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ALTA 2020 Gold-PM Conference

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ALTA

ALTA Metallurgical Services

Celebrating 35 years of service

about us

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Alan Taylor has over 40 years' experience in the metallurgical, mineral and chemical processing industries in Australasia, New Zealand, North and South America, Africa, Asia and Europe. He has worked in metallurgical consulting, project development, engineering/construction, plant operations, plant start-up and technology development. Projects and studies have involved copper, gold/silver, nickel/cobalt, uranium and base metals.

Since 1985, as an independent metallurgical consultant, Alan has undertaken feasibility studies, project assessment, project development, supervision of testwork, flowsheet development, basic engineering, supervision of detailed engineering, plant commissioning and peer reviews and audits. Clients have included a variety of major and junior mining, exploration and engineering companies throughout Australia and overseas.

Alan is Founder and Chair of the annual ALTA metallurgical conference.

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Gold-PM Proceedings Contents

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Gold-PM Proceedings

Keynote Address

Gold-PM Keynote

POX – HAS IT REACHED ITS FULL POTENTIAL, OR IS THERE STILL ROOM FOR IMPROVEMENT FOR TREATING REFRACTORY GOLD ORES?

By

Karel Osten
Consulting Metallurgist
METTKO Pty Ltd

ABSTRACT

As many will already know, pressure oxidation (POX) is an oxidative pre-treatment of refractory (sulphide hosted) gold ores and concentrates prior to leaching and recovery of gold typically by cyanidation and recovery onto activated carbon. Commercial gold POX operations use one or more horizontal multi compartment pressure vessels lined with a corrosion barrier and layers of protective masonry. Agitators in each compartment to provide mixing and most importantly mass transfer of gaseous oxygen for the aqueous oxidation of the sulphides and their reaction products such as iron and arsenic. Operating temperatures typically range from 200°C to 230°C at pressures of between 25 bar.g and 35 bar.g. The high pressure allows for an increase in dissolved oxygen concentration to drive mass transfer and the high temperature significantly increases reaction rates and consequently process intensity. For example, at these elevated conditions the reactions may be complete within less than 60 minutes in comparison to leaching at atmospheric conditions which may require 20 hours or more for the same oxidation extent.

The characteristics of high process intensity, efficient oxygen utilisation, high gold recovery and robust process performance have made POX the technology of choice in recent year for major refractory gold projects. These include the Copler Sulfide Expansion Project in Turkey, the Mansourah & Massarah Project in Saudi Arabia, the Amursk and Petropavlovsk POX Hubs in Russia, and Pueblo Viejo in the Dominican Republic. Closer to home, the POX operations at Porgera and Lihir in Papua New Guinea and Macreas in New Zealand have each been operating for more than 20 years.

In spite of this commercial success the author contends there is still room for improvement, but having said this, what do we understand by the term “improvement”? This could simply be seen in a process context, improved extractions, reduced residence times, improved oxygen utilisation and so on. Alternatively, there are issues of reliability such as the life of vessel linings, severe service control valves and agitator impellers. In an overall sense however, the author’s view is that the three key areas for improvement in the control of the designer and operating company can be captured in terms of improved safety, reduced capital cost and increased operating time. Low operating costs inputs such as labour and power costs are obviously beneficial, but these are generally a function of the site location and do not represent an improvement to design or operation. That said if the three suggested improvements are addressed these will naturally lead to a reduced operating cost and thus to improved economic outcomes.

Operational safety provides a legal and ethical license to operate. Although historical performance has been adequate, avoidable incidents have occurred that potentially could have been more significant. In some ways understandably, many incidents and near misses have been downplayed by operating companies so the full picture is unclear, particularly in light of the geographic and corporate spread of operating sites and corporate offices. It is the author’s contention that greater transparency and a better understanding of the potential risks is required whether by designers, operators or regulators given the contained energy of these systems and the potential consequences of failure.

The process efficiency of POX technology is well established but the technology is complex and together with the associated oxygen production facility are the most capital-intensive areas of the process plant. An oft voiced criticism of POX is its capital cost, and certainly compared to less sophisticated processes this is a step up from what some may be used to. The capital intensity of the technology demands additional diligence in terms of project definition and engineering to ensure that the ultimate design is pragmatic and fit for purpose, in other words not wastefully over designed or under designed to the point that the project is unsuccessful. In principal this is no different for any other project but given the high capital intensity the negative consequences of poor project definition, excessive design margins or errors are significantly magnified. Once in service, changes to the design are generally challenging to execute and impose a significant cost burden not only for the modification itself but also in terms of the opportunity cost of the interruption to production.

