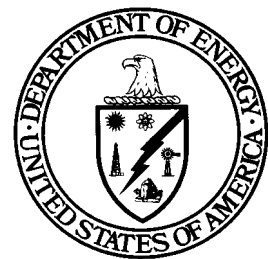


# Comparative Testing of Pipeline Slurry Monitors

Tanks Focus Area and  
Characterization, Monitoring and  
Sensor  
Technology Crosscutting Program



*Prepared for*  
**U.S. Department of Energy**  
Office of Environmental Management  
Office of Science and Technology

September 1999

# Comparative Testing of Pipeline Slurry Monitors

OST Reference #1547

Tanks Focus Area and  
Characterization, Monitoring and  
Sensor Technology Crosscutting  
Program



*Demonstrated at*  
Oak Ridge National Laboratory  
Oak Ridge, Tennessee



## ***Purpose of this document***

Innovative Technology Summary Reports are designed to provide potential users with the information they need to quickly determine if a technology would apply to a particular environmental management problem. They are also designed for readers who may recommend that a technology be considered by prospective users.

Each report describes a technology, system, or process that has been developed and tested with funding from DOE's Office of Science and Technology (OST). A report presents the full range of problems that a technology, system, or process will address and its advantages to the DOE cleanup in terms of system performance, cost, and cleanup effectiveness. Most reports include comparisons to baseline technologies as well as other competing technologies. Information about commercial availability and technology readiness for implementation is also included. Innovative Technology Summary Reports are intended to provide summary information. References for more detailed information are provided in an appendix.

Efforts have been made to provide key data describing the performance, cost, and regulatory acceptance of the technology. If this information was not available at the time of publication, the omission is noted.

All published Innovative Technology Summary Reports are available on the OST Web site at <http://OST.em.doe.gov> under "Publications."

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# SECTION 1 SUMMARY

## Technology Summary

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### Problem Definition

Millions of gallons of radioactive liquid and sludge wastes must be retrieved from underground storage tanks at U.S. Department of Energy (DOE) sites, transferred to treatment facilities, and processed to a final waste form. To retrieve waste from storage tanks, sludge wastes are typically mobilized and mixed with liquid wastes to create a slurry of liquid and suspended solids. The slurry is then transferred by pipeline to the desired location for treatment prior to disposal. Slurries from retrieving tank waste have high viscosity and solids content. Slurries with high viscosity are difficult to pump and generate large back pressures. If pump back pressures exceed the rating of the transport pipeline, pumping cannot continue. A pipeline blockage can occur because of gravity sedimentation of solids in the transfer line.

### How the Devices Work

Monitoring the transport properties (i.e., the percentage of suspended solids, density, viscosity, mass flow rate, and particle size) of the slurries in transfer lines can prevent pipeline blockage and ensure safe transport of the waste. Slurry monitoring instruments measure transport properties during pipeline transfers to enable operators to maintain acceptable control limits and thereby prevent pipeline blockage. In-line instruments provide real-time measurements of slurry properties to operators, who can respond quickly to prevent any conditions that could lead to pipeline blockage.

### Potential Markets

Many DOE sites have wastes that need to be retrieved from tanks for treatment and disposal. Three DOE sites have identified the need for slurry monitoring to improve tank waste treatment operations:

- The Hanford Site has 54 million gal of waste.
- Savannah River Site (SRS) has 34 million gal of waste.
- The Oak Ridge Reservation (ORR) has about 700,000 gal of legacy waste and generates about 500,000 gal of new liquid waste annually.

### Advantages over Baseline

The baseline instrumentation plan calls for grab sampling of the waste followed by off-line laboratory analysis. The innovative in-line slurry monitors outperform the baseline technology by

- providing real-time data on the density, particle population, and particle dimensions of the slurry material throughout the transport process, starting at the source tank, then along the pipeline and at destination location;
- reducing the required number of grab sample and thus reducing personnel exposure to radiation during grab sampling; and
- reducing the potential for pipeline blockages that negatively impact project costs and schedules.

## Demonstration Summary

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Pipeline slurry monitors were demonstrated to assess instrumentation to monitor slurry transport properties on line and in real time.

- In fiscal year 1997 (FY97), nine pipeline and three in-tank instruments were evaluated in a cold-test loop under conditions similar to field environment at ORR. (Hylton et al. 1998)
- In FY98, under the Slurry Monitoring Technology Deployment Initiative, ORR's Slurry Monitoring Test Loop (SMTL) was installed at the Gunite and Associated Tank (GAAT) Slurry Transport System.

- In FY99, the Endress+Hauser Promass 63M Coriolis meter (Figure 1) and the Lasentec® M600P analyzer (Figure 2) were demonstrated in the SMTL. (Hylton and Bayne 1999)



**Figure 1. Endress+Hauser Promass 63M Coriolis meter installed in GAAT Slurry Monitoring Test Loop.**



**Figure 2. Lasentec M600P analyzer installed in GAAT Slurry Monitoring Test Loop.**

The Endress+Hauser Promass 63M Coriolis meter and the Lasentec M600P analyzer have been successfully deployed at ORR. Slurry monitors are used as slurry is transported to GAAT W-9, which is used as a consolidation tank. The waste is transferred from GAAT W-9 to the Melton Valley Storage Tanks (MVSTs). Initial operation of slurry monitors with supernatant from the GAAT consolidation tank was accomplished in May 1999. By late June, a total of 60,000 gal had been transferred from GAAT W-9 to the MVSTs.

