Mineral Processing and Sustainability Working Group Case Study

CASE STUDY: AGNICO EAGLE FOSTERVILLE OPERATIONS IMPROVES GOLD RECOVERY WITH ADVANCED TECHNOLOGIES

AGNICO EAGLE

EXECUTIVE SUMMARY

The Agnico Eagle Fosterville Gold Mine is a high-grade, low-cost operation located 20 km east of the city of Bendigo in the state of Victoria, Australia.

Commissioned in 2005, the operation comprises a crushing and grinding circuit followed by flotation, Metso Outotec bacterial oxidation (BIOX®), and carbon in leach (CIL) circuits. In 2008, Fosterville Gold Mine pioneered the 'Heated Leach' Process (Metso Outotec HiTeCC™), a high temperature preg-robbing mitigation process. In 2009, this highly successful technology was commercialized onsite, and has since been demonstrated to increase overall gold recoveries by up to 12% and reduce WAD cyanides discharged in leach tailings to below environmentally regulated concentrations. The facility has also pioneered novel applications for the capture of colloidal gold from tailings streams and continues to develop industry partnerships to improve agitation technology and online elemental analysis.

As a non-discharge facility, Fosterville Gold Mine has maintained their commitment to strengthening the sustainability of the facility's water balance through the application of innovative technologies amongst which, the Metso Outotec activated sludge tailings effluent remediation (ASTER™) process for degrading thiocyanates and total cyanides from leach liquors, and a mine water treatment plant removing arsenic, antimony, and sulphates. These processes enable the facility to adopt a 'reduce, reuse and recycle' approach and retain a high level of flexibility in utilizing process waters within a unique bacterial oxidation circuit.

CHALLENGES

- Reduce gold losses
- Minimize process variability for sustained bacterial oxidation
- Reduce capital cost
- Implement integrated water balance processes

SOLUTIONS

- Metso Outotec BIOX®
- CSIRO Mineral and Elemental Analyzer, 'MEA'
- Colloidal Gold Recovery Process
- Fosterville 'Heated Leach' Process (marketed by Metso Outotec as HiTeCC™)
- Metso Outotec ASTER™ Process

BENEFITS

- Improves gold recovery
- Security of processing variable mineralogy
- Low CAPEX and operating costs
- Reduce, Reuse, Recycle mindset

OPTIMISING GOLD RECOVERY PROCESSES

The primary ore at Fosterville is highly refractory, with less than 10% gold dissolution achievable on the flotation concentrate without any pre-oxidation. The gold occurs primarily as submicron particles within a pyrite and arsenopyrite matrix and has been described as a 'solid solution' and therefore not amenable to direct cyanidation. Throughout Fosterville's pre-feasibility studies, various oxidative technologies were assessed against such factors as environmental, safety and technical risks, operability, maintainability, and economic risks. The BIOX® process was selected as the preferred oxidative technology. Once liberated through oxidation, the gold is then available for cyanide leaching.

The Fosterville BIOX® circuit has been in operation since April 2005 and has proven to be a robust and reliable technology, consistently achieving gold recoveries over 99%.

1. Figure Fosterville BIOX® Circuit

MONITORING METRICS

The bacterial oxidation circuit consists of a feed surge tank, six BIOX® reactors with operating volumes of 900 m^3, three 9 m diameter counter current decantation thickeners, and produces a diluted acidic gold-bearing ferric-arsenate liquor.

To maintain consistent recoveries, the health of the BIOX® circuit is monitored via four key metrics, dissolved oxygen levels, ferrous levels, temperature, and pH. If any of these metrics drift out of defined operational limits, then remedial action is taken. Contaminants that can impact the circuit include minerals (e.g., antimony), hydrocarbons, and cyanide species. Rapid rates of change in process operating parameters, such as feed flow rate and air, can also impact the circuit's performance. To mitigate the impact of potentially deleterious minerals on the health of the bacterial population, Fosterville, in collaboration with Commonwealth Scientific and Industrial Research Organisation (CSIRO), are currently trialling a Mineral and Elemental Analyser (MEA) for process slurries. The MEA consists of both a patented CSIRO X-ray diffraction (EDXRD) and an X-ray fluorescence (XRF) analyzer which monitor a continuous flow of slurry from the plant and assess the composition of the stream in real-time, reporting results in 5–10 minute intervals.

A portion of the liberated gold can become suspended in the acidic ferric-arsenate liquid phase as colloidal gold during the oxidation process. This liquid becomes a waste stream during washing of the oxidized solids and the suspended gold is lost. To counteract this and maximize gold recoveries, Fosterville developed a method using the addition of tannin to reduce gold losses through the formation of an iron-tannin precipitate which captures colloidal gold allowing it to report to the cyanide leach circuit for adsorption.

