WHAT'S HAPPENING IN GOLD ORE PROCESSING?

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Factors driving new developments in gold technology include increasing environmental concern and government regulation over the use of cyanide, the trend towards refractory, complex, and lower grade resources, and the pressure to reduce operating cost and increase plant performance efficiency.

Developments reviewed in this presentation include alleviation of the issues around the use of cyanide, non-cyanide lixiviants, processes for refractory ores and concentrates, improvements in analytical, control and monitoring systems, and upgrading of gold resources by sensor-based automatic ore sorting,

Cyanide Alleviation

ReCYN Process

Green Gold Engineering has been awarded a ReCYN™ Process design and install contract with PT Agincourt Resources to detoxify tailings and recover cyanide and copper at its Martabe gold-silver operation in Sumatra, Indonesia(1). It will be the first application of the technology outside of the Mirah, IMK Group. Commissioning is due in October 2019. An independent review by Whittle Consulting, Australia, predicted a net project benefit of $US 125M(2).

Using an innovative resin-bead absorbent, the ReCYN™ Process typically reduces cyanide consumption by 50% by recovering free cyanide from the plant tailings and recycling it back into the leach circuit, while recovering copper for sale as a by-product, and detoxifying the tailings stream to achieve a guaranteed 100%-compliant clean water discharge.

In the typical flowsheet, the CIL discharge slurry flows through several stages of adsorption contactors. The resin stream is pumped countercurrent to the slurry flow to maximize resin loadings and minimize tailings values. Loaded resin is transferred either as a batch or continuously to the elution section of the plant. Copper elution and cyanide elution occur in separate columns at ambient temperature, and the stripped resin is returned to the final adsorption stage. The relative flows of loaded resin to copper and cyanide recovery sections depends on the cyanide and copper levels in the CIL tailings solution. Gold is typically recovered by electrowinning and copper by precipitation as a chloride. Cyanide recovery involves volatilization and scrubbing with NaOH to form a concentrated sodium cyanide solution that can be returned directly to the leach circuit. The detoxified slurry is discharged to the tailings dam.

The cyanide levels are kept high, to at least 750 ppm NaCN, to minimize the copper loading on the carbon. In the case of Martabe, this is also beneficial for the recovery of silver. The soluble copper level is limited by economics to around 0.2%. Above this value it is worth looking at a different system such as flotation because of the value of the copper, though there is no technical limit, and levels of 1% soluble copper have been successfully tested(3).

On-Site Cyanide Generation

Synergen Met, Australia, are continuing to progress their on-site cyanide production process towards full scale commercial application following the successful operation of a 60 t/a pilot plant at an operating gold mine in Australia(4). They are targeting a modular design rated at 450-750 t/y, with additional modules to be added for larger output. An average mine uses 500-1,000 t/y rising to over 10,000 t/y at some large-scale operations(5).

The process involves combining nitrogen directly from the air with methane from a hydrocarbon gas source using a plasma torch at 10,000^{o}C then quenching to form HCN. The HCN gas is mixed with NaOH to form NaCN, and the remaining hydrogen and nitrogen are vented to atmosphere. The NaCN solution is produced at the concentration and dosage required by the plant, and is pumped directly into a holding tank in a closed system without any handling by personnel(6).

Key benefits include elimination of risk of spills during transport, alleviation of environmental and community opposition, security of supply for remote sites, avoidance of worker exposure during handling and dilution, reduced cost in niche markets such as highly rugged terrain and remote mining sites, and reduced insurance cost and liability of toxic chemical storage.

Colorant in Cyanide

The use of a colorant in cyanide has been approved by the ICMI Board and takes effect on 1 July 2019(7). The purpose is to provide a means of visual identification of leaks or spills at mine sites or during transportation. It will require that dye be included in high-strength cyanide solutions prior to delivery at the mining operation and to solid cyanide prior to or at the time of mixing. High-strength cyanide solutions are defined as those with a minimum cyanide concentration of 15%, which would provide coverage to cyanide in both liquid and briquette form. Cyanide used in laboratories is exempted.