#### **Parties Involved in the Development**

DOE sponsored comparative testing of slurry monitors through cooperation of the Characterization, Monitoring, and Sensor Technology Crosscutting Program and the Tanks Focus Area. The slurry monitor deployments were funded under an Accelerated Site Technology Deployment (ASTD) project. The Oak Ridge Waste Management Program was responsible for the ORR deployment.

#### **Regulatory Considerations and Policy Issues**

The installation of slurry monitoring instruments is considered a maintenance activity, and permits are not required.

#### **Commercial Availability and Readiness for Application**

- The Endress+Hauser Promass 63M Coriolis meter is available from Endress+Hauser, Inc., Greenwood, Indiana.
- The Lasentec M600P analyzer is available from Laser Sensor Technology, Inc., Redmond, Washington.

## **Future Plans**

The Endress+Hauser Promass 63M Coriolis meter and the Lasentec M600P analyzer are used as process flow monitors during transfers from ORR GAAT W-9 to the MVSTs. The Endress+Hauser Promass 63M Coriolis meter is used to measure slurry density and estimate suspended solids concentration based on a calculational method. The Lasentec M600P analyzer is used to estimate the distribution of particles. These two instruments will continue to be used for such transfer campaigns until April 2000. Slurry monitors are available for deployment at Hanford, SRS, and other locations across the DOE complex.

## **Contacts**

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### **Other**

All published Innovative Technology Summary Reports are available on the OST Web site at <http://ost.em.doe.gov> under "Publications." The Technology Management System (TMS), also available through the OST Web site, provides information about OST programs, technologies, and problems. The OST/TMS ID for comparative testing of pipeline slurry monitors is 1547.

## SECTION 2 TECHNOLOGY DESCRIPTION

### Overall Process Definition

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Slurry monitoring requirements can potentially be met by numerous commercial instruments and laboratory prototype devices. Several of these commercial and prototype slurry monitors were evaluated in a comparative testing program. Two measures of quantitative performance were used to evaluate the slurry monitoring instruments:

- bias—the difference between the average of the measurement readings by a slurry monitoring instrument and the accepted reference value, and
- variance—a measure of dispersion of replicate measurement readings by a slurry monitoring instrument.

The Endress+Hauser Promass 63M Coriolis meter and the Lasentec M600P analyzer performed successfully. These instruments are described below.

#### Endress+Hauser Promass 63M Coriolis Meter

The Endress+Hauser Promass 63M Coriolis meter is approximately 28 inches long from flange to flange (see Figure 1). The meter measures the mass flow, density, and temperature of fluids or slurries simultaneously. Once mass flow and density are determined, other functions can be calculated (e.g., volumetric flow, suspended solids concentration). Measurement of the slurry density was the major parameter evaluated in this project; however, the suspended solids concentration—as determined from the slurry density, supernatant density, and dry solids density—was also assessed. The mass flow rate was not evaluated in this study but was used to determine the flow rate of the slurry through the SMTL.

The measuring principle of the Endress+Hauser Promass 63M Coriolis meter is based on the controlled generation of Coriolis forces, which are present when translational (straight-line) and angular (rotational) movements occur simultaneously in a moving system (see Figure 3). The amplitude of the Coriolis force depends on the moving mass, its velocity in the system, and, therefore, its mass flow. The Endress+Hauser Promass 63M Coriolis meter uses two parallel measuring pipes with liquid flowing through them. The slightly curved measuring pipes are made to oscillate at their resonant frequency like a tuning fork. This resonant frequency adjusts automatically as soon as the mass of the oscillating system—and therefore the density—changes. The resonant frequency is thus a function of the density of the flowing liquid and enables the microprocessor to produce a signal indicating density. The mass flow rate is indicated by the oscillation phase difference between the ends of the tubes.

#### Lasentec M600P Analyzer

The Lasentec M600P analyzer (see Figure 2) uses a technique known as focused-beam reflectance measurement<sup>®</sup> (FBRM<sup>®</sup>), which involves focusing a laser to a fine point. The FBRM technique provides a continuous, high-speed count of particle population by dimension, making it possible to track the rate and degree of change on the basis of both particle count and particle

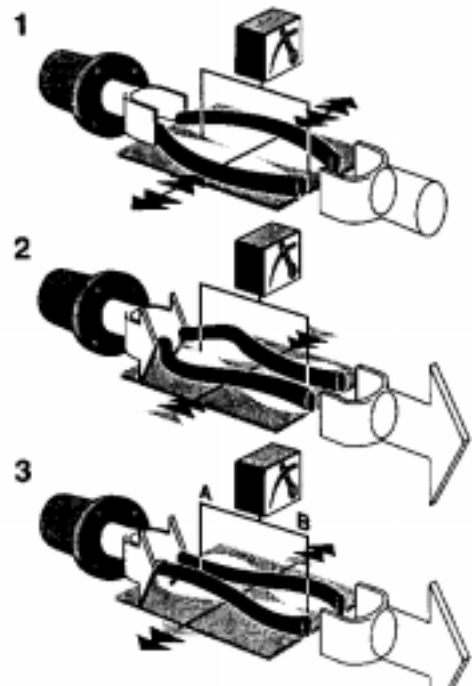


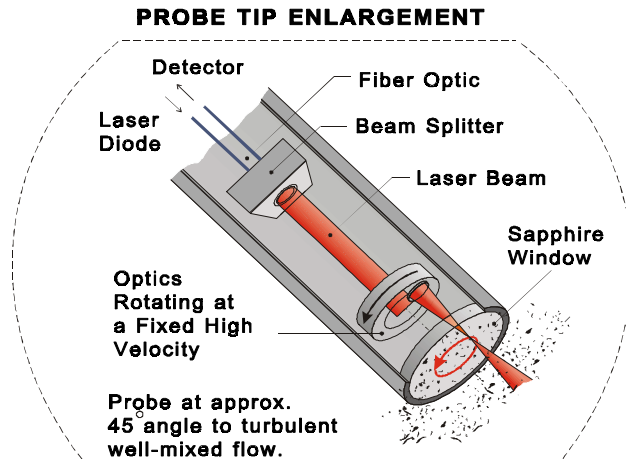
Figure 3. Promass measurement principle.



dimension. FBRM is a real-time, in-process measure of particle count and dimension by chord length distribution. The chord length distribution is a function of the shape and dimension of the particles in the flowing medium.

