Design fire scenarios and fire simulations for the CMS experimental cavern

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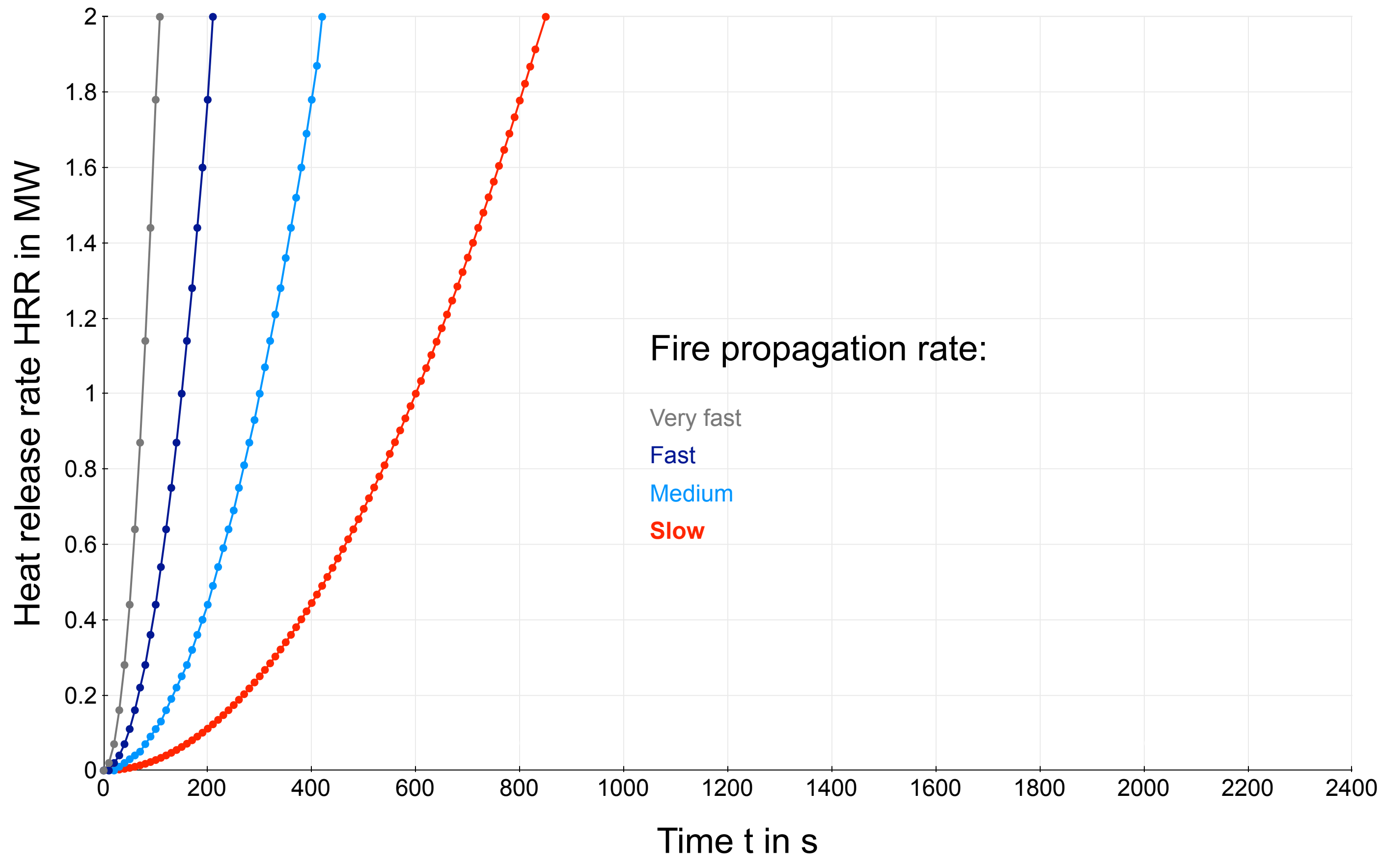
Risk assessment – where to start?

Photos taken in USC55 by Niels Dupont-Sagorin, Deputy GLIMOS, October 2011

Design fire scenarios



Alpert, Ronald L., Ceiling Jet Flows, in Chapter 2: Fire Dynamics, SFPE Handbook of Fire Engineering, 4th ed., 2008