Maximising operating time is another means of increasing plant throughput for a given plant capacity. In other words, for a given nominal plant capacity a smaller plant is required resulting in lower capital and operating costs if properly defined, designed and operated. Consistent operation with a sustainable increase in operating time is indicative of improved safety performance and lower maintenance costs.

This keynote invites a review of the past, the present, and more subjectively a look to the future of the technology. The items for improvement suggested above together with some purely technical opportunities will be discussed in the context of the title of this paper.

Keywords: Refractory Gold, Pressure Oxidation, Improvement

Gold-PM Proceedings

PhotonAssaying

PHOTONASSAY UPDATE: VALIDATION WORK, GOLD PERFORMANCE IMPROVEMENTS AND PROSPECTIVE SILVER AND MOISTURE SERVICES

By

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Presenter and Corresponding Author

Olivia Lannan

ABSTRACT

Assaying for gold and other valuable metals in ore samples is crucial for mineral exploration and deposit evaluation and exploitation. Mining companies conventionally rely on destructive chemical techniques, such as fire-assay, to ascertain gold grades. These methods are time consuming, labour intensive and involve caustic or toxic reagents that pose both OH&S and environmental concerns.

In 2017, we introduced the concept for an alternative approach, PhotonAssay, that enables non-destructive, accurate, and fully automated bulk analysis of gold and other elements using high-energy X-rays. The larger sample sizes used in PhotonAssay are beneficial for resource evaluation and grade control applications, as sample preparation requirements are simplified and sampling errors reduced.

The first PhotonAssay system was deployed to MinAnalytical Laboratory Services' Perth facility in 2018, and two additional systems were deployed to their Kalgoorlie facility in 2019. These three units have a combined capacity in excess of 1.5M samples per annum. The units deliver rapid and reliable results, including a 24-hour turn-around PhotonAssay service.

Since the installation of the first system, hardware and software improvements have resulted in improved gold measurement precision, and a reduction in the 3-sigma detection limit on blank materials to approximately 0.012 ppm. We present data on the system performance on a wide range of reference and real ore materials.

Extensive testing and validation of the PhotonAssay technology on over 10,000 samples has led to PhotonAssay receiving NATA accreditation in 2018, and the technology has been used in both NI 43-101 compliant studies and JORC-compliant ASX reports. Over 50 comparative studies of PhotonAssay and fire-assay have been conducted using material from mining operations around the world and a selection of these results will be presented. These tests demonstrate that the two methods can be used interchangeably for a wide range of deposit types, with PhotonAssay samples requiring significantly less preparation.

PhotonAssay can be extended to other commercially important elements such as silver, as well as samples with substantial moisture content. We discuss the development, implications and expected performance of these new services. Simultaneous multi-element analysis and the ability to measure undried samples provide further opportunities to reduce sample analysis and preparation times.

Keywords: Gold Assay, Fire-assay, Activation analysis, X-ray analysis

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Gold-PM Proceedings

Cyanide Alleviation & Alternative Lixiviants Forum

RECYN III – THE NEW GENERATION OF GOLD PLANTS- REPLACING CARBON.

By

Malcolm Roy Paterson

PT GreenGold Technology, Indonesia

Presenter and Corresponding Author

Malcolm Roy Paterson

ABSTRACT

The Merrill-Crowe process, introduced at the turn of the 19th century, was for decades the standard method of recovering gold from cyanide solutions through the addition of zinc, and it is still in limited use today.

In the 1970's Merrill-Crowe met competition from activated carbon, which overcame the need for solid-liquid separation and was suited to low-grade oxide ores. Carbon circuits are now the most widely used recovery method, with Merril-Crowe mainly restricted to high silver ores.

Both carbon and Merrill-Crowe systems use cyanide as the gold lixiviant. The negative perception of cyanide as a toxic, environmental contaminant has encouraged researchers to look for an alternate lixiviant. However, there has been a limited success, and cyanide continues to be the mainstay of gold processing(1).

