The Power of Passive Sonar Technology

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Beginning in the early 1950s, the United States and British navies began to investigate the use of passive sonar in which an array of sensors detect noises emanating from the target submarine. Prior to this new method of detection, navies would use active sonar whereby a submarine would emit a signal that would reflect off the target submarine. Unfortunately, this would, in turn, let the target know it was being monitored. Passive sonar systems allow the submarine to become 'stealthy' by 'listening' to noise emitted from the target submarine and by utilizing a series of sensors, equally spaced on a cable, to receive the signals from the target passively. Powerful sonar algorithms convert the signals (pressure fields) into information whereby the submarine can take action.

Passive sonar flow technology, utilized for over 17 years in some of the world's most extreme environments and challenging process applications, is the newest flow measurement technology since the introduction of the vortex, Coriolis, and ultrasonic flow meters introduced in the 1960's and early 1970's. Passive sonar flow technology, engineered for a wide range of multi-phase and single-phase flows, is especially well-suited for erosive and corrosive slurry flows, such as in the mineral processing industry, since the flow meter installs and measures from outside of the process pipe and therefore does not contact the process media. The ability of the sonar technology to *passively* measure flows from the outside of the pipe, enables unprecedented measurement performance and reliability in highly aggressive slurries and fluids which, virtually eliminates maintenance costs associated and process downtime experienced with traditional slurry flow technologies such as the electromagnetic flow and ultrasonic meters.

Sonar Technology: More than 'Just a Flow Meter' - Leveraging Dual Measurement Capability for Enhanced Value in Industrial Processes

The passive sonar flow technology provides two distinct, but synergistic measurements - volumetric flow and entrained air percent by volume - thereby providing process engineers, metallurgists and operations personnel with a powerful combination of unique, real time, value-based tools to reduce process variability and help optimize the process. Efficient operation of each key process stage in a minerals processing facility, as an example, requires accurate information of the process production rate through an accurate mass balance calculation. Often flow measurement offsets and reliability issues, experienced with conventional flow instrumentation such as the electromagnetic flow meter, are due to the nature of the meter technology which requires contact with the process media. Whether the issues are due to slurry abrasion causing wear and drift in the measurement or changes in material or magnetic properties of the ore being processed, plant personnel have no practical way of knowing which process variable is contributing to the error or anomaly in the flow measurement. To add to the number of variables that can cause error in the flow measurement, air bubbles (entrained air) in the slurry or fluid, negatively impact the measurement and performance of conventional flow meters. Therefore, one can readily understand with all these variables it is difficult for plant and process personnel to identify the exact nature of the problem so that root cause be determined and corrective actions taken to increase efficiency and optimize the process.

Unlike the electromagnetic meter, the sonar flow and entrained air meter is externally mounted onto a pipe and does not contact the process media; therefore, it is an ideal process monitoring and control tool, eliminating two of the variables that process engineers have to deal with – flow and entrained air. Correlating these two measurements with tank levels, pump output, density and other process equipment metrics, process engineers and metallurgists are better positioned to help determine root cause of process upsets and be assured of flow accuracy for better control and process optimization.

Sonar flow meters have been in service for over 14 years with zero maintenance and no need for recalibration. Besides measuring flow from outside of the pipe, the passive sonar array-based technology can measure the percent air by volume in a slurry or liquid stream. Entrained air in slurry streams can lead to appreciable offsets in mass balance calculations and make it difficult to optimize the process for increased efficiencies in production. So how is this unique combination of synergistic measurements made and how are they utilized in practice to provide process and operational efficiencies that conventional flow meters can't provide?

Sonar Technology – Principles of Operation

Passive sonar flow processing employs two distinct but synergistic measurement techniques. The first technique measures volumetric flow rate by monitoring the turbulent "eddies" within the process flow. Passive sonar flow technology provides a direct measurement of the average bulk velocity and provide a full-bore measurement. As with other velocity-based flow meters, knowing the inner diameter of the pipe, the volumetric flow is derived. The second technique measures the speed at which sound propagates through the fluid to provide compositional information. The sound speed measurement made by the passive sonar meter is also a real time, direct measurement from which the gas void fraction (entrained air percent by volume) measurement is derived. Both the volumetric flow and entrained air measurements can be provided as separate outputs to the DCS. The entrained air measurement is particularly synergistic with the sonar volumetric flow meter in that the measured sound speed can be used to determine the volumetric fraction of the two component mixture, whereby the total volume of the flow can be adjusted to a 'true' flow measurement of the slurry or liquid flow as shown in the below Figure 1.