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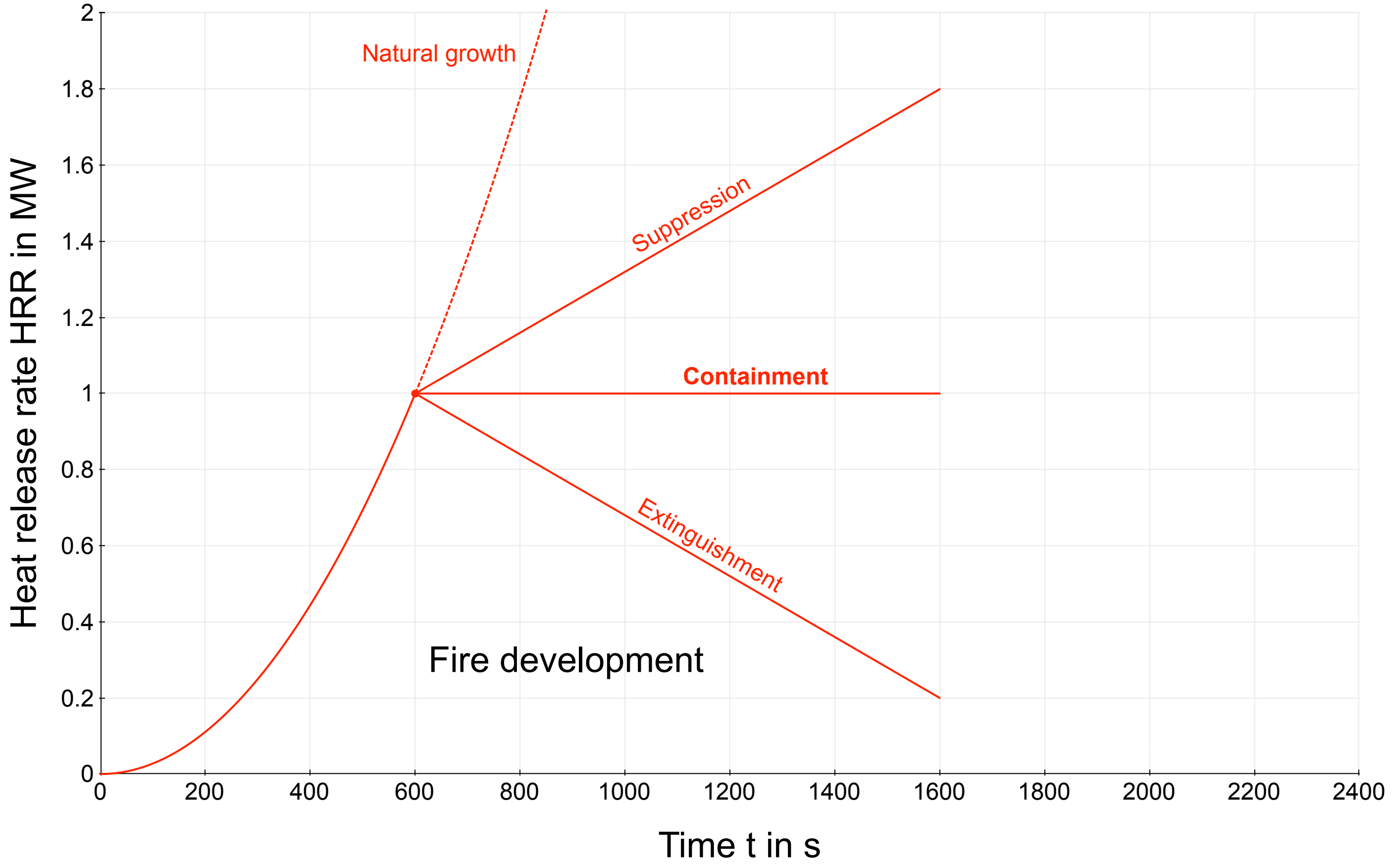
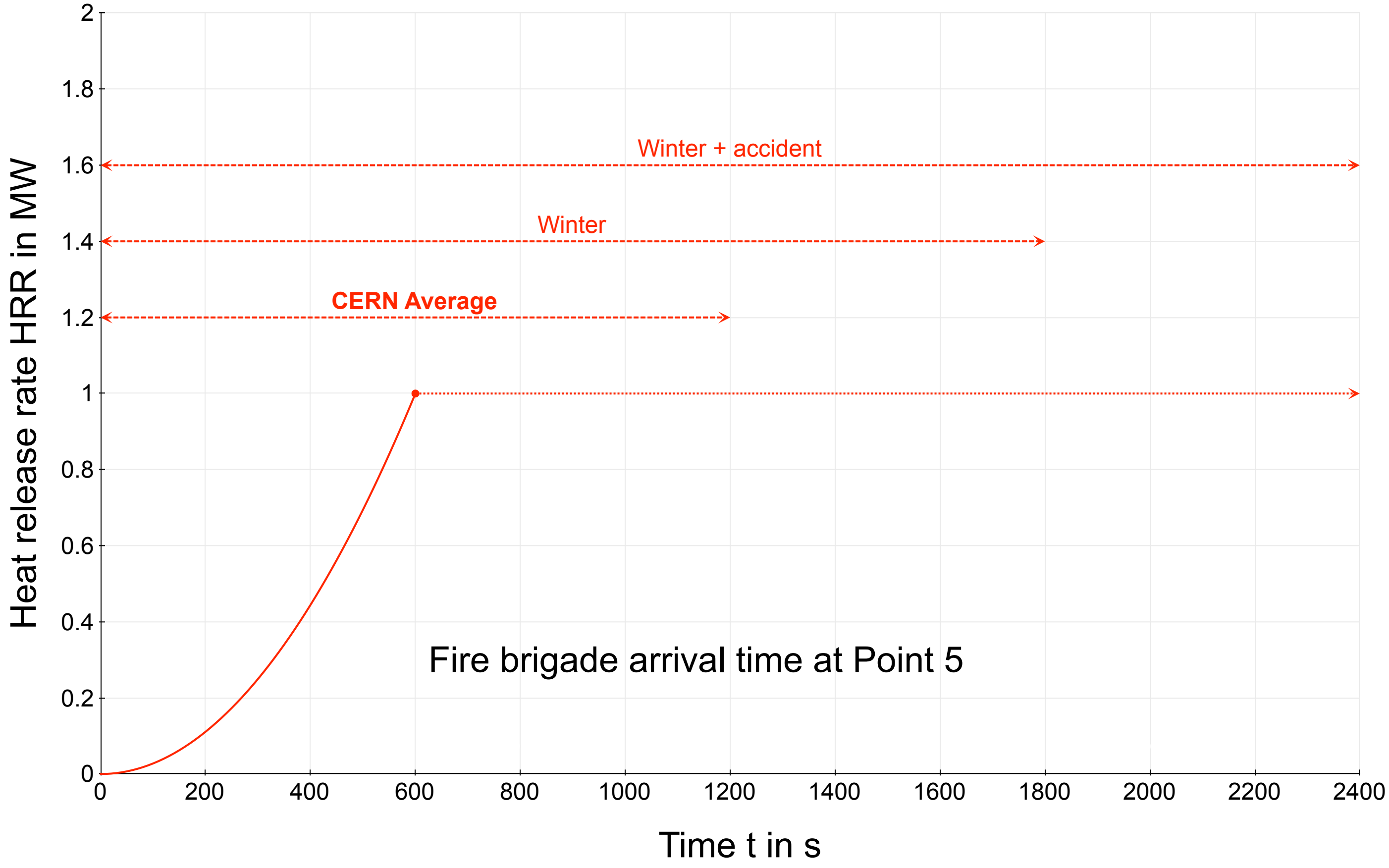


Hosser, Dietmar (editor), Leitfaden Ingenieurmethoden des Brandschutzes (German fire safety engineering guidelines), Technical report TB 04-01, vfdb, 2009

