Uses and Benefits of Flow Measurement in the Operation of Tailings Thickeners

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ABSTRACT

The control of process variables is critical for the effective operation of minerals processing plants. In the thickener operation there are three important process control variables for effective performance and are responsible for measuring the flow rate in three thickener applications: the feed, the underflow discharge, and in the clear water outlet in the overflow.

These applications have distinct challenges that can potentially affect the ability to measure flow accurately, such as: pipe size, flow density, pump type, entrained air, and pipe access. Considering this, appropriate instrument selection and implementation are crucial factors to obtain a reliable measurement that can be incorporated in the plant's control system. This technical paper will review the operation of thickeners commonly used in mining and will focus on describing the challenges and solutions for flow measurement with a passive sonar technology meter in the three critical applications.

INTRODUCTION

The thickener process is one of the staple elements of a large-scale minerals processing operation. Thickeners are used to increase the percentage of particle solids in the tailings to maximize water recovery for reuse. The need to efficiently recover water in minerals processing is a priority because copious quantities of water are used for other steps of the process, such as comminution and classification, and at the same time operations must strive to minimize their social and environmental impact in the communities where they operate.

The addition of synthetic flocculants has been key to accelerating the sedimentation process in slurries, which results in a more efficient thickener operation. Moreover, the advances in thickener technology and flocculants have allowed to get clearer water on the overflow and denser tailings in the underflow. These advances include the use of instruments of various kinds, which provide valuable variables so that the operator can make control and emergency changes to the process. As a result, the use of instrumentation, such as flow metering technology, has become a necessity for a modern and efficient operation.

SONARtrac® TECHNOLOGY – OPERATION PRINCIPLES

In the same way that a submarine draws a cable with sensors in the sea to measure the fields of pressure and length of frequencies to determine the distance, speed, and physical characteristics of its target through signal processing techniques, the passive sonar technology from the *SONARtrac*® utilizes this same process for flow measurement and entrained air.

The processing of flow measurement by means of passive sonar employs two different techniques for measurement. The first technique measures the volumetric flow through a monitoring of "eddies" in the process flow. Passive sonar flow technology provides a direct measurement of average mass velocity, as do other velocity-based flow meters.

By knowing the inner diameter of the pipe, volumetric flow is calculated. The second technique measures the speed at which sound travels through the liquid to deliver information about the composition. The measurement of the sound velocity is also carried out in real time, a direct measurement of where the air entrained by volume is derived. The volumetric flow as well as the entrained air can be delivered as individual outputs to the DCS. The measurement of entrained air is especially synergistic with the volumetric flow in that the measurement of the sound velocity can be used to determine the volumetric fraction of the double component mixture, where the total volume of the flow can be adjusted to a measurement of "real flow" of the slurry or liquid as shown in Figure 1.

Industrial processes around the world have realized the added value delivered by real-time air measurement to optimize processes and increase efficiency. The passive measurement of entrained air is used in several industries to correct the measurement of density calculation from a nuclear density meter when entrained air is present, which enables a correct calculation of mass balance. Depending on the specific gravity of the process material, even the smallest presence of entrained air in a liquid or slurry can cause large errors in density measurement, as seen in Figure 2. As mentioned earlier, process engineers, metallurgists, and operations professionals struggle daily with a range of variables that convert predictability and control into an extremely challenging process, to say the least. With the use of passive sonar flow technology, two of these variables, flow and entrained air, can already be used with confidence when one is calculating mass balance in daily monitoring and process control.

