The golden age

Gold is king in these difficult times. Replacing cyanidation with more environmentally friendly processes remains a goal for many.

In its March Gazette, Mineral Engineering Technical Services (METS) considered Refractory Gold: Opportunity or Problem?

METS noted “free milling simple gold ores will always generate the maximum profitability. Complex and refractory gold ores on the other hand involve higher capital and operating costs as well as higher technical risks.

“The degree of ‘refractoriness’ can vary from mild to extremely refractory gold ores (solid solution gold). Scanning Electron Microscopy can determine the nature and occurrence of the gold and its liberation characteristics.

“In the majority of cases, but not always, refractory gold ores are sulphidic in nature. This means that flotation is invariably the first process option to consider. This is relatively straightforward and achieves high gold recovery. The higher the gold to sulphur ratio the better in terms of downstream processing options. For refractory gold ores gravity recovery is usually poor and of little benefit.

“The processing options for the concentrate represent the greatest challenge technically. The concentrates can be roasted, sold to a smelter, bacterially oxidised, subjected to pressure oxidation (POX), subjected to ultra fine grinding (UFG), or processed by some of the new technology options.

“If the concentrate contains marcasites or pyrrhotite, shipment may be a problem because of spontaneous combustion.

“Traditionally roasting of the concentrates was used to remove sulphur and arsenic followed by leaching of the calcine. This was the lowest capital and operating cost. However with changing environmental regulations it represents the highest capital and operating cost when the cost of meeting new regulations is taken into account.

“POX is a high capital cost option that usually requires its own oxygen plant and has a very high capital cost. Gold recovery is usually very high and a low cost neutralising calcrete is required. Macraes, Lihir and Porgera are examples of such projects.

“Bacterial Oxidation (BIOX) has a chequered history of success and failure. There are many issues such as water quality, cooling, nutrients and materials of construction but the technology is getting better. Harbour Lights, Youanmi, Beaconsfield and Wiluna are examples of such Australian projects.

“Ultra Fine Grinding (UFG) uses Isamill technology to grind the ore to sub 10 microns and then leach the ore. The risks are low but power costs and suitable low cost grinding media are important. This is particularly applicable to particulate refractory gold ores. An example of the use of this is by Kalgoorlie Consolidated Gold Mines.

“The Albion process represents atmospheric leaching technology, which is emerging and attractive.

“Geobiotics represents using barren concentrate coated scats which are bacteriially oxidised in heaps and then processed in a conventional carbon in pulp (CIP) plant.”

Flotation for extra values
Cyanide cannot be used in the initial stages of processing in various parts of the world and this hindrance can lead to a loss of gold values to tailings. Cie Miniere Esperance (CME), based in French Guyana, is a good example, with a process flow sheet that includes crushing, grinding and gravity separation in two stages: a top plant and a bottom plant. A ‘coarse’ pond contains tailings from the top plant; this product feeds the bottom plant. Tailings of the bottom plant are stored in the ‘fine’ pond. Analyses of the fine ponds proved a residual gold grade sufficient for a chemical treatment. CME decided to test the feasibility of pre-concentration using flotation.

The CME mill currently achieves a global recovery of about 67% with flotation estimated at 84%. Crushing is performed by one jaw crusher and two hammer crushers. Ore then passes through a Knelson KC 48 gravity concentrator, producing a first gold concentrate. The remainder is stored in the coarse product pond. Material is rehandled with a shovel to feed the grinding circuit. There are two parallel lines, each including a ball mill, a magnetic separator and a hydrocyclone. Ground ore (d80 = 160µm) passes through a KC 48, producing a second gold concentrate. The tailings are stored in the fine product pond.

SGS Lakefield undertook preliminary flotation tests, which showed this could be a positive improvement so CME contracted French process engineering company Caspeo to carry out an on-site flotation pilot campaign, design an industrial flotation circuit and evaluate the profitability of using flotation.
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On-site laboratory tests were performed alongside the pilot plant tests, in a 2.5-litre Denver cell. The feed size varied between a d80 of 150 µm and a d95 of 106µm. pH was regulated by soda between 6 and 8.5. The flotation reagents used were CuSO4 as an activator (100 g/t), PAX as collector (40 g/t) and MIBC as a frother (20 g/t). The main conclusions were:

- There is a direct link between gold recovery and size distribution: the finer the size distribution, the higher the recovery. A recovery of 80% was achieved with a d95 of 106µm.
- The regulation of pH to 8.5 improved recovery and selectivity (higher grade).

CME has confirmed that the use of flotation is an attractive answer to limiting gold losses to tailings and to preconcentrate gold before cyanidation. The pilot plant tests conducted on site by Caspeo have proved gold flotation feasibility. With the help of the USIM PAC software, the flotation circuit has been designed and several economic simulations have been performed.

Another ‘clean’ way to recover gold can be General Kinematics all new Vibra-Drum wet grind leaching system, which provides efficient chemo-mechanical processing of ore for precious metal recovery, the company reports. Recoveries of 93-97% can be achieved without the use of toxic chemicals due to the unique fracturing in the ore from the General Kinematics mill as well as leach solution. The liberation of precious metals is achieved due to the non-compression nature of milling. Other system advantages include:

- Fracture of ore saturated in zones of microcrystalline areas
- Low energy and chemical consumption means higher revenue per tonne of ore treated
- Heavy pulp density for maximum ore processed per unit of liquid.