Design fire scenarios



Design fire scenarios

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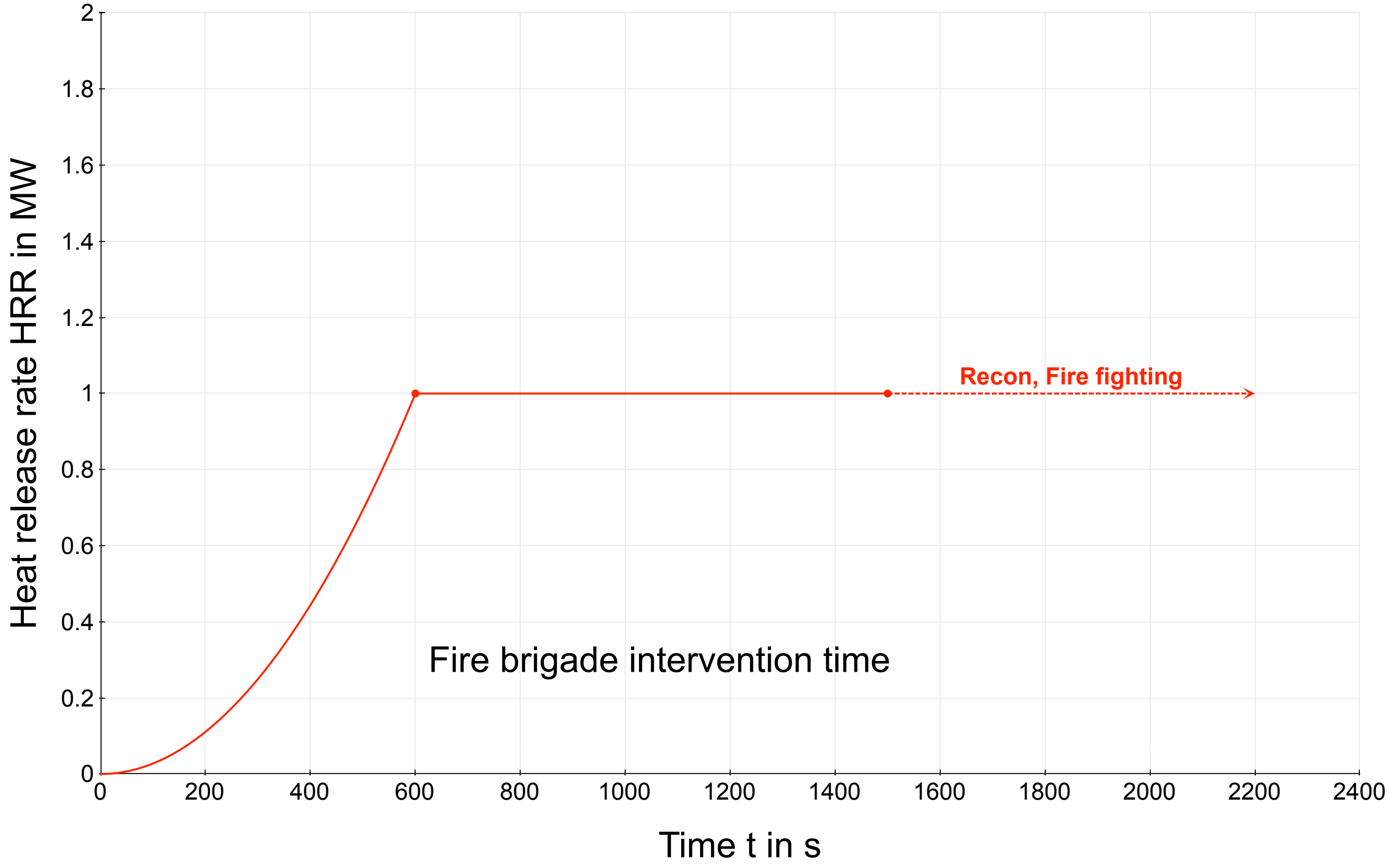

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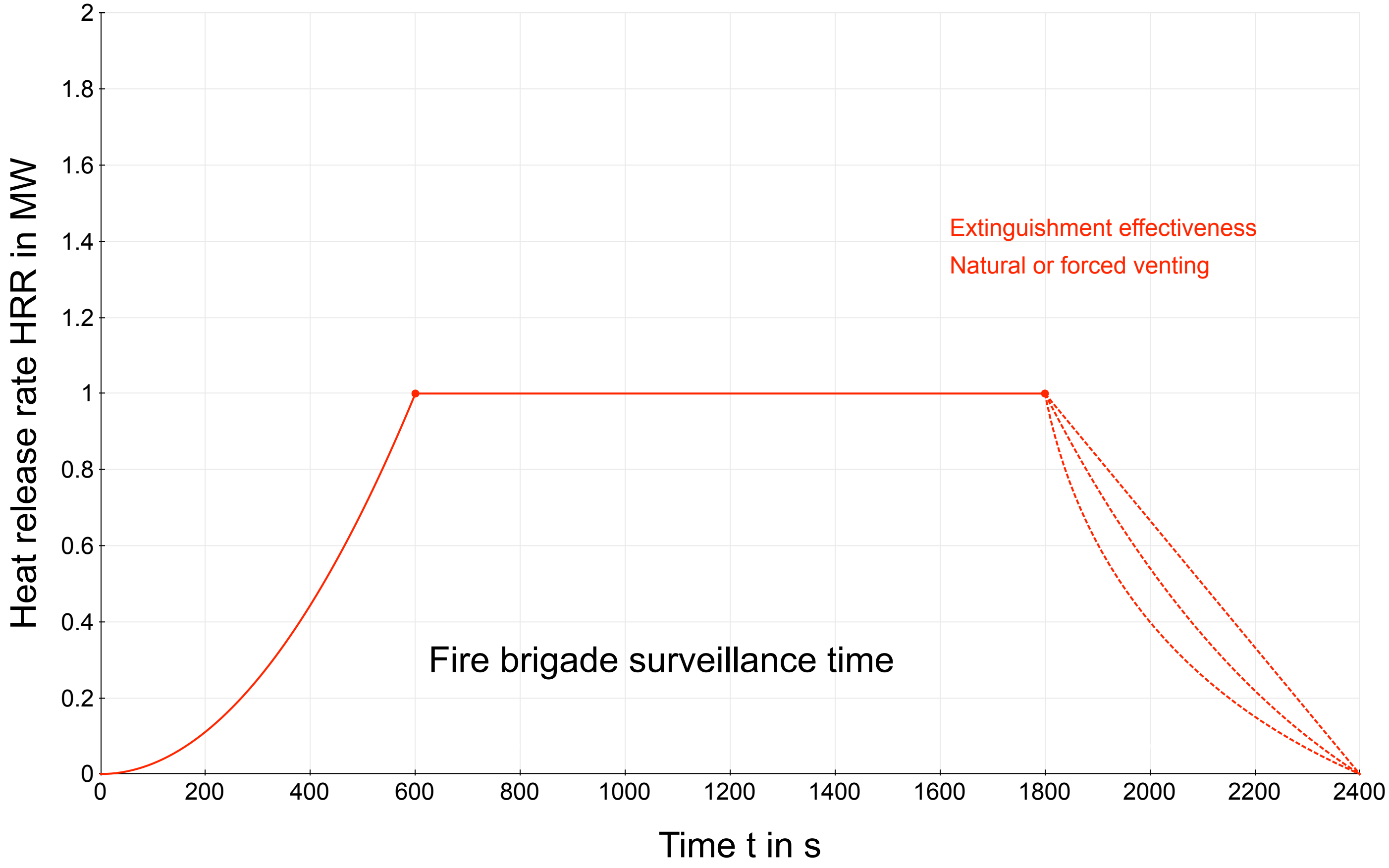