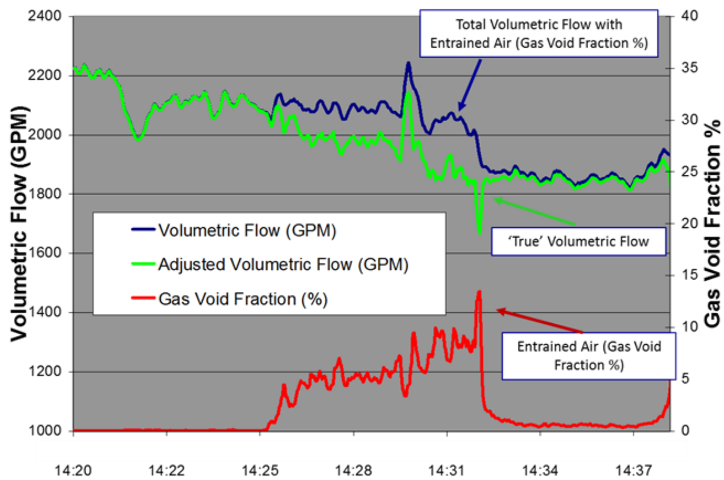

Figure 1: Gas void fraction and adjusted volumetric flow

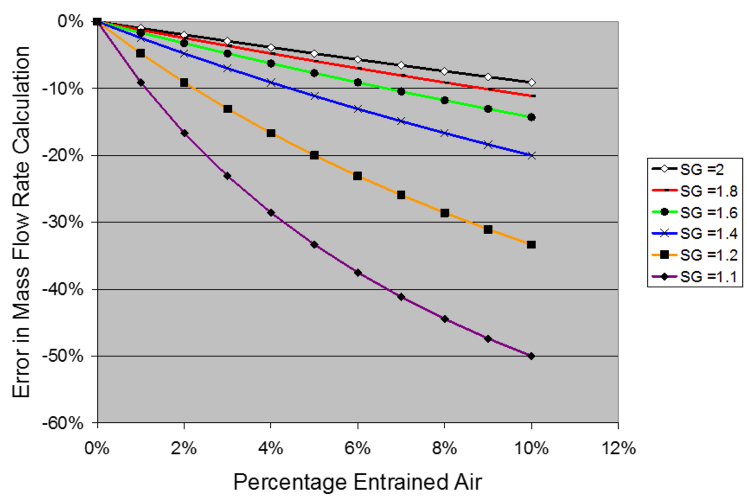

Figure 2: Entrained air measurement used to correct density measurement errors

Thickener operations

Thickener operations work to recover clear water and to generate thickened tailings. In the thickener, the solids separate from the water by means of decantation, and they descend to the bottom of the tank. Consequently, the water becomes clearer at the top of the tank, creating separation layers all the way to the bottom. Flocculants and coagulants are used to increase the decantation rate of the solids and accelerate the clear water recovery.

The objective of the thickener process is to work continuously, which can only be achieved by using variables and implementing process control strategies. When controlling a thickener operation, dependent variables are used to control independent variables, for example using density to control the flow rate in the underflow [1]. In Figure 3, a common thickener configuration is depicted next to dependent variables such as underflow density, bed pressure, rake torque, solids settling rate, and independent variables such as flocculant rate, underflow flow-rate, and feed rate.

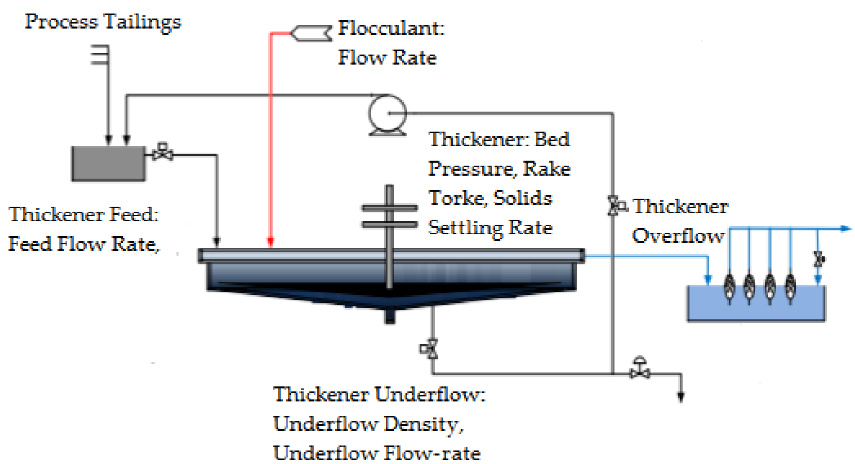

Figure 3 Common thickener configuration with independent and dependent variables

Thickener feed

Thickeners are commonly fed from a distribution tank. The line that feeds the thickener often has a slight incline and the flow is driven by gravity. Therefore, it is possible that the feed line is partially full. Proper process control involves using the feed flow rate along with a feed density measurement. These two measurements are used to calculate the mass flow rate to the thickener, which is crucial to optimize flocculant utilization. Additionally, the mass flow rate of the feed can be used in advanced control strategies for monitoring the dosage of flocculants and coagulants used.

Operators attempt to measure the feed flow rate with level sensors in sections where the pipe is partially full. Using this methodology, the level of the liquid is taken to be a linear or non-linear measure of the rate of flow. Alternatively, a passive sonar technology flow meter can be installed in a full pipe section to get an accurate and reliable measurement. Sonar meters are non-invasive, light, and easy to install, making them viable to install in this application, where the pipe is often elevated and has a large diameter.

