

### Mining: Gold Processing

While there are many different processes to remove gold from its encapsulating ore, cyanide leaching (cyanidation) is perhaps the most common and well known. A cyanide solution (NaCN or KCN) is elevated to a high pH level (>10.5pH) so that free cyanide (CN<sup>-</sup>) will dissolve the gold in the ore. The chemical reaction is as follows:



In this paper we will look at the various mining processes and the role that pH control plays in the gold extraction process.

#### Gold Processing

Gold ore comes in a wide variety of formations. The type of ore will influence the grinding and milling steps along with the extraction strategy. It is a common belief that gold is only found in veins in the rock. This type of formation accounts for only 20-25% of the world's production. More common is microscopic gold particles mixed with silver and metal sulfides of lead, copper, and zinc. The latter formations are referred to as "refractory" ores and must have pretreatment with roasting or oxidation done prior to cyanide leaching. *These processes also have pH measurements but will be reviewed in a separate paper.*

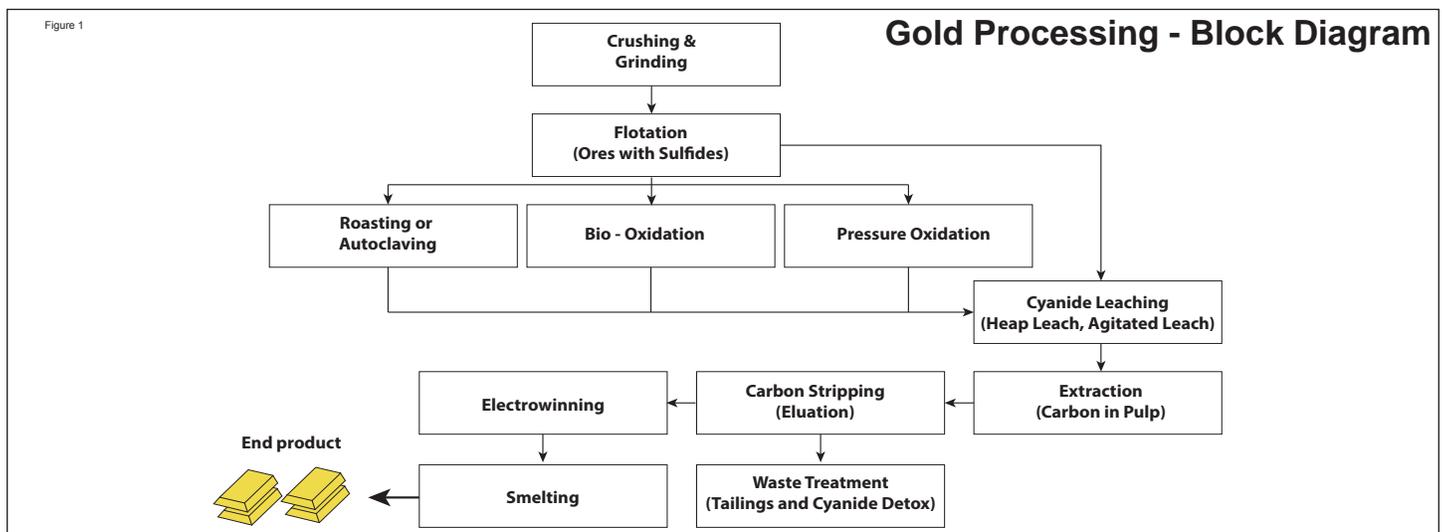
Low grade ore is often processed using a heap leach process. Heap leaching involves crushing the ore to <3/4" (<19mm) diameter chunks and piling on a puncture-proof liner. The liquid cyanide solution is poured over the heap and allowed to percolate down through the ore. The gold containing solution (pregnant leach) is collected from the liner into a leach pond and sent off to carbon adsorption. The leaching process will take from 60-90 days.

High grade ore is typically reserved for agitated leaching. finely ground ore (< 200 mesh) is combined with the cyanide solution in a series of tanks. This slurry is referred to as "pulp". Agitators and air / oxygen are added at each tank. The oxygen reacts with the sodium cyanide to create the desired aurocyanide gold complex. Typically lime (CaO) or sodium hydroxide (NaOH) is added during this stage to keep >10.5pH so that toxic hydrogen cyanide (HCN) is not produced.