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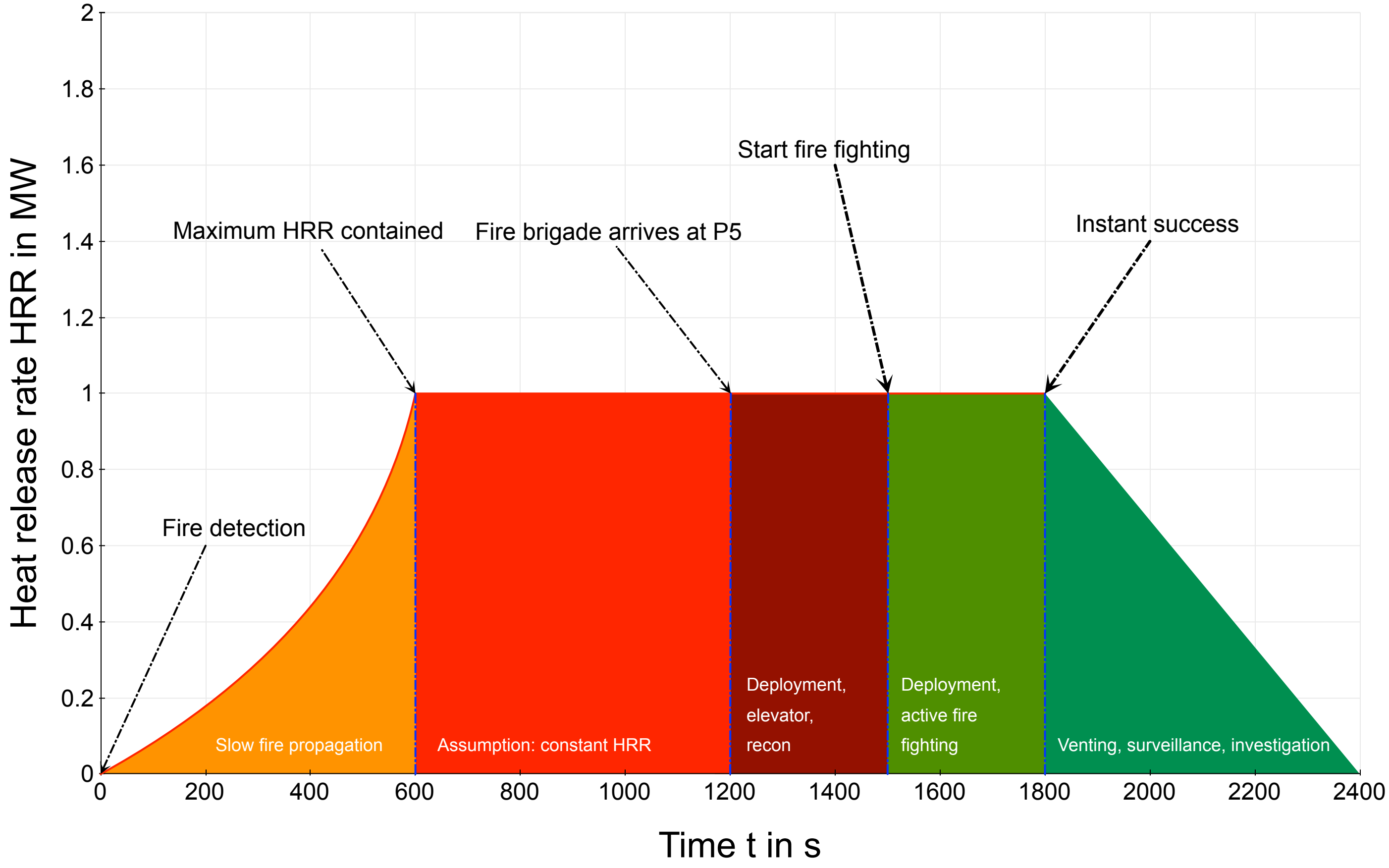
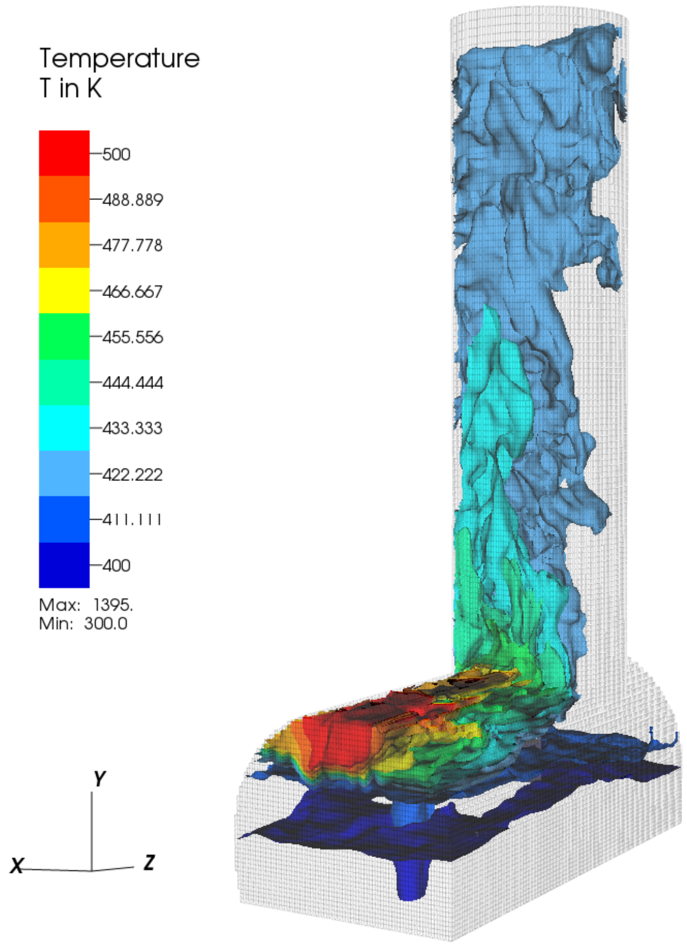