Application description

To determine the section in which the pipe is full, distance L must be calculated. This will provide the distance between the tank outlet and when the flow goes from full to partially full. In Figure 4, the variables are schematized in a common thickener feed configuration. In this example both vent pipes and the tank are open to the atmosphere.

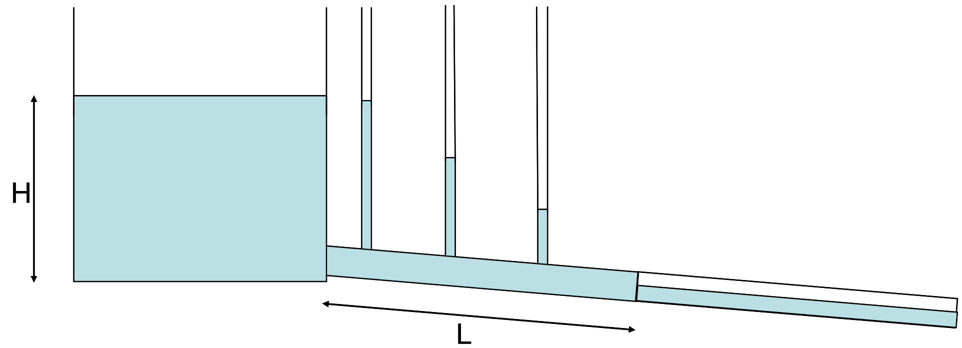

Figure 4 Thickener Feed Line

This schematic can be expressed mathematically by solving for L [2], in which the result is a balance equation. θ represents the top angle pipe shown in Figure 5:

$$\pi^2\left(\frac{H}{L}+\sin\alpha\right)=\frac{\sin\alpha}{4}\frac{(\theta-\sin\theta)^3}{\theta}$$

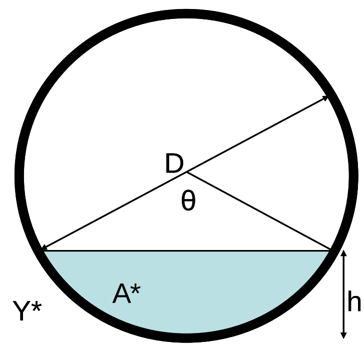

Figure 5: Variables in Partially Full Pipe

The algebraic expression establishes the proportionality and a linear relationship between H and L. This equation provides a straightforward way to solve for L without needing possibly unknown variables such as volumetric flow, friction factor, and density. For the top angle θ, the value is assumed to be the "worst case", that is, the maximum top angle θ value that causes distance L to be the smallest possible, which would give least space to install the flow meter.

