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THE EFFECTS OF TURBULENCE ON DROPLET DRAG AND SECONDARY DROPLET BREAKUP

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OVERVIEW:

The objective of this research is to obtain an improved understanding of the behavior of droplets in vaporizing sprays, particularly under conditions typical of those in high pressure rocket sprays. Experiments are conducted in a variety of high pressure, high temperature, optically-accessible flow systems, including one which is capable of operation at pressures up to 70 atm, temperatures up to 600 K, gas velocities up to 30 m/sec and turbulence intensities up to 40%. Single droplets, 50 to 500 micron in diameter, are produced by an aerodynamic droplet generator and transversely injected into the flow. Measurements are made of the droplet position, size, velocity and temperature and of the droplet's vapor wake from which droplet drag, dispersion, heating, vaporization and breakup are characterized.

RESULTS:

The main results from this study[1,2] to date are the following:

1. Under laminar flow conditions, vaporization was found to reduce droplet drag, in quantitative agreement with the drag correlation of Chiang, Raju and Sirignano, as illustrated in Figure 1.
2. Under laminar flow conditions, droplet drag was not affected by unsteady curvilinear motion.
3. Under laminar flow conditions, unsteady curvilinear motion was found to result in small but non-negligible droplet lift ($C_L/C_D \approx 0.1$), but only at relatively high droplet Reynolds numbers ($20 < Re < 38$), as illustrated in Figure 2.

4. Turbulence was found to result in an apparent increase in droplet drag, however, this can be accounted for by an appropriate redefinition of the mean relative velocity, as illustrated in Figure 3.
5. Turbulence was found to result in an apparent decrease in the critical Weber number for secondary droplet breakup, however, this can be accounted for by an appropriate redefinition of the mean relative velocity.
6. The phenomenological nature of secondary breakup was observed to be fundamentally different in turbulent and laminar flows.
7. Under conditions of large relative droplet velocity typical of sprays, droplet dispersion increases with a t^3 dependence and not the t^2 dependence predicted by classical dispersion theory, as illustrated in Figure 4.

The research plan for this current year includes an extension of the study of the effect of turbulence on secondary droplet breakup to vaporizing conditions, the first demonstration of the use of Raman scattering to characterize droplets injected into supercritical environments, the completion of the calibration of the exciplex droplet thermometry technique and the demonstration of a vapor wake visualization technique for determining the phenomenological effect of turbulence on droplet drag and of acoustic waves on droplet vaporization.

REFERENCES:

1. Song, Y.-H. and Santavicca, D. A., "An Experimental Study of Drag and Lift Acting on Evaporating Droplets Following Curvilinear Trajectories in a Laminar Flow," submitted to *Combustion Science and Technology*.
2. Song, Y.-H. and Santavicca, D. A., "The Effect of Turbulence on Droplet Drag and Secondary Droplet Breakup," in preparation.

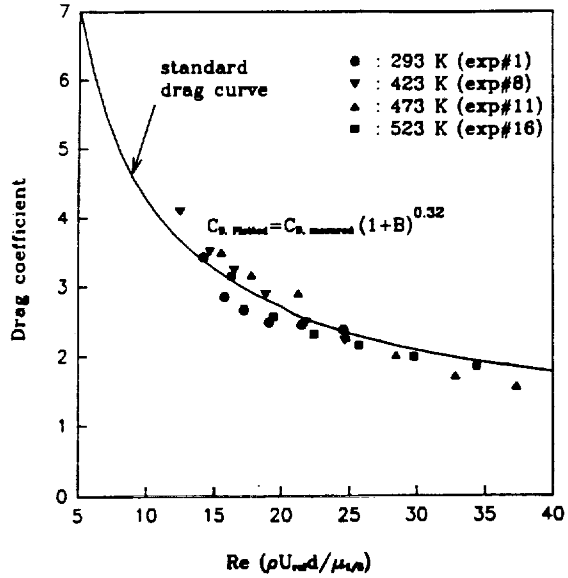

Figure 1. A comparison of the standard drag coefficient and the measured drag coefficient corrected to account for vaporization as proposed by Chiang, Raju and Sirignano.

