**PROJECT ID: 54890**

# On-Line Slurry Viscosity and Concentration Measurement as a Real-Time Waste Stream Characterization Tool


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Number of Graduate Students: Three
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## DOE ISSUES BEING ADDRESSED

This work seeks to directly address the need for a robust technique to provide a comprehensive characterization of the rheological and other physical properties of tank slurries. In particular we have developed two techniques that have the potential to be used as an in-line viscometer to measure the viscosity of complex wastes during processing or, even in the tank. Such an instrument allows for the more precise control of the rheological properties and thereby allows for better control of the process itself. Ultimately it leads to the possibility of processing wastes at higher concentrations and reducing the need for diluting the wastes prior to pipeline transfer.

## RESEARCH OBJECTIVE

The principal objective of this work is to provide the theoretical and experimental foundations for a new in-line viscometer that can be used for radioactive waste slurries. A secondary objective is to understand how the suspension microstructure affects the rheological properties in order to make estimates of the properties based on the properties of the particles.

## RESEARCH PROGRESS AND IMPLICATIONS.

As of March 1, 2000, this report summarizes work after 3 1/2 years of a 4-year project. There have been accomplishments in three areas, two involving in-line rheometry and the third dealing with modeling of suspensions.

We have developed two techniques for use as an in-line rheometer: nuclear magnetic resonance imaging (NMRI) and ultrasonic Doppler velocimetry (UDV). A central feature of both techniques is that they provide pointwise measurements of viscosity in flow with a non-uniform shear. In such flows, for example, pipe flow, it is expected that the viscosity of a complex liquid (e.g., slurry or polymer) will vary with the local shearing conditions. Hence, if the viscosity can be spatially resolved, then the variation of viscosity with shear rate will be known. With the NMRI, we have demonstrated that very accurate measurements of the viscosity can be obtained using pipe flow. We have tested the technique with a range of fluids and have found excellent agreement when compared with conventional rheometrical techniques. Typically, from a single measurement, we can determine the viscosity as a function of shear rate over one and one half decades of shear rate to within 5% of data obtained by a cone and plate viscometer. We can also directly measure the yield stress and obtain agreement to within experimental error. Further, we have developed design criteria that could be used if this technique were implemented on, for example, a transfer pipeline.

We have shown that UDV can also provide spatially resolved viscosities. This technique is not as developed as NMRI so that the accuracy is not as good. However, UDV offers the opportunity for a very flexible and cheap instrument that can work in hostile environments. It is also likely that we will obtain better accuracy once the influence of flow and the test material on the measured signals are known. There have been discussions of using such a device at the Hanford Site.

The modeling studies have sought to understand the influence of particle size and size distribution on the rheological properties of slurries. We have developed three-dimensional simulations that permit colloidal and Brownian effects to be modeled. Further, our simulations allow us to use populations of spherical particles of arbitrary size, assuming that the Reynolds number is very small. To date, we have obtained predictions for the sedimentation velocity for a suspension and the viscosity of a suspension of having particles of two different sizes.

**PLANNED ACTIVITIES**

During the remainder of the grant period, we expect additional progress in two areas. First, we are seeking to better understand the effect of small-scale velocity fluctuations induced by the particles in a slurry on the signals measured with both NMRI and UDV. If we can characterize these, it should help increase the resolution of both instruments. Secondly, the modeling studies will be continued to fully map the impact of colloidal and particle size distribution effects on the rheological properties.