ICIMI's decision was influenced by the use of dye addition by the Goldcorp Group, Canada, which originated at the Musselwhite Mill, Ontario, after the operations team heard about its use at the Placer Dome Mine, Ontario (which became Goldcorp's Porcupine Gold Mine in 2006)(8). After further development in co-operation with the die supplier and cyanide supplier, Chemours, USA, the present practice of adding red dye at the manufacturing level to eliminate the need for a mixing system at site was adopted. The practice spread to other Goldcorp sites and is now mandatory company-wide.

Development of Alternative Lixiviants

Thiosulphate

CSIRO, Australia, has developed a thiosulfate-based reagent system for gold leaching that has excellent stability and shown broad applicability in the laboratory compared to the thiosulfate system commercially implemented by Barrick to treat double refractory gold ore following pressure oxidation at its Goldstrike Mine in Nevada, USA. The CSIRO reagent system is an alternative to cyanide and has particular application where cyanide cannot be used and to unlock stranded high-grade deposits.

CSIRO in collaboration with Eco Minerals Research Limited, Australia, commenced a project in July 2017 to undertake a demonstration at scale in the field using the CSIRO reagent system. The mobile demonstration plant setup on the Menzies Battery site in Western Australia uses a low capex vat leach process to recover gold from ores having good gold liberation at a p80 greater than 300 micron. In under 10 months the demonstration project has taken a laboratory developed concept and transformed it into a demonstration plant involving design, build and commissioning through to successfully producing a gold ore bar. The demonstration plant processed up to 30 tons of ore per day by vat leaching and operated successfully for more than six months to validate the reagent performance and stability(9). The successful validation in the field at scale has paved the way for commercial application of the technology and a commercial launch is imminent.

Glycine

GlyCat™ leaching is being developed for implementation at Newcrest's Telfer Gold Mine in Western Australia to facilitate a change in circuit design that would then allow for increased concentrations of soluble copper to be tolerated in an expanded gold cyanidation circuit(10). Reusable glycine is added to the leach to enable a five-fold reduction in cyanide usage while eliminating detox requirements. Copper is recovered by either sulphide precipitation or resin ion exchange. Gold is recovered by conventional carbon adsorption or alternatively using gold-selective resins.

Over a two to three-year period, an extensive program of batch testwork has defined the optimum leaching chemistry and proved the effectiveness of downstream processes. Three continuous piloting campaigns have shown that the process is robust and controllable, while verifying the reagent consumptions and gold recovery under steady-state conditions. Bench-scale testwork, process modelling, and engineering studies have narrowed down the circuit configurations to a preferred flowsheet involving single stage leaching and conventional downstream recovery. Implementation at Telfer will require extra leach tanks, solid-liquid separation equipment on the leach feed and discharge, and a copper recovery section. Glycine consumption is anticipated to be less than 3 kg/t of concentrate while the resulting saving in cyanide is at least 30 kg/t if the same concentrate were treated using cyanidation leaching alone.

Glycine leaching, an environmentally benign leaching process carried out in alkaline conditions, was developed by Curtin University in Perth. Mining and Process Solutions have acquired exclusive rights to progress the technology through to commercial application. GlyCat™ is the application of glycine with cyanide to mixed base metal and precious metal ores.

Processing of Refractory Ores and Concentrates

Bio-Oxidation

BIOX© Developments

Outotec Biomin, South Africa, have developed the MesoTherm process which utilizes a combination of the traditional BIOX mesophile process for the primary bio-oxidation stage followed by a thermophile bio-oxidation stage to complete the oxidation. The higher oxidation rates and more complete oxidation at the higher temperature results in lower cyanide consumption during subsequent leaching of the bio-oxidation product. Development of the process included several stages of batch and continuous pilot plant testing. The final stage in the development is the successful operation of a 21 m3 demonstration tank at the Fairview BIOX plant which has shown a 50% reduction in cyanide consumption for similar sulphide oxidation to the commercial plant(11).

They have also introduced the OKTOP® 3105 dual impeller to give superior gas handling and oxygen mass transfer rates under typical BIOX operating conditions. It was tested in water and BIOX slurry using a 21 m^3 test reactor at the Fairview Mine in South Africa, and the results indicated overall savings for the agitator and blower of 5% in capex and 5% in opex compared with the benchmark dual hydrofoil(11).

