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# COMPARATIVE TESTING OF SLURRY MONITORS

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## INTRODUCTION

The U.S. Department of Energy (DOE) has millions of gallons of radioactive liquid and sludge wastes stored in underground tanks. These wastes must be retrieved, transferred to treatment facilities, and processed for disposal. Before removal from the storage tanks, the sludge and liquid wastes will typically be combined to create a mixture of suspended solids, generally referred to as a slurry; the slurry is then pumped from the tank to the treatment facilities by pipelines. Depending on the location of the tank and the treatment facility, the slurries may have to be transported several miles. Since the wastes are radioactive, it is critically important that the slurries are transported safely and successfully.

The consequences of pipeline plugging are unacceptable from the perspectives of schedule, cost, and safety. If a pipeline plugs, the waste cannot be transported and the treatment facility experiences delays. If conventional methods for unplugging a pipeline are unsuccessful, the options include (1) building a new pipeline, and (2) removing and replacing plugged sections of the pipeline. Construction of pipelines for transporting radioactive wastes is expensive, particularly for long distances. Because the slurries are radioactive, removal and replacement of the pipe sections would likely have to be performed remotely. This operation would also be expensive, and personnel would be exposed to radiation.

The baseline method of ensuring that the transport properties of the slurries are correct is to sample the slurry in the tank and analyze the sample in the laboratory. This method has some problems. First, there is a delay between the time that the sample is taken and the time that the analytical results are reported. For some types of analysis, this delay could be from 24 to 48 hours. Second, although the tank is being mixed to keep the solids in suspension during this period, there is no way to determine whether the contents of the tank are homogenous unless multiple samples are collected at various depths and locations. Therefore, an on-line system that monitors slurry transport properties in real time is needed to evaluate the slurry prior to and during transfer. The on-line information would provide controllers or operators with immediate feedback to respond quickly and prevent conditions that could lead to the pipeline plugging.

## PROJECT INFORMATION

### Testing

The objective of this project was to test, demonstrate, and evaluate instrumentation for on-line monitoring of slurry transport properties in real time. To accomplish the task, an extensive experimental performance evaluation was conducted with commercially available instruments and several new instruments recently developed for the DOE.

Since the actual wastes are radioactive, simulant slurries with physical properties similar to those of high-priority DOE tank wastes stored at the Oak Ridge National Laboratory (ORNL) and the Hanford Site were formulated. Although the slurry properties obtained from both DOE sites were similar, some differences, particularly with regard to particle size distribution, were noted. A multistage evaluation was designed, and testing was conducted with the fluids and simulated slurries shown in Table 1. Testing was conducted with flow velocities ranging from 1 to 9 ft/s and with slurry temperatures of 25 and 50°C.

The instruments that were included in the test program are shown in Table 2, along with the transport properties each measures and the name of its developer or manufacturer. Most of the instruments were mounted in the pipeline (Figure 1), but two were mounted in the feed tank for evaluation. Some of the instruments that were evaluated are commercially available; others were recently developed by DOE laboratories under the sponsorship of the Characterization, Monitoring, and Sensor Technology Crosscutting Program (CMST-CP) and the Tanks Focus Area (TFA), both programs within the Office of Science and Technology, Office of Environmental Management, in DOE. One instrument that was tested was developed

**Table 1.** Composition of fluids and simulated slurries used for testing.

| Matrix number | Fluid medium | Suspended solids concentration (wt %) | Suspended solids composition (%) | | |
|---|---|---|---|---|---|
| | | | Kaolin clay[1] | Sand[2] | Gravel[3] |
| 1 | Water | 0 | | | |
| 2 | 40, 50, and 60 wt % sucrose | 0 | | | |
| 3 | Water | 10, 20, 30 | 100 | | |
| 4 | 50 wt % sucrose | 10, 20, 30 | 100 | | |
| 5 | 50 wt % sucrose | 10, 20, 30 | 75 | 25 | |
| 6 | 50 wt % sucrose | 10, 20, 30 | 74.5 | 24.5 | 1 |
| 7 | Water | 0 | | | |

[1]EPK kaolin, manufactured by Feldspar Corp. Particle size analysis indicated a range from 0 to 93 μm, with the peak at approximately 20 μm.

[2]Play Sand, manufactured by Quikrete Company. Particle size distribution ranged from 90 to 1000 μm with over 75% between 250 and 500 μm.

[3]Chert gravel, manufactured by the Rogers Group, Inc. Gravel was sieved to include only those particles between 1000 and 4000 μm.

