

APPLICATION OF PASSIVE SONAR TECHNOLOGY TO MINERALS PROCESSING FLOW MEASUREMENT SITUATIONS

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Abstract

In this presentation, CiDRA's patented technology platform and its applications will be described. CiDRA's non-invasive, passive sonar array-based flow meter technology provides the volumetric flow rate of single or multiphase fluids by measuring the speed at which naturally occurring structures such as turbulent eddies or density variations convect with the flow past an axial array of sensors. These sensors are incorporated in a band that is wrapped around the outside of the pipe, resulting in no process downtimes for installation and unprecedented reliability. This technology has resulted in a unique ability to measure the flow rate of most fluids – clean liquids, high solids content slurries, pastes, and liquids and slurries with entrained air. Unique and difficult minerals processing flow measurement problems and their solutions will be described. Examples of these problems include flow measurements in froth lines and flotation feed lines with entrained air, slurry lines with magnetite and other magnetic ore, slurry lines with abrasive or corrosive materials, high pressure lines, and lines exhibiting scale buildup. Recent technology developments will be covered.

Introduction

The minerals processing industry faces many unique and challenging process control conditions and environments. In terms of flow measurements, many of these situations are not being properly served by traditional

flowmeters such as ultrasonic meters, magmeters, turbine meters, orifice plate meters, vortex flow meters, Coriolis flow meters, and venturi meters. A new class of flowmeter has been developed that operates well in these unique situations and solves these flow measurement problems. This new class of flowmeter technology utilizes sonar-based processing algorithms and an array of passive sensors to measure not only flow, but also fluid composition. It does so accurately, reliably and without making contact with the fluid. These measurements are performed on practically any type of fluid within virtually any type of pipe.

Principle of Operation

Sonar array-based flowmeters are ideal for tracking and measuring the mean velocities of disturbances traveling in the axial direction of a pipe. These disturbances generally will convect with the flow, propagate in the pipe walls, or propagate in the fluid or slurry. First let us focus on the disturbances that convect with the flow. The disturbances that convect with the flow can be density variations, temperature variations or turbulent eddies. The overwhelming majority of industrial flows will have turbulent eddies convecting with the flow, thus providing an excellent means of measuring the flow rate as described below.

Turbulent Eddies and Flow Velocity

In most mineral processing flow measurement applications, the flow in a pipe is turbulent. Turbulent flow

is composed of eddies, also known as vortices or turbulent eddies, which meander and swirl in a random fashion within the pipe but with an overall mean velocity equal to the flow, that is they convect with the flow. An illustration of these turbulent eddies is shown in Figure 1. These eddies are being continuously created. Once created they break down into smaller and smaller vortices, until they become small enough such that they are dissipated as heat through viscous effects of the fluid. For several pipe diameters downstream, these vortices remain coherent retaining their structure and size before breaking down into smaller vortices. The vortices in a pipe have a broad range of sizes, which are bracketed by the diameter of the pipe on the largest vortices and by viscous forces on the smallest vortices. On the average, these vortices are distributed throughout the cross section of the pipe and therefore across the flow profile. The flow profile itself is a time-averaged axial velocity of the flow that is a function of the radial position in the pipe with zero flow at the pipe wall and the maximum flow at the center as seen in Figure 1. In turbulent flow, the axial velocity increases rapidly when moving in the radial direction away from the wall, and quickly enters a region with a slowly varying time-averaged axial velocity profile. Thus if one tracks the average axial velocities of the entire collection of vortices, one can obtain a measurement that is close to the average velocity of the fluid flow.

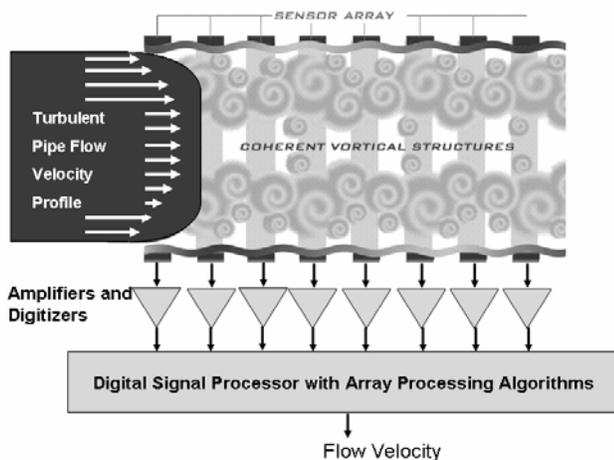


Figure 1. Diagram of Pipe with Turbulent Flow Showing Fully Developed Flow Profile and Turbulent Eddies

Array Measurement of Flow Velocity

Through the combination of an array of passive sensors and the sonar array processing algorithms, the average axial velocities of a collection of vortices is obtained. The

sequence of events that occur to make this measurement possible is as follows:

- The movement of the turbulent eddies creates a small pressure change on the inside of the pipe wall
- This small pressure change results in a dynamic strain of the pipe wall itself (Figure 1 exaggerates)
- The mechanical dynamic strain signal is converted to an electrical signal through a passive sensor wrapped partially or fully around the pipe – no couplant gels or liquids are required
- This electrical signal is detected by each element of the array of sensors. These sensors are spaced a precisely set distance from each other along the axial direction of the pipe.
- The resulting electrical signal from each sensor element is interpreted as a characteristic signature of the frequency and phase components of the acoustic waves under the sensor.
- An array processing algorithm combines the phase and frequency information of the characteristic signature from the group of sensor array elements to calculate the velocity of the characteristic signature as it propagates under the array of sensors.