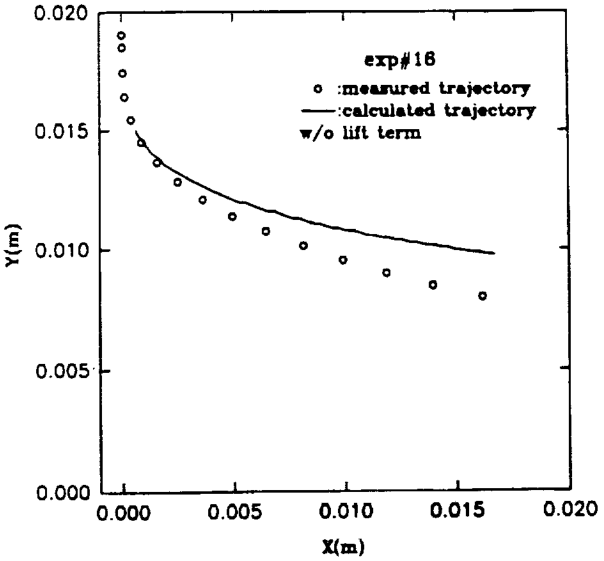

Figure 2. A comparison of the measured droplet trajectory and the predicted droplet trajectory calculated without lift.

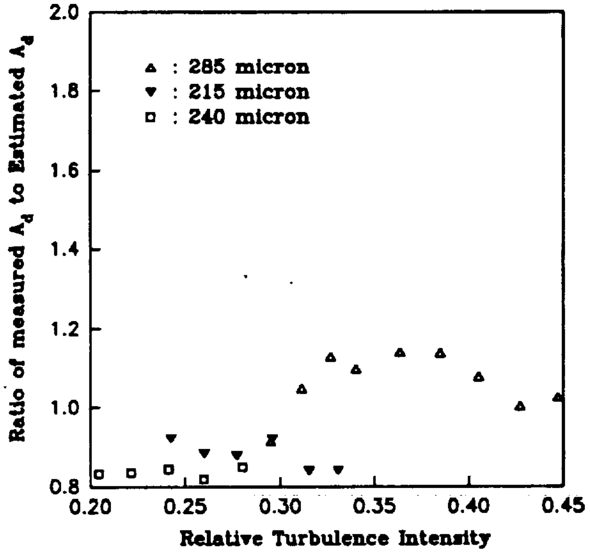

Figure 3. A comparison of the measured droplet acceleration and that calculated with the relative droplet velocity modified to account for gas velocity fluctuations.

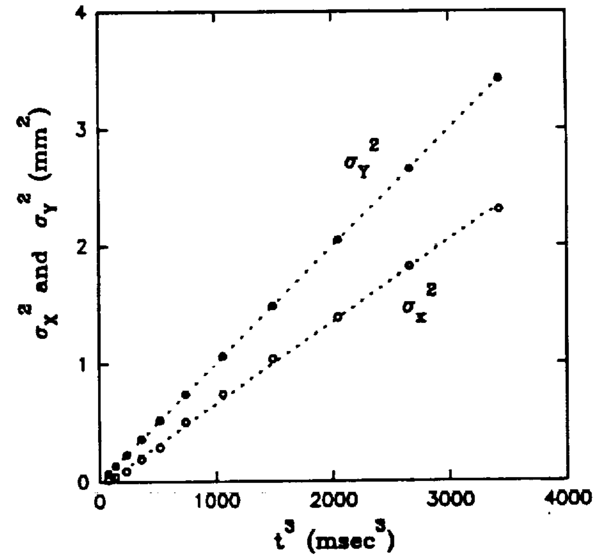

Figure 4. Measured droplet dispersion versus t^3.