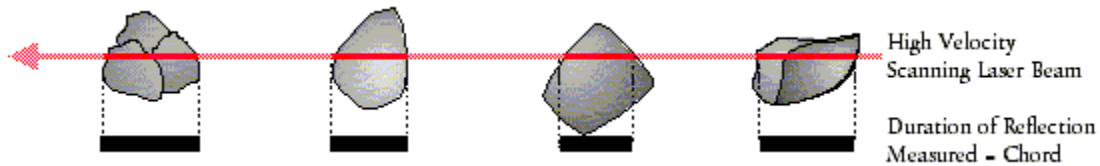
When the Lasentec analyzer is used, a FBRM probe is inserted into a flowing medium of any concentration or viscosity. A highly focused laser beam is projected through the probe window and, at a fixed velocity, rapidly scanned across particles and particle structures flowing past the probe window (see Figure 4).

The most intense part of the focused beam is approximately 2 μm in diameter and 10 μm in depth. The light intensity is distributed across the cross section of the beam spot with the center being far more intense than the edges. The focal point, which is just inside the window of the probe, is then rotated around the window with a linear velocity of 2 m/s.



**Figure 4. Lasentec probe tip.**  
 Source: Laser Sensor Technology, Inc.  
 Used with permission.

When the focused beam intersects the edge of a particle, the particle begins to backscatter the laser light. The particle continues to backscatter until the focused beam has reached the opposite edge of the particle. This backscatter is collected by the FBRM optics and then converted into an electronic signal. A unique discrimination circuit is used to isolate the time period of the backscatter from one edge of an individual particle to its opposite edge. This time period is multiplied by the scan speed, and the result is a distance (see Figure 5). This distance is a chord length, which is a straight line between any two points on the edge of the particle or particle structure. Hundreds of thousands of chords are typically measured per second, resulting in a chord length distribution (number of counts per second sorted by chord length).



**Figure 5. The focused laser beam scanned across each particle and the resulting chord length.**  
 Source: Laser Sensor Technology, Inc. Used with permission.

The chord length distribution is a highly precise and sensitive means to track change to both particle dimension and particle population. In addition, with a number/length/second distribution, specific regions of the distribution can be isolated to enhance resolution (i.e., the number of fine particles or number of particles over a given dimension).

### Support Equipment

The technologies must be supported by electronics, data analysis, and data reduction equipment located in a remote field unit, usually no more than 10 m from the probe. Data reduction requires a computer located in a nearby trailer or accessed via phone line from the field site. In remote locations, power may need to be supplied by a generator.

### Specific DOE Application

The objective of the GAAT project is to remediate and permanently close several inactive storage tanks constructed in the 1940s. The GAAT project removes the sludges from the various tanks by creating

slurries for transport and consolidating them into a single tank. Once the slurries are in the consolidation tank, they are mixed to homogenize and keep them suspended in a slurry form.

A pipeline loop is used to circulate the slurries out of and back into the consolidation tank. The slurry monitoring test system is installed in the circulation loop. While the slurries are being circulated, the various monitoring instruments determine their transport properties. Samples are collected and analyzed to verify the accuracy and precision of the data reported by the instruments. The slurry monitoring instruments determine whether and when the transport properties are acceptable. When the transport properties are deemed acceptable, the slurry flow is diverted and transferred to the MVSTs for storage and processing.

## **System Operation**

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In-line instruments measure the transport properties as the slurry flows through or by the instrument. Data are provided to operators, who respond to counteract conditions that could lead to pipeline plugging and to control those conditions within specified limits while the slurry transfer is in progress. Operating requirements are described in more detail below.

### **Endress+Hauser Promass 63M Coriolis Meter**

No special precautions need to be taken during mounting for turbulence-generating devices such as valves, bends, pipe tees, etc., as long as no cavitation occurs. External forces are absorbed by the secondary containment vessel. The high-frequency oscillation of the measuring tubes protects the measuring system from being affected by plant vibration.

Vertical mounting is recommended with the process material flowing upwards. This arrangement allows entrained solids to sink down and gases to rise away from the measuring tube. It also allows the measuring tube to be completely drained during periods of no flow, protecting the tubes from solids buildup. When correctly installed, the transmitter housing is either above or below the piping, ensuring that no gas bubbles collect and solids are deposited in the curved measuring tubes.

The sensor must not be suspended in the piping without support to avoid excessive stress on the material around the process connection. The housing base plate of the sensor allows table, wall, or post mounting. The post mounting option requires a special mounting set available from Endress+Hauser.

### **Lasentec M600P Analyzer**

Per the manufacturer's recommendation, the Lasentec M600P analyzer is installed at a 45° angle to help make the probe self-cleaning: the impinging slurry keeps the sludge from building up on the surface of the probe's window.