The challenges of performing this measurement in a practical manner are many. These include the challenges of operating in an environment with large pumps, flow generated acoustics, and vibrations all of which can cause large dynamic straining of the pipe. The impact of these effects is that the dynamic strain due to the passive turbulent eddies is usually much smaller than the dynamic strain arising from pipe vibrations and acoustic waves propagating in the fluid. The strength in the array processing algorithm is its ability to isolate and measure the velocities of these different components, including the weak signal from the convecting turbulent eddies, and the strong signals from the acoustic waves and vibrations. The velocity of the acoustic waves is used to calculate the fluid composition or the amount of entrained air (gas void fraction), both of which are the subjects of another paper.

The technology lends itself to the generation of a measurement robustness indicator otherwise known as a quality factor. Most other flowmeters do not provide an indication of the quality of the measurement. Conversely, in the sonar processing algorithm such a quality factor can be generated by comparing the strength of the signal from the flow against background energy levels. A quality factor ranging from 0 to 1.0 is generated, with any flow measurement providing a quality factor above 0.1 to 0.2 (depending on the application) having the confidence as being a good measurement.

Currently this technology can report the volume flow rate on liquids and slurries with flow velocities extending from 3 (0.9 m/s) to several hundred ft/sec. The technology lends itself to measurement on practically any pipe size, as long as the flow is turbulent, and for some non-Newtonian fluids, even without turbulence. The pipe must be full to give an accurate volumetric flow rate but it can have entrained air in the form of well mixed bubbles.

Calibration and its Maintenance

The volume flow measurement provided by tracking the turbulent eddies does require some adjustment or calibration. In practice the calibration adjusts the reported output by only a few percent, depending on the Reynolds number.

Since the flow measurement and hence calibration are not dependent on the absolute values of any analog signals, they will not drift with time or temperature. Maintenance of the calibration from meter to meter as well as from temperature effects and aging is dependent on maintaining the spacing between the sensor elements and maintaining the stability of the clock used in the digitizer. The spacing between the sensors is set in the factory where they are bonded to a stainless steel sheet and cannot be adjusted by the customer. Pictures of the lightweight sensor band are shown in Figure 2.



Figure 2 Pictures of the Sensor Band with Drift-Free Sensor Elements

The clock stability is better than 0.01% and thus is 50 times better than needed to maintain the flowmeter’s typical accuracy of +/- 1% in the field; and +/- 0.5% under reference conditions or after in-field supplemental calibration. As a result, the impact of clock stability can be neglected. In Figure 3 one can see the results from applying the same calibration coefficients to six flowmeters, all of the 6-inch variety and all tested at a NIST traceable calibration facility. As can be seen, the meter to meter variation is quite low, within 0.5%, and with the added advantage that it will not change with time.

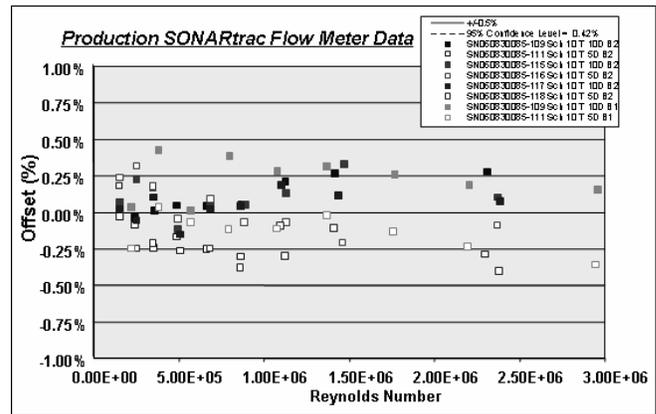


Figure 3 Illustration of Calibration Consistency from Meter to Meter. All Meters Have Same Calibration Coefficients

Application of Array-Based Technology to Solve Volumetric Flow Measurement Problems

CiDRA’s array-based flow instruments have been installed in over fourteen countries and have proven themselves in grinding/classification, refining, slurry hydrotransport, leaching and smelting operations. These include hydrocyclone feed lines, hydrocyclone overflow lines, hydrocyclone underflow lines, water feed and recovery lines, SAG mill discharge lines, ball mill discharge lines, thickener underflow lines, tailings lines, final concentrate lines, red mud and green liquor bauxite lines, pregnant leach solution lines, raffinate lines, organic lines, acid lines, and scrubber water lines. A few examples of these applications are outlined in this section.

Flow Measurement for Continuous Processes where Safety and Maintenance Free Operation is Paramount

An industrial process plant, such as an alumina refinery or copper concentrator, is held accountable for an annual production rate while meeting cost, safety, and product quality targets. These conflicting requirements force plant management to make difficult decisions about how much to monitor their process and then how to monitor the process. They consider issues such as accuracy, capital cost, installation cost, process downtime, maintenance costs, safety, training, and human resources. Solutions that meet the performance requirements; are installed with no process downtime; and provide safe maintenance free operation will

be considered first. The sonar flow meter is a device that has been designed to meet all of these requirements.

