Liquid Analysis for Metals Extraction and Processing

Visualize > Analyze > Optimize
Visualize the benefits of optimizing yields and minimizing expenses for metal extraction processing.

Analyze with Emerson’s exclusive PlantWeb® concept using a scalable control system with independent devices and final control elements that link these various steps together to optimize production parameters for a complete mining operation.

Optimize production parameters with Rosemount Analytical instruments and PlantWeb by monitoring conditions in liquid solutions containing metals and other chemicals, enabling feedback control of important liquid parameters such as pH, electrical conductivity and ORP. These products can also be used in standalone mode to control individual processes as needed. Processes will vary depending on the metal involved, the grade of ore, and the technology employed. This brochure shows examples of how Rosemount Analytical liquid analytical products are used throughout extraction and processing.
Rich ores are ground down to about 80% -200 mesh and mixed with a 0.1% cyanide solution and enough lime to keep the pH between 11 and 12. An agitated leach is faster and more efficient than a heap because the smaller particles have more surface area. The leaching process is conducted in leach tanks that have a total residence time of about 24 hours. The gold cyanide in the pregnant solution is typically adsorbed on granular activated carbon inside the carbon in pulp (CIP) tanks. The coarse laden carbon particles are screened out of the last tank, washed with caustic to remove the gold cyanide, and the gold metal is produced using electrowinning.

Due to the rapid reactions taking place in an agitated leach process, automatic pH control is strongly recommended. See Application Data Sheet #3300-08 for more information on cyanide leaching.

When the pregnant liquor contains large amounts of silver, zinc metal is added to liberate the gold metal instead of carbon adsorption.

**pH for Safety and Efficiency**

pH values below 11 favor the formation of hydrogen cyanide that interferes with the leaching process and is a colorless, poisonous gas that can quickly become deadly. Gas leaks into the environment are a risk to the mine personnel and a future liability to the mining corporation that can be avoided with continuous pH control.

Gas leaks are a risk to the mine personnel and a future liability to the mining corporation. Continuous monitoring is necessary to prevent these leaks from occurring.

**Jet Spray Cleaning Attachment**

Jet spray cleaners are essential for cleaning pH sensors used in leaching processes, as the fine particles of ore can coat the sensor over time.

**PERpH-X High Performance pH Sensor**

The PERpH-X is designed to withstand abrasive conditions and is resistant to coating. It includes a refillable reference electrolyte and a replaceable reference junction for long life.

**Model 1056 Dual Measurement Analyzer**

The Model 1056 analyzer can monitor pH and process variables simultaneously, providing a comprehensive view of the leaching process. It includes features such as two 4-20 mA outputs, three process alarm relays, and pH sensor diagnostics.

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In the flotation process, crushed sulfide ore (containing 1 to 2% copper), along with water and lime slurry for pH control, is fed into a ball mill. A rotating drum with steel balls crushes the ore to a fine powder. When the ore/lime slurry emerges from the mill, it is fed to a rake classifier. Particles that are too large to pass from the classifier are returned to the mill, while the overflow is discharged to flotation cells. The ground ore is mixed with a collector chemical such as potassium amyl xanthate which reacts with the copper sulfide to make it hydrophobic. Air is injected into the flotation cells, and foaming agents are added, creating a froth. The hydrophobic copper sulfide particles latch onto the air bubbles and ride them to the surface, forming a froth that is skimmed off. When the pH is high enough, the collector chemical bonds to the copper ore chalcopyrite (CuFeS₂) and not the iron ore pyrite (FeS₂), enabling the concentrating step. The copper-rich froth, containing 20 to 40% copper, is separated from the solution and dried to form copper concentrate, which can be sold as a commodity product or further processed. Copper concentrate may be treated by either hydrometallurgical methods or sintered before pyrometallurgical methods are used to produce copper metal.

The efficiency of this concentrating step is directly dependent on pH. The flow rate of lime slurry is therefore regulated to keep the pH within the acceptable range. If pH is too low, iron will be entrapped with the copper, decreasing the value of the copper concentrate. If too much lime is added, the result is a dilute froth that requires additional concentration in later stages, increasing operating costs and wasting lime.

Reliable pH measurement in this location can be difficult because of the fine powder particles coating the pH sensor. High area reference designs like the TUPh sensor model 396P have performed well in this environment. The Model 5081pH transmitter can be field mounted near the flotation cells and performs continuous diagnostics to determine if the pH sensor requires cleaning or is not immersed in liquid.
CONCENTRATION AND SEPARATION

Phase difference

A powerful technique for increasing the concentration of a product metal is to use a phase difference (such as solid to liquid) to separate the product from the base metals. Alumina is refined from raw bauxite in precisely this way. In this process, Emerson’s flow-through toroidal conductivity sensor is used to monitor the digestion step, while the large bore submersion sensor is used to optimize chemical recovery from the tailings.

