Gold Leach Tank Aeration

Gold Leaching, Gas Injection and Bubbles

The processing of low-grade gold ores is largely made possible through the use of the cyanide leaching process. The goal of any leaching process is to selectively bring a desired mineral into solution in order to efficiently separate it from the solid waste material. While many leaching processes typically use acid or alkali solutions at high temperatures and pressures, the cyanidation process allows for gold leaching to occur at or near ambient temperature and pressure. This is possible by the formation of soluble gold-cyanide complexes (Figure 1), which is defined by the Elsner Equation. As can be seen in Equation 1, both oxygen and cyanide are required for this reaction to progress.

$$4Au_{(s)} + 8CN^-_{(aq)} + O_{2(aq)} + 2H_2O_{(l)} \rightarrow 4Au(CN)^-_{2\,(aq)} + 4OH^-_{(aq)}$$

Equation 1 Simplified Elsner equation

In industrial application it is typically the practice for cyanide to be used in excess, with oxygen being the rate limiting reactant. Note that in the reaction O_2 is shown as aqueous; this is typically referred to as dissolved oxygen (DO). While there are several methods for increasing the DO in leaching circuits, such as gas injection and peroxide addition (hydrogen or calcium), the use of peroxide addition has tailed off significantly over the years, primarily due to the high cost. Gas injection is the most common method and is the subject of this review.

Unlike peroxide addition, gas injection requires that the oxygen first enter solution before it can participate in the reaction. The rate of dissolution of oxygen (Equation 2) is controlled by two processes: 1) mass transfer of O_2 to the gas-liquid interface and 2) mass transfer of O_2 into the solution through the interface. The second process being the slower of the two typically controls the rate of dissolution. The simplest way to improve this rate is by increasing the area of the gas-liquid interface. This is done by injecting (sparging) an oxygen source into the leach tank directly rather than relying on the exposed surface at the top of the tank. By injecting a gas into the leach tank bubbles are formed and the surface area of these bubbles increases the area of the gas-liquid interface.

$$1)\ O_{2(g,\ inside\ bubble)} \rightarrow O_{2(g,\ bubble\ surface)}$$
$$2)\ O_{2(g,\ bubble\ surface)} \rightarrow O_{2(aq)}$$

Equation 2 Oxygen dissolution

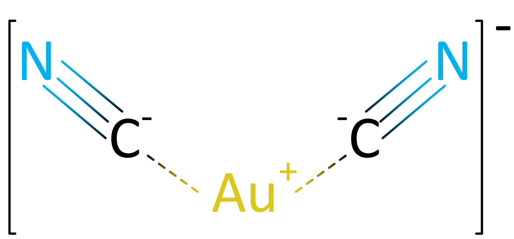

Figure 1 Gold-cyanide (dicyanoaurate) complex ion

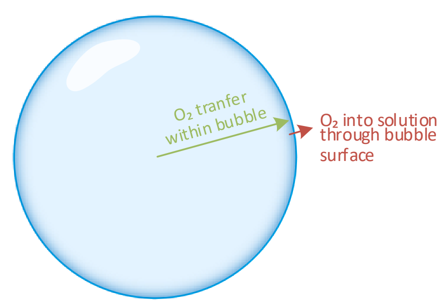

Figure 2 Oxygen mass transfer

The next step to improving the oxygen dissolution rate is increasing the surface area of the bubbles. This can be done by decreasing the average bubble size, for an equivalent volume of gas. The change in surface area caused by decreasing bubble size is significant, particularly below diameters of 2 mm (see Figure 3). Smaller bubbles also have lower rise velocities and are more easily distributed within the tank, both of which increase the time a bubble spends in the solution, increasing the efficiency of the oxygen dissolution.