Since the sensor band and cover mount on the outside of the pipe there is no need to stop the process to conduct the installation. This also means that there are no safety concerns with opening the process pipe or cleaning out pressure taps. The installation is easy as seen in Figure 4 and typically takes about two hours. It consists of sanding the pipe smooth, securing the band to the pipe, and installing the sensor cover. There are no coupling gels required and the sensors do not require alignment.

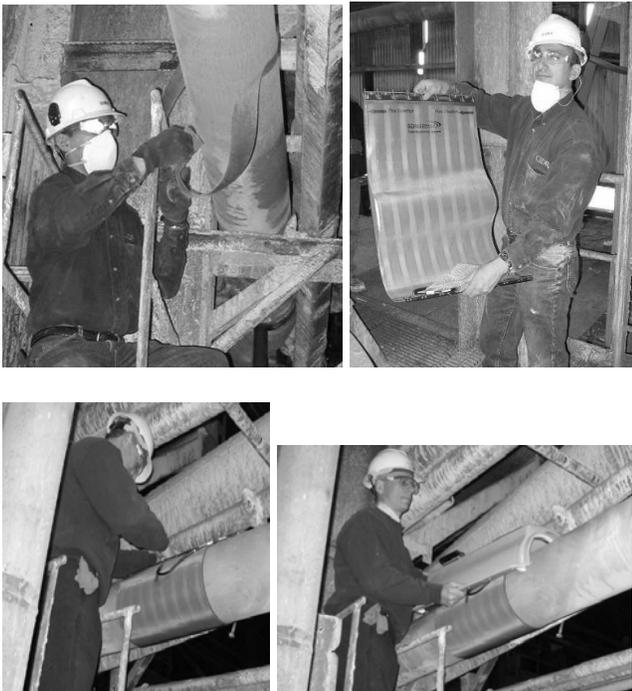


Figure 4 Installation Procedure from a) Pipe Preparation b) Sensor Band c) Band Attachment to Pipe d) Installation of Sensor Cover

Alumina refineries typically use what is called the Bayer process to extract alumina from bauxite ore. This process relies on the use of hot caustic solutions to dissolve and precipitate the alumina. Therefore there are process pipes that carry hot caustic solutions throughout the entire plant. Traditionally these plants would use orifice plates and pressure transducers to measure flow rate. This imposes heavy maintenance requirements and safety issues for the maintenance team. An example of this orifice plate use is shown in Figure 5



Figure 5 Invasive Orifice Plate Flowmeter with Pressure Taps

The maintenance team will typically clean the pressure taps once a shift to be sure the lines stay clean. Each time they do this they run the risk of exposing the technician to hot caustic solution. This constitutes a large annual maintenance cost as well as undue safety risk. The maintenance free benefits of the sonar flow meter have been proven in multiple refineries world wide and have been in service for many years.

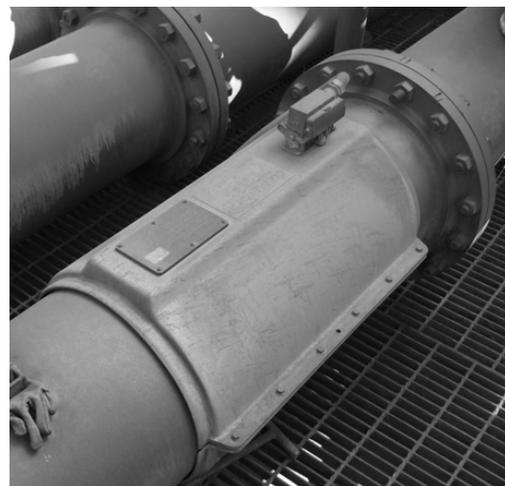


Figure 6 Non-invasive Sonar Array Based Flowmeter

In the mining industry, milling operations in concentrator plants are running continuously to capitalize on the high mineral prices. Ore is finely ground and classified using hydrocyclones. The feed lines to the hydrocyclone batteries are a main artery in the process which carries the slurry of ore and water. If one of those lines is shut down the production rate is reduced proportionally. Therefore this condition is avoided at all cost. Traditionally in-line flow devices are used to measure the volumetric flow rate feeding the hydrocyclone battery. These devices are in contact with the highly abrasive slurry and need to be service on a regular basis. This maintenance

cycle will range from every 6 months to every 5 years depending on the ore body and the velocity of the slurry.



Figure 7 Failed Magmeter with Slurry



Figure 8 Sonar Based Flowmeter Exhibits Lifetime > Pipe

Replacing an in-line device may take a crew eight hours to replace and requires heavy lifting equipment. During that time the process is shut down and production is sacrificed. The installation or replacement of a sonar meter does not require the process to be shut down.

Accurate Non-Invasive Flow Measurements for High Pressure Applications

Due to its non-invasive nature and easy installation, the sonar array-based flowmeter is ideally suited for abrasive and/or high pressure applications. As an example, there was a need to have a reliable flowmeter to measure flow at the beginning and end of a >50 km pipeline. The requirement was to accurately measure flow in order to

detect any leaks, as well as monitor the load out rate. The challenge for the plant was to do so without breaking into the pipe due to the high pressures (>1000 psi, >70bar) seen on the second flowmeter site. A picture of the high pressure installation (Figure 9) shows how the external nature of the flowmeter makes for a quick and safe installation, as well as a safe operation.