The Lasentec instrument does not account for the velocity of particles as they pass the probe. To offset this effect, the focal point is scanned at 2 m/s. The manufacturer recommends a slurry velocity of approximately 1.8 m/s; however, the flow rate should be turbulent to mix the particles in the pipe to ensure that uniformly random material is presented to the probe window. The manufacturer advises that for constant flow speeds in excess of 1.8 m/s, a constant offset will occur in the measurement caused by the slurry's flowing faster than the scan rate used for the chord length calculation.

### **Materials, Energy, and Other Expendable Items**

The Lasentec probe has one moving part, a bearing assembly that rotates the laser light. If the instrument is turned off when not in use, the bearing should never have to be replaced. Otherwise, the bearing should last for a year of 24-h/day operation.

The Endress+Hauser Promass 63M Coriolis meter housing/containment vessel is surface-resistant to acids and alkalis. Its measuring tubes are Grade 9 titanium. It has no internal gaskets. The sensor connection uses O-rings.

**Personnel Required**

The instruments can be operated by a single person; however, operation is easier with two people. Installation time for slurry monitoring equipment should not impact project schedules.

**Secondary Waste Stream Considerations**

The SMTL is a fully contained system, so no job waste is generated.

**Potential Operational Concerns and Risks**

Risk is minimal because the system is fully contained.

## SECTION 3 PERFORMANCE

### Demonstration Plan

In 1997, nine pipeline and three in-tank slurry monitoring instruments were tested in nonradioactive conditions at either ORR or Pacific Northwest National Laboratory. See Table 1 and Figure 6.

**Table 1. Slurry monitoring instruments included in the 1997 cold test**

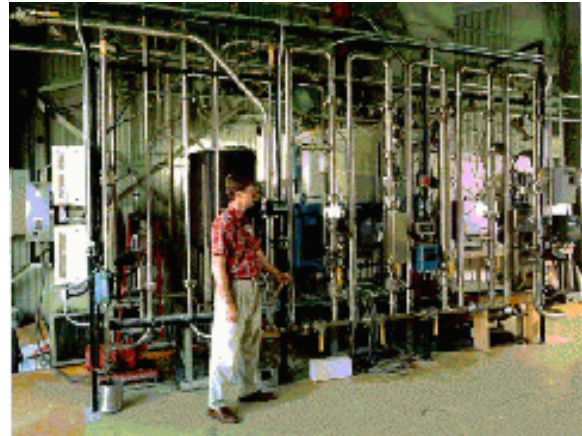
Instrument	Technique	Mounted	Organization
Particle size probe	Ultrasonic signal attenuation	In tank	Pacific Northwest National Laboratory
Density probe	Ultrasonic reflection coefficient	Pipeline, in tank	Pacific Northwest National Laboratory
Viscosity-density product	Quartz crystal resonance	Pipeline, in tank	Sandia National Laboratories
Density probe	Gamma-ray attenuation	Pipeline	Oak Ridge National Laboratory
Density, viscosity, and volume percent solids	Ultrasonic impedances and scattering	Pipeline	Argonne National Laboratory
Percent solids	Image processing system	Pipeline	Items purchased separately and merged to form a system
Density (U-loop)	Pressure drop	Pipeline	Fabricated in house
Density meter	Coriolis effect	Pipeline	Endress+Hauser (Promass)
Density meter	Coriolis effect	Pipeline	Endress+Hauser (m-Point)
Percent solids	Backscattering of light	Pipeline	BTG (SMS-3000 System)
Particle probe <sup>a</sup>	FBRM	Pipeline	Laser Sensor Technology, Inc.
Line pressure <sup>a</sup>		Pipeline	Red Valve, Honeywell

<sup>a</sup>Tested at Pacific Northwest National Laboratory. (Reynolds et al. 1996)

The Endress+Hauser Promass 63M Coriolis meter and the ultrasonic instrument from Argonne National Laboratory were selected by the Characterization, Monitoring, and Sensor Technology Crosscutting Program and the Tanks Focus Area for testing in a radioactive application. The Lasentec instrument was included in the evaluation at the request of the ASTD Program.

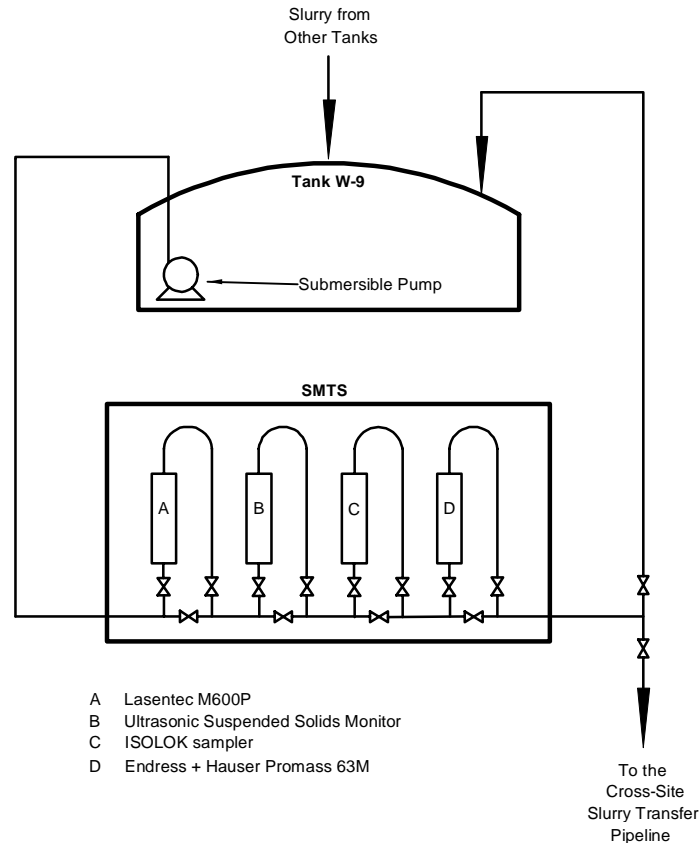
In February 1999, as a follow-up to the FY97 study, scientists tested these instruments to monitor the transport properties of radioactive slurry. The object was to determine whether the instruments could accurately monitor radioactive slurries to help prevent pipe blockage, a problem encountered at the various DOE radioactive waste storage sites.