**CELP at Kupol**

Natural Resources Canada and Wardrop Engineering have worked on samples from the Kupol mine in far east Russia (Kinross Gold). In Part I of the work, gold and silver were shown to be efficiently extracted from Kupol samples using lead nitrate in a cyanide leach system. In Part II, a comparison of the technical and economic merits of a new technology called CELP (CANMET Enhanced Leaching Process) was made with the cyanidation/AVR(Acidification-Volatilisation-Recycling) process using eight metallurgical variability samples as well as a...
large composite sample which represented the initial two years of Kupol mill feed. The composite sample grades were 33.4 g/t Au and 289 g/t Ag. It was demonstrated that the CELP produced very similar gold and silver leach extractions compared to the standard cyanidation/AVR leach conditions at half the cyanide concentration (1,000 ppm NaCN in CELP versus 2,000 ppm for cyanidation/AVR). It was estimated that the total cost per tonne, was about the same for the two technologies (total cost of the CELP with the use of Merrill-Crowe at $46.48/t, with cyanidation/AVR at $46.13/t). However, the implementation of the CELP would eliminate a capital expenditure of approximately $5 million.

Eight variability samples used to confirm the previous results showed that on average the gold and silver leach extractions with the CELP and the feasibility leach conditions were very similar for gold extractions, but 4.6% higher for silver extractions compared to conventional cyanidation. The decision was made to remove AVR cyanide recovery from the Kupol flowsheet and implement the CELP at Kupol.

Green technology
High metal prices and new global standards and accounting for environmental liability in financial disclosures are creating markets for metals that are produced using ‘green technologies’. A promising ‘green’ gold leaching system uses a polysulphide based lixiviant which is non-toxic and non-polluting.

D. Earley III formerly of Daniel B. Stephens and Associates of Boulder, Colorado, and now President/Senior Geochemist of STEP, presented a paper on this at this year’s SME Annual Convention. He explained that “laboratory testing has demonstrated selective gold extraction rates comparable to those of cyanide. The polysulphide lixiviant is a dilute aqueous solution which can be inexpensively produced from readily available chemical reagents and even mining wastes. The reagent system is self-buffering and maintains the optimal chemical environment for leaching. Treatment of residual leach solutions is not necessary because the lixiviant itself is not toxic, and breaks down as the system equilibrates.

“Simple closed system boiling is used to recover gold from process solutions. The polysulphide lixiviant can then be readily renewed and recycled back into the system, forming a closed loop system that conserves reagents and energy which minimises operating costs. Economic projections have shown that the system can be used profitably for standard ore types and grades.”

Earley also notes “several alternative lixiviant systems for precious metals have been developed and researched thoroughly, but none have
contributed significantly to production. New mine project investment instruments and regulations also often lack the flexibility necessary to allow for innovative technology. Furthermore, certain technology advancements may only work if incorporated into a project from the outset and integrated with the entire project management system. Hence, the mining industry has not readily embraced alternative leaching technologies such as polysulphides and other alternatives to cyanide. Even mature technologies such as thiosulphate and other alternative leaching systems have been under development for decades and have received much research support, full scale demonstration projects have not been evoked. However, the incentives for development of green technologies has never been higher and a system such as polysulphide which is thought to be a natural agent for mobilising gold in nature is more likely to be accepted by the public than systems that require artificial chemicals. Indeed, polysulphide solutions could conceivably be derived from mining wastes thereby incorporating the principal of recycling. For example YES Technologies has demonstrated how the bisulphide reagent can be generated from by bioprocessing of refractory sulphide ore or acid mine drainage and used for gold leaching. However, the polysulphide ligand dissolves gold at a rate that is orders of magnitude faster with a higher solubility than bisulphide alone."

Yes Technologies’ cyanide-free biocatalysed leaching uses micro-organisms for the recovery of precious metals from metal-containing processes and streams. This technology is targeted at using naturally-occurring, sulphate-reducing bacteria for the recovery of gold and silver from ores.

In step one, aerobic bacteria catalyses biooxidation of low-grade, hard to treat (refractory), sulphidic gold ore. This step is currently being adopted by gold producers for freeing gold from base-metal sulphides (e.g., pyrite). A waste stream from the bio-oxidation step is used in a second step.

Step 2: Naturally-occurring, sulphatereducing bacteria are used to convert the dissolved sulphate in acid mine drainage (AMD) into a dissolved bisulphide leaching agent and to neutralise the AMD. These bacteria can use wood alcohol, grain alcohol or vinegar as food, and they are also capable of consuming hydrogen produced by the gold dissolution process. Gold dissolves in the bisulphide solution and is recovered with activated carbon or zinc dust. If needed, excess sulphur can be recovered as a byproduct. By using the natural sulphur cycle, the process provides a complete solution to the gold recovery problem.

Yes Technologies says the potential competitive advantages are:
■ "More environmentally friendly – the bisulphide leaching agent used is about 200 times less toxic than cyanide"
■ "Improved economics – with increasing awareness for the environment worldwide, containment, treatment costs and time spent on environment impact studies associated with cyanidation plants have increased significantly. These factors have raised the economic hurdle necessary to justify a working mine. Environmentally acceptable alternatives could broaden the definition of an attractive mine, through reduction of the economic and environmental risks. In addition, preliminary results indicate chemical reagent costs could be 80% lower than cyanide." IM

References