Numerical simulations with OpenFOAM

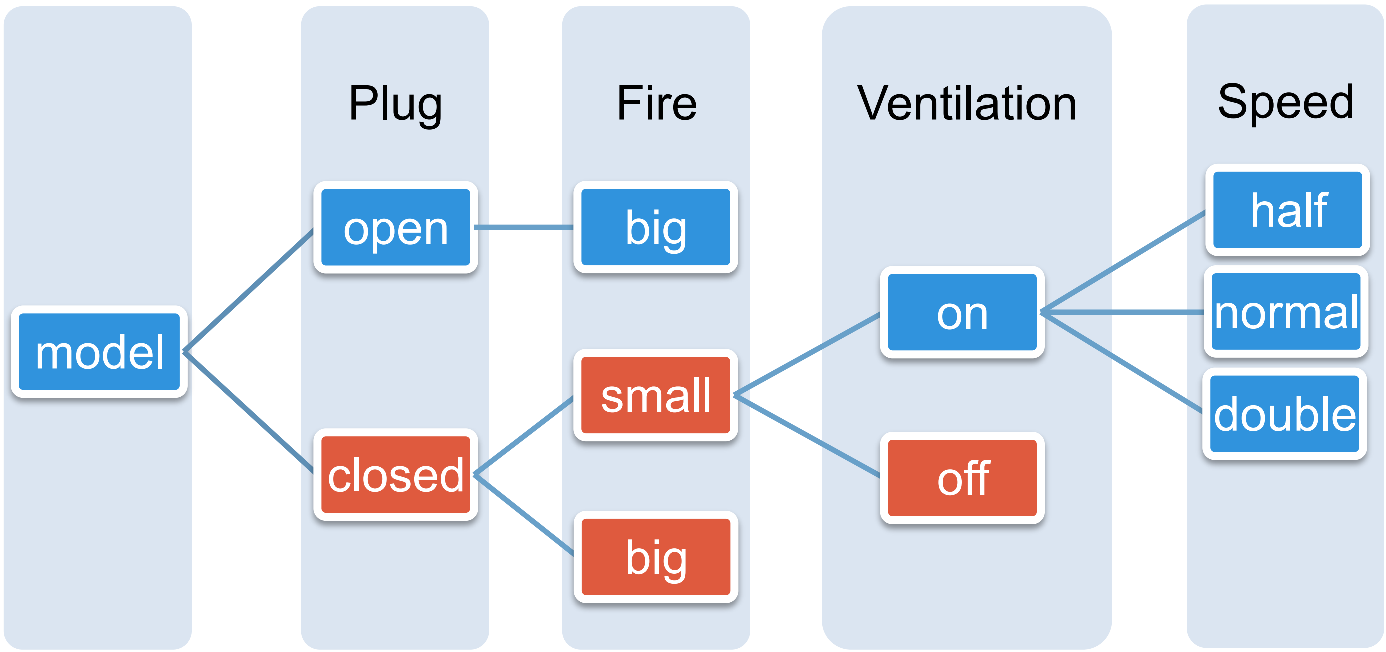
- UXC55 volume w/o detector
- 700,000 to 6,000,000 cells
- About 20 equations per cell
- Implicit/explicit solving schemes
- 5 species: CH_4,O_2,N_2,CO_2,H_2O
- 1-step infinite fast reaction
- Mass and heat transfer
- Single burner w constant HRR
- Parallel computationally expensive



