

PRESSURE LEACHING

COMING OF AGE OR HAS IT BEEN HERE FOR A LONG TIME?

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RPMGlobal has been recently been involved with several reviews of pressure oxidation facilities including application in gold, silver, copper and aluminum. The use of this technology is becoming more prevalent as ores are becoming increasingly complex, but it's interesting to note that this technology has been used successfully for 75 years, in a number of different applications, and on every continent. This robust process has been adapted to operate in acid, neutral and alkaline pH as well as under strongly oxidizing, neutral or reducing conditions.

The technical advantages of pressure leaching over atmospheric leaching stem from a combination of elevated operating temperature and oxygen overpressure, both of which increase reaction kinetics. Increased operating temperatures above the ambient boiling point can only be achieved by increasing pressure.

Early Applications of Pressure Leaching

The earliest applications of pressure leaching were low-temperature pressure systems likely in the processing of aluminum. The Bayer process, which is still being used today, was invented in 1887 by Carl Josef Bayer in Saint Petersburg,

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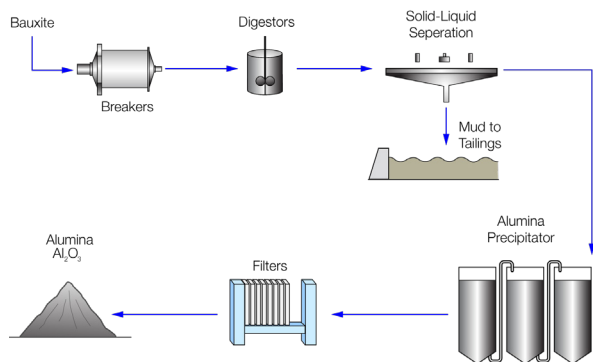


Figure 1: General flowsheet of alumina production.

Russia where it was found that aluminum bearing bauxite ores convert to sodium alunate (NaAlO_2) in the presence of caustic (NaOH). The resulting solutions were then filtered to remove insoluble impurities and pure alumina (Al_2O_3) precipitated. Depending on the bauxite mineralogy, this reaction begins at temperatures of approximately 143°C and pressures of approximately 425 kPa. These pressure temperature conditions require the use of a pressure vessel which in the aluminum industry are called "digesters." It is fitting that one of the first large scale aluminum pressure leach circuits was built in St Petersburg, Russia in 1939. A general flowsheet demonstrating the unit operations of alumina production is shown below in Figure 1.

Other early applications of pressure oxidation were driven by uranium demand during the Cold War era. Uranium may be solubilized from ores (very approximate formula of U_3O_8) when uranium is oxidized from the U^{4+} state to the U^{6+} state. A multitude of lixiviants may be used to form soluble complexes such as sulfates, amines and carbonates. Many early autoclaves were built using low temperature-pressure conditions (approximately 100°C - 120°C and pressures of 200 kPa – 500 kPa) under both acid and alkaline conditions for pressure leaching of uranium. These plants were predominantly constructed in the western United States at locations such as Grants, New Mexico (1953), Moab, Utah (1956) and Cañon City, Colorado (1970), with other plants constructed at Beaverlodge, Canada (1953) and in the USSR (1950's).

Lateritic nickel-cobalt ores are also processed through autoclaves utilizing the "pressure-acid leach" process (PAL). Process chemistry consists of an acid digestion, but recovery is increased temperatures (255°C - 270°C) and pressures (4,000 kPa – 5,300 kPa). Many examples of this type of plant exist in Australia and New Caledonia and the most recent plant, Ambatovy, in Madagascar.

Sulfide Pressure Oxidation

Pressure leaching of sulfide ores is complicated by many items such as sulfur viscosity and the passivation of reactive surfaces. "Low" temperature conditions (100°C to 140°C) are generally

not used in sulfide pressure leaching as this temperature range is conducive to formation of liquid elemental sulfur. This liquid sulfur has a very high viscosity at these temperatures resulting in excessive agitator power requirements as well as coating reactive particles surfaces reducing metal extraction.

There are multiple sulfide oxidation plants using medium temperature autoclaving conditions with temperature-pressure conditions of 150°C and approximately 1,500 kPa as well as high temperature total pressure oxidation conditions, sometimes referred to as TOPOX, with temperature-pressure conditions of approximately 225°C and 3,200 kPa. Under medium temperature pressure leaching, at least some of the sulfur is converted to elemental sulfur (S_0). As temperature is increased and acid is optimized, copper extraction increases and a greater percentage of the sulfur is converted to acid. Conversion of elemental sulfur to sulfate continues up to approximately 220°C where essentially no elemental sulfur remains.

One of the earliest applications of sulfide pressure oxidation was at the Calera Mining Company's Garfield (Utah) cobalt refinery. In 1953, Calera was originally developing a roast-leach process for their ore, but found pressure oxidation a better alternative. The plant was a high temperature circuit operating at 190°C and 3,600 kPa, using air as the oxidant. Cobalt extraction was reported to be 95%-97%. The feed to the Garfield cobalt refinery also contained approximately 24% arsenic that was successfully precipitated as a stable ferri-arsenate. The effort was a significant step forward in understanding materials of construction for pressure leach vessels as it resulted in the development of many of common autoclave construction techniques such as lead lined autoclaves and the use of acid resistant brick and titanium.

Sherritt Gordon (now Sherritt International) built one of the earliest, most successful pressure leaching flowsheets which is still in operation today: the Fort Saskatchewan plant was constructed in 1954, primarily to process complex copper-nickel-cobalt ores. The process consists of a series of pressure leach vessels to oxidatively leach nickel and copper in an ammonium lixiviant.