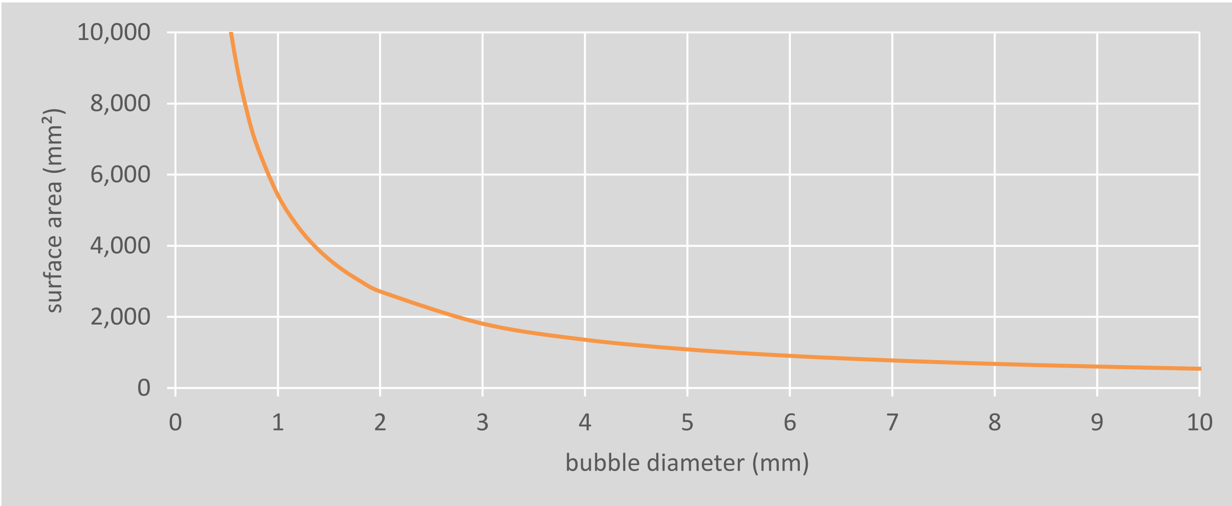

Figure 3 Surface area vs bubble size (equivalent volume)

Oxygen vs Air

As mentioned, increasing the dissolved oxygen (DO) levels is typically achieved through the introduction of gas into the leach circuit. Pre-aeration, oxidization, leaching, as well as cyanide destruct processes all employ some form of gas sparging system. The type of gas used depends on the oxygen requirements of the process. Typically, air, oxygen enriched air or high purity oxygen are used. The reason for the use of different gases is because higher DO levels that can be achieved by gases that have a higher concentration of oxygen. This relationship is governed by Henry's law which relates the partial pressure and temperature of a gas to the amount of gas dissolved in the solution (See Figure 4). This relationship means that there is an upper limit to the DO. At some point adding more air or forming smaller bubbles will not result in an increase in DO and increasing the partial pressure of oxygen (by either enriching the air or using pure oxygen) will be necessary.

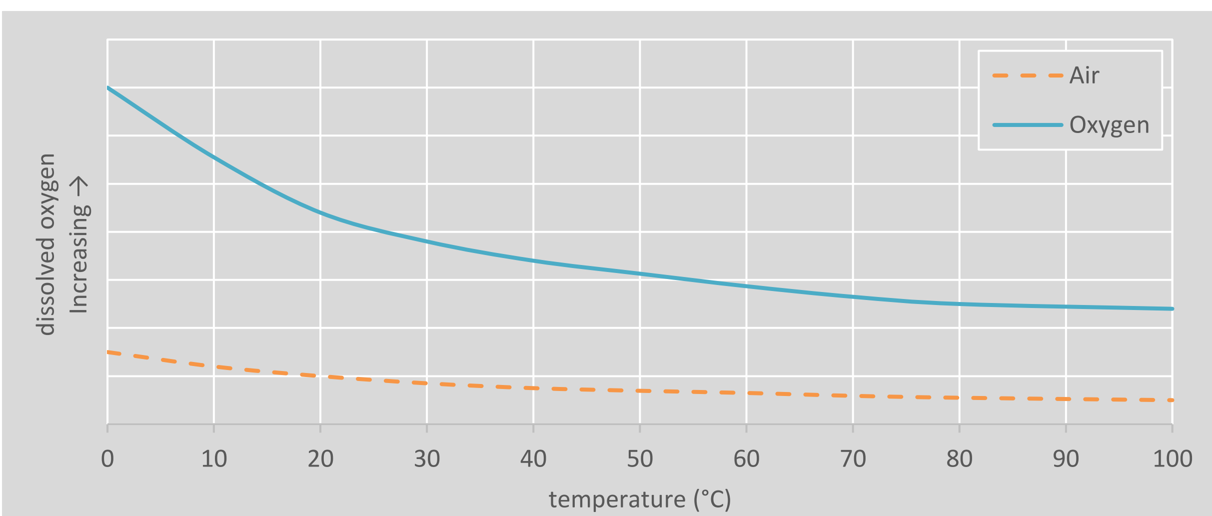

Figure 4 Maximum amount of dissolved oxygen

With this in mind, the use of air and oxygen is very common. While, the cost of oxygen is higher, the metallurgical gains realized through the use of oxygen sparging, more often than not, offset this higher cost. However, site specific considerations sometimes make air injection the preferred sparging media.