Figure 9 Safety in High Pressure Lines (>1000 psi, >70 bar)

The resulting flow measurements seen in Figure 10 clearly show the two flowmeter signals (dark lines) lying on top of each other. The only way to see the small differences between the two readings is by looking at the ratio of the two outputs (light line). Except where transitions cause a difference in flow between the top and bottom meters due to the transit time of the flow change in the pipeline, the averaged ratio is within approximately +/- 1%, which is within the specifications of the meters and the requirements of the plant.

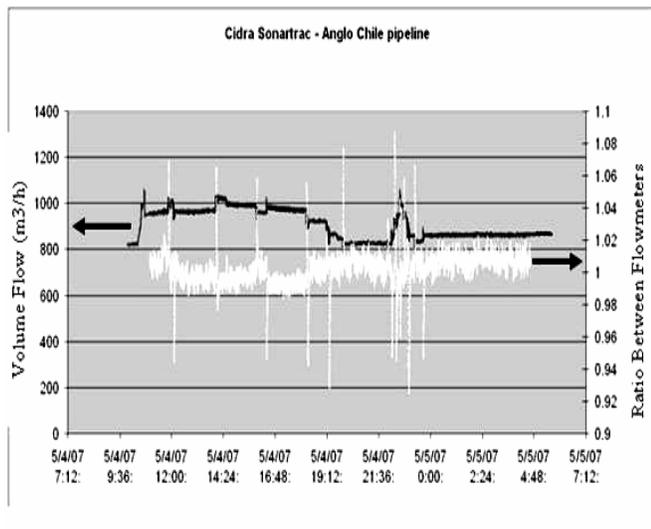


Figure 10 Leak Detection using Sonar Array-Based Flowmeters. Overlapping Dark Lines are Flowmeter Outputs. Light Line is Ratio Between the Two Outputs

Accurate Flow Measurement without Drift

There are many cases where the measurements provided by flowmeters cannot be verified through an accurate gold standard test such as a tank fill or draw down calibration. Most flowmeters will drift with time and/or temperature resulting in a change in the signal that is not noticed or cannot be verified. As an example, magmeters rely on the stability of analog electronics that can drift with time and temperature, the absence of magnetic particles in the ore, and/or clean electrodes to accurately report flow. When any of these conditions are not met, which happens frequently, the operator is not even aware that an error has taken place unless the magmeter is compared to another meter, or is recalibrated via a gold standard test.

As an example data is shown in Figure 11 from two magmeters placed in series in close proximity to each other at a gold and copper mill. In that figure the two dark lines are the magmeter outputs, while the light line between the two dark lines is the sonar array-based flowmeter. The sonar array-based flowmeter was configured using the universal calibration coefficients used for this meter.

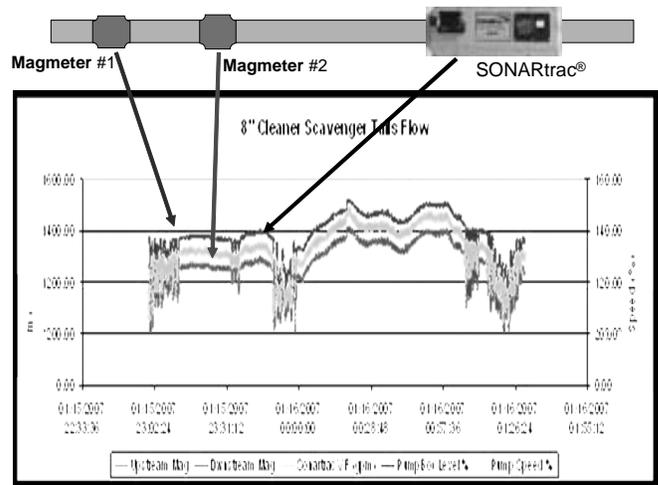


Figure 11 Two Magmeters in Series with Array-Based Flowmeter

Here the two magmeters differ on the average by over 12%. The data from an sonar array-based flowmeter is seen to provide a flow reading that is approximately an average of the two magmeters, but with the confidence that it will not drift with time.

Flow Measurement with Build-up of Scale on Interior Pipe Walls

A common situation in hard water lines, scrubber lines, bauxite lines, and lines carrying lime, is the buildup of scale on the interior of the pipe walls. This scale buildup can vary from a thin layer to several inches thick, depending on the pipe material and lining, the fluid composition, the flow rate and the time intervals between maintenance actions performed to remove the scale. The impact of this scale buildup on most flowmeters varies from small such as an increase in noise, to large such as a drift in the reported flow measurement, or a complete failure of the flowmeter to report any flow. No flowmeter is truly immune to the effects of scale buildup but flowmeters commonly used in mineral processing such as magmeters and ultrasonic flowmeters are particularly sensitive to scale.

Impact of Scale Buildup on Ultrasonic and Electromagnetic Flowmeters

In transit time ultrasonic flowmeters, an ultrasonic wave injected into the fluid has to travel between two transducers using known bending or refraction of the ultrasonic wave at the pipe to fluid interface. The impact of scale on such a meter involves three effects: 1) attenuation of the ultrasonic signal in the scale, 2) scattering of the

ultrasonic signal at the scale to fluid interface, and 3) change in the refraction angle at the scale to fluid interface.