Alumina Refining

Raw bauxite (mostly Al₂O₃·H₂O) ore contains iron oxide and silica that are removed by treatment with caustic in a digester. This dissolves the alumina and allows separation and purification in later steps.

The caustic feed rate is controlled to optimize extraction of the alumina. Feedback control is achieved using electrical conductivity which tends to drop as caustic reacts with the bauxite ore. If insufficient caustic is present, the conductivity transmitter will read low and the caustic feed can be increased.

Impurities remain solid in the form of ‘red mud’ that tend to scale the process equipment, requiring frequent cleaning. Emerson’s model 242 flow through toroidal conductivity sensor has been specifically designed for this rugged application by locating the sensor’s detection circuit outside of the process where it is not subject to the abrasive scouring of the alumina slurry. The Model 242 conductivity sensor uses externally-mounted toroids to measure conductivity in a lined pipe. The lining is available in teflon, PEEK, or alumina – which is especially recommended for this abrasive application. Sensors for line sizes from 1” (25mm) to 4” (100mm) are available.

Following the digester, the product slurry is cooled in heat exchangers and then separated, usually by gravity into a coffee colored liquid and the red mud. The level of red mud is determined using Emerson’s Model 226 large bore toroidal conductivity sensor that can be lowered into the separator until the conductivity set-point is reached. The red mud is washed free of caustic and then disposed as tailings. The product liquor is filtered and turned into alumina product through precipitation and drying.

Electrical conductivity is an additive and non-specific property. All acids, bases, and salts will contribute to the total value. In applications where mixtures are present, such as this one, detailed information on the process is needed to provide quantitative information.

Conductivity can be used to control digestion because the process consumes caustic and produces hydrated alumina that has much lower conductivity. Establishing a certain minimum operating conductivity (typically in the 300-500 mS/cm range) insures that enough caustic has been added to dissolve the bulk of the alumina. Conductivity measurement of wash water is used to prevent loss of caustic and minimize waste volume.
**Sulfate Process**

In the sulfate process, ilmenite (FeTiO$_3$) is soaked in sulfuric acid to dissolve the titanium as titanium sulfate and bind the iron as solid ferrous sulfate for removal by settling. The titanium sulfate reacts with caustic and water in a hydrolysis tank at high temperature to produce a hydrated form of titanium dioxide. This precipitate is filtered and washed to remove traces of iron impurities. Other metal ions such as potassium, phosphorus, or aluminum may be added to control particle size and durability. The hydrate paste then undergoes a high temperature calcination stage that yields the solid white product.

The properties of the product titanium dioxide pigment are strongly affected by the conditions present during the hydrolysis and calcination stages.

Temperature, pH, deposition rate, ore quality, and additives all play a factor in determining the crystal structure. Specifically, the pH in the hydrolysis step influences the reactivity of the TiO$_2$ and the ease of removing the impurities. However, the finely dispersed ore particles tend to badly coat standard pH sensors, first causing sluggishness and eventual total failure. This problem is compounded if the process is allowed to dry on the pH sensor. The PERpH-X model 3300HT is rated for operations up to 145°C and designed for a long lifetime in difficult applications like this one. The replaceable reference junction allows rapid troubleshooting and maintenance when the sensor is responding slowly due to coating.

In addition, the PASVE Mounting and Service valve can be used to enable automatic flushing and cleaning of the sensor as need be. The PASVE removes the sensor from the process line by rotating the sensor into a cleaning position and has many mounting options. For additional information on the PASVE valve see the PDS-71-PASVE.
Steel Treatment

Stainless steel is an alloy of various different formulations that is widely used in industry. Each different formulation has different specifications for the final product but despite the best production methods some off-spec product may result. Frequently, impurities can be removed with a short soak in acid, a common finishing technique for steel rolls. Control of the acid concentration is crucial in removing just the right amount of surface contamination. The process is frequently called steel pickling, and is one of the largest bulk consumers of hydrochloric acid worldwide.

Steel is produced in long thin rolls for convenient transportation to end users. Contaminants from production processes and storage oxidation are heavily concentrated on the surface of the rolls and can therefore be removed by surface active chemical processes. A short dip in hydrochloric or sulfuric acid is beneficial in removing contamination, but a long dip or a highly concentrated acid can remove too much product, lowering yield. The temperature of the bath is around 180°F (82°C) to increase the speed of the pickling process. The concentration of HCL acid can be monitored using Emerson’s rugged Model 228 toroidal conductivity sensor and any of Emerson’s analyzers listed on page 10. Toroidal conductivity sensors are virtually immune to surface coating effects and are the sensors of choice for liquids with suspended solids. The model 228 sensor is injection molded of polyetheretherketone (PEEK), an extremely robust engineering thermoplastic.