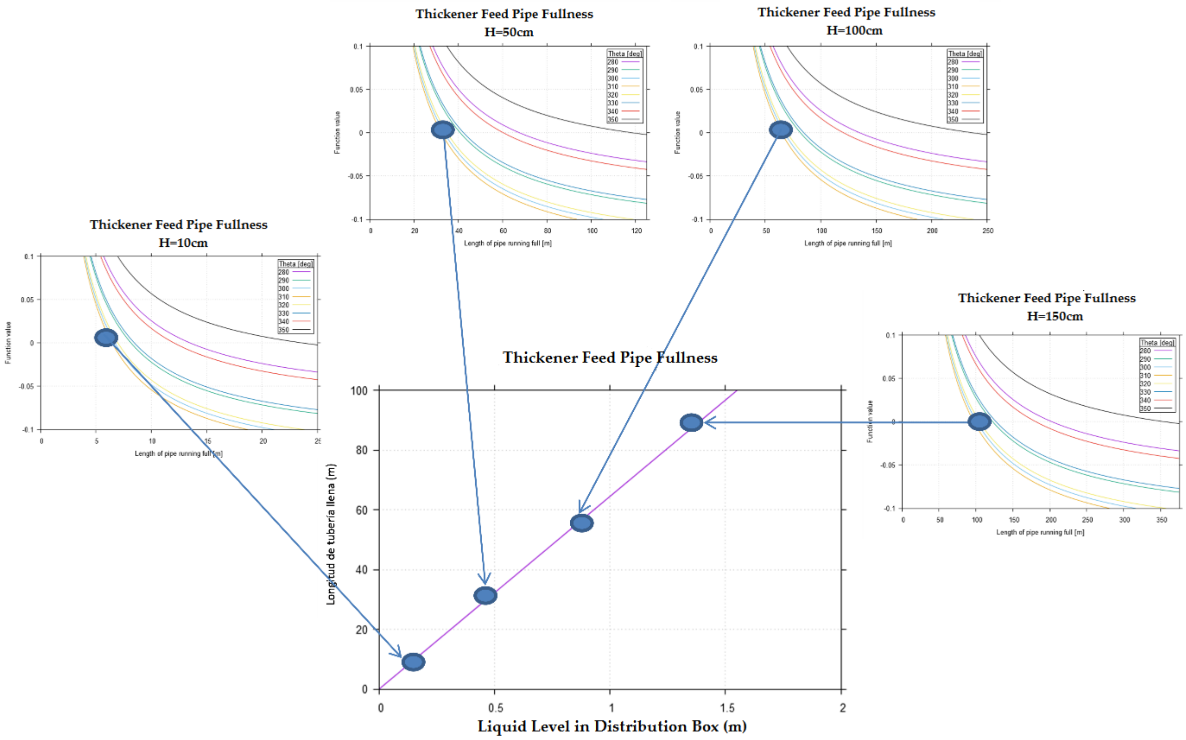

Figure 6: Solutions of the Hydraulic Balance Equation

After establishing the "worst case scenario" the distance L is calculated with different fill levels in the feed box (considering the top of the feed as the zero point) represented by variable H. In the center panel plot it is shown that when H is between 10-150 cm there is a range in distance L from 10-90 meters. The results indicate that even when assuming low pressure (lowest possible H value) and the "worst case scenario" for the top angle θ, there is more than enough full pipe length for a passive sonar flow meter to be installed.

Field experience

The theory expressed above was applied in a mine in central Chile where three 30-inch flow meters were installed in the thickener feed application. These three lines come from the same distribution box and each one was instrumented with a sonar meter. This field experience demonstrated that the pipe is full, since the clamp-on meter only works in full pipe conditions, where the pressure fields are propagated by the flow across full area of the pipe. Also, the field experience confirmed that the used fluid height in the tank provided a full pipe section that was long enough to install the flow meter, even with relatively low tank levels. The real time flow measurement allowed the operator to create a control strategy for the addition of flocculants and coagulants in the thickener, resulting in a more efficient process.

Entrained air measurement

Entrained air is part of the flow process, intentionally or not, depending on the application. The presence of air affects the accuracy of volumetric flow measurement in most flow meters, causing deviations, measurement spikes, and even total loss of reading at times. The array of sensors is capable of not only measuring the flow with elevated levels of entrained air but also measure the entrained air percentage or gas void fraction (GVF), which in some applications can help control the process.

A mine site in northwestern Canada implemented the use of GVF measurement with a passive sonar meter to increase efficiency and avoid cavitation in the pumps. The entrained air measurement along with the volumetric flow measurement provided the operator with two powerful control tools from just one instrument. In this case, the entrained air percentage increases 6% to 8% which coincides with the volumetric flow lowering from ~2300 GPM to ~1900 GPM. In this site, this change in GVF and volumetric flow alerts the operator that the condition needs to be taken care of. The tendency discussed is shown in Figure 7.

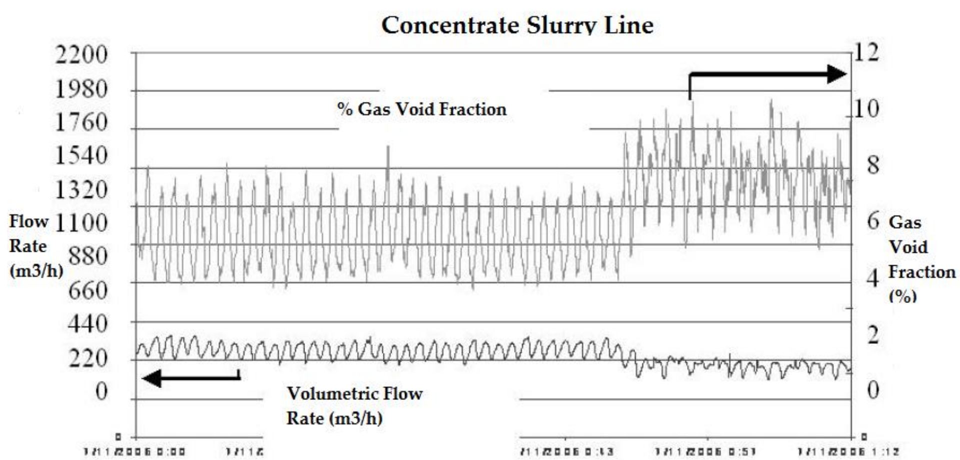

Figure 7 Relationship between Gas Void Fraction and Volumetric Flow Rate

For the thickener feed application, the entrained air measurement helps the operator to get an accurate feed flow measurement as well as feed mass flow. These measurements are used to optimize flocculant dosage.