The second successful commercial implementation of the HiTeCC technology to combat the preg-robbing of double refractory ore has been achieved at Nordgold's Suzdal mine in Kazakhstan which treats double refractory ore with both visible and invisible gold hosted in sulphide associations of pyrite and arsenopyrite, and also carbonaceous black shale. Following extensive laboratory and demonstration scale testing of the Outotec HiTeCC technology over the period 2012 to 2015, Suzdal commenced the construction of a 385 ton per day facility. The plant was designed to recover gold from both the current and historic CIL tailings and was successfully commissioned in 2016. In the process, the preg-robbed gold is efficiently desorbed from the carbonaceous matter by manipulating the ionic strength and temperature of the Suzdal CIL product leading to enhanced metal recovery(12).

Bio-Oxidation in China

In his keynote address at the ALTA 2018 Gold-PM conference(13), Dr James Wang's, then Deputy Executive Director of Zijin Mining Group, China, reported that there has been a significant application of bio-oxidation in China with 11 plants, of which 7 are still operating. The first commercially successful bio-oxidation plant was built in 2001 at Laizhou Gold Processing Plant in Shandong Province with a capacity of 100 t/d, adopting BacTech technology. The largest was built in 2007 in Guizhou Jinfeng with a capacity of 750 t/d, utilizing BIOX™ technology.

The typical plant has three stages of agitation tanks in parallel for primary oxidation, and three to four stages of agitation tanks in series for secondary oxidation. Air is introduced into the tanks and dispersed with an agitator to achieve oxidation of the sulphur in pyrite concentrates. The temperature is usually controlled at 38-45°C using cooling water in an indirect heat exchanger to provide an optimum environment for the bacteria, and the pH is controlled at 1.5-2.0 by limestone to neutralize acid produced by oxidation of sulphur. Under suitable conditions the bacteria can be adopted to oxidize gold arsenopyrite concentrates with an arsenic content of less than 3%.

Rapid Oxidative Leach (ROL) Process

FLSmidth, USA, is developing the application of their mechano-chemical pre-treatment process to oxidize refractory sulphide gold ores and concentrates under atmospheric pressure without ultrafine grinding and at temperatures much lower than traditional roasting or autoclave pre-treatment(14).

They are particularly targeting refractory low-grade ores with >3 g/t gold coupled with small resources, and existing operations with low-grade stockpiles to be processed at end of mine life. Laboratory testwork indicates >70% gold extraction in eight hrs. They are working with several gold producers with the goal of progressing to pilot scale testing in 2019. Projected advantages include low capex and lower environmental impact compared with existing technologies. The process is a direct application of technology developed for copper chalcopyrite ores which has been successfully piloted and is moving towards a demonstration plant in South America in 2019(15)(16).

Pressure-Oxidation

Unique operating conditions have driven designers and manufacturers to use explosion welded titanium clad construction for the world's largest pressure oxidation gold autoclave for the expansion of Polymetal International's gold processing facility in Amursk, Eastern Russia. The decision is based on titanium clad being considered to be a more economical and reliable solution than the commonly used acid resistant brick lining system(17).

This is the first use of Ti Clad for the gold POX that NobelClad are aware of. While some pilot lines use titanium for autoclaves, and have for many years, this is its first use in a full commercial production plant(18).

Gold Analysis

OnLine Gold Analyser (OLGA)

Gekko, and CSIRO in Australia are partnering to commercialize a new technology that provides real-time analysis for gold content in a slurry or solution stream. Delivering an updated sub-parts per million (ppm) Au measurement every 10 minutes, the OnLine Gold Analyser (OLGA) provides insights into process performance that are unobtainable with assayed sample sets. While traditionally assayed samples consist of homogenised samples that are collected once per shift and then delayed up to 12 hours by lengthy processing, OLGA provides live data. This enables real time monitoring and adjustment of process systems and empowers mining operators to minimize gold losses from process excursions.