The process typically will have several acid baths of varying percent concentration and at least two rinse baths. Care must be taken to remove all traces of acid from the steel or long term exposure will cause extensive damage to the metal roll. Conductivity measurement is a versatile tool for monitoring concentrated acids since many solutions have been measured and documented for conductivity levels at various temperatures. Over time, buildup of iron and other metals in the acid baths will change the conductivity behavior of the solution somewhat, so it is sometimes advisable to monitor the conductivity directly and not rely on published data.

STEEL TREATING PROCESS
Waste products from mining and refining operations can be in the form of liquid, gas, and solids. Liquid analytical products are involved in all of these operations. They help minimize disposal costs involved with chemicals adhering to tailings, toxic cyanide, noxious gases, and acid mine runoff. Emerson’s analytical sensors respond quickly to changes in pH and ORP, protecting both the environment and the mine from the dangerous effects of these chemicals.

**Oxidation**

Cyanide, commonly used in precious metals extraction, is a toxic chemical with discharge limits typically around 0.5 ppm, depending on the governing regulatory body. Since mining solutions can contain thousands of times that concentration, the best policy is to totally destroy the cyanide before discharging any liquid waste. A common method for destruction is to add an oxidant, typically chlorine, to the waste stream until the cyanide is gone. pH and ORP measurements are used to control the destruction process and verify completion. ORP stands for Oxidation Reduction Potential and indicates whether the solution is under oxidizing (high ORP) or reducing (low ORP) conditions. Since cyanide can only be present under reducing conditions, adding an oxidant both destroys the cyanide and raises the ORP. The cyanide compound is converted to cyanate and then to harmless nitrogen and carbon dioxide. pH measurement protects against discharge of cyanide gas during the multi-stage process and improves the accuracy of the ORP reading by removing interference from other chemicals.

Emerson’s PERpH-X model 3500 pH and ORP sensors are ideal for monitoring this chemical reaction because they respond quickly to changes in ORP and can be recharged with reference gel when needed. Diagnostics notify the operator immediately when the reference junction is becoming coated or if the process is attacking the reference electrolyte.

Tailings, depleted ore remains, are typically a major discharge hazard and large piles can usually be found...
near any operating mine. These solids typically contain various sorts of heavy metal compounds in ore form and will have traces of acid or caustic used in the mining process. Rinsing the tailings to reclaim these chemicals and regenerating or reusing them renders the tailings less hazardous. Monitoring the rinse water for electrical conductivity is a low-cost method of reclaiming the chemicals without wasting water. The recommended sensor is the model 228 toroidal conductivity sensor which monitors water conductivity levels down to below 250 µS/cm.

**Scrubbers**

Scrubbers are used to remove harmful and odorous gases that are collected from various locations throughout the facility. These gases are typically acidic and are therefore removed by contact with a caustic liquid stream. Monitoring the reused scrubber solution for pH ensures that the gases are trapped in the liquid phase for subsequent treatment. Conductivity measurement monitors the buildup of dissolved solids in the scrubbing liquid so that some of the liquid can be removed before the nozzles are scaled up. Emerson’s PERpH-X pH sensors and 228 toroidal conductivity sensors are designed to conduct these measurements with a minimum of maintenance. All the Emerson instruments on page 10 are compatible with these sensors, but the field-mounted 5081 model is most popular in this application.
<table>
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<th>6081 Series</th>
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PLANTWEB® BRINGS IT ALL TOGETHER

Increase Accuracy and Throughput, Reduce Costs – PlantWeb Makes the Difference

Rosemount Analytical field devices are core components of the PlantWeb digital plant architecture, and capture rich diagnostic data about the health of the device, as well as the process itself. Device functionality is presented at the user interface in ways that are consistent, intuitive, and easy to use.

PlantWeb architecture consists of intelligent field devices, scalable platforms and integrated modular software, all working together. The result is optimal plant performance by getting the right information to the right user, in time to make a difference. The advanced diagnostics in Rosemount Analytical sensors alert users to device or process problems, before they happen. Control in the field can provide more reliable process control.

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Emerson Process Management is part of Emerson, a global company that brings together technology and engineering to provide innovative solutions for our customers in a wide range of industrial, commercial and consumer markets. Our priority is to design, produce and deliver products, systems and solutions that make people's lives better.

Rosemount Analytical SMART Technology – The smart solution for pH measurement

SMART pH measurement loops which include SMART pH sensors and SMART-enabled instruments have the advantage of not requiring calibration of pH sensors in the field. All SMART sensors automatically download critical calibration data and performance parameters to the instrument upon calibration in the lab. Simply reconnect the pre-calibrated sensor to a SMART-enabled field instrument and the pH loop is automatically calibrated.

Sensor data transferred to analyzer

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