Cyanide leaching is typically followed by an extraction step to remove the solubilized gold from solution. Carbon adsorption is often used to isolate the aurocyanide complex. This is typically referred to as CIP (Carbon In Pulp). Sometimes the leaching and carbon adsorption steps are combined. This is referred to as CIL (Carbon In Leach). The pulp from the leach circuit is cascaded through 4-6 tanks via gravity flow. Activated carbon is added at the opposite end and is pumped upstream through the tanks. Tank-to-tank screening separates the increasingly loaded carbon from the pulp in solution. The final loaded carbon is sent to a stripping process.

"Elution" or desorption of the gold complex from the carbon is the next step. This is accomplished by moving the loaded carbon through a stripping vessel at elevated pH and high temperature (95°C or higher if pressurized). The pregnant solution is pumped to electrowinning cells while the regenerated carbon is reused in the carbon adsorption process.

Electrowinning involves passing a current through the solution to break the chemical bond between the gold and cyanide. pH at this point in the process is critical to



# Application Note

## Cyanide Leach Process - pH

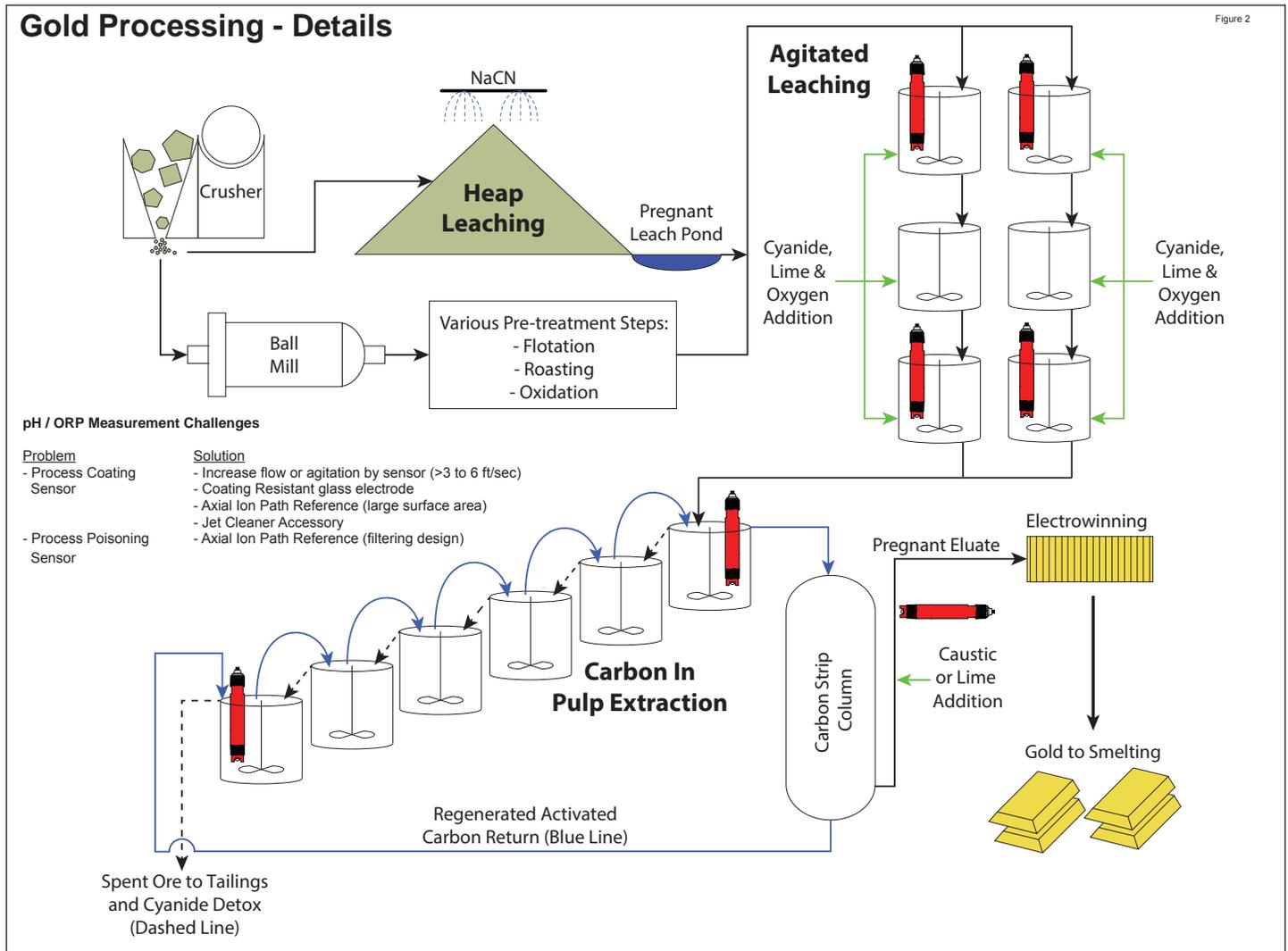
prevent corrosion of the anodes and limit the creation of hydrogen gas. Caustic (NaOH) is used to elevate the level to >12.5pH. The final barren cyanide eluate solution is pumped back to the leach circuit. Gold collected on the electrowinning cathodes is melted off in the smelter for final processing.