MITIGATING PREG-ROBBING RISKS

In 2008, Fosterville spearheaded the creation of a high temperature preg-robbing mitigation process, today known as 'Heated Leach' and marketed as HiTECC™ (a high-temperature caustic conditioning technology).

This process evolved into a cost-efficient alternative for improving gold recovery when treating preg-robbing and double-refractory ores and concentrates. The preg-robbed gold is efficiently desorbed from the carbonaceous matter and then recovered onto freshly activated carbon.

The simplicity of this process ensures low CAPEX and operating costs are maintained, along with a safe and consistent performance. Fosterville commissioned the world's first commercial installation onsite in 2009, and this successful technology has been demonstrated to increase overall gold recoveries by up to 12%. This technology is also being used successfully in other gold operations around the world.

Figure 2. Heated Leach/ HiTeCC™ Circuit at Fosterville

SUPPORTING AN INTEGRATED WATER BALANCE

The ASTER™ process was developed to deliver an improved and integrated water balance for reuse in BIOX® applications. It has been successfully implemented in three metallurgical facilities around the world, with the Fosterville facility (commissioned in Q1/2021) being the fourth commercial application to-date of the ASTER technology.

The process configuration is modular, with a number of primary oxidation reactors in parallel, feeding a set of secondary reactors in series. This technology can treat leach tailing solutions with concentrations of up to 5,000 mg/L of thiocyanate and degrade them down to concentrations as low as 0.1 mg/L.

DESIGINING A COST-EFFECTIVE METALLURGICAL OPERATION

The metallurgical team at Fosterville established an ASTER™ pilot in 2017, commencing a test work program in partnership with Metso Outotec. The test work campaign focused on adapting locally sourced microbes to the Fosterville tailings solution and optimizing the process parameters accordingly. The success of the testing confirmed the required destruction rates and other process design criteria allowing Fosterville and Metso Outotec to develop a specific remediation process design for the facility.

This ASTER™ facility has been designed to treat 792 m^3/d with a feed of up to 5,000 mg/L thiocyanate. The processing is solution based, and thus the reactors

Figure 3. Fosterville ASTER™ facility in Victoria, Australia

have no installed agitators with homogenisation brought about by aeration only.

The Fosterville plant consists of six tanks each with an operating volume of 180 m^3, followed by a static settler. The static settler enables recycling of thickened biomass to the reactors, thereby increasing the biomass concentration and increasing the thiocyanate degradation rate. The feed to the reactors is heated to maintain the optimum temperature for the bacterial culture. Construction of the plant commenced in 2019 and commissioned in Q1/2021.

STRENGTH IN PARTNERSHIPS

The collaboration and partnership between various industry groups, research facilities, and Agnico Eagles Fosterville Gold Mine has allowed the mine to enhance their operations and output. Since its implementation, BIOX® has proven to be reliable by consistently achieving recoveries through the BIOX® circuit over 99%. The Heated Leach/ HiTeCC™ treatment of the CIL plant residue can increase overall gold recovery by over 10% depending on mineralogy, and water treatment processes have resulted in the degradation of thiocyanate levels as high as 2,500 ppm in leach tailings solutions to below 0.2 ppm.

Close collaboration, dynamic relationships, and an open mindset to the implementation of advancing technologies has assisted in establishing Fosterville as one of the highest grade and lowest gold-only cost producers in Australia. There is strength in partnerships and that's why, together, Fosterville see themselves as partners for positive change.

REFERENCES

- *'Fosterville Gold Mine – Adapting to new challenges', A. Nash et al, 15th AusIMM Mill Operators Conference. June 2021*
- *Recovery of Colloidal Gold from Oxidised Concentrate Wash Liquor', R. Symes, 10th AusIMM Mill Operators Conference. Oct 2009*

About Mineral Processing Working Group

This working group, formerly the Industrial Comminution Efficiency Working Group, is a community of interest for operators, suppliers, subject-matter experts, and other stakeholders interested in discussing and addressing common industry challenges for mineral processing.

About Sustainability Working Group

This Working Group aims to develop resources and foster collaboration on operationalizing sustainability, which refers to the process of making sustainability practical, implemented, measurable, technically applied, and integrated throughout operations. This group will focus on addressing a range of topics with a focus on best practices, guidance, strategies, and tools to enable incremental and short-term practical changes that will help to create more sustainable operations.

About GMG

The Global Mining Guidelines Group (GMG) is a network of representatives from mining companies, original equipment manufacturers (OEMs), original technology manufacturers (OTMs), research organizations, academia, regulatory agencies, consultancies, and industry associations who collaborate to tackle the challenges facing our industry. GMG aims to accelerate the improvement of mining performance, safety, and sustainability by creating guidelines and white papers that address common industry challenges, facilitating collaboration and expanding the industry's knowledge base. GMG also hosts and supports events that bring mining stakeholders together along with external industries to address the industry's challenges, successes, and innovations. Learn more about GMG at https://gmggroup.org/

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