The public perception of cyanide as the bad boy of gold processing is not wholly justified, as the reputation mainly stems from its use in different historical applications and further degraded with several significant dam failures releasing toxic tailings.

GreenGold Technology, (GGT), has taken the view that rather than continue an arduous and time-consuming search for an alternative lixiviant, the effort is better directed to enhancing what is a proven, cost-effective, and efficient product.

GGT initially aimed the commercialisation of the ReCYN process at recycling cyanide from gold plant tailings to reduce the quantity of cyanide purchased (ReCYN I) and detoxifying CIL tailings before discharge to a storage facility (ReCYN II). Both these objectives result in a nett revenue instead of the high cost of destructive detox methods.

Clean-up of plant tailings with the ReCYN process also involved the scavenging of residual solubilised gold escaping the carbon circuit. The question coming back from mining companies is "Can ReCYN fill all three objectives of recovering cyanide, detoxifying tailings, and being the primary circuit for recovering gold"?

Hence ReCYN III, which combines active (Free) cyanide recycle, complexed cyanide metal recovery and gold/silver recovery in a single, simplified circuit.

Two previous ALTA papers, (2017, 2019), have described ReCYN I and ReCYN II. The following article describes the ReCYN III process and its application to the Mt. Morgan Tailings Project in Queensland.

Keywords: Cyanide, gold, copper, resin, carbon, detoxify, recovery, economic and environmental.

NON-TOXIC REAGENT FOR GOLD LEACHING

By

Kristina Kazakoff and Paul Kelly

Clean Mining Ltd – part of the Clean Earth Technologies Group, Australia

Presenter and Corresponding Author

Kristina Kazakoff

ABSTRACT

Clean Mining's new technology reflects a decade of development by Australia's national science agency, the Commonwealth Scientific and Industrial Research Organisation (CSIRO). Our parent company – Eco Minerals Research Limited – partnered with CSIRO in 2018 to build the first Clean Gold processing plant to refine and test the technology in an industrial setting. The success of the trial, established in the rich, historic Kalgoorlie goldfields of Western Australia, led to Clean Mining acquiring the patented technology from CSIRO. With the rights to produce, distribute and develop the technology worldwide, Clean Mining has now embarked on a global sales and distribution program – enabling miners around the world to access the solution that will transform their operations.

The innovative, cost-effective processing technology replaces cyanide with a safer, less hazardous chemical reagent, thiosulphate. This inorganic compound helps dissolve fine gold out of ores into a solution, which can then be recovered through further processing.

Currently, around 75% of gold extracted from ore is processed using the hazardous chemicals of cyanide or mercury, which are toxic to humans and the environment. These chemicals are often contained in large storage tanks and, once used, expelled into large tailing dams that can potentially leach into the local surrounds or, worse, burst as we've seen in recent years in Brazil and Canada. Eliminating cyanide and the associated tailing dams from the gold recovery process is a game-changer for the sector and, importantly, for the communities where gold miners operate. The new technology is suitable for new greenfields mines, locations where cyanide cannot be used or is banned, as well as in existing mines looking to upgrade and transition to the new technology.

Clean' Mining means much more than eliminating traditional toxic mining processes involving cyanide and mercury. The concept of 'clean' goes further to embrace practices, enterprises and operators that are responsible, transparent, honest, reliable and have integrity. The 'clean' approach is demonstrated in how employees, communities, customers, clients, regulators and other authorities are valued and respected. Our own processes, business dealings and obligations to communities, the environment and governments reflect this philosophy.

Keywords: Clean Mining, Thiosulphate, non-toxic

NON AND REDUCED CYANIDE GOLD EXTRACTION SYSTEMS

By

Frank Trask

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Presenter and Corresponding Author

Frank Trask

ABSTRACT

Mining and Process Solutions are the owner of several patents that use glycine to extract gold and other base metals from ores. These processes are in varying stages of development and vary from advanced pilot plant stage to experimental.

The most advanced process is our GlyCat^{TM} technology that uses a glycine base under cyanide starved conditions. It requires the need for oxygen but works best with small amounts of copper, that seems to enhance the ability of both the cyanide and glycine to extract gold quicker under lower reagent concentrations.

Next advanced is our glycine alone process. Glycine is capable of slowly leaching gold at ambient temperatures but when the pH is made quite basic (pH >12.5) and the temperature increased, leaching rate are dramatically improved. MPS are evaluating this process for in situ and In Mine leaching purposes.