http://code.google.com/p/firefoam-dev/

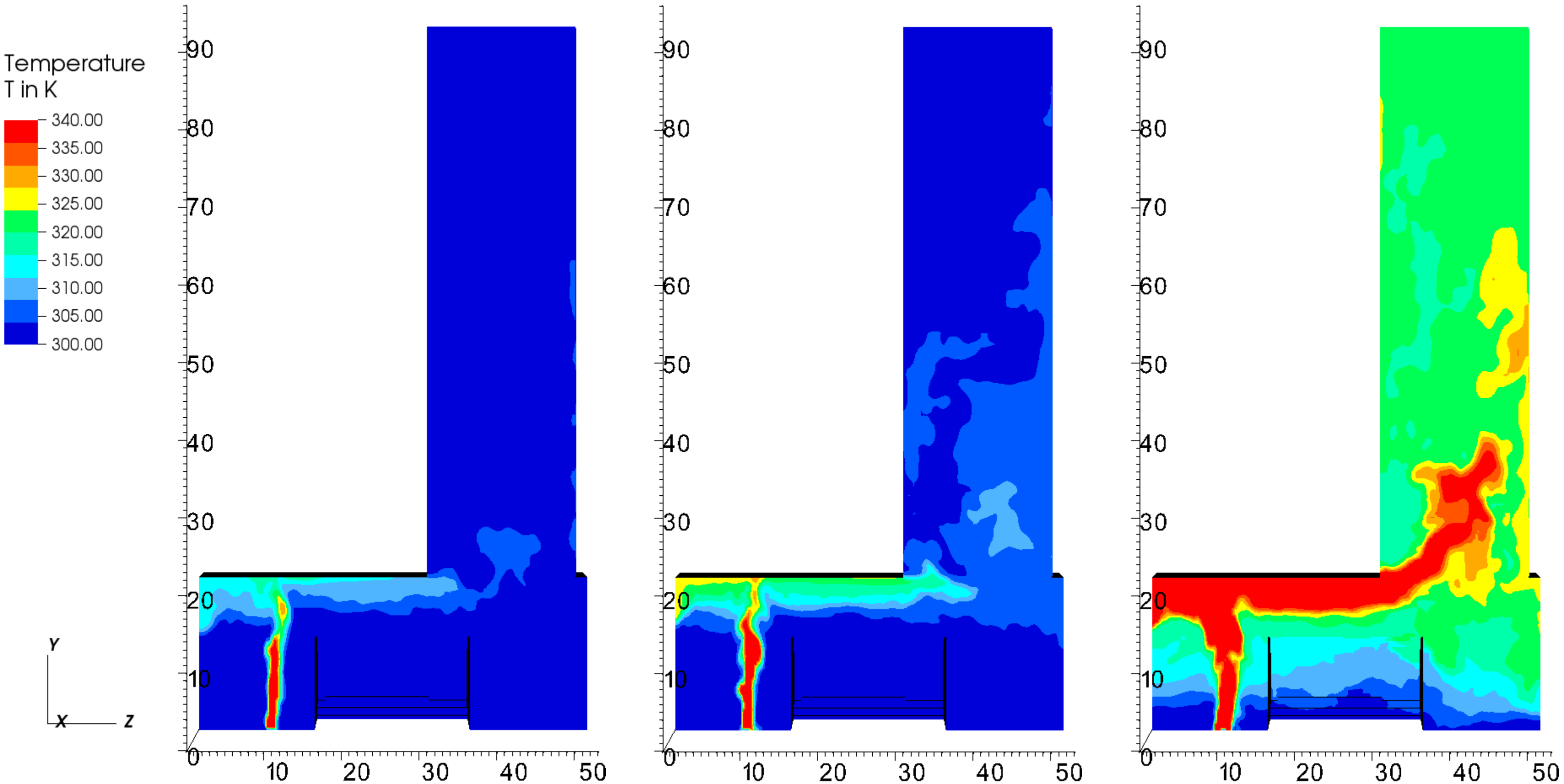
http://www.openfoam.org/

Comparison 0.5, 1 and 5 MW steady fire with closed plug



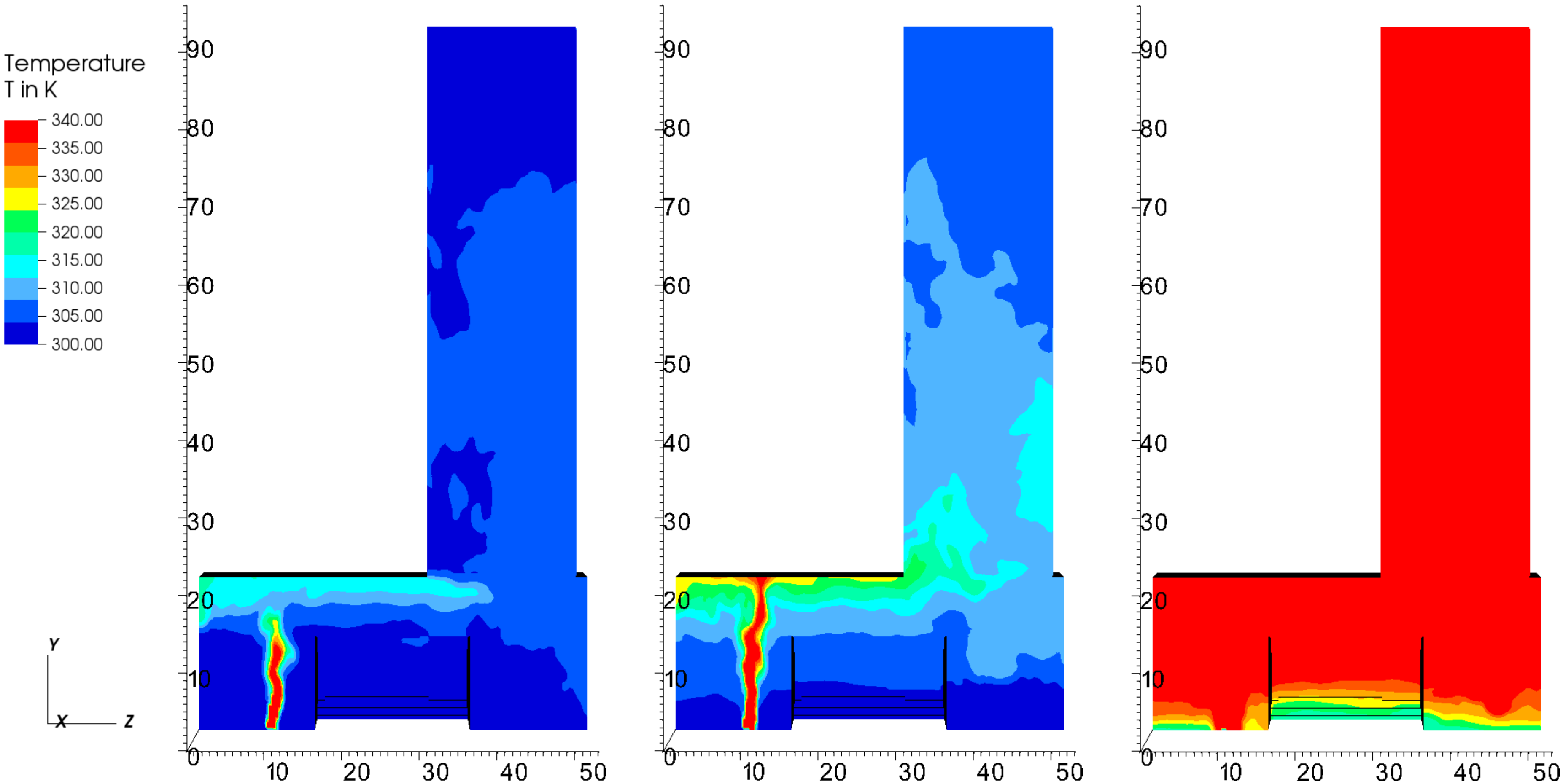
Fire: gaseous CH_4, 0.5, 1 and 5 MW max. HRR, 20 min steady combustion