Process industries around the world have realized the full value that a real time entrained air measurement can provide in terms of process optimization improvements and efficiencies. Passive sonar entrained air measurements are being used across diverse industries to correct the density measurement from a nuclear density gauge when entrained air is present thus enabling the accurate calculation of true mass flow rates. Depending on the specific gravity of the process media, even a small amount of entrained air in a slurry or fluid can cause exponential errors in the density measurement as shown in Figure 2. As mentioned earlier, process engineers, metallurgists and operations personnel struggle daily with a wide spectrum of variables that make process predictability and control challenging to say the least. With the utilization of the sonar flow technology, two of the variables, flow and entrained air, can now be relied upon when performing a mass balance and in daily monitoring and control situations.

Figure 1: Utilizing Passive Sonar to Adjust the Volumetric Flow to a 'True' Flow When Entrained Air is Present in Slurry and Liquid Flows

Figure 1: Measurement of Air Volume and Volumetric Flow Correction

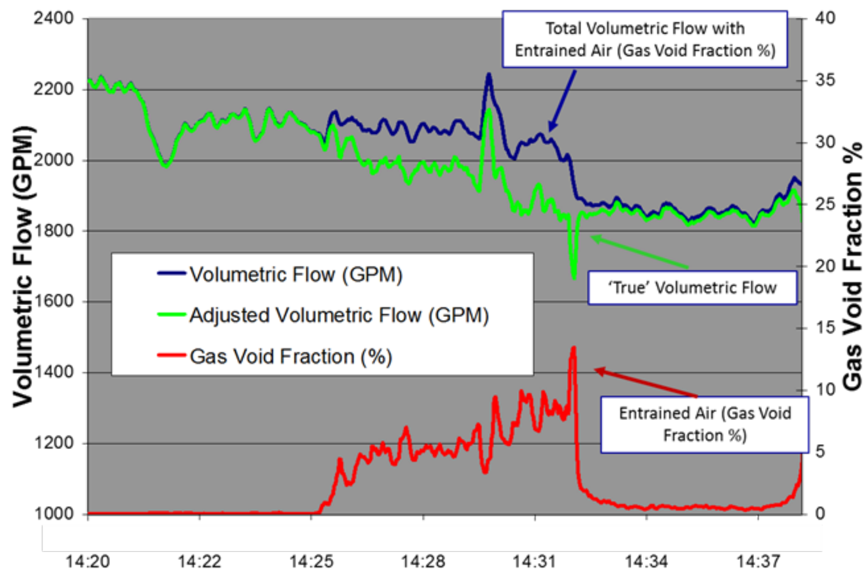
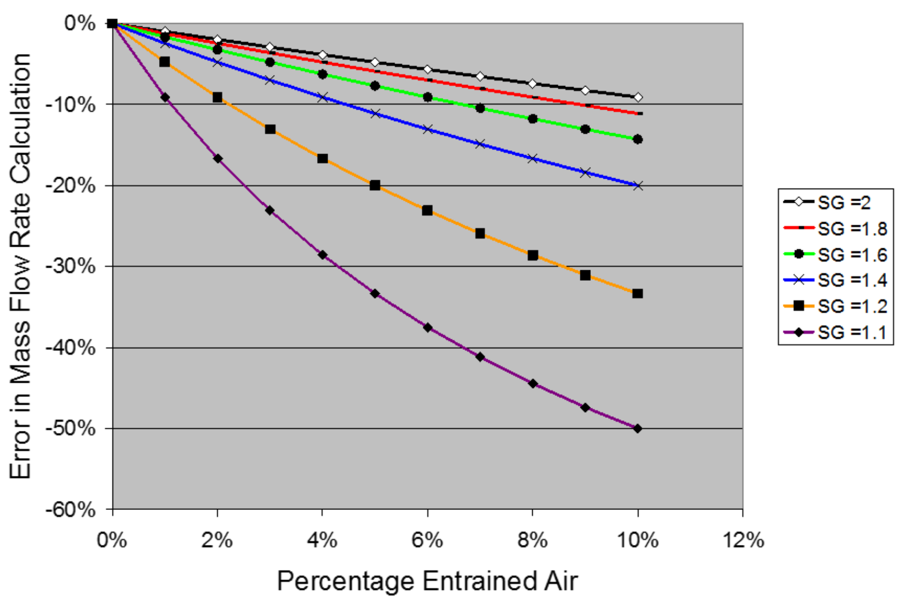


