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Book of Abstracts
November 2-5, 1998

Kellie Ann Beall, Editor

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Gaithersburg, Maryland 20899

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U.S. Department of Commerce
William M. Daley, *Secretary*
Technology Administration
Gary Bachula, *Acting Under Secretary for Technology*
National Institute of Standards and Technology
Raymond G. Kammer, *Director*

Numerical Modeling of Methanol Liquid Pool Fires for Fire Suppression

Kuldeep Prasad[1], **Chiping Li, K. Kailasanath**
Laboratory for Computational Physics and Fluid Dynamics
Naval Research Laboratory, Washington DC.

Chuka Ndubizu[2], **Ramagopal Ananth and P. A. Tatem**
Navy Technology Center for Safety and Survivability, Chemistry Division
Naval Research Laboratory, Washington DC.

This study is part of a larger program on numerical modeling of fire suppression using water-mist. Water-mist fire suppression has been studied for at least 50 years. Recent research in water-mist technology has been motivated by 1) the phase out of Halons and search for alternative technologies and 2) the need for low weight sprinkler systems on commercial ships as required by IMO regulations. Fine water-mist relies on relatively small (less than 200 μm) droplet sprays to extinguish fires. In Reference 1, we reported on the numerical modeling of water-mist suppression of gaseous methane-air diffusion flames. A two-continuum formulation was used in which the gas phase and the water-mist are both described by equations of the Eulerian form. The model was used to obtain a detail understanding of the physical processes involved during the interaction of water-mist and flames. The relative contribution of various mist suppression mechanisms was studied. The effects of droplet diameter, spray injection density and velocity on water-mist entrainment into the flames and flame suppression were quantified. Droplet trajectories were used to identify the regions of the flame where droplets evaporate and absorb energy. The model was used to determine the water-mist required for extinction, and this was reported in terms of the ratio of mist supply rate to the fuel flow rate. In Reference 2, a numerical study on optimizing various water-mist injection characteristics for maximum flame suppression were reported. The effects of droplet diameter, mist injection angle (throw angle), mist density and velocity on water-mist entrainment into the flame and flame suppression were quantified. Numerical results were presented for symmetric and asymmetric spray pattern geometries resulting from base injection and side injection nozzle orientation. Results indicate that smaller droplet diameters produce optimum suppression under base injection configuration, while larger droplets diameters are needed for optimum suppression for the side injection configuration.

We are currently extending the previous work on fire suppression to liquid pool fires. As a first step, we focus on the development of a numerical model to simulate the evaporation and burning of liquid methanol. The complete set of unsteady, compressible Navier-Stokes equations are solved in the gas phase to describe the advection of the fuel gases and the diffusion of these gases into the surrounding air. Heat transfer into the liquid pool and the metal container through conduction, convection and radiation are modeled by solving a modified form of the energy equation. The local burning rate of a two-dimensional pool is obtained by assuming that the gas phase and the liquid phase are in equilibrium with each other. The governing equations along with appropriate boundary and interface conditions are solved using the Flux Corrected Transport (FCT) model. Numerical results exhibit a flame structure that compares well with thermocouple experimental data. The overall burning rate was also found to compare well with experiments in single compartment and three compartment laboratory burners.

Figure 1 shows vorticity contours for a pulsating fire stabilized above a methanol liquid pool. These contours clearly show the presence of coherent vortical structures which are shed periodically by the fire. This phenomena has been documented for a wide range of burner diameters, heat release rates and fuel types. The pulsing nature of the flow field propagates downstream leading to a time varying flame length. The puffing frequency obtained from our simulations compares favorably with data compiled by various researchers. The local burning rate (or the rate of evaporation) as a function of distance along the pool surface has been shown in Figure 2 for an air co-flow velocity of 40 cm/s. We observe that the burning rate is very high at the pool edges and is smallest at the pool center. An energy equation is solved to obtain the temperature distribution (Figure 2) in the methanol liquid pool. It is observed that pool surface temperature is very close but lower than the boiling point temperature of pure liquid methanol ($T_{boil} = 337.5K$). The pool surface temperature is highest in the center of the pool and falls down to 332.5 K at the pool edge. This reduction in pool temperature is due to heat losses to the surrounding air and the metal container, as well as due to the high burning velocities at the pool edges.

1. Prasad, K., Li, C., Kailasanath, K., Ndubizu, C., Gopal, R. and Tatem, P. A., *Numerical Modeling of Water-Mist Suppression of Methane-Air Diffusion Flame,* Comb. Sci. & Tech., V. 132, 1-6, p. 325 (1998).
2. Prasad K., Li, C. and Kailasanath, K., *Optimizing Water-mist Injection Characteristics on Jet Diffusion Flames,* 27^{th} Symposium (Int.) on Combustion, (1998).