Ultrasonic Doppler Flowmeters operate on a different principle than transit time flowmeters and their transducer arrangement differs as well, but they do suffer from similar problems induced by scale. Whereas the change in refraction angle may not necessarily cause the ultrasonic signal from one transducer to miss the second transducer, it certainly will change the reported flow. The conversion of the Doppler frequency shift to a flow reading requires that the instrument know the angle between the ultrasonic wave propagation direction and the axial direction of the pipe. Scale will change this angle thus producing an erroneous flow reading.

Magmeters operate by using the interaction of a magnetic field with a flowing conductive fluid to create an electric field within the fluid. The electric field is in turn detected and measured by a pair of electrodes placed on opposite sides of the interior of the pipe. Scale buildup on the electrodes serves to electrically isolate the electrodes preventing the flowmeter from measuring the flow induced voltage. The only recourse is to stop the process or divert the flow, remove the magmeter and remove the scale.

Impact of Scale Buildup on Sonar Array Flowmeter

The passive sonar array technology does not rely on the contact of any electrodes with the fluid, nor does it rely on the injection and retrieval of a signal into the fluid. The turbulent eddy induced pressure signals simply strain the scale which in turn strains the pipe wall and then the sensors. The impact of scale buildup is that the effective stiffness of the pipe may increase which will reduce the magnitude of the strain. Since the absolute magnitude is not used in the flow calculation, there is no change in the measurement of the flow velocity. Like most velocity meters, the sonar array-based flowmeter uses the effective inner cross-sectional area of the pipe to convert the velocity to a volumetric flow. Scale buildup will decrease this inner cross-section area thus requiring some adjustment of the inner diameter entered into the transmitter. The difference is that, unlike older generation flowmeters such as magmeters, ultrasonic meters, differential pressure based meters, etc., the sonar array-based flowmeter will continue to operate thus eliminating periods of time in which the operator is “operating blindly” at those measurement points.

This technology has been proved on a variety of pipes with scale buildup from scrubber water, bauxite green liquor, and lime. An example of the ability to operate in the presence of scale is shown in Figure 12. Here a sonar based flowmeter is operating on an 18-inch pipe which is feeding water to a ball mill. In this case, based on previous magmeter cleanings, the pipe is estimated to have about two inches (5cm) of lime scale. Downstream of the meter is a

magmeter that is cleaned out every few months to remove the scale from the electrodes and allow the magmeter to function again. This operation is labor intensive, it results in the loss of flow measurements and it relies on a bypass system to prevent a process shut down. Unfortunately, the valve used to divert the flow is developing problems from the same scale build up and the bypass system has a limited life. As can be seen in the figure, both flowmeters have similar noise levels, flow rate changes responses, and outputs. The difference is in the maintenance requirements, and the flow measurement downtime.

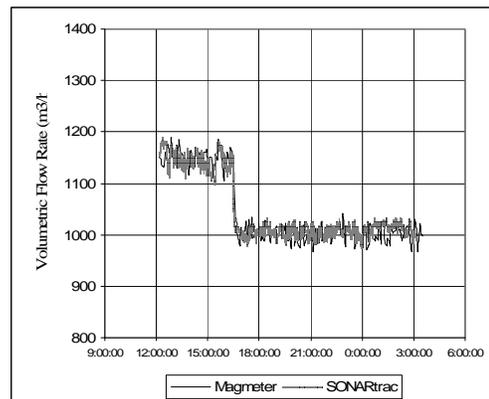


Figure 12 Sonar Array - Based Flowmeter Operation in Water Pipe with Two Inches of Scale Buildup. Comparison to Recently Cleaned Magmeter is Shown.

Measuring Flow in the Presence of Magnetic Ore such as Magnetite, Arsenopyrite or Pyrrhotite

Magnetic ore in a slurry line, whether intentional in an iron ore mill or whether unintentional in mills concentrating other metals, poses a potential problem for magmeter flow measurements. Quite a few locations mining copper, gold or other non-ferrous metals have magnetic ore in or near their ore body. The magnetic ore, even in small quantities, changes the magnetic field within the magmeter and can cause the magmeter to register a higher flow rate than the actual flow rate, or introduce a high quantity of noise in the flow rate output. Magmeter manufacturers have attempted to circumvent the impact of magnetic ore with a third coil, with magnetic field measurements, and with manual offset adjustments based on laboratory samples of the typical slurry. These methods have resulted in mixed results in which many times, the calibration or offset changes depending on the quantity of magnetite present.

A better solution is to use a flowmeter technology that is not impacted by the presence of magnetite. Since the passive array technology used in the sonar based flow monitoring system does not rely on the use of any magnetic fields, it is totally impervious to the effects of magnetite.

An example of this is illustrated in Figure 13 in which a sonar-based flowmeter is compared against a magmeter. In the figure, one can see that as the density of the magnetic ore increases, the magmeter erroneously reports a higher flow rate, whereas the sonar based flowmeter correctly continues reporting no change in the flow rate.