Figure 2: Entrained Air Corrects Errors in Density Due to Presence of Entrained Air/Gas



Application Case Study – Hydrocyclone Feedline Installation

Measuring the volumetric flow rate on a hydrocyclone feed line in a copper concentrator is a challenging endeavor for any conventional flow meter. Doing so with highly abrasive slurry containing entrained air and, in some cases magnetite, poses additional challenges to both the performance and maintenance of the electromagnetic meter.

Hydrocyclone Feed Line Installation

The following are some pictures of example installations for a passive sonar flow meter (Figure 3) and an electromagnetic flow meter (Figure 4). Even though this is a very challenging piping configuration, the passive sonar meter performs exceptionally well and since the flow meter is installed on the outside the pipe there is no possibility of leakage. Note that the picture of the electro-magnetic flow meter shows the leakage problems that can occur within a very brief time in service.

Figure 3: Passive Sonar Flow and Entrained Air Meter

Figure 4: Electromagnetic Meter

As previously noted, the nuclear density gauge measurement is subject to error produced by the entrained air in the slurry which is typically caused by low sump levels drawing air into the slurry, or leaks in the pump feed pipe to name a couple. It is extremely important that entrained air be eliminated from the slurry to the hydrocyclone for the following reasons: (1) if entrained air is present, the lining wear rate will increase and cyclone performance will deteriorate and (2) more important to mineral recovery and throughput, entrained air can cause coarse particles to report to the overflow.

Passive sonar flow technology is the only process instrumentation that can provide a real time entrained air measurement that can be used to monitor and measure the amount of entrained air in a slurry. This capability can then enable an operator to take preventative action for increased cyclone recovery and correct errors in the density measurement for improved mass balance accuracy.

Having a more accurate reading of flow will enable a more accurate control of the mill circulating load; for example, a 1% tighter control of the circulating load will equate to a 1% increase in mill throughput. This mill throughput increase could translate to about US$2,000,000 per year (100,000 tons per day, copper grade of 0.5%, 85% recovery, 28% con grade, $2.50/lbs). In addition, tighter control of the slurry feed density to the hydrocyclone battery will translate to a tighter particle size distribution to flotation. The sensitivity of product recovery to particle size distribution is highly dependent on site specific parameters. Also, assuming that a 1% increase in recovery can be achieved by controlling feed density; then this would translate to approximately another $2,000,000 per year.

Passive sonar flow meters also provide tremendous savings related to maintenance expenses and process downtime. Typically, an electromagnetic flow meter will last anywhere from six months to 5 years and require periodic recalibration depending on the ore body composition and the slurry velocity. Therefore, the maintenance of these flow instruments is very costly when all factors are considered. These factors include the initial capital cost, installation cost, safety, meter performance, maintenance, spare requirements, equipment lead time, and process down time. The actual lifecycle cost of an electromagnetic flow meter in a concentrator is significantly greater than just the initial capital cost – not even including the cost of process downtime when the flow meter must be removed for repair, recalibration, and replacement.

Summary

The volumetric flow rate in a hydrocyclone feed line is an important measurement when processing ore in a closed-circuit milling operation. Indeed, to optimize any circuit, reliable instruments are a must. Control systems depend on repeatable and accurate measurements to first, reduce the system's variability, and second, shift the operating point to the point of maximum efficiency. Flow measurement is an integral part of any flotation circuit control strategy. An entrained air measurement provides value in the following ways:

- The passive sonar flow meter is not subject to loss of performance due to entrained air or when there is magnetic ore present in the slurry such as magnetite, arsenopyrite, and pyrrhotite. (like electromagnetic meters)
- Circulating load calculations improve when removing air from the calculation
- Mass balance accuracy increases when removing air from the calculation
- Frother addition rate may be adjusted using volumetric feed rate vs. tons of ore in mill feed.

The additional accuracy gained by leveraging passive sonar's entrained air measurement can provide the mill with increased throughput and recovery gains.