[1] Science Application International Corporation, VA.
[2] Geo-Centers Inc., MD

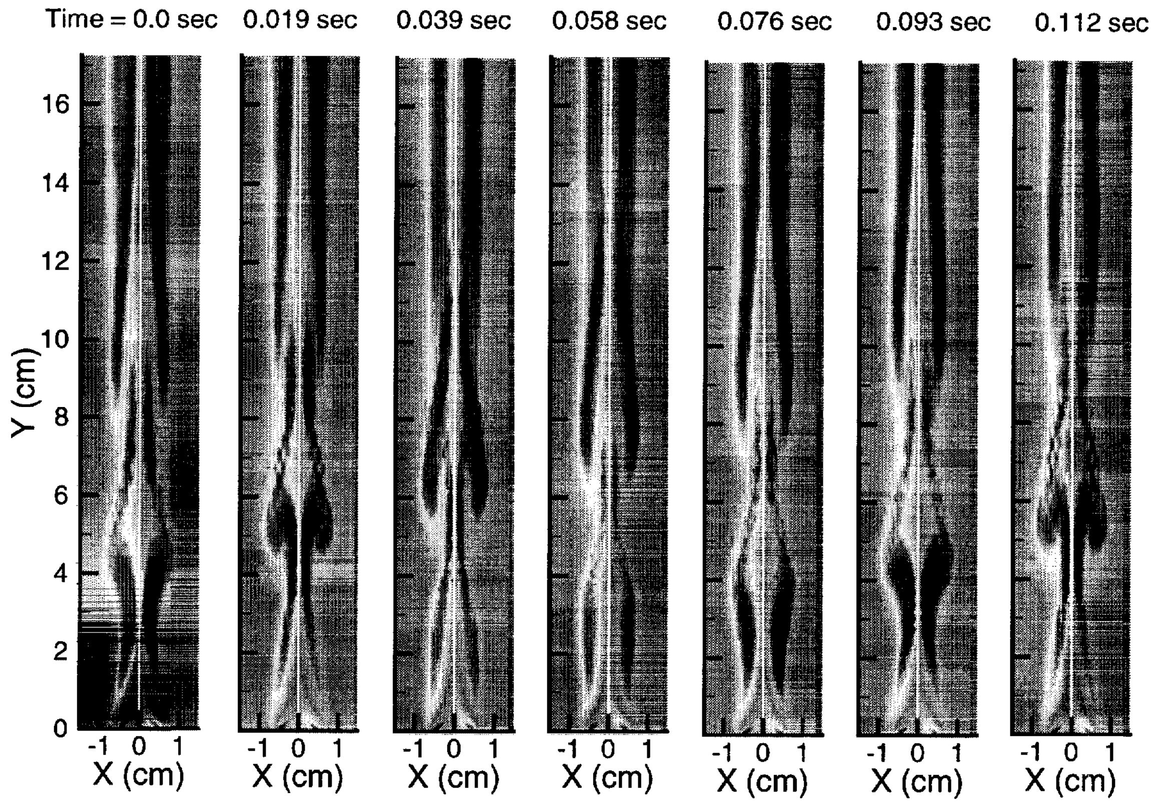

Figure 1: Vorticity contours at different time levels, above a pulsating methanol liquid pool fire illustrating the puffing nature of the diffusion flame for an air co-flow velocity of 10 cm/s.

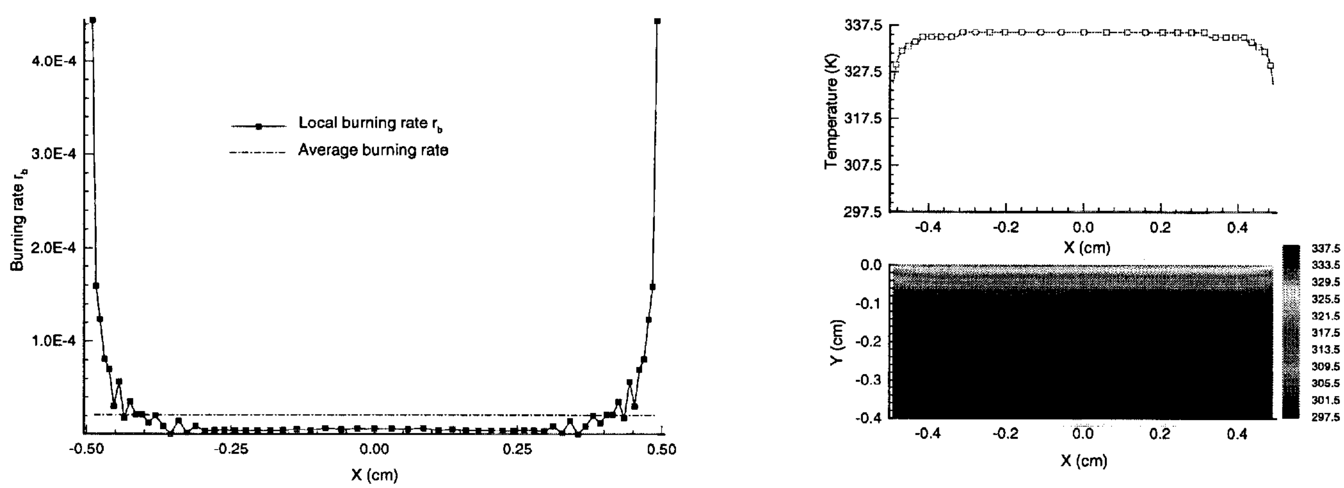

Figure 2: Variation of burning rate as a function of time for air co-flow velocities of 40 cm/sec. On the right are temperature contours in the liquid pool showing the structure of the thermal wave and pool surface temperature profile.