Science.

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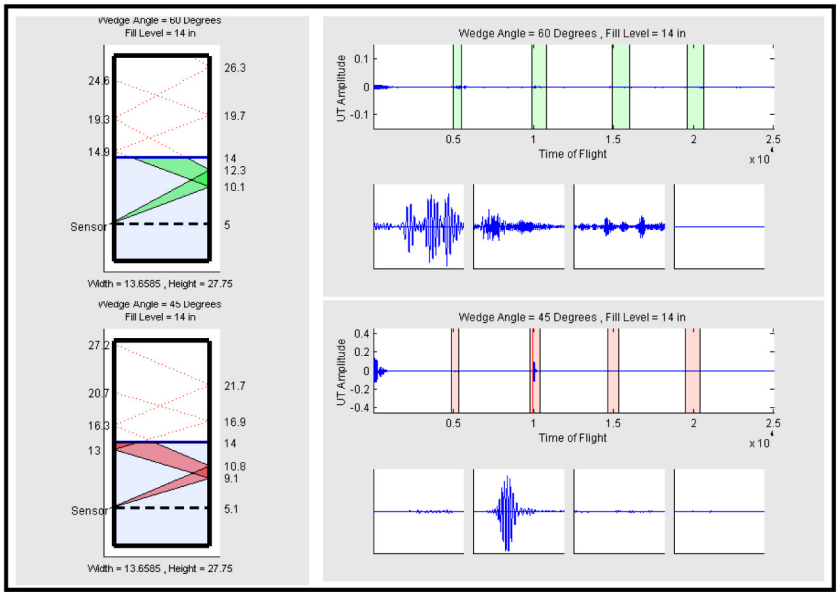
# Ultrasonic Liquid Level Monitor

## Product Development Opportunity




***Battelle's concept for an ultrasonic liquid level monitor is comprised of a single transducer mounted to the outside surface of the tank and an estimation algorithm that relies on the markedly larger echoes that return from the* corner reflectors *formed at the interface of the liquid surface and the tank sidewalls.***

## Concept Operating Principles

Battelle's concept for an ultrasonic liquid level monitor is comprised of a single transducer mounted to the outside surface of the tank. The single transducer employs either multiple piezoelectric elements or mechanical impactors to generate acoustic burst signals with transverse or oblique propagation paths. The transverse propagation path is directly across the tank at the height of the transducer location. The time-of-flight of this echo depends mainly upon the transverse distance (vessel diameter), the liquid temperature and the acoustic properties of the liq-

### Next Generation Liquid Level Sensor

Battelle's level monitor concept is responsive to a market opportunity for a low cost, non-invasive liquid level monitor that can be easily installed, maintained and operated.

- External mounting at single point
- Automated calibration for composition and temperature.
- Accurately and precise fill level predictions insensitive to surface foams and crusts .
- Refined fill-level predictions and fill-level trend prediction via Kalman Filter methods

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uid. The oblique paths are directed at angles toward the top of the tank so that they reflect off the liquid surface in order to return to the transducer. Accordingly, the time-of-flights of these oblique echoes depend upon the height of the liquid surface above the transducer. The liquid level, and its precision, is estimated from these time-of-flights using a physical model and rigorous mathematical algorithm developed by Battelle. The estimation algorithm relies on the markedly larger echoes that return from the ***corner reflectors*** formed at the interface of the liquid surface and the tank sidewalls. A unique feature in this estimation is the self-calibration provided by the transverse burst traveling a path of known length.

The level of the liquid is estimated by comparing the ultrasonic traces from one or more oblique paths to the ultrasonic trace from the transverse path, and in particular, by comparing the distinct burst travel times from the oblique and transverse paths. Battelle has developed a *Corner-Reflection Theorem* as part of its level estimation algorithm. The accuracy of this estimation algorithm is further improved by using a fill-level analysis based, in part, on a Kalman Filter model, developed by PNNL for Hanford tank fill-level tracking. The Kalman Filter model not only improves the fill-level estimate, but also provides robust information about the fill-level trend that is important for fill-level management. Preliminary laboratory studies show a fill level accuracy of 2 to 5 %.

## Corner Reflection Algorithm

For a simple convex vessel and assuming the Law of Reflection, the shortest oblique line-segment path (i.e., not parallel to the vessel side-wall **S1**) between a point **A** on side-wall **S1** and a horizontal plane **H** normal to **S1** lies along a line between the point **A**, and the point **B** at the intersection of side-wall **S2** and two planes: the horizontal plane **H** and the vertical (orthogonal) plane **V** containing **A** that is normal to **S2** at **B**.

### Distinguishing Features

The advantages of Battelle's Ultrasonic Liquid Level Monitor technology include:

- A single device that is attached to the outside surface of a storage container near the bottom.
- ***Corner Reflection*** algorithm provides continuous, accurate, and precise fill-level predictions using time-of-flight data from several beam paths. Kalman Filter model provides robust fill level trending.
- The transverse echoes provide real-time automated calibration for tank geometry, fill composition, and temperature.
- The precision of the liquid level estimate is more strongly a function of the ultrasonic pulse characteristics and not the characteristics of the tank, nor its contents.
- Lower operating frequency and coded pulse compression signal processing provide the signal penetration and high signal-to-noise needed in monitoring the larger bulk storage containers.
- Lower operating frequencies offer lower development and manufacturing costs by leveraging existing electronic com-

## *Commercialization Path*

***Ultrasonic level monitors represent a very mature technology in a large commercial market where cost and connectivity features often serve to differentiate vendors' ultrasonic products offerings. There is a market opportunity for a low cost (hundreds of dollars), non-invasive ultrasonic liquid level monitor that can be easily installed, maintained and operated. The findings from a preliminary patent search suggest the Battelle liquid level monitor (LLM) concept offers an intellectual property position that can be protected.***

***Battelle's corporate strength lies in applications research and the early stages of technology development, including breadboard development and testing. Battelle's Pacific Northwest Division maintains an expertise in the development of advanced measurement technology and breadboard or prototype monitoring systems based on ultrasonic measurement methodologies. The ultrasonic liquid level monitor discussed herein is a new type ultrasonic monitor whose design concept draws upon Battelle's extensive ultrasound expertise. Battelle frequently seeks commercialization collaborators for the manufacturing, sales, and marketing phases of new product development.***

Battelle (PNNL) developed acoustic inspection technology commercialized for use in national security applications

ponents for cell phones and music gadgets.

## Development Activities

Battelle has identified critical design features that will be addressed in the development and commercialization of the ULLM:

- Judicious selection of ultrasonic transducer design parameters including element size, frequency, angles, and fabrication materials.
- The external mounting of the ultrasonic transducer at single point requires robust acoustic coupling for reliable monitoring over extended periods of time.
- Verification of fill level estimation accuracy performance of ***Corner Reflection*** algorithm under field conditions.

## Summary

Battelle's level monitor concept is based on a monostatic, multi-element transducer capable of generating and receiving acoustic bursts with distinct propagation paths that reflect off the liquid surface. A proprietary level estimation algorithm provides high accuracy and precision. The system offers novel features including completely external mounting and an accuracy insensitive to surface foams and crusts .

## About us. . .

Battelle develops new technologies, commercializes products, and provides solutions for industry and government. Our innovations range from medical products and pharmaceuticals to products for the automotive, chemical, and agrochemical industries.

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