The instruments were installed and tested in a recirculation loop at the GAAT project at ORR (see Figure 7). A pipeline loop is used to circulate the slurries out of and back into the W-9 consolidation tank. The slurry monitoring test system is installed in the circulation loop. While the slurries are being circulated, the various monitoring instruments determine transport properties. Samples are collected and analyzed to verify the accuracy and precision of the data reported by the instruments. Hydrostatic tests



**Figure 6. Oak Ridge National Laboratory cold-test loop.**

of slurry monitors installed in the SMTL were successfully initiated in February 1999. Results of these tests are discussed below.



**Figure 7. ORR's Slurry Monitoring Test Loop.**

### Demonstration Site Description

The GAAT at ORR includes six large underground gunite tanks, designated as tanks W-5 through W-10, built to collect and store wastes generated by ORR operations (see Figure 8). These tanks have a volume capacity of 643,000 L (170,000 gal), an inside diameter of 50 ft, a sidewall height of 12 ft, and a dome height of 18 ft at the center. GAAT waste is being consolidated in W-9.

Six smaller gunite tanks and four stainless steel tanks constitute the remainder of the GAAT. These tanks eventually became an integral part of the ORR waste system. When the gunite tanks were taken out of service in 1980, approximately 1.5 million L (400,000 gal) of sludge containing between 0.5 and 1 million curies had accumulated.

### Major Objectives

This project tested and evaluated slurry monitors that are commercially available and those being developed under the Characterization, Monitoring, and Sensor Technology Program; the Tanks Focus Area; and the Oak Ridge National Laboratory (ORNL) Waste Management organization. Slurry monitoring was demonstrated to improve slurry transfer operations, so slurry monitors were deployed for the GAAT Remediation Project. The goal of the GAAT Remediation Project is to remove the remaining sludge and to permanently close the tanks. Slurry monitors facilitate safe and efficient GAAT waste removal, transfer to GAAT W-9, and cross-site transfer to MVSTs.



## The North and South Tank Farms at ORNL

**Figure 8. Gunite waste tanks at Oak Ridge National Laboratory.**

### Major Elements of the Technology

A recirculation loop receives wastes being transferred into and out of GAAT W-9. Slurry monitors are installed in a recirculation loop with a waste conditioning system (WCS). The WCS consists of an enclosure for the primary conditioning system components. The tank contents are mixed using a pulsed-air mixer developed by Pulsair™ Systems, Inc. A solids classifier and a sampler are used to monitor the particle size of the sludge in the WCS. Waste passes through a separate SMTL enclosure containing slurry monitoring instrumentation.

### Boundaries

This demonstration was not intended to address the efficacy of the slurry transport process or to find alternative methods of cleanup.

### Results

#### Area/Volume Characterized

The volume of material in GAAT W-9 varied from 104,000 to 113,000 gal during the testing period. Dwell time (the time between the air injections) was varied for the pulsed-air mixer during testing (see Table 2).

**Table 2. Conditions for testing the slurry monitors**

Test	Date	Tank W-9 volume (gal)	Recirculation pump position <sup>a</sup> (ft)	Pulsed-air mixing parameters		
				Dwell time (s)	Injection time (s)	Air supply pressure (psig)
1	02/17/99	104,000	4	10	1	35
2	02/22/99	104,000	4	18	1	35
3	02/25/99	103,000	4	14	1	35
4	03/02/99	105,000	6	10	1	35

5	03/05/99	105,000	6	14	1	35
6	03/11/99	113,000	6	18	1	35

<sup>a</sup>The distance from the bottom of the tank to the pump.

### Efficiency Rate

The Endress+Hauser Promass 63M Coriolis meter was positioned downstream from the sample collection device in the test loop. Test results were examined for the 6-minute periods before and after sampling, for a total of 24 data points. Table 3 summarizes the test results for density and suspended solids concentration recorded for these two time periods for each test run and compares them with the analytical results from the grab samples.

The differences between the average density measurements and the analytical density results are estimates of the instrument bias. The analytical density results were reported with a projected error of 0.010 g/mL. Table 3 shows that the average density measurements using the meter are greater than the analytical density results; however, all the biases (0.0003 to 0.0008) are small. The suspended solids measurement was higher for the Promass 63M instrument, potentially because of settling during sampling.

**Table 3. Endress+Hauser Promass 63M Coriolis meter average test results for six experiments, with 24 data points per experiment**

Recirculation pump position <sup>a</sup>		Density for different pulsed-air dwell times (g/mL)			Suspended solids for different pulsed-air dwell times (wt %)		
(ft)	Result	10 s	14 s	18 s	10 s	14 s	18 s
4	Test result	1.0464	1.0433	1.0427	4.13	3.67	3.58
	Analytical result	1.043	1.041	1.040	3.11	2.75	2.86
	Standard deviation	0.0004	0.0005	0.0004	0.06	0.07	0.06
6	Test result	1.0382	1.0356	1.0349	3.24	2.70	2.64
	Analytical result	1.035	1.034	1.035	2.26	2.12	2.15
	Standard deviation	0.0008	0.0005	0.0003	0.13	0.07	0.05

<sup>a</sup>The distance from the bottom of the tank to the pump.