There are a number of chemicals that can be combined with glycine in basic solutions that do not use cyanide. The principal combination being studied is glycine combined with potassium or sodium ferricyanide. The ferricyanide salt is commonly used as a food additive. At very high concentrations ferricyanide is known to be able to leach gold by itself but when combined with glycine, it has proven to be able to leach gold at much lower concentrations. The second option is glycine combined with sodium or potassium permanganate. The chemistry is still not well defined, but there is enough empirical data that demonstrates good gold recovery from a number of different ores.

Lastly, there is our acidic G&T process which operates in an acid environment. It uses thiourea, which is a well-known lixiviant for gold. The typical thiourea leaching of gold operates in a reasonably acidic environment (pH 1-2) and uses ferric ion as an oxidant. However, the process suffers from high reagent consumption due to the ferric ion also oxidising and destroying the thiourea and this demands very high thiourea concentrations. When glycine and thiourea are used in combination in much lower concentrations at pH values between 2 to 6 it can be a very efficient process to extract gold from ores.

The last 4 glycine processes are still in experimental stage, but MPS/Curtin are expending a lot of effort in developing their capabilities. Glycine technology offers a means to not only extract the gold but also other base metals.

Keywords glycine, GlyCat^{TM}, potassium ferricyanide, potassium permanganate, thiourea

MEASURING GOLD LIXIVIANT CONCENTRATIONS: LET'S MAKE IT EASY FOR THE OPERATORS

By

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Presenter and Corresponding Author

Danielle Thompson

ABSTRACT

Interest in the applicability of chemical systems (other than cyanide-only) in full-scale, gold recovery processes is increasing year on year with notable applications now in the treatment of carbonaceous ores (thiosulfate), high copper-bearing, gold ores (glycine via the GlyCat™ process) and in situ recovery. At the core of a successful gold recovery process – regardless of the chemical system used – is the need to be able to measure (and maintain) the lixiviant's concentration (to ensure the desired gold recovery rate is achieved). At full-scale gold operations (that use cyanide), the measurement and control of the lixiviant is relatively straight-forward, with the free cyanide in the leach typically measured by titration against silver nitrate using either rhodanine indicator (visual end-point) or potentiometrically using a silver wire. This method (for the most part) is considered suitable for process plant operators to use as it is easy, efficient and generates results that are easy to interpret – there are some exceptions, of course! For some of the other chemical systems, however, the measurement of the lixiviant concentration requires complicated techniques. In addition, many of methods generate outputs that require a significant amount of expert analysis and interpretation (to enable an accurate measurement). For the research community, this is likely to be inconsequential; however, for process plant operators, this can be challenging (especially if they are inexperienced in the methodologies being used).

This paper reviews the methods currently in use by both the research and early-stage-of-commercialisation communities (especially where the work is being conducted at the small scale) and reflects upon the applicability of these methods within a full-scale, commercial context.

Keywords: Gold lixiviants, lixiviant control, analytical methods

THIOCYANATE RECOVERY FROM WASTE SOLUTIONS USING SOLVENT EXTRACTION

By

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David Dreisinger

ABSTRACT

Thiocyanate may be formed by reaction between sulfur and cyanide in alkaline gold processing. Thiocyanate formation may be a significant consumer of cyanide when cyanide leaching sulfur-rich ores and residues (e.g. elemental sulfur-forming atmospheric or pressure leach residues). Thiocyanate may also be used as a reagent for gold leaching from acid solutions. Thiocyanate is also used widely as a chemical in other pharmaceutical and industrial applications.

The recovery of thiocyanate from waste solutions by solvent extraction using LIX 7820 has been demonstrated. LIX 7820 is a mixed reagent containing quaternary amine (Aliquat 336) and nonyl phenol. Aliquat 336 is a strong extractant for thiocyanate and by itself is difficult to strip. Nonyl phenol is deprotonated to form an anion at pH +12 which competes successfully with thiocyanate for loading. This behaviour assists in the stripping reaction of thiocyanate from LIX 7820.

A complete solvent extraction process concept has been developed for thiocyanate recovery from simulated gold plant effluents to produce a strong thiocyanate strip solution for further use (e.g. Recycle or regeneration of cyanide) or sale (commercial grade calcium or sodium thiocyanate solutions).

