PARAMETRIC STUDY WITH A COMPUTATIONAL MODEL SIMULATING INTERACTION BETWEEN FIRE PLUME AND SPRINKLER SPRAY

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A parametric study to improve sprinkler performance is being carried out using numerical models predicting actual delivered densities (ADDs) of early suppression fast response (ESFR) sprinklers in heptane-spray fire scenarios. The computational models were developed through the following stages.

First, in order to supply input data for development of numerical models and experimental data for validation of the models, four sets of measurements were carried out. The measurements were momentum and water flux distribution of two ESFR sprinkler sprays without fire, temperature and axial velocities along the axis of free-burn fires, and actual delivered densities. Then, a numerical model for a sprinkler spray was completed by assigning representative drop size, mass flow rate, discharge speed, and discharge angle of 275 trajectories in such a way that they produce reasonable agreement with the measured water flux distribution and spray momentum in absence of fire. A numerical model for the free-burn fire was created by assigning a heat flux distribution on the horizontal surface and simulating a central, vertical air jet used in the experiment, varying parameters until a reasonable match was established with the measured temperatures and the axial velocities along the axis.

Numerical computations of actual delivered densities were carried out by combining the water spray model and the free-burn fire model of predetermined fire sizes for different water flow rates of the sprinklers. ADDs obtained from the simulations compared reasonably well with those from the measurements. Figure 1 shows the ADDs with 1.88 l/s flow at 500, 1000, 1500 kW fires.

Once the models were completed, routine computations using the models are being carried out to study the impact of parameters in sprinkler performance. The most significant parameters dictating the penetration capability of water spray from a sprinkler are drop size distribution, spray momentum, ceiling clearance, and fire size. The performance will be compared in terms of sprinkler penetration ratio, the ratio of ADD without a fire to ADD with the fire, with different combinations of the parameters.

Preliminary results with varying water flow rates at an invariant fire size show the trend that Heskestad(1) observed during his experiment. When a fire intensity remain constant regardless of the water flow rates applied, the penetration ratio decreases as the flow rate increases up to a critical flow rate, after which the trend reverses itself. Figure 2 shows that the dominant parameter shifts from the drop size at relatively low flow rates to spray momentum as the flow rate increases, as indicated from the experiment(1).

References

1. Heskestad, G., "Sprinkler Performance as Related to Size and Design: Volume I–Laboratory Investigation," FMRC Serial No. 22437, RC79–T–1, Factory Mutual Research Corporation, Norwood, MA, 1979.

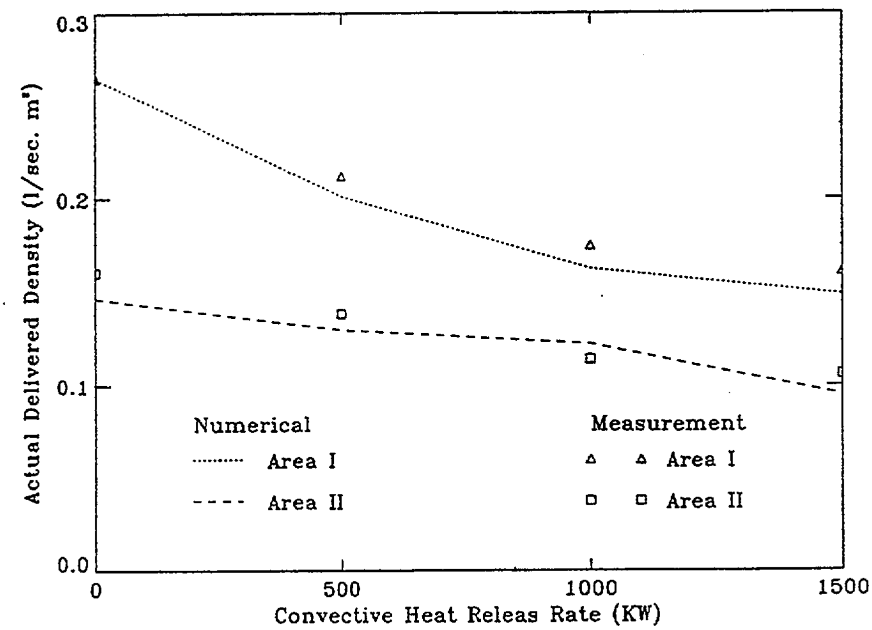

Figure 1. Actual delivered densities: 1.88 l/s flow at 0.5, 1.0, 1.5 MW fire.

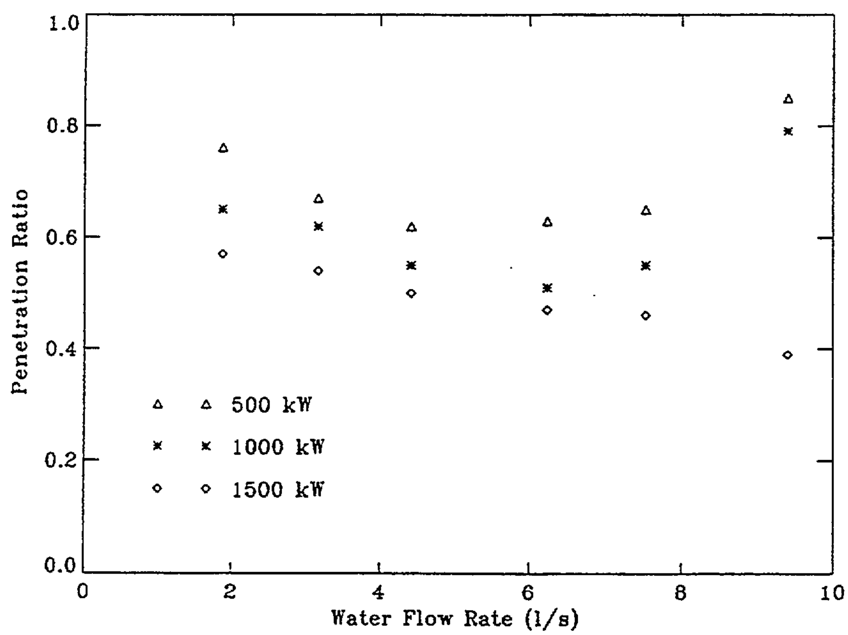

Figure 2. Penetration ratio vs. water flow rate (comp.).