Abstract

A method is proposed for small-scale testing with fire-induced smoke and heat in building compartments. In order to replicate the ceiling jet from the fire, an analogy is drawn between the purely buoyant smoke plume and a combined buoyancy and momentum-driven flow, i.e., hot air with an initial velocity. The analogy is based on preserving the momentum and energy of the actual smoke plume and translating these quantities into a uniform temperature and velocity for the flow of hot air. Estimation of the momentum and energy is based on empirical correlations for the smoke plume and integration of the Gaussian temperature and velocity profiles. The effect of plume diameter in integration is examined by comparing ceiling jets from full-scale FDS simulations with different diameters against the ceiling jets from simulations of $1 MW$ to $3 MW$ fires. Next, simulations with the hot air model and actual fires are downscaled with three scale factors of 1/10, 1/15, and 1/20, and a comparison of ceiling jet characteristics is made between both cases against full-scale fire simulations. The input parameters including the inlet temperature and velocity, the cross-section area, and the height of injecting hot air into the compartment are based on Froude scaling. Small-scale experiments with similar configurations using the proposed method are used to validate the simulation results by means of comparing temperature measurements. Experimental and simulation measurements of ceiling jet temperatures using the proposed method are in acceptable agreement with respect to existing empirical correlations derived from full-scale experiments. Based on the present outcomes, the proposed method can partially eliminate the discrepancies in the ceiling jet temperatures due to the weak turbulence in small-scale building spaces. However, this method is applicable for studies where the ceiling jet and smoke behavior at further distances from the fire source are more relevant than flames and smoke plume.