Types of gas injection systems

Having established that creating small bubbles is advantageous to the dissolution of oxygen, it should be noted that generating bubbles requires energy. It is generally true that the smaller the bubble, the more energy that is required to produce it.

A large amount of the energy goes into achieving the gas pressure needed for the sparging system to operate. The pressure is generated using either blowers or compressors, blowers use less energy and generate lower pressure and are typically used with older technologies such as inverted cone or dispersion chambers. Compressors on the other hand produce higher pressures, are typically needed to produce the fine bubbles and are used by insertion style sparging systems.

Low energy systems (Blower system)

The simplest form of gas sparging a tank is the open or perforated pipe. Gas is simply injected into the tank below the agitator through an open pipe or a pipe with holes in it at relatively low pressure. Under these conditions the bubbles generated are large and the gas transfer efficiency is exceptionally poor.

To improve these simple pipe systems, inverted cone or dispersion chambers were developed (see Figures 5 & 6). These systems are designed to delay the rise of and improve dispersion of the injected gas by collect it in the top of the chamber and forcing it out the of the serrations along their edge, producing bubbles. The agitator is then relied on to further shear these bubbles into smaller ones. These systems are simple however, the relatively slow agitator speeds and relatively high-density slurry in leach tanks results in these systems doing a poor job of reducing bubble size.

Figure 5 Inverted cone

Figure 6 Gas dispersion ring

Other “under the agitator” systems can include a series of rubber plates held together and compressed with flanges and an internal threaded rod. As the internal chamber is pressurized the gas seeps out of the cracks between the rubber layers. These work well when new but performance (fine bubble generation) reduces significantly over time due to wear (see Figure 7). All systems discussed in this section require that the tank be drained in order to perform maintenance on or replace the units.

Figure 7 Cylinder gas dispersion system after approx. one year of operation

High energy systems (Compressed gas system)

These high energy systems require a compressor to reach the gas pressures required for operation. The most common system is the insertion style spargers (see Figures 8 & 9) and are increasingly gaining favor as preferred injection systems in leaching applications. They offer several advantages compared to low energy gas injection systems, particularly their ability to produce very fine bubbles and evenly distribute them.

Figure 8 Eriez SlamJet

Figure 9 Glencore HyperSparge

These systems force high pressure gas through a converging nozzle (Figure 10), the resulting pressure drop creates a very high shear environment generating a cloud of microfine bubbles (Figure 11). Unlike the "under the agitator" systems insertion style sparges are typically installed at multiple evenly spaced injection points around the outside of the tank (Figure 8), this layout provides improved gas dispersion and easier access for maintenance. Additionally, for very large diameter tanks the lengths of the spargers can also varied to further increase the gas dispersion.

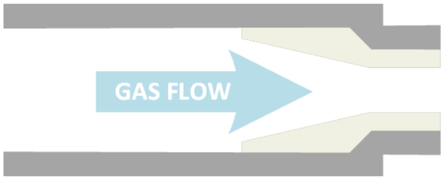

Figure 10 Cross-section of SlamJet sparger nozzle

Figure 11 Gas discharge of injection sparger

A relatively new approach to increasing DO levels in leach circuits has been to use sparging systems external to the tank. Either by aeration (or oxidation) of the feed (Figure 12) or a recirculated stream (Figure 13). Both methods function in the same way the slurry stream is injected with high pressure gas and the air/slurry mixture is forced through a pipe spool with a type of restriction. This high shear environment generates small bubbles, and oxygenated stream can be introduced (or reintroduced) into the tank. Both methods make use of orifice or static mixer type spargers such as the Eriez CavTube which is widely used in flotation applications.

Using this type of gas injection on the feed of the cell allows for small footprint boost the gas injection of the circuit. The recirculation approach, on the other hand, can be simpler to retrofit as existing ports on the tank can be used. It is, however, more reliant on the agitator for dispersion and requires a pump to recirculate the slurry.