Keywords: Gold processing, thiocyanate, solvent extraction, environmental treatment

LIFE CYCLE ASSESSMENT OF HYDROMETALLURGICAL PROCESSES BASED ON FLOWSHEET SIMULATION – CASE STUDY OF GOLD FROM THE DEPOSIT WITH BATTERY METALS

By

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Presenter

Marja Rinne

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Mari Lundström

ABSTRACT

Gold and platinum group metals are frequently recovered as byproducts from the processing of sulfidic nickel and copper concentrates. The conventional way to treat these raw materials is by matte smelting and refining, which is becoming increasingly costly and energy intensive due to the diminishing ore grades and increasing complexity of raw materials. There is a demand for more flexible and environmentally friendly processes, and several hydrometallurgical flowsheets have been developed for the recovery of base and precious metals from complex ores. The development of novel processes is slow, and it is therefore essential to evaluate their performance and environmental impacts long before industrial realization. Process simulation and life-cycle assessment are effective tools in assessing key information such as plant water balance and the properties of waste streams based on laboratory-scale results during the development stage.

Sustainable recovery of battery metals and cyanide-free leaching of gold have both been extensively studied in the Research group of Hydrometallurgy and Corrosion at Aalto University. This study combines the two topics by demonstrating the option of a two-step leaching process to recover nickel and gold from a Finnish Ni-Cu-PM sulfide concentrate through process modeling. In the first leaching step, the sulfides in the ore are pressure-oxidized, and copper and nickel are recovered through sulfide precipitation. The leaching residue rich in precious metals is subjected to a second leach in cupric chloride media to dissolve and recover gold. The process was simulated with HSC-Sim 9, and the life cycle assessment (LCA) was conducted with GaBi software.

Keywords: Gold processing, Battery metals, HSC Chemistry, Process simulation, Complex ore processing

Gold-PM Proceedings

Refractory Ores

AN INVESTIGATION OF PRESSURE, ATMOSPHERIC AND BACTERIAL OXIDATION PROCESSES FOR THE TREATMENT OF A REFRACTORY GOLD CONCENTRATE

By

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Presenter

Chad Czerny

ABSTRACT

Hydrometallurgical processing of refractory gold ores often entails the production of a gold-rich bulk sulphide concentrate which then requires oxidation to enable recovery of the precious metals by cyanidation leaching. Whilst it can be argued that there are some key similarities in the chemical mechanism(s) whereby the key sulphide minerals are oxidised, there is no question that the chemical and mineralogical compositions of the oxidation products vary depending on the oxidation process that is used.

Metallurgical testwork was undertaken by SGS Minerals Metallurgy (Malaga, Western Australia) in which a refractory gold ore was beneficiated by bench-scale flotation to produce a bulk sulphide concentrate containing 10-11 g/t Au, 13-14% S, 11-12% Fe, 0.2% C and 2.4% As. Mineralogical analyses showed that the gold in the primary ore was primarily associated with pyrite, and arsenian pyrite.

The amenability of the concentrate to oxidative leaching was investigated by testing using three different processes: (i) mesophile bacteria in an agitated oxygenated reactor, (ii) intensive agitation under atmospheric conditions, and (iii) autoclave pressure oxidation (POX). Timed samples were collected used to measure the sulphur speciation in the leach residues, and thus establish the sulphur oxidation kinetics. Selected residue samples were also subjected to batch cyanide leach (bottle roll) tests to investigate the relationship between gold leach extractions, and the extent of sulphur oxidation. The elemental compositions of the leach solutions and residues were measured by ICP-OES/MS and lithium metaborate fusion-XRF methods, respectively, which enabled the deportments of iron, and arsenic, for example, to be determined.

The pressure leach tests were conducted at test conditions of: 210 to 225 °C, 2500 to 3000 kPa, with oxygen overpressures of 500 to 700kPa and up to 120 mins residence time, whilst the atmospheric leaching was performed at 90 °C for 48 hrs with oxygen sparging, and limestone addition to maintain a slurry pH of ~5. Bacterial leaching entailed adaptation of a mesophile bacterial inoculum to the concentrate which was then used to conduct the bioreactor tests. The duration of the bacterial leach test ranged between 3 and 4 weeks. For each process examined, intermediate and final oxidation products were taken to evaluate their chemical and mineralogical composition.