Temperature distribution at t=300 s



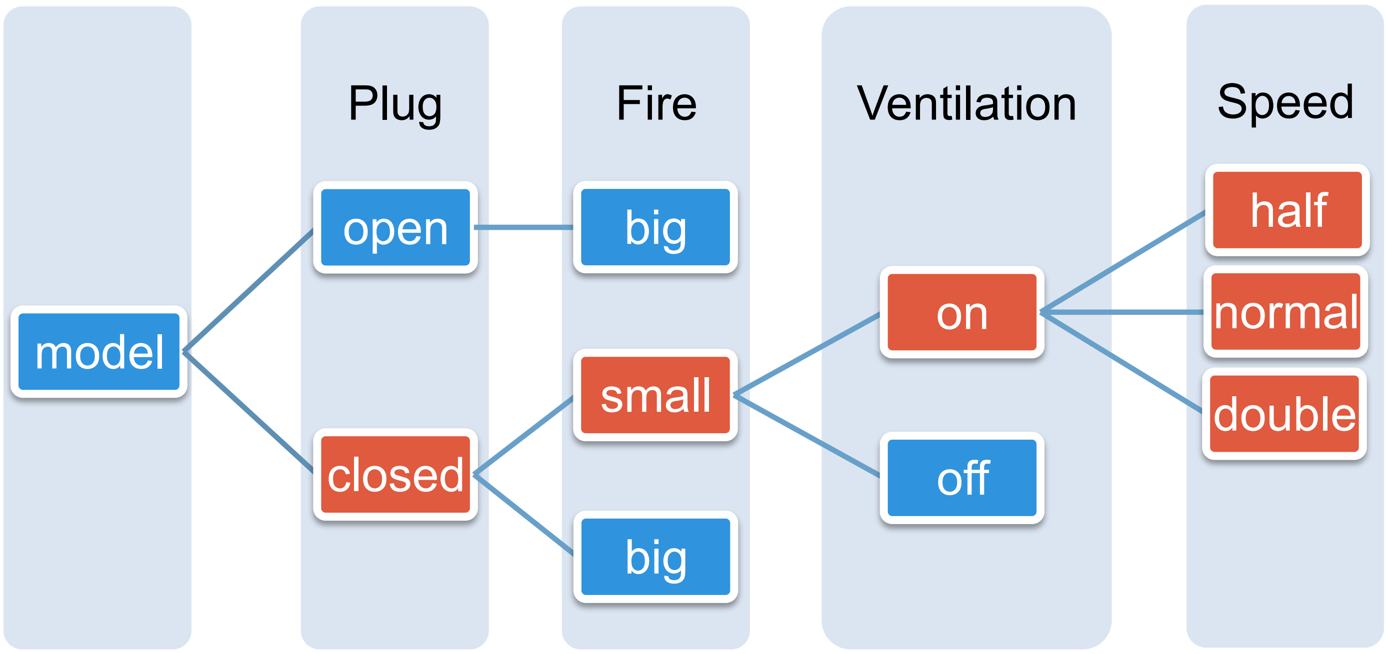
Maximum HRR 0.5 MW 1.0 MW 5.0 MW

Temperature distribution at t=600 s



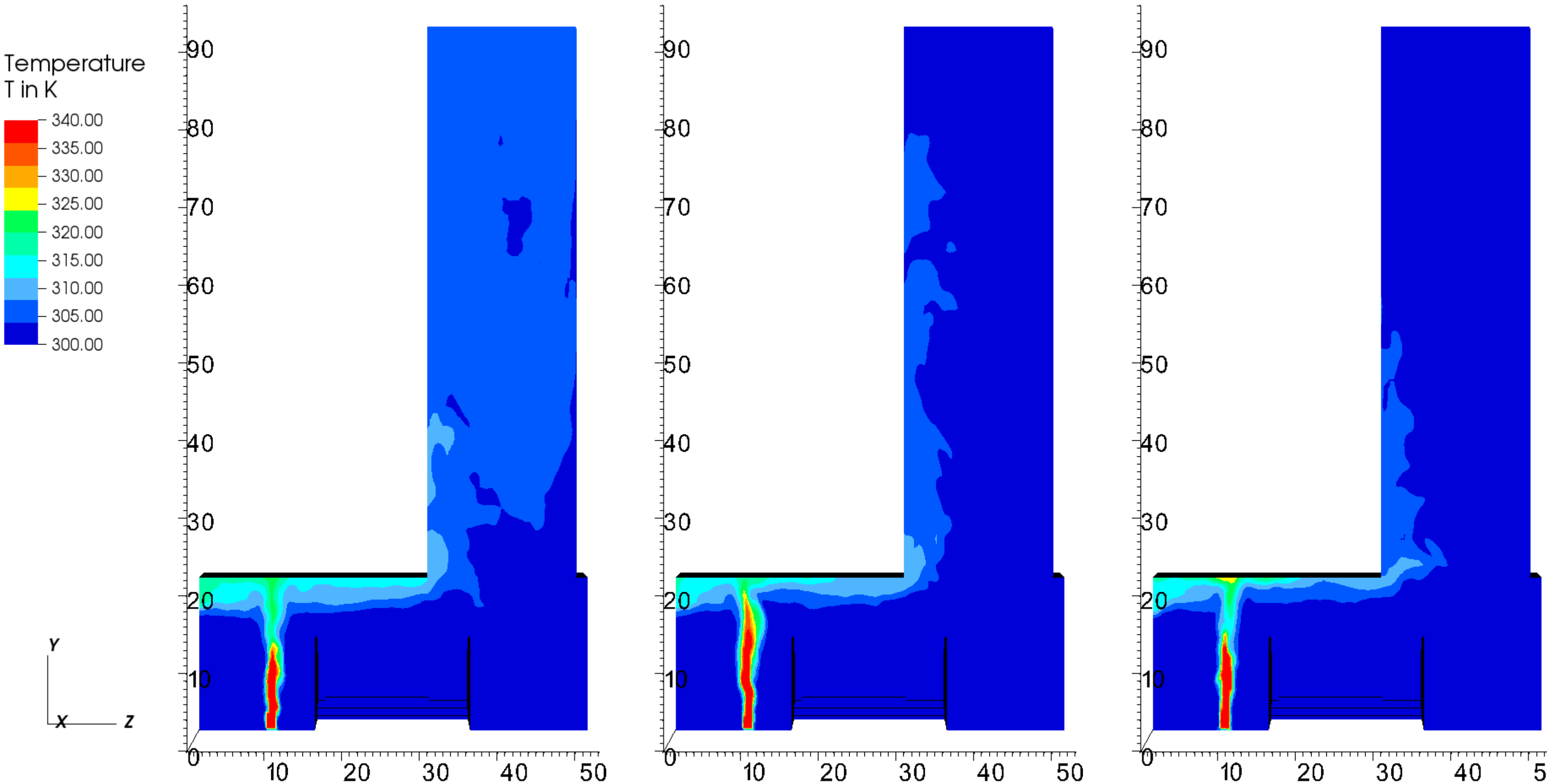
Maximum HRR 0.5 MW 1.0 MW 5.0 MW

Comparison 0.5 MW steady fire with different ventilation speeds



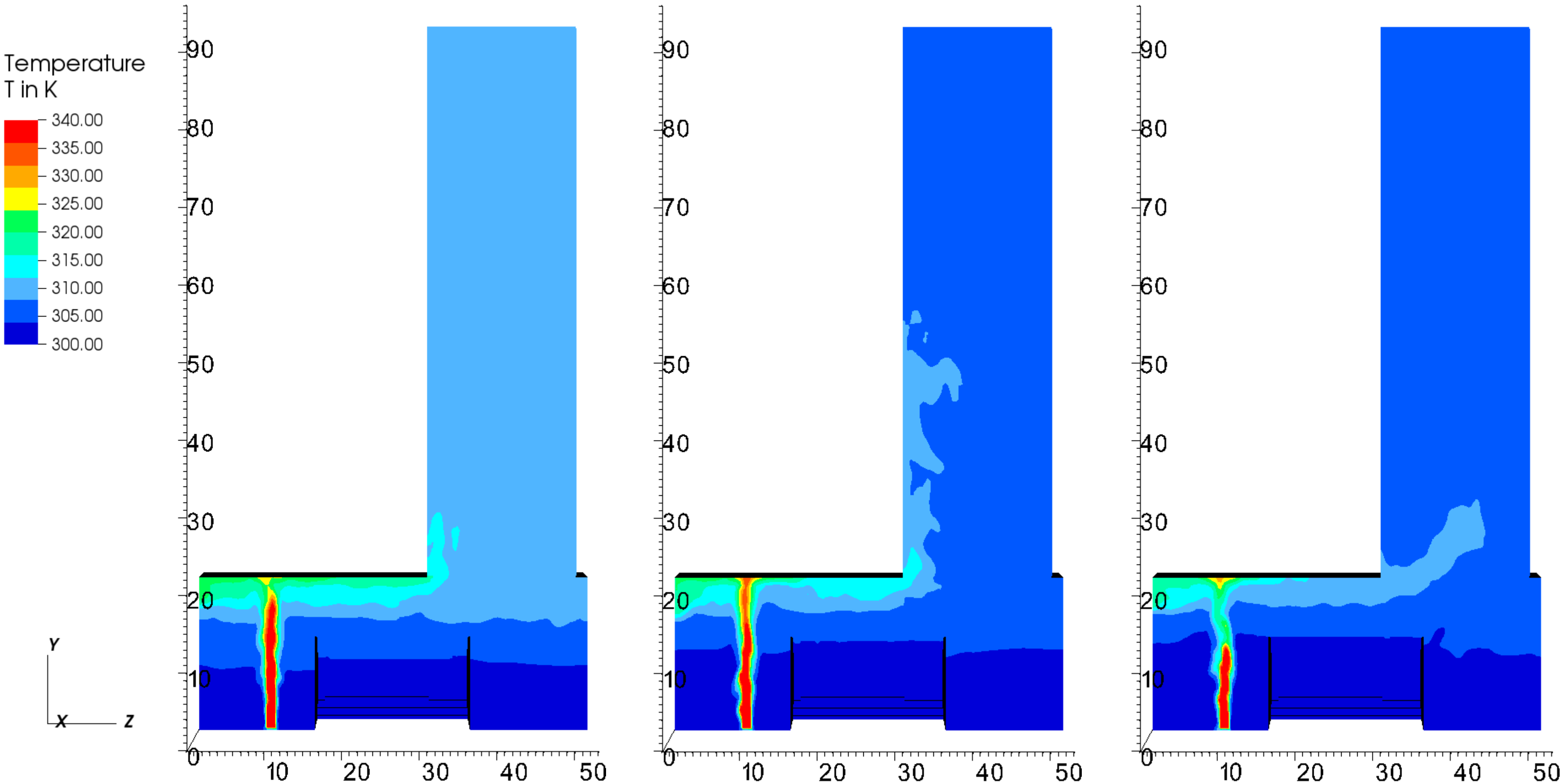
Fire: gaseous CH_4, 0.5 MW max. HRR, 20 min steady combustion
Ventilation flows: 20,000 m^3/h, 40,000 m^3/h and 60,000 m^3/h