The software for the Lasentec M600P analyzer counts the number of particles that have chord lengths within a specified range. Table 4 summarizes the estimated distribution averages and standard deviations for six tests, indicating no effects that are due to either the pump position or the dwell time.

**Table 4. Lasentec M600P analyzer particle distribution averages and standard deviations of chord lengths**

Recirculation pump position <sup>a</sup>		Particle chord length for different pulsed-air dwell times		
(ft)	Result	10 s	14 s	18 s
4	Distribution average, $\mu\text{m}$	6.30	6.42	6.43
	Standard deviation	7.49	7.28	7.48
6	Distribution average, $\mu\text{m}$	6.39	6.56	6.42
	Standard deviation	7.24	7.13	8.04

<sup>a</sup>The distance from the bottom of the tank to the pump.

The manufacturer reports that the latest version of the FBRM can discriminate between 0.5- and 1000- $\mu\text{m}$  chord lengths in 0.25- $\mu\text{m}$  increments.

### Comparison to Baseline

The baseline technology for tank waste slurry monitoring is laboratory analysis of grab samples. During comparative testing of slurry monitors at ORNL, laboratory instrumentation was used to analyze grab

samples to provide data for comparison with results from the in-line monitors being tested. The assay data obtained in the laboratory were comparable in quality to the results obtained from the Coriolis density monitor and the Lasentec M600P analyzer. (Hylton and Bayne 1999)

During testing, the innovative in-line slurry monitors outperformed the baseline technology by:

- providing real-time data on the density and particle distribution of the slurry material throughout the transport process, starting at the source tank, then along the pipeline and at destination location;
- eliminating unnecessary personnel exposure to radiation during grab sampling; and
- reducing the potential for pipeline blockages that negatively impact project costs and schedules.



## SECTION 4 TECHNOLOGY APPLICABILITY AND ALTERNATIVES

### Competing Technologies

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In FY97 numerous in-line, real time monitoring instruments were tested for their ability to measure a range of waste slurry properties (Hylton et al. 1998). An analysis of the operational characteristics and measurement results of the in-line instruments, when tested with surrogate waste slurries, supported a decision process to determine and select the best instrumentation for testing with real tank waste. The Endress+Hauser Promass 63M Coriolis meter and the Lasentec M600P analyzer and were judged to have performed better than the competing technologies during surrogate waste testing and were selected for testing with real waste.

### Technology Applicability

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#### Other Potential Applications To Be Considered

Hanford and ORR both plan to retrieve and transport millions of gallons of radioactive sludges and slurries from radioactive waste tanks. At Hanford alone, 54 million gal of slurry must be retrieved from tanks for treatment and disposal.

The in-line monitoring instruments also have potential applications at SRS, which currently monitors the interarea slurry transfer line with pressure sensors and flow meters. The type of pressure sensor used at SRS requires the slurry to travel through a small capillary tube to act against a diaphragm. These sensors are prone to failure if solids block the capillary tube.

#### Scale-Up Requirements

There are no scale-up requirements. The monitors tested are all commercially available or use off-the-shelf components and can be deployed without development costs. All the instruments have been demonstrated.

#### Future Technology Selection Considerations

The Lasentec M600P analyzer will be the first slurry instrument installed in the DOE nuclear complex to measure particle distribution in line. The proposed monitor is not included in current transfer line designs because the technology has been very recently demonstrated.

### Patents/Commercialization/Sponsor

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#### Commercial Involvement by Private Industry

Lasentec and Endress+Hauser designed their own instruments and hold all patent and licensing rights. Both instruments can be purchased directly from the manufacturers.

#### Sponsors

Potential sponsors for slurry monitoring deployment include

- user organizations;
- the Office of Science and Technology through the Tanks Focus Area, Technology Deployment Initiative (TDI), and the Characterization, Monitoring, and Sensor Technology Program; and
- Site Technology Coordination Groups, which manage and coordinate technical needs at their respective sites.

#### Potential Privatization of Technology

Operation of slurry monitors can be privatized if appropriate. The instruments could be used to monitor the slurry transfer systems that provide feed to private vendors under Hanford Phase I Privatization. During Phase II Privatization at Hanford, slurry transfers will become the responsibility of the privatization contractor.

## SECTION 5 COST

A slurry monitor deployment will result in cost savings by preventing pipeline blockages. Slurry monitoring provides an additional value beyond replacing grab sampling by eliminating the need for unnecessary radiation exposure of workers collecting samples or repairing blocked pipelines.

### Methodology

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The baseline and innovative technology cost and schedule information was obtained from the draft deployment plan of the slurry monitoring TDI proposal. The costs are provided below for GAAT. The use of in-line slurry monitors instead of grab sampling allows for continuous sampling of the waste stream for more representative data with no project downtime and no personnel exposure.

### Cost Analysis

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#### Slurry Monitoring Costs

Table 5 summarizes life cycle costs for deployment of the Endress+Hauser Promass 63M Coriolis meter and the Lasentec M600P analyzer at GAAT. The capital costs include equipment procurement, calibration, and installation. Safety analyses, permitting, design modifications, other project expenses not directly related to capital equipment costs, and calibration tests are included in the installation cost. The table shows operating and maintenance costs separately from decontamination and decommissioning costs.