Thickener underflow

Solids will settle towards the center of the thickener and flow out of the tank. The thickened tailings will be pumped out with centrifugal pump, a positive displacement or driven by gravity. The thickened fluid is abrasive and has a high solids percentage, which makes it hard to measure by conventional meters. The flow abrasiveness increases the wear for intrusive meters, which also increases maintenance needs. The high solids percentage can prevent other non-intrusive meters from getting a measurement (ex: ultrasonic meters), because the high fluid density blocks the signal [5].

Use and relevance of thickener underflow flow measurement

The underflow flow rate measurement is useful for the operator when it is combined with a density measurement, given that the underflow mass flow can be calculated. A mass balance allows the operator to control the flocculant addition. Flocculant dosage control became more important with the implementation of modern high rate thickeners, which achieve higher settling rates and work with higher density fluids.

The volumetric flow measurement can be used in control strategies to optimize the operation by using variables such as bed level, bed pressure, polymer addition, and underflow density. Controlling with multiple variables allows for the development of advanced control systems that deal with matters in a preventive manner, rather than responding to the higher priority event when it develops [1]. Figure 8 illustrates a five-variable control strategy that exemplifies this concept:

Underflow Density	*Bed Level*	*Bed Pressure*	*Polymer Addition*	*Underflow Rate*
above target	above target	Rising	increase	increase
above target	above target	Steady	increase	increase slightly
above target	above target	Falling	no action	increase slightly
above target	on target	Rising	no action	increase
above target	on target	Steady	no action	increase slightly
above target	on target	Falling	no action	no action
above target	below target	Rising	decrease	increase
above target	below target	Steady	decrease	increase slightly
above target	below target	Falling	decrease slightly	no action
on target	above target	Rising	increase	increase
on target	above target	Steady	increase slightly	no action
on target	above target	Falling	increase slightly	no action
on target	on target	Rising	no action	no action
on target	on target	Steady	decrease slightly	no action
on target	on target	Falling	decrease slightly	decrease slightly
on target	below target	Rising	decrease	increase
on target	below target	Steady	decrease	no action
on target	below target	Falling	decrease slightly	no action
below target	above target	Rising	increase	no action
below target	above target	Steady	increase	decrease
below target	above target	Falling	decrease slightly	decrease
below target	on target	Rising	no action	no action
below target	on target	Steady	no action	decrease
below target	on target	Falling	decrease slightly	decrease
below target	below target	Rising	no action	decrease slightly
below target	below target	Steady	decrease slightly	decrease
below target	below target	Falling	decrease	decrease

Figure 8 Example of Thickener Control Strategy

Proven solution in mine site

For thickener controls to be carried out, it is crucial to have an instrument that maintains high availability. Passive sonar meters have no moving parts, are non-intrusive, and do not need coupling gel, making it practically maintenance free and increasing the meter availability. In a comparative study of various non-invasive and semi-invasive flow meters for mining applications, it was determined that passive sonar meters are ideal for abrasive and high-density applications because of the non-invasive and limited maintenance features [5]. In a field experience at a mine located in northern Chile, data was collected where the sonar meter measured flow transitioning from water to high density slurry. The flow velocity started at 2 m/s, was lowered to 1.2 m/s until the velocity was low enough that the pipe plugged at 0.5 m/s. After the pipe was plugged water was pumped to clear the pipe. The flow measurement was observed against a tank draw-down test to verify the instrument's accuracy. The data from the test is shown in Figure 9.

