0.8 m plenum height
- Three loss coefficients, C = 6, C = 50 and C = 70
- After initial phase, the room/plenum sprinkler temperatures seem to deviate even more than for the larger room



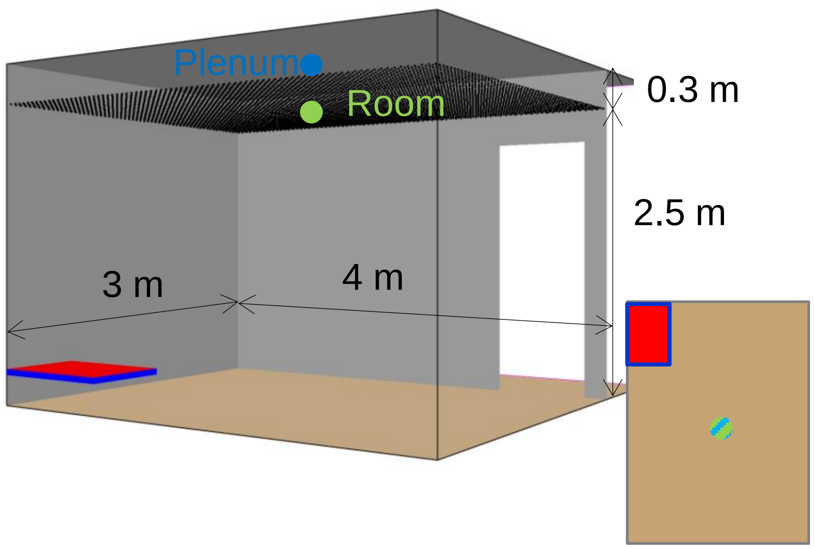
Dimensions of the simulated room



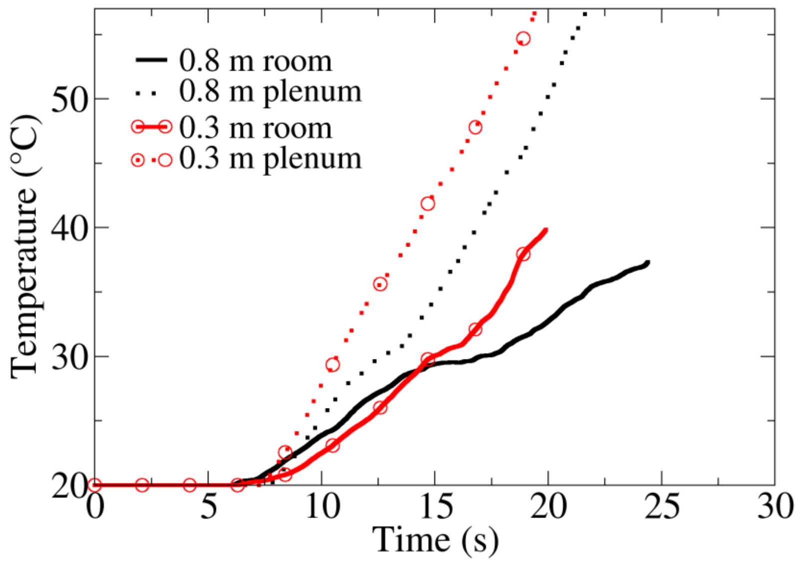
Bulb temperatures, plenum or room

Small room with shallow plenum

- The effect of the plenum height was checked by simulating the small room with 0.3 m plenum
  - Three loss coefficients, 6, 50 and 70, but showing results for C = 50
- Like with larger room case, decreasing space between false and real ceilings made sprinkler heating faster, but deviation between room and plenum sprinklers remained about the same



Dimensions of the simulated room



Bulb temperatures, plenum or room

Overall trends from computer simulations

Room	Conditions	Results
40 m² room with 0.8 m plenum	Fully open/closed and half open ceiling materials with different fire growth rates	Fully open: ”plenum” sprinkler activates first Fully closed: plenum sprinkler remains cool Differences are larger with faster fire growth rate
	A range of ceiling material loss coefficients	Activation time in general gets longer with increasing loss coefficient. With all simulated coefficients the plenum sprinkler activates first. With highest coefficients (C = 70 or 90) the delay of room sprinkler is rather small.
	Heat collectors	Heat collectors have no significant effect on activation times.

Overall trends from computer simulations

Room	Conditions	Results
40 m^2 room with 0.3 m plenum	Two ceiling material loss coefficients	With less space in plenum, activation times get shorter but room/plenum order does not change
12 m^2 room with 0.8 m plenum	Three ceiling material loss coefficients	With smaller room, activation times get shorter but room/plenum order does not change
12 m^2 room with 0.3 m plenum	Three ceiling material loss coefficients	Same consequence as in larger room

Conclusions

According to FDS fire simulation results with sparse suspended ceilings:

- Using sprinklers below false ceilings with conventional glass bulb activation leads to a significant delay in activation
- Using a separate activation mechanism in plenum minimizes the delay in activation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