**Table 5. Life cycle costs for deploying slurry monitors  
at the Oak Ridge Gunite and Associated Tanks**

Item	Endress+Hauser Promass 63M Coriolis meter (\$K)	Lasentec M600P analyzer (\$K)
Capital equipment	10	85
Calibration	2	5
Installation	30	30
Operating and maintenance	6	6
Decontamination and decommissioning	10	10
<b>Total</b>	<b>58</b>	<b>136</b>

Costs for the Endress+Hauser Promass 63M Coriolis meter are not included in the TDI proposal. Installing the Endress+Hauser Promass 63M Coriolis meter would increase cost by 30%. The capital equipment cost of the Endress+Hauser Promass 63M Coriolis meter is approximately \$10K. Other costs are similar to those for the Lasentec M600P analyzer.

#### Grab Sampling Costs

Table 6 summarizes parameters and costs for baseline grab sampling for GAAT. Grab sampling requires the use of sampling teams to collect the samples and analytical services to provide the necessary particle distribution data.

- Volume of waste—The volume of waste used to calculate cost savings is based on the planned total volume to be transferred as part of GAAT, plus 20% for added sluicing water. Estimates are based on information obtained from the TDI draft deployment plan, the GAAT Web site ([gaat.stepenv.com](http://gaat.stepenv.com)), and Eric Daymo, Senior Scientist, Pacific Northwest National Laboratory.

- Sampling events—The cost for collecting grab samples is based on project information and communication from project personnel. Past sampling events are used to determine the batch size per transfer, the number of samples required per batch, and the sampling team cost.
- Cost of project downtime—The cost of project downtime is calculated from project information and communication from project personnel. No waste is transferred while samples are collected. Staff needed to manage, perform, or oversee waste transfer wait until the grab sampling data is obtained. The estimated number of people affected includes the field project managers, craft workers, health physicists (HP), and operations personnel. In many cases, the cost for downtime during sample analysis is minimized because the crew can be assigned to another job until needed.

**Table 6. Grab sampling at the Oak Ridge Gunite and Associated Tanks**

Item	Estimate
<b>Parameters affecting sampling costs</b>	
Volume of waste processed	350,000 gal
Volume with assumed 100% increase for sluicing water: 2 x 350,000 = 700,000 gal	700,000 gal
Waste transfer batch size	40,000 gal
Number of batches	18
Samples per batch	3
Total number of samples [samples/batch (3) x number of batches (18)]	54
Length of time per sample	2 h
<b>Sampling costs</b>	
Sample team costs: two samplers and one HP, 2 h each @ \$100/h/sample	\$600
Materials cost (gloves, PPE, sample bottle, plastic sheets) @ \$100/sample	\$100
Total sampling costs [sample team costs (\$700) x total number of samples (54)]	\$37,800
<b>Radiological analytical costs</b>	
Laboratory setup cost: 8 h x \$125/h	\$1,000
Analysis cost: 4 h for suspended solids + 2 h for density + 8 h for suspended solids concentration x \$125/h/sample	\$1,750
Total analytical costs [setup + analysis (\$2,750) x total number of samples (54)]	\$148,500
<b>Project downtime costs during sampling events</b>	
Hourly project personnel cost (20 @ \$100/h)	\$2,000/h
Total sampling time over project (2 h x 54 samples)	108 h
Total project personnel downtime costs during sampling [hourly cost (\$2,000/h) x total time (108 h)]	\$216,000
Estimated project personnel downtime costs during sample analysis (2 persons x 8 h x \$100 h x 54 samples). Other personnel assigned to productive tasks.	\$86,400
Total project downtime costs	\$302,400
<b>Total project costs for grab sampling at GAAT</b>	
Total sample team costs	\$37,800
Total analytical costs	\$148,500
Total downtime costs	\$302,400
Total project costs for grab sampling at GAAT	~\$489,000

### Cost of Line Blockage

Table 7 shows the cost of a pipeline blockage for GAAT. The cost to either repair or replace a section of line because of a blockage is estimated to be \$100,000. This estimate assumes that 100 ft of pipeline at \$1,000/ft would be required and would take 10 days to be completed. Costs for excavating and working in a radiological zone were not included and would significantly increase the cost of repair of a pipeline blockage.

**Table 7. Cost for Pipeline Blockage**

Item	Cost (\$K)
Cost to repair blockage	100
Downtime cost to blockage (10 8-h days @ \$2,000/h)	160
Total cost per blockage	260

## Cost Conclusions

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Table 8 estimates the cost savings from using in-line slurry monitoring versus grab sampling at GAAT. The GAAT cost savings is conservative since more than one pipeline blockage might have been avoided. Some grab sampling may still be required for radiological and other analysis. Savings at sites such as Hanford are potentially greater as the cost of plant downtime from a pipeline blockage is as great as \$1 million per day.

**Table 8. Summary of GAAT cost savings**

Item	Cost (\$K)
Total cost of grab sampling (baseline)	489
Cost of one pipeline blockage (baseline)	260
<b>Subtotal for baseline</b>	<b>749</b>
Cost of Lasentec M600P analyzer (innovative)	136
Cost of Promass 63M meter (innovative)	58
<b>Subtotal for innovative</b>	<b>194</b>
<b>Total savings (baseline minus innovative)</b>	<b>555</b>

## SECTION 6 REGULATORY AND POLICY ISSUES

### Regulatory Considerations

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There are no specific regulatory considerations with the use of in-line slurry monitoring instruments. The use of in-line slurry monitoring instruments will indirectly support DOE requirements and milestones for the final closure of waste tanks at Hanford, Idaho National Engineering and Environmental Laboratory (INEEL), ORR, and SRS.