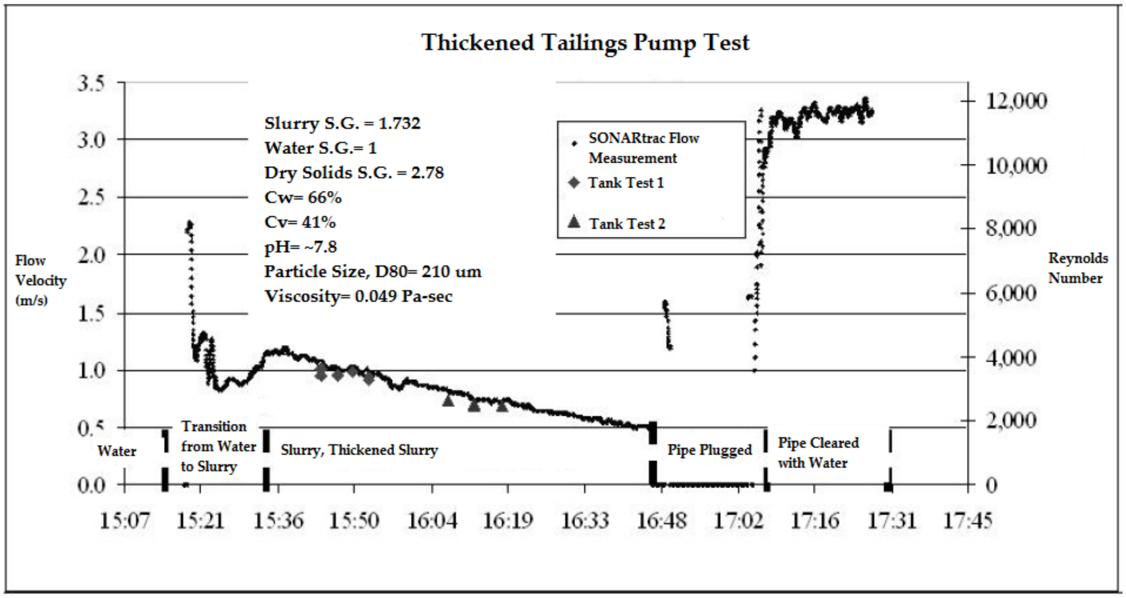

Figure 9 Thickened Tailings Flow Measurement

This experience validated the instrument's measurement accuracy, given that the measurement and the tank draw-down test followed the same pattern at various flow velocities.

Overflow water outlet

The recovered water exits the tank through a collection channel on the peripheral area of the thickener tank. The clear water is usually pumped to distribution tank or directly fed back to the process.

Figure 10 Clear Water Exit Channel

Steps in the minerals recovery process, such as grinding, classification, and flotation demand high water usage. High water usage and the increasingly remote location of mine sites make the water recovery a key factor for the operation. As a result, the operators want to accurately measure how much water is being recovered and sent back to the process.

Volumetric flow measurement and field experience

To select the appropriate flow meter for this application one must consider the two main challenges: the large fluid volumes and pipe diameters. Given that thickeners used in minerals processing plants can be measure up to 125 meters in diameter, the volume of recovered water is high. In large plants it is common to see multiple large tailings thickeners feeding a recovered water tank that pumps water back to the process. Large pipe diameters that go up to 54 inches are used to transport these high-water volumes. Therefore, in addition to considering meter accuracy for instrument selection, the operator must also consider the instrument's weight and ease of installation. Passive sonar meters feature an easy installation that does not require pipe drilling and have a light weight design.

Passive sonar flow meters have been installed in multiple mine sites that have large diameter water lines, such as a field experience where a meter was installed on a 48-inch pipe in a mine located in southern Peru. At the time of the installation, this became the largest flow meter installed in Peru. This installation became a staple on the site, as due to the local geography water is a scarce resource that must be used effectively. The 48-inch sonar meter is installed in a line that is fed from four tailings thickeners and the flow is driven with up to six pumps depending on the water usage. The recovered water is then sent to the process plant to be used in the grinding and flotation processes. For the installation there was no pipe drilling and the process was not stopped, as would have been necessary with other types of flow meters, allowing this to be the first flow instrument to ever be installed in this application at this site.

CONCLUSIONS

1. Measuring volumetric flow rate allows the operator to control other process variables and to monitor the thickener performance. A gas void fraction (GVF) measurement can also add value to the operator for certain applications.
2. Each application has various parameters that will guide the selection of the right instrument. For flow meter instrumentation, parameters such as fluid density, pipe fullness, min/max flow rate, pipe size, pipe accessibility, and maintenance needs steer the decision-making process towards the best fit meter.
3. Multiple parameters are present in the three flow meter thickener applications commonly instrumented. Considering the passive sonar meter features, these have a good fit based on the theory and field experiences.

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