Temperature distribution at t=600 s



Ventilation flow 20,000 m³/h — 40,000 m³/h — 60,000 m³/h

Temperature distribution at t=1200 s

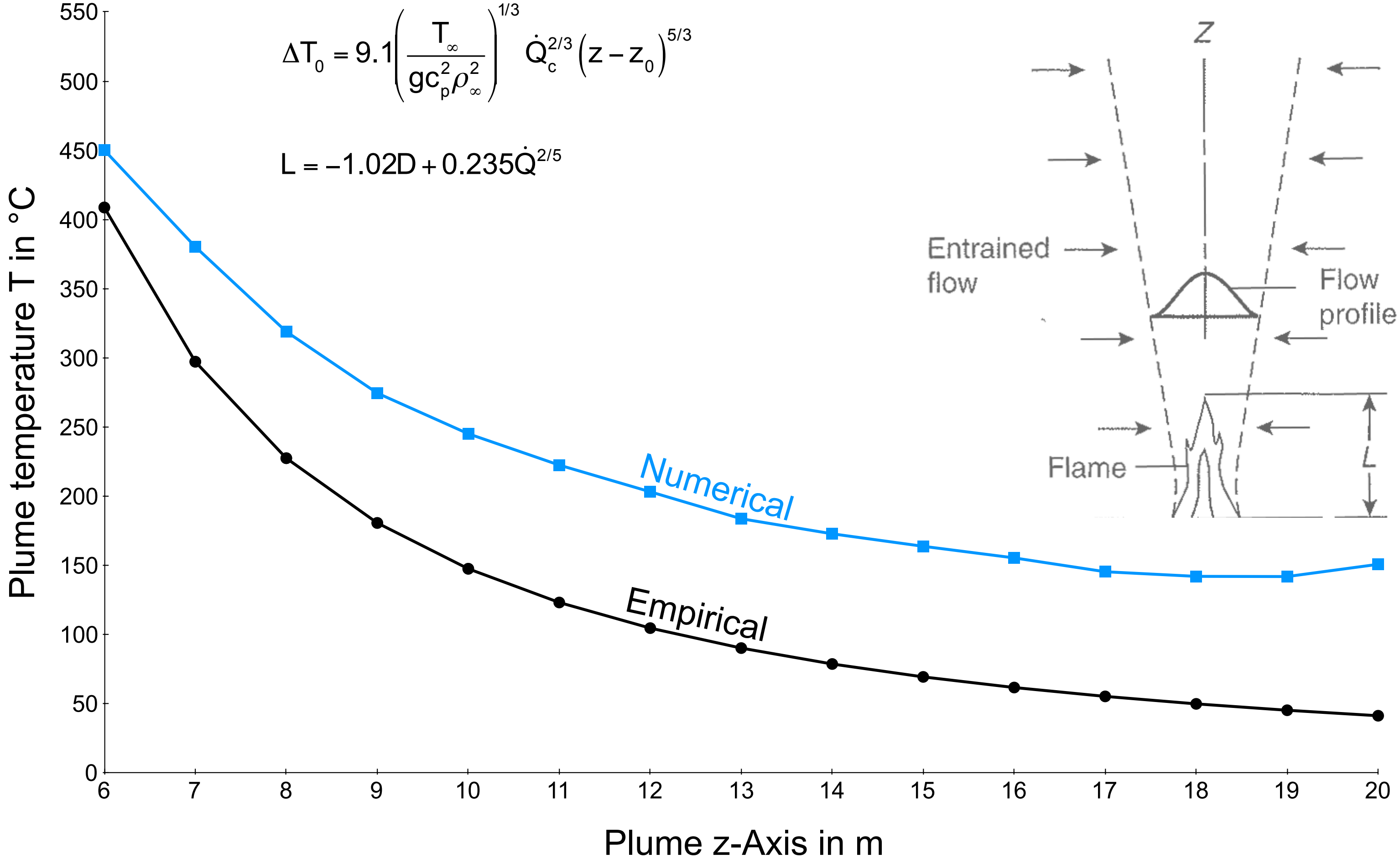


Ventilation flow 20,000 m³/h 40,000 m³/h 60,000 m³/h

Comparison with empirical solutions

$$\Delta T_0 = 9.1\left(\frac{T_\infty}{g c_p^2 \rho_\infty^2}\right)^{1/3} \dot{Q}_c^{2/3}\left(z - z_0\right)^{5/3}$$

$$L = -1.02D + 0.235\dot{Q}^{2/5}$$



Heskestad, Gunnar, Fire Plumes, Flame Height and Air Entrainment, in Chapter 2: Fire Dynamics, SFPE Handbook of Fire Protection Engineering, 4th ed.,2008

Conclusions

- Model shows qualitative agreement with hand calculations and empirical correlations
- Solid part to be investigated
- Diffusion model or similar needed
- Aerosol interaction model necessary