Regulatory drivers for remediation of GAAT wastes at the ORR include the following:

- Oak Ridge Federal Facility Agreement and Consent Order between the U.S. Environmental Protection Agency (EPA) Region IV and Tennessee Department of the Environment and Conservation
- Tennessee Department of Environment and Conservation Commissioner's Order for the ORR Site Treatment Plan
- DOE Order 5820.2A requiring treatment of transuranic waste for disposal at the Waste Isolation Pilot Plant
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980

#### **Secondary waste**

The baseline technology approach will generate wastes from sampling activities and repair of blocked pipelines. These wastes will not be generated using in-line slurry monitoring.

#### **CERCLA Evaluation**

This section summarizes how in-line slurry monitoring addresses the nine CERCLA evaluation criteria.

##### 1. Overall Protection of Human Health and the Environment

- In-line slurry monitoring minimizes radiation exposure to workers.
- Environmental contamination from repairing pipeline blockages is avoided.

##### 2. Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)

- The system was designed and deployed according to applicable regulatory requirements.

##### 3. Long-Term Effectiveness and Permanence

- This technology can help accelerate tank remediation and closure schedules.

##### 4. Reduction of Toxicity, Mobility, or Volume through Treatment

- The system prevents environmental contamination from repair of blocked pipelines.

##### 5. Short-Term Effectiveness

- Radiation exposure to workers is maintained "as-low-as-reasonably-achievable" (ALARA) because sampling activities are no longer required or the number is reduced substantially.

##### 6. Implementability

- Slurry monitors are widely used in the private sector in nonradioactive environments.

7. Cost data are provided in Section 5.

8. State (Support Agency) Acceptance

- Both the state of Tennessee and EPA are parties of the Federal Facilities Agreement that covers regulatory issues and establishes requirements for management of tanks.

9. Community Acceptance is discussed below.

## **Safety, Risks, Benefits, and Community Reaction**

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### **Worker Safety**

The use of in-line slurry monitoring instruments will reduce worker exposure to unnecessary radiation by eliminating the need for grab sampling prior to and during the pipeline transfers and potentially by avoiding the need for workers to unplug or replace the blocked pipeline or install a new pipeline.

### **Community Safety**

There are no risks to the community as a result of using the in-line slurry monitoring instruments.

### **Potential Environmental Impacts**

There are no potential environmental impacts as a result of using the in-line slurry monitoring instruments.

### **Potential Exposures**

There are no increased hazardous or radiation exposures using the in-line slurry monitoring instruments.

### **Liability Risks**

There are no liability risks as a result of using the in-line slurry monitoring instruments.

### **Potential Socioeconomic Impacts and Community Perceptions**

There are no socioeconomic impacts or negative community perceptions using the in-line slurry monitoring instruments.

### **Comparison with Baseline or Competing Technologies**

The in-line slurry monitoring instruments provide increased safety and operational benefits with reduced risks over the baseline technology of grab sampling. Personnel are not exposed to unnecessary radiation exposure to collect grab samples prior to and during pipeline transfers. The potential for pipeline blockage will be reduced, further minimizing worker exposure to radiation while maintaining project costs and schedule.

## SECTION 7 LESSONS LEARNED

### **Implementation Considerations**

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The technologies are used during the transfer of slurries so that operators can quickly respond to plugs. There is no routine release of contaminants caused by this technology or potential impact from transportation of equipment, samples, waste, or other materials associated with this technology.

Having few moving parts and requiring little maintenance within the radioactive environment, slurry monitoring devices are inherently designed to ALARA conditions. Installation uses existing tank pump pits and piping runs. Radiation exposure must be minimized during installation by wearing protective clothing, and actions must be taken to prevent the inadvertent release of tank contents. Engineering analyses indicate that slurry monitors can safely be placed on the tanks and pipelines.

### **Technology Limitations and Needs for Future Development**

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Required electronics and software may have to be developed for each application. Measurement accuracy may vary from application to application depending on the operating conditions. For example, ultrasonic instruments may, if gas bubbles are present, drastically overestimate the solids concentration. Acceptable measurements can be made only in the absence of entrained air bubbles.

### **Technology Selection Considerations**

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It is critically important for both worker and environmental safety that these radioactive slurries be successfully transferred through the pipelines with minimal risk of plugging the pipeline. If a pipeline blockage does occur, there is an increase in worker exposure to radiation while trying to unplug the pipeline. If the pipeline cannot be unplugged, an enormous cost and schedule delay will occur. Tests conducted at the ORNL hot-test facility provide data for selecting instruments for a specific application, including how well an instrument functions in a radioactive environment.



## APPENDIX A

### REFERENCES

- Hudson, J. D. 1996. *Defining waste acceptance criteria for the Hanford replacement cross-site transfer system*. PNNL-11146. Richland, Wash.: Pacific Northwest National Laboratory.
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- Reynolds, B. A., E. A. Daymo, J. G. H. Geeting, and J. Zhang. 1996. *Instrument validation project*. PNNL-11221. Richland, Wash.: Pacific Northwest National Laboratory.

## APPENDIX B LIST OF ACRONYMS

ALARA	as low as reasonably achievable
ARAR	applicable or relevant and appropriate requirements
ASTD	Accelerated Site Technology Deployment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
FBRM	focused-beam reflectance measurement
FY	fiscal year
GAAT	Gunite and Associated Tanks
HP	health physicist
MVST	Melton Valley Storage Tanks
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
OST	Office of Science and Technology
PPE	personal protective equipment
SMTL	Slurry Monitoring Test Loop
SRS	Savannah River Site
TDI	Technology Deployment Initiative
WCS	waste conditioning system