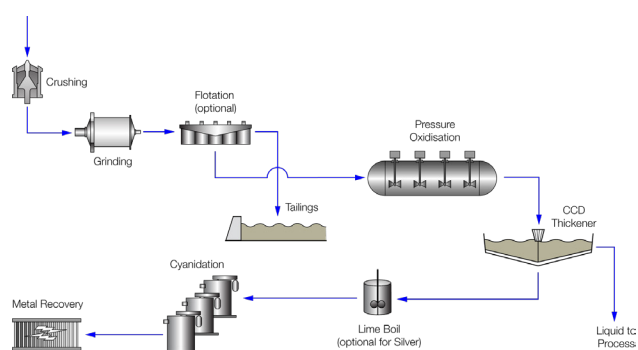


Figure 2: General flowsheet of processing refractory gold ores using pressure oxidation

The science of sulfide pressure leaching was advanced dramatically when the Cominco (now Teck) Trail plant built a pressure leach facility for zinc concentrates (1971). This plant was a "medium" temperature process where sulfides were oxidized at 150o C and approximately 1,400 kPa using oxygen. Its' success resulted in the construction of an additional plant at the Flin Flon mine (1993).

A major revolution in gold processing was the pressure oxidation of refractory, pyritic ores. In these ores, gold is chemically entrained in sulfides which require oxidation prior to standard cyanidation techniques. Many of these plants were built in the western United States in the early 1980's including McLaughlin (1985), Mercur (1988), and Getchel (1989). Additional plant commissioning's such as Sao Bento (1986), Goldstrike (1990 and 1992), Lone Tree (1994), Twin Creeks (1996), and Macraes in New Zealand (1999) followed. The largest autoclaves in the world were started up by Barrick at the Pueblo Viejo Mine in the Dominican Republic in 2011 oxidizing 24,000 tons per day of refractory pyritic gold ores. Refractory sulfide gold autoclaves can be designed to process flotation concentrates or accept whole ore as feed based on sulfur grade and operating and capital expense. Essentially all of these plants utilize high temperature oxidation facilities with temperature conditions ranging from 190o C to 225o C and pressures of 1,900 to 3,200 kPa. All plants achieve high gold extractions generally exceeding 90%. High temperature oxidation is critical in these designs to minimize elemental sulfur formation and limit cyanide consumption.

A general flowsheet demonstrating the unit operations of pressure oxidation of The most recent sulfide pressure oxidation plant development has been the processing of copper concentrates. Copper concentrate leaching has been applied as long ago as 1964 at Manduel GOK in the USSR and the Sunshine Mine process plant at Kellogg, Idaho (1980), but copper concentrate leaching was advanced to larger scales with the commissioning of the Bagdad, Arizona, concentrate leach plant (2003) and then the Morenci, Arizona, concentrate leach plant (2006).

Copper concentrate leaching has been driven by two principal opportunities:

- 1) Depletion of heap leachable ores at existing solvent extraction/electrowinning (SX/EW) copper operations – this results in excess SX/EW capacity which can be filled through the pressure leaching of sulfide concentrates generated through milling of the underlying copper sulfide mineralogy
- 2) The increase in penalty elements in some ore bodies – the principal penalty element being found today is arsenic which is fixed through pressure oxidation, but other elements are sometimes found, depending on the ore body, including bismuth, etc.

There are two principal copper concentrate pressure leaching methods commercially available: high temperature total pressure oxidation and medium temperature oxidation such as the CESL process. High temperature oxidation fully oxidizes all sulfides resulting in higher copper extraction (approximately

98.5% for high temperature verses approximately 96% for medium temperature) and higher sulfuric acid generation, while the medium temperature processes convert a significant percentage of the sulfide to elemental sulfur which can be disposed of in a standard tailings facility. If low grade acid is required for heap leaching activities, most mines consider high temperature pressure leaching, but if acid must be neutralized, medium temperature oxidation is preferred. Both methods are effective in the fixing of penalty elements such as arsenic. A general flowsheet demonstrating the unit operations of pressure oxidation of copper concentrates is shown below in Figure 3.

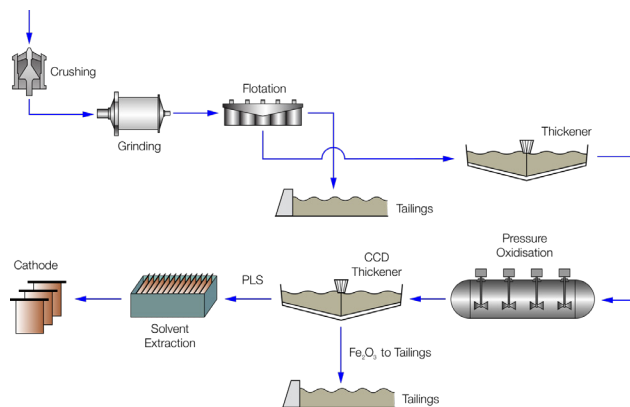


Figure 3: General flowsheet of copper concentrate pressure oxidation

Conclusions

Pressure leaching is not a new technology and indeed conventional with over 100 plants constructed and successfully operated over the previous 75 years. The process has proven to be robust, cost effective, and environmentally acceptable for the processing of a variety of different ores. Pressure leaching is likely to find increased application in upcoming years as even more complex ores are mined. RPMGlobal has extensive experience in pressure leaching including test work, engineering and design, operation and independent engineer evaluation and can assist your team in these projects.