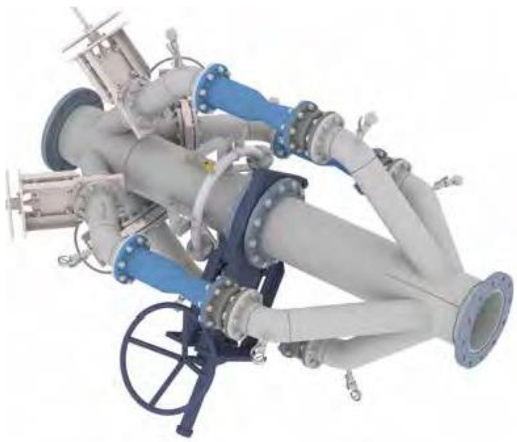

Figure 12 Feed Air Jet an inline slurry pre-aeration device

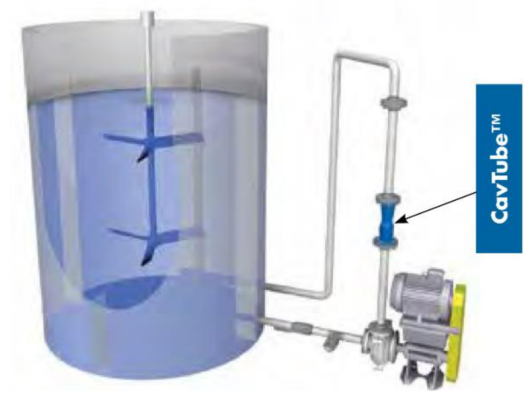

Figure 13 Slurry recirculation using a CavTube sparger

SlamJet design

SlamJets have been an industry standard for nearly 20 years and thousands are installed around the world in both flotation and leaching applications. They are a proven, robust and efficient sparging solution, available in many different configurations.

All Oxygen SlamJets are supplied fully degreased to meet the rigorous safety specifications required for high purity, high pressure oxygen applications.

A significant advantage of the Eriez sparging system is the ability to remove, inspect and reinstall the spargers from outside the tank with no process interruptions.

The auto-close feature on the SlamJets means that when gas pressure is lost for any reason, the internal mechanism “slams” the sparger closed (the internal rod tip is forced against the nozzle) so slurry is unable to flow up the sparger and foul the sparger or the gas delivery system.

Reduced maintenance on the agitators is an additional benefit reported by end users, as moving the gas injection points away from the agitators eliminates areas of variable slurry density around the agitator and reduces agitator shaft wobbling. This reduction in agitator maintenance offers significant cost savings.

The SlamJet sparging system provides better (more even) gas distribution which helps reduce instances of tank sanding.

A practical approach

Gas injection can be accomplished in a variety of ways and the approach taken is dependant on the needs of the process. These needs can be determined by investigating the current state of the circuit. Looking at the overall performance of the leaching circuit, is there opportunity to:

A. Improve:
   i. Production?
   ii. Recovery?
B. Reduce:
   i. Agitator maintenance?
   ii. Cyanide consumption?
   iii. Power consumption?

Typically, the answer one or more of these questions is yes and it is very likely that optimizing the gas injection system will help address these opportunities. Investigating the performance of oxygen dissolution in a circuit need not be an overwhelming task, consider the following questions:

- Are the following known / measured:
    - Dissolved Oxygen?
    - Gas consumption?
    - Cyanide consumption?

Knowing these values is important as they provide quantifiable metrics for measuring improvements in gas injection systems. Next consider the following:

- What type of gas injection system is currently being used?
    - Is it properly maintained?
    - Does the current system capable of meeting the DO requirements?
- What type of gas is being used?
    - Does the oxygen content of the gas need to change to meet DO requirements?

If the current installation is not taking advantage of the oxygen currently being added to the circuit alternative technologies such as insertion type spargers should be considered. Whether the circuit uses air or oxygen, a gas injection system should be designed to optimize the dissolution of oxygen by decreasing bubble size and improving gas dispersion.

While the approach will be specific to the needs of the process, ensuring adequate dissolved oxygen levels are present in a leach circuit is essential for efficient and economical processing of the gold ores regardless of the site, grade or mineralogy.

EFD provides advanced engineering, metallurgical testing and innovative flotation technology for the mining and minerals processing industries. Strengths in process engineering, equipment design and fabrication position EFD as a leader in minerals flotation systems around the world. Eriez manufactures and markets these products through 12 international facilities located on six continents. For more information, please call 613 8401 7400, email efdau@eriez.com or visit www.eriezflotation.com.

Written by Eriez Flotation Division: Craig Hutchison - Global Manager-Sparging Systems and Solutions and Adrian Bill - Technical Sales Engineer