This will complement Gekko's existing Carbon Scout measurement system and enhance Gekko's metallurgical accounting system which is currently under development in collaboration with Rockwell Automation. It is specifically designed to enable direct measurement of gold in tailings, feed and concentrate slurries down to sub-ppm levels, unlike conventional x-ray fluorescence (XRF) systems that have detection limits in the tens to hundreds of ppm range. Following successful in-house testing at CSIRO, plans for field trials at a number of Australian gold mining companies are well advanced and should see OLGA undergo full product release in 2019(19).

PhotonAssay Gold Ore Assay System

Chrysos Corporation, Australia, commercialized their PhotonAssay gold analyser at a commercial assay laboratory in Perth, Australia, in 2018, as a direct replacement for conventional fire assay, The first unit, a

PhotonAssay Max, is a fully automated system capable of handling 59,000 gold samples per month. Factory testing has shown that the system provides accurate analysis comparable to or better than fire assay for samples containing concentrations of gold above about 0.3-0.4 ppm[20]. Future developments include the PhotonAssay Mine platform designed for deployment on mining and mineral processing sites, which is scheduled to be available in 2020, and the PhotonAssay Mine Mobile system providing a fully relocatable, truck-mounted analysis laboratory, for which development is expected to commence in 2020. With potential applicability to more than half the elements in the periodic table, PhotonAssay can be used to measure a wide range of commodity, pathfinder and penalty elements[21].

Based on the principles of photon activation analysis, the system uses a high-power, high-energy X-ray source to excite nuclear changes in any gold atoms present in a sample, and then measures a characteristic signature emitted by these atoms. The process is non-destructive, rapid, highly specific and capable of providing a true-bulk analysis of samples weighing 500 g or more. The basic physics principle, also known as gamma activation analysis, was adapted in the former Soviet Union for gold analysis. However, the sensitivity and accuracy of these early implementations, particularly for samples containing less than 1 gram per tonne of gold, limited their more widespread application. Over the past 15 years, CSIRO has developed and patented methods that significantly improve both absolute accuracy and sensitivity to very low concentrations. These improvements form the basis of Chrysos™ PhotonAssay technology[21].

Au-Isomer Gold Ore Assay System

Baltic Scientific Instruments, Latvia, commercialized their second generation gamma-activation (GAA) Au-Isomer Gold Ore Assay System in 2017, an improved version of their first generation system installed in 2016. Both systems are located at the GAA Laboratory of Muruntau Mine in Zarafshan, Uzbekistan[22][23]. The two systems were designed to analyse the gold content of raw ores in a gold mine and achieved a detection limit of under 0.05 g/t in real industrial conditions. Baltic's Au-Isomer systems are based on three industrial GAA laboratories commissioned in Zarafshan, Uzbekistan in 1977, in Magadan, Russia in 1979 and in Batagay, Russia in 1986, and are potentially applicable to a wide range of elements.

Baltic are currently designing a third generation industrial GAA system based on the analysis of the advantages, disadvantages and special features of all major system components that can influence sensitivity and accuracy. The analytical software and economic aspects of the development of a system for application to gold, silver and rare earth elements are being considered[24]. They are also completing the design of relocatable GAA system which can be truck-mounted.

Ore Sorting

There is increasing interest in the use of sensor-based automatic ore sorting to upgrade gold resources including[25]:

- Brownfields expansion of an existing mining operation with no requirement to increase mineral processing capacity downstream from the ore sorter.
- Upgrade of previously sub-economic low-grade stockpiles, enabling them to be treated economically while also potentially reducing mine closure environmental liabilities.
- Treatment of satellite ore bodies requiring trucking of ore (and often involving toll treatment through a third-party mill), delivering a higher grade to the mill with reduced trucking and toll treatment costs.
- A reduction in recirculating loads in the pebble circuit of SAG milling operations through waste rock rejection, thereby potentially increasing SAG milling capacity and lowering unit costs of milling.

For further information on what's happening in gold ore processing, attend the ALTA 2019 Gold-PM Sessions on May 23, which features a Forum and Panel focusing on Fit-for-Purpose Gold Leaching Systems.

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