Science.

Technology.

Innovation.

Ultrasonic Measurement of Slurry Density and Solids Concentration

Real-Time In-Situ Multi-Phase Process Monitoring and Control

Sensor

- **Non-invasive**
- **Provides real-time, in-situ process characteristics**
- **Compact, rugged, inexpensive**

Ultrasonic Fluid Measurements

Fluids

- **Density**

Slurries

- **Density, wt% solids concentration, stratification**

Colloids

- **Density, gelation detection**

Multiphase flow

- **Interface detection**
- **State of mixing, homogeneity**
- **Slurry transport**

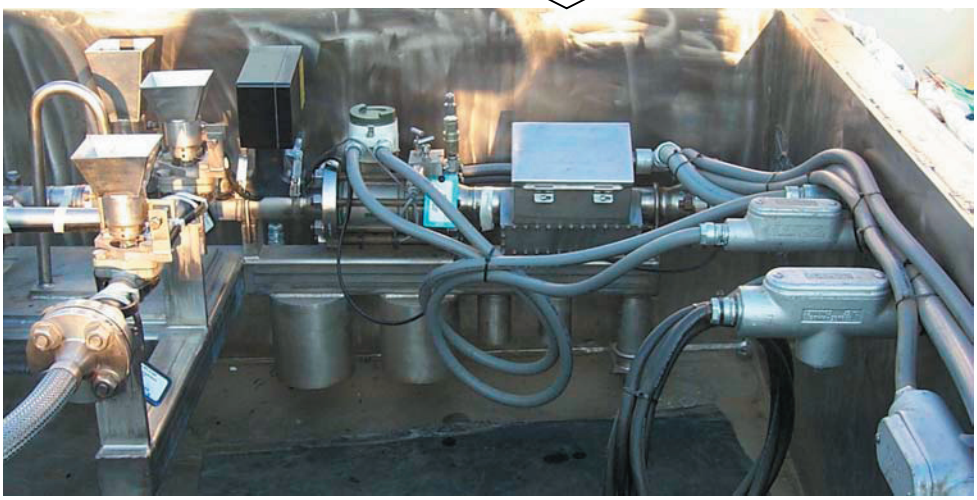
Ultrasonic Signal Attributes

- **Interrogates fluids and dense opaque suspensions**
- **Penetrates vessel and process walls**
- **Measurement not affected by flow rate or concentration or degraded by noisy process conditions**

Sensor Developed for Process Monitoring of Industrial and Radioactive Fluids and Slurries

Pacific Northwest National Laboratory is developing and deploying ultrasonic sensing systems to monitor the density and solids loading of radioactive waste slurries during pipeline transport.

Density Sensor



Ultrasonic Densimeter Installed in Radioactive Waste Transfer Piping Manifold at Tank SY-101 on the Hanford Site

Radioactive Waste Transport – Slurry Density and Solids Concentration

This sensor uses ultrasonic signal reflection to measure fluid and slurry density, in situ, in real time. The radiation-hardened sensor and spool piece can withstand radiation exposures of up to 10^6 R. The spool-piece housing the sensor is designed for deployment in a 2-in. pipeline constructed to operate at 400 psi. Accuracy for density determination ranges from $\pm$ 0.3% for homogeneous fluids to $\pm$1 to 2 % for slurries. Multiple sensors, placed around the pipe perimeter, can monitor solids stratification.

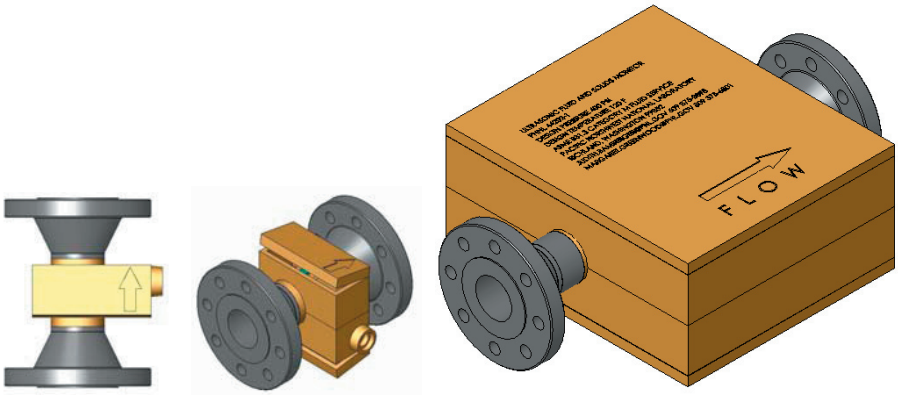
Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

PNNL-SA-37352

Ultrasonic Densimeter Spool Piece

Non-invasive Second Generation Probe

A non-invasive approach has been developed to measure the density *through* the stainless steel wall of the pipe or vessel. As implemented, the ultrasonic sensor is mounted to the outside of the pipe spool piece. Clamp-on sensors have also been demonstrated. The non-invasive configuration shown below was developed for deployment at Hanford to monitor both fluid density and solids loading.



Non-invasive Fluid and Solids Monitor 2-in. pipe probe showing two compact and an extended length sensor configuration for measuring slurry density and solids concentration

About Us…

Pacific Northwest National Laboratory (PNNL) is a premier, multi-program U.S. Department of Energy (DOE) national laboratory. PNNL is focused on meeting DOE needs in the areas of fundamental science, environmental science and technology, energy, and national security. Since 1965, **Battelle**, based in Columbus, Ohio, has operated PNNL for DOE.

References

Bamberger, J.A. and M.S. Greenwood. 2000. *Measuring Slurry Density and Viscosity In-Situ in Real Time During Pipeline Transport Using an Ultrasonic Sensor.* FEDSM00-11121, American Society of Mechanical Engineers, New York.

Bamberger, J.A., M.S. Greenwood, and K. Witwer. 2001. *Development of an Ultrasonic Sensor to Measure Density of Radioactive Waste Slurries during Pipeline Transport.* ANS 9th International Topical Meeting Robotics and Remote Systems, Seattle, Washington, March 4-8, 2001.

Greenwood, M. S. and J. A. Bamberger. 2002. *Ultrasonic sensor to measure the density of a liquid or slurry during pipeline transport.* UI'01: **Ultrasonics** 40 (2002) 413-417

Greenwood, M. S. and J. A. Bamberger. 2001. *Measurement of viscosity and shear wave velocity of a liquid or slurry for on-line process control.* **Ultrasonics.** 39 (2002) 623-630

Greenwood, M.S., J.R. Skorpik, J.A. Bamberger, and R.V. Harris. 1999. *On-line ultrasonic density sensor for process control of liquids and slurries.* Ultrasonics 37 (1999) 159-171.

Greenwood, M.S. *Ultrasonic fluid densitometer having liquid/wedge and gas/wedge interfaces.* US Patent 6,082,181

Greenwood, M.S. *Ultrasonic fluid densitometer for process control.* US Patent 6,082,180

Greenwood, M.S. and J.C. Lail. *Ultrasonic Fluid Densitometry and Densitometer*, US Patent 5,708,191

Greenwood, M.S. and R.V. Harris. *Pitch-catch only ultrasonic fluid densitometer*, US Patent 5,886,250

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Web Site of Interest
http://www.technet.pnl.gov/sensors/macro/projects/es4slrden.html