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# Numerical Study of Smoke Dynamics in Vertical Shaft of High-Rise Buildings

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## Extended Abstract

Smoke dynamics in high-rise buildings is of interest to building engineers because of safety concerns. The temperatures, velocities, pressures, and flowrates of smoke rising in buildings of various heights as a function of fire size are simulated using the Fire Dynamics Simulator software. Numerical results are validated against analytic solutions in confined and un-confined systems. As the building width decreases and the fire size increases, buoyancy-driven flow is accelerated, hence increasing overall building temperature. In addition, low pressure at the bottom of the building increases the vertical pressure gradient throughout the building. These parametric studies can be used to develop design-safety guidelines for building engineers who are concerned with smoke dynamics.

A turbulent flame propagation inside a building is an extremely complex phenomenon because the heat-release rate nonlinearly changes as the fire grows [1]. Furthermore, the motion of smoke is never symmetric because air supplies through windows and doors are essentially random while the locations of fires constantly change as the fire grows [2].

The theory of self-similar laminar plane and axisymmetric plumes developed by Zeldovich [3] was the starting point in this field. This jet theory is a part of the general boundary layer theory of buoyancy-driven flows described in the well-known monographs of Jaluria [4] and Yarin [5], as well as in the review of Turner [8]. Self-similar solutions for turbulent plane and axisymmetric plumes in the framework of the Prandtl mixing length theory of turbulence are available in [5]. Here, the analytical predictions of the self-similar turbulent plume theory are compared to the numerical simulations using FDS and verified against experimental data.

Parametric studies were performed to analyze the effect of fire size in various building cross-sectional areas of 25, 100, 400, and 1600 m$^2$ on smoke temperature. The computational results are compared against the empirical fit of McCaffrey. To change the heating power of the fire, its physical diameter was changed to yield 2, 5, 10, and 20 MW heating sources. It should be reminded that the numerical data are the time-averaged values obtained over 600 s duration at the centerline of the computatonal domain.

When the building size is further reduced to 100 and 25 m$^2$, a clear deviation is shown from the empirical fit. While narrowing the building size, the smoke rise accelerates owing to the simple principle of continuity equation. This acceleration promotes a cooling of the smoke and thus $\Delta T$ is reduced. This flow acceleration effect is further magnified when the building size is reduced from 100 to 25 m$^2$.

When the building size is downsized to 25 m$^2$, the smoke velocities are constant throughout the entire building up to the top, showing no sign of momentum redistribution even up to the top. This trend indicates that flow acceleration dominates the flow physics herein and the classical plume flow physics does not apply in such a case.

## References

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