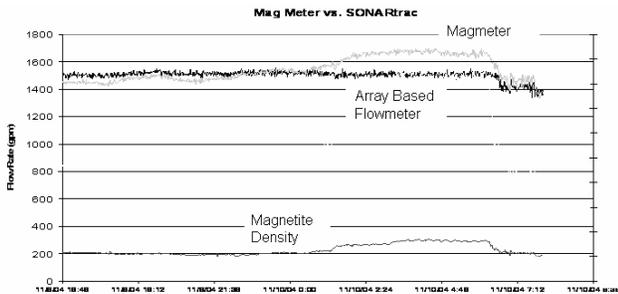


Figure 13 Magmeters Erroneously Respond to Magnetite while Array Based Flowmeter Reports Correct Reading

VolumeFlow Measurement in Presence of Entrained Air

In most cases, plant engineers are unaware of the amount of air entrained within their slurry. Despite the best care in plant design, air can enter the slurry through a variety of sources including leaks on the suction side of pumps, low sump levels, discharge into a sump, from hydrocyclones, and from mills. Not only can the same sensor head and transmitter measure volumetric flow in the presence of high levels of entrained air, but as mentioned earlier it can measure the amount of entrained air. This latter ability is the subject of another paper.

In terms of volumetric flow measurement, most flowmeters are adversely affected by air entrained within a liquid or slurry. As a minimum, they cannot provide the true liquid or slurry flow, while in many cases the entrained air will cause a large increase in flow meter noise or a total loss of flow readings. The ability of the array based technology to measure flow in the presence of high levels of entrained air as well as the entrained air level itself lead to better control of the process. Some of these entrained air situations and the use of the array based technology to resolve these flow measurement and control situations are given in the following sections.

Case Study Flow and Entrained Air Measurement at Kemess Mill

Northgate Minerals uses CiDRA Corporation’s sonar array-based (SONARtrac®) technology to measure bulk concentrate flows and the feed to the flotation columns at Kemess mine in British Columbia, Canada, as shown in Figure 14. The non-intrusive technology measures these

abrasive slurries accurately with no process downtime due to maintenance issues with the flow meter.

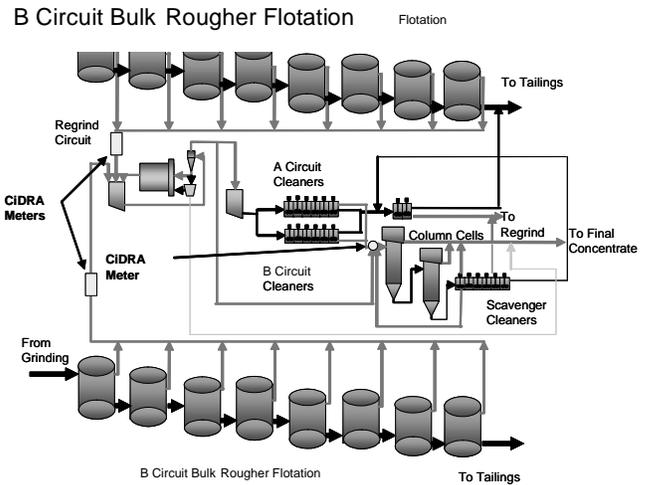


Figure 14 Kemess Mills Flowsheet Showing Locations of Three Sonar Array-Based (CiDRA) Flowmeters

Kemess also uses the Gas Void Fraction capability of the sonar array-based meter as a tool to monitor increases of air in these lines. Increased air will cause pump inefficiencies and could lead to pump damage due to cavitations. Knowing the volume of entrained air provides a true volumetric flow rate and provides operators with another tool for process control. In the following figure the step increase of entrained air from approximately 6% to 8% coincides with the decrease in flow from ~2300 GPM to ~1900 GPM. This may indicate that the increased entrained air is impacting the operation of the pump and alert the operator to a condition that needs attention.

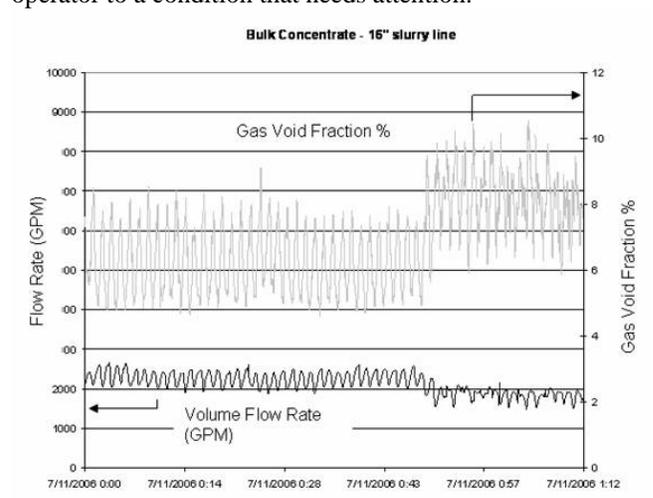


Figure 15 Flow and Entrained Air (Gas Void Fraction%) Measurements Show Impact of Air on Flow Rate

Entrained air levels vary from 8% to 0.1% in flotation feed lines as seen in Figure 16. The ability of sonar array-based technology to measure flows with large amounts of entrained air over varying conditions improves the accuracy and reliability of the flow measurement. Also, it is possible that the varying air content of the feed will affect the gas holdup within the flotation process itself.