### pH Measurement Challenges

Gold processing operations are highly dependent on online pH measurements for process control as well as safety requirements. All processes involving cyanide must be kept >10.5pH (typically 11-12pH) to avoid the conversion to dangerous HCN gas. Lime (CaO) and caustic (NaOH) are most commonly used to keep the pH elevated. Lime is added to water to create "milk of lime". In these applications the excess calcium compounds from the milk of lime are well known to coat pH sensors. Beyond chemical addition, fine ground ore and carbon particulates can also coat as well as plug up the porous reference junction used in most pH sensors.

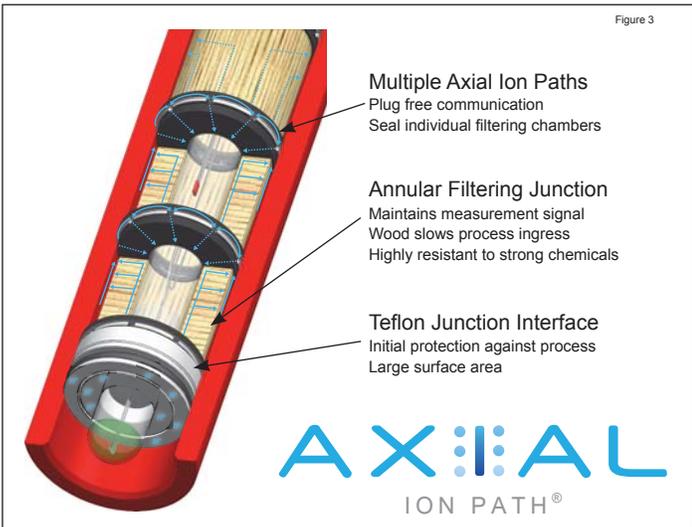
The most common installations found in mining processes will be submersible sensors mounted vertically into tanks and vats. Proper agitation of the fluid helps to reduce some of the coating issues. If the sensor is installed in-line then flowrate past the electrode at 3 - 6 ft/second (1 - 2M/second) helps to prevent build-up. In some applications a jet cleaner can be used to help blast off coating on the tip of the sensor (see figure 6).

For most submersible and sample line installations we recommend the Barben Performance Series 546 threaded sensor. The 546 uses Barben's patented Axial Ion Path<sup>®</sup> reference design (Figure 3). The reference half cell uses multiple filtering chambers to greatly slow the ingress of process chemicals from poisoning the sensor internals. The large annular Teflon junction provides a much greater surface area than conventional pH sensors. The increased area is effective in reducing the plugging due to particulate matter and simplifies cleaning of sensor.



# Application Note

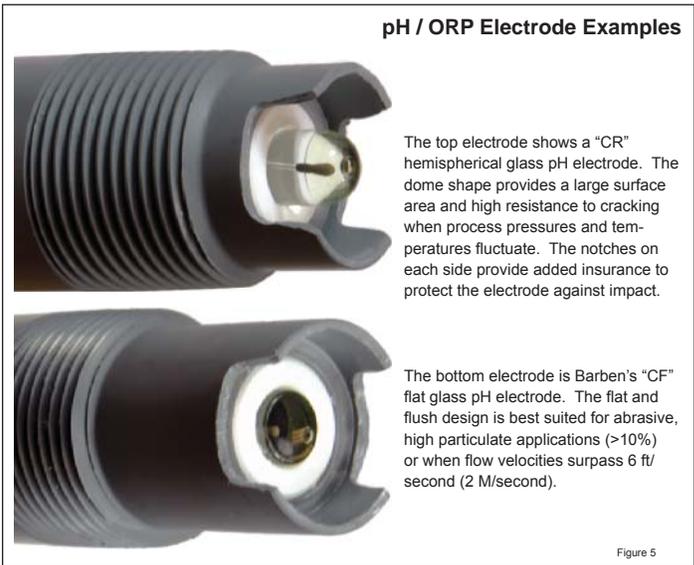
## Cyanide Leach Process - pH



A typical installation of the 546 sensor would use the 3/4" Male NPT threads for installation on a submersible dip tube. For slurry installations such as shown below, "CR" coat resistant hemispherical glass electrode should be specified with a dual notch tip configuration. The notched tip provides additional protection against accidental breakage of the electrode. In high velocity flow streams or abrasive applications >10% solids the "CF" coat resistant flat glass electrode can be specified. A Kynar (PVDF) body and Viton® Extreme seals provide chemical compatibility with most mining chemicals.



