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DOE/PC/94119--T10

Quarterly Technical Progress Report  
October 1996

PROJECT NAME: Development of a Phenomenological Model For Coal  
Slurry Atomization

DOE Grant #: DE-FG22-94PC94119

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## PROGRESS SUMMARY

### Atomization

Atomization tests on simulated fluids are being performed. For each sample tested,  $\Delta P_c$  is being determined as described in the last quarterly report. The results will be reported when the coal slurry testing is completed for comparative purposes.

### Viscoelastic Properties

The viscoelastic properties on the simulated fluids and coal water slurries are being determined using the Adelphi Stresstech Viscometer. A discussion of viscoelastic properties and their relationship to atomization is presented below.

### Viscoelastic Properties

In systems such as coal water slurries which can have internal structure, viscoelastic properties can be exhibited. These properties could affect the stability and the slurry breakup into ligaments upon exiting a nozzle orifice as well as the subsequent breakup of ligaments. Assume a deformation  $\gamma$  given by  $\gamma_0 e^{i\omega t}$  where  $\gamma_0$  is the maximum shear strain. Then for  $\omega T \ll 1$ , the fuel behaves like a viscous fluid.

$$\tau = \eta \dot{\gamma} = i\omega \eta \gamma \quad (1)$$

However, for large frequencies,  $\omega T \gg 1$ , the fluid behaves as a solid and the shear stress is given by the theory of elasticity

$$\tau = \mu \gamma \quad (2)$$

where  $\mu$  is the elastic storage modulus. For intermediate frequencies,  $\omega \sim 1/T$ , the stresses given by the two expressions must be of the same order of magnitude, which implies that

$$\omega \eta \sim \eta/T \sim \mu \quad \text{or} \quad \eta \sim \mu T$$

From these arguments, it is possible to develop a simple model (Maxwell model)

$$\tau = \mu \gamma / (1 - i/\omega T) \quad (3)$$

for which  $\omega \rightarrow 0$  yields  $\tau = i\omega T\mu \gamma$  and for  $\omega \rightarrow \infty$  yields  $\tau = \mu \gamma$  where  $\eta = T\mu$  is the fluid viscosity.

The complex shear modulus,  $G^*$ , can be defined by

$$\tau = G^* \gamma \quad (4)$$

where

$$G^* = \mu / 1 - i / \omega T = G' + iG'' \quad (5)$$

with

$$G'(\omega) = \mu \omega^2 T^2 / 1 + \omega^2 T^2 \quad (6)$$

$$G''(\omega) = \mu \omega T / 1 + \omega^2 T^2 \quad (7)$$

Theoretical analysis has shown that viscoelastic effects can impact the the break-up of liquid jets. Viscometric measurements on the slurries that were atomized will be performed in order to determine the relationship between  $G'$  and  $G''$  and the atomization quality. The slurries with the higher elastic component atomized poorly as compared to those slurries with the lower elastic components in previous studies. This is not unexpected since the break-up of ligaments or segments of fluid are caused by the growth of wave-like instabilities on the surface which is a frequency dependent phenomena. Elastic effects would be expected to inhibit fragmentation.

#### ACTIVITIES SCHEDULED FOR THE NEXT QUARTER

Atomization and viscoelastic testing on coal water slurries will be performed and results for both simulated and coal slurries presented.