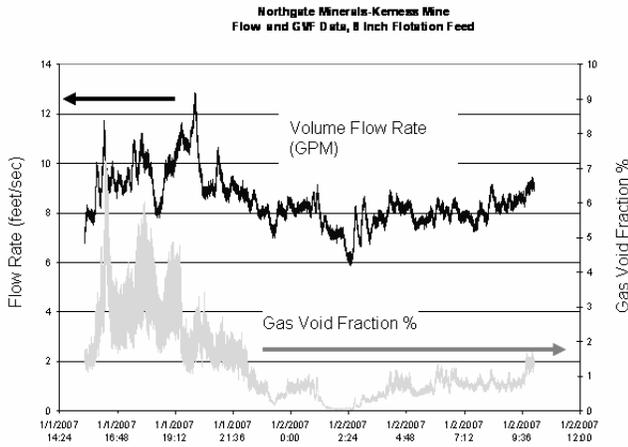


Figure 16 Flotation Feed Line and Varying Air Levels Measured by Sonar Array-Based Instrumentation

The sonar array-based meter is used as a control set point in the flotation expert control system and allows the operator to maximize throughput. Thus the sonar array based flowmeter provides the flow accuracy and slurry characteristics to improve the operation of the flotation system.

Case Study: Volume Flow and Entrained Air Measurement in High Air Content Flotation Overflow Lines at Newmont Facility

The flotation process, by its very nature, will always introduce large amounts of air into the overflow line. Thus it is very difficult for older generation flowmeters such as magmeters or ultrasonic meters to accurately measure the flow or even operate in these applications. Even when a sump or tank is used to collect the flotation overflow, thus allowing for some of the air to escape, the amount of air is still too high for older generation flowmeters. A secondary impact is that the amount of air can change quite dramatically with operating conditions thus making it difficult to determine the true slurry flow rate. A sonar array based flowmeter was used in this application to solve both problems. The meter not only robustly measured the volumetric flow, but it also measured the quantity of

entrained air (gas void fraction %). This is illustrated in Figure 17. Other cases in the same facility demonstrate its ability to measure volumetric flow at even higher gas void fraction percentages.

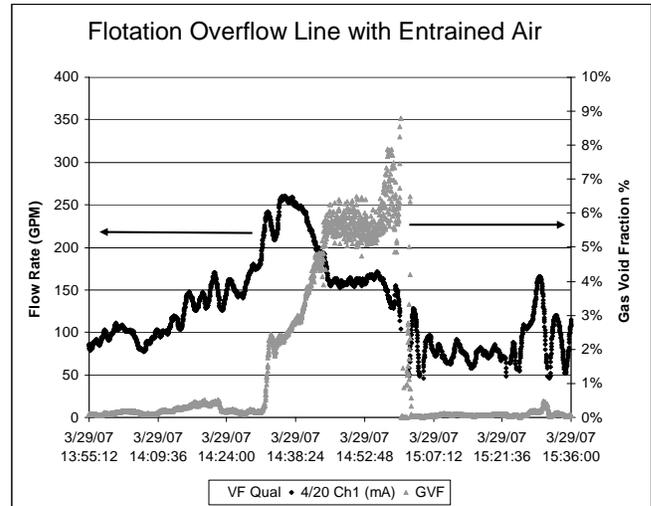


Figure 17 Problems Measuring Flow in the Presence of Entrained Air (Gas Void Fraction) in a Flotation Overflow Circuit is Solved

Additional Measurement

The sonar array technology has led to the development of a hardware platform that supports many other measurement capabilities. These include the acoustic monitoring of pipelines and equipment, as well as determination of the stratification of slurries and the onset of sanding. In another paper other measurement features such as entrained air and slurry/water separation capabilities are discussed.

Valve Movement Monitoring

During the course of measuring flow, the passive sonar-array based flowmeter developed by CiDRA detects the acoustic levels within the pipe. By monitoring these acoustic levels over selected frequencies, additional information about events occurring in a pipeline can be obtained. As an example, valve movement in a pressure reduction choke station corresponds with changes in the acoustic levels during the movement, as well as before and after the movement as the flow is diverted through a different pipe. The flow shown as the dark line in Figure 18 changes by about 8% due to a change in the valve

position which directs the flow through a different path in the choke station. The acoustic level changes by a factor of three to four (200% to 300%) during the valve movement and by a factor of three (200%) between valve positions. The combination of the flow measurement and acoustic level provides the necessary information to monitor the valve.

Therefore the meter provides not only the flow rate of the slurry, but it also provides verification that the valves have changed position. This is particularly important in situations requiring remote monitoring and verification of critical events.

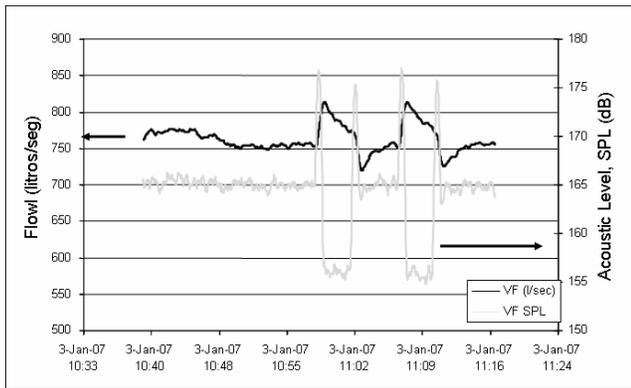


Figure 18 Flow Measurement and Acoustic Level Measurement for Valve Movement Monitoring at Choke Station

Velocity Profile and Sanding Detection

One key problem that continues for operators of hydrotransport pipelines is the possibility that solids material will settle to the bottom of the pipe and lead to a blockage in the pipe. Operators strive to avoid this “sanding out” condition by keeping flow rate above a certain empirically determined or calculated value. Unfortunately, incomplete models and changes in the slurry properties including viscosity, fines content, and particle size distribution changes result in large error bars with either approach.