**Table 2.** Instruments tested with the surrogate slurries.

| Principle of operation | Slurry transport property measured | Developer or Manufacturer |
|---|---|---|
| Backscattering of light[1] | % solids | BTG (Model SMS-3000) |
| Coriolis effect[1] | Mass flow rate[2]<br>Density | Endress + Hauser (Model Promass) |
| Coriolis effect[1] | Mass flow rate[2]<br>Density<br>% solids | Endress + Hauser (Model m-Point) |
| Gamma attenuation[1] | Density | Oak Ridge National Laboratory (ORNL) |
| Image processing[1] | % solids | Kodak/Corel |
| Pressure drop[1] | Density<br>Viscosity | Oak Ridge National Laboratory |
| Quartz crystal resonation[3] | Product of density and viscosity | Sandia National Laboratory (SNL) |
| Ultrasonic attenuation[4] | Particle size | Pacific Northwest National Laboratory (PNNL) |
| Ultrasonic coefficient of reflection[1] | Density | Pacific Northwest National Laboratory |
| Ultrasonic cross-scattering[1] | Density<br>% solids<br>Viscosity | Argonne National Laboratory (ANL) |

[1]Instrument was installed in or on pipeline.

[2]Mass flow rate is measured by the instrument, but it was not evaluated in this study.

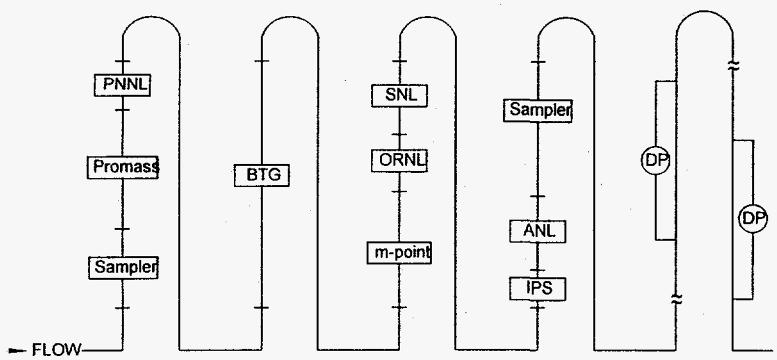
[3]Developer provided a pipeline model and an in-tank model for evaluation.

[4]Instrument was installed in the feed tank.

under the sponsorship of the Waste Management and Remedial Action Division at ORNL. Lastly, some of the devices that measured slurry properties based on pressure-drop measurement (e.g., pipeline viscometer, U-loop) were fabricated by craft personnel at ORNL.

To ensure that each instrument measured the same slurries under the same conditions (e.g., solids concentration, temperature), the devices were installed so that the slurry flowed upward through each instrument in a closed-loop flow system, as shown in Figure 1. The upward flow of the slurry was designed to counteract the settling of the solid particles caused by gravity.

The baseline technology for comparing the instrumentation results was sampling and analysis. On-line systems to collect representative samples were procured from Bristol Equipment Company and installed at the start and end of the instrumentation section. Each sampler consisted of a piston with an annulus that extended into the pipeline. The annulus filled with slurry, and the piston was retracted. The sample then drained into the collection jar. This cycle was repeated until the desired volume was obtained.




| Symbol | Description |
|---|---|
| Promass | Density instrument (Coriolis) |
| PNNL | Density instrument (ultrasonic reflection) |
| BTG | Percent solids instrument (backscatter of light) |
| m-point | Density instrument (Coriolis) |
| ORNL | Density instrument (gamma attenuation) |
| SNL | Density-viscosity instrument (quartz resonator) |
| IPS | Percent solids (image processing system) |
| ANL | Density, viscosity, percent solids (ultrasonic cross-scatter) |
| DP | Density, viscosity (differential pressure) |

**Figure 1.** Schematic of pipeline instrumentation test section.

## Status

The test program has been completed; however, analyses of samples are still ongoing. An assessment of the performance of the instruments cannot be done until all the data are available. A technical report will be published that details the results of the testing. Copies of this report will be available as follows:

| | |
|---|---|
| To DOE and DOE contractors: | Office of Scientific and Technical Information<br>P.O. Box 62<br>Oak Ridge, TN 37831 |
| To the public: | National Technical Information Service<br>U.S. Dept. of Commerce<br>5285 Port Royal Road<br>Springfield, VA 22161 |

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