The slurry seen in this picture shows the type of coating that can occur in cyanide leach applications. The pH sensor is mounted on the end of the submersible dip tube in the center of the stilling well leading into an open vat. The recirculated leach solution is entering from the piping on the right.



### pH / ORP Electrode Examples

The top electrode shows a "CR" hemispherical glass pH electrode. The dome shape provides a large surface area and high resistance to cracking when process pressures and temperatures fluctuate. The notches on each side provide added insurance to protect the electrode against impact.

The bottom electrode is Barben's "CF" flat glass pH electrode. The flat and flush design is best suited for abrasive, high particulate applications (>10%) or when flow velocities surpass 6 ft/second (2 M/second).

In severe coating applications the 546 pH sensor can be used in conjunction with our B37 /C37 Jet Cleaner. The jet cleaner uses either water or air pressure to blast off soft particulate coatings that may occur in some processes. The jet cleaner can be automated with our Distribution Valve Assembly to provide cleaning via relay logic from a remote controller, PLC, or DCS system (figure 6).

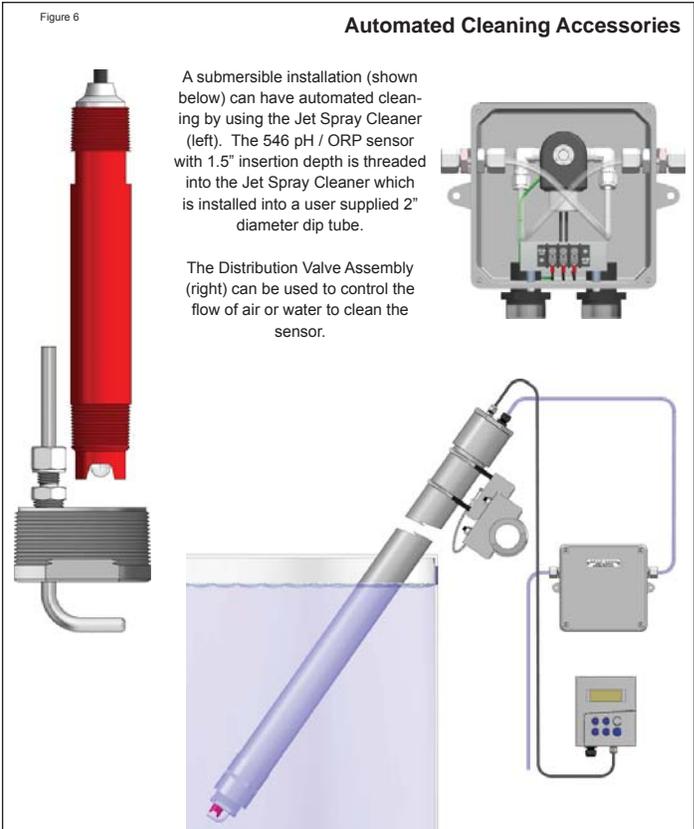


Figure 6

### Automated Cleaning Accessories

A submersible installation (shown below) can have automated cleaning by using the Jet Spray Cleaner (left). The 546 pH / ORP sensor with 1.5" insertion depth is threaded into the Jet Spray Cleaner which is installed into a user supplied 2" diameter dip tube.

The Distribution Valve Assembly (right) can be used to control the flow of air or water to clean the sensor.

# Application Note

## Cyanide Leach Process - pH

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### Summary

Barben Performance Series pH sensors offer many advantages for gold processing facilities including the following:

- Less frequent cleaning and calibration intervals
- High pH / ORP measurement accuracy
- Increased pH / ORP sensor lifespan
- Simplified sensor specification

Maintenance expenses are decreased as spares inventory is reduced and fewer calibration hours are required to keep measurements accurate.

### Contact Us

Barben Analytical is a leading supplier of analytical measurement technology targeting the industrial marketplace. It is a wholly owned subsidiary of Ametek.

Ametek has nearly 14,000 colleagues at over 120 manufacturing locations around the world. Supporting those operations are more than 80 sales and service locations across the United States and in more than 30 other countries around the world.

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