A better solution is to actively monitor the flow profile in the pipe to see the reduction in flow velocity at the bottom of the pipe as the larger, denser particles settle and approach a very slow velocity as seen in Figure 19. Through a different instrument including a specially engineered sensor and multiple processing units, the flow at heights in the pipe can be measured.

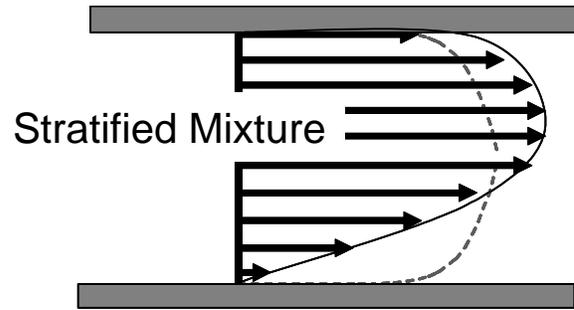


Figure 19 Illustration of Flow Profile Change that Occurs During Onset of "Sanding Out"

Results from testing this custom instrument are shown in Figure 20. Here the change in the flow profile due to the stratification of particles is evident in the lower velocities seen near the bottom of the pipe as the “sanding out” condition is approached.

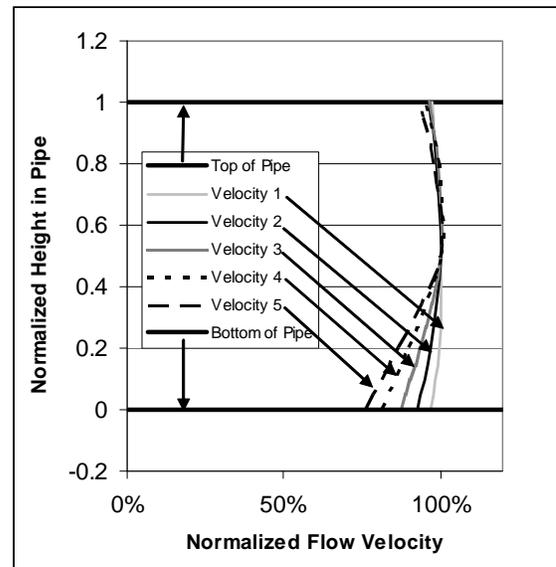


Figure 20 Velocity Profiles at Different Flow Rates. Note the Drop in Velocity at the Bottom of the Pipe at the Lower Flow Rates

By processing some characteristic features of the flow profile, an alarm condition can be generated. By extending this processing to examine not only the condition where a small level of “sanding out” has occurred but has now reached a higher level in the pipe (>25% of the pipe height) we can set a higher level in the alarm. This is illustrated in Figure 21

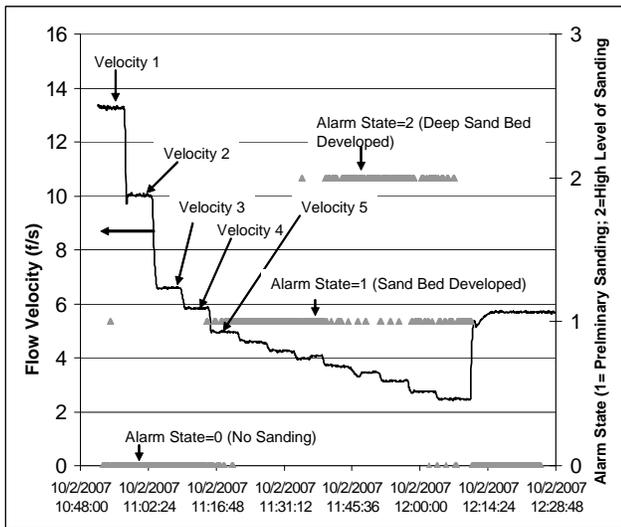


Figure 21 Flow Velocity and Alarm Condition for Low Levels of Sanding (Alarm Level=1) and High Levels of Sanding (Alarm Level=2)

and other support. For this paper, these include, but are not limited to Newmont Gold, Anglo American Chile, and Kemess Mine. The authors wish to acknowledge the work performed by mineral processing team members at CiDRA including Tim Griffin for analyzing data and performing the nuclear density gauge tests, Mark Fernald and Tim Bailey for performing the velocity profiling tests.

Summary

Sonar array-based flow and entrained air measurement instruments are a new class of industrial flow and compositional analyzers leveraging over 60 years of sonar development and utilization. Sonar array-based flow meters are installed worldwide in many industrial applications and are ideally suited for a wide range of minerals processing applications and provide new measurement insight and quantifiable value to operators. Besides performing flow measurements that can be achieved by older generation flowmeters, the sonar array-based technology can measure flow in situations in which these other flowmeters technologies fail. These include robust measurements in the presence of magnetic ore slurries, scale build-up, abrasive slurries, high pressures, and entrained air.

Sonar array-based, clamp-on *SONARtrac*[®] technology is a scalable platform that is more than just a flow technology. It has the ability and capability to provide several other value added measurements and information such as speed of sound, entrained air/gas, gas hold-up, and acoustic levels.

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