The major findings are reported and used to illustrate the relative performance of each process under the conditions examined. Relationships between overall gold recovery via intensive cyanide leaching under standard conditions, and the extent of sulphide oxidation are presented and discussed.

Gold recoveries from oxidised residues (by cyanide leaching) displayed a strong positive correlation with the extent of sulphide sulphur oxidation. Similar gold extractions were obtained from the residues generated by each process, at the same degree of sulphur oxidation. However the extents of iron and arsenic fixation in the final leach residues was dependent on the process used, as expected.

Keywords: Gold, Sulfide, Ore, Refractory, Oxidation, Leaching, Bacterial, POX, Cyanidation

RECENT DEVELOPMENTS IN THE METSO OUTOTEC BIOX® PROCESS

By

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Outotec BIOMIN Pty Ltd, South Africa

Presenter and Corresponding Author

Jan van Niekerk

ABSTRACT

RioZim selected BIOX® as the preferred technology for the treatment of the refractory gold concentrate for their Cam & Motor gold mine located near the town of Kadoma, approximately one hour's drive south-west of Harare, Zimbabwe. The BIOX plant was designed for an ultimate capacity of 200 tpd of concentrate, but the project will be implemented in two phases: phase 1 will have a capacity of 100 tpd, which will be expanded to 200 tpd in phase 2. The project is currently in construction and commissioning is expected to take place during Q2–Q3 of 2020.

The Fosterville mine is a high-grade, low-cost underground gold mine located 20 km from the city of Bendigo in the State of Victoria, Australia. The current operation was commissioned in 2005 and includes a BIOX plant. Fosterville has been evaluating the implementation of the Metso Outotec ASTER™ process for a number of years to improve the mine water balance by allowing treatment and then recycling of tailings dam water back into the process. In 2019 Fosterville decided to continue with the implementation of the ASTER plant, which will be the fourth application of ASTER technology.

Metso Outotec has developed and commercialised the MesoThem process, using a combination of mesophilic bacteria as the primary oxidation stage followed by thermophilic bacteria, operating at ~ 65°C, to complete the oxidation. The higher operating temperature in the thermophile stage allows for more complete oxidation of the sulphur in the concentrate, thereby reducing the cyanide consumption during the subsequent cyanidation step. Development of the process was done at Pan African Resources' Fairview BIOX plant, located near the town of Barberton in South Africa.

Development included operating the process at different scales, from a 120 l continuous pilot plant through 1 m^3 and 21 m^3 demonstration scale tanks. The final step in the development of the process included converting one of the secondary BIOX reactors at Fairview into a thermophile reactor. The results confirmed that the process was able to operate stably at the different reactor sizes and generate consistent results. Scaling the process up sequentially allowed for confirmation of the design equations and operating procedures at the different reactor sizes.

Keywords: RioZim, Cam&Motor, Obuasi, Fosterville, BIOX, ASTER, MesoTherm, Refractory, Gold, Fairview

COMMISSIONING EXPERIENCE ON RECENT OUTOTEC POX PROJECTS

By

Antti Saarikoski and Tuomas Hirsi

Metso Outotec, Finland

Presenter and Corresponding Author

Antti Saarikoski

ABSTRACT

Commissioning of a new hydrometallurgical plant always brings challenges and as well as successes. Outotec Pressure oxidation (POX) delivery projects at Pokrovskiy, Russia and Mazidagi, Turkey came to the commissioning stage in The late 2018. Pokrovskiy project was originally designed in 2010, but the commissioning of the plant was delayed to 2018. Mazidagi project design work started 2014 and project delivery and commissioning were a continuous timeline without significant delays. Outotec provided process and equipment design, equipment delivery and commissioning services to both plants. Both plants commissioning has been characterized by fast production ramp-up to nominal capacity without significant health and safety issues.

The Mazidagi plant owned and operated by Eti Bakir A.S was originally designed for 46.9 tph calcine feed. The Pokrovsky plant owned and operated by Petropavlovsk Plc was originally designed for 52 tph concentrate feed. The Mazidagi plant was designed with a single autoclave train while Petropavlovsk was designed with 4 parallel trains due to logistics reasons.

Now both plants are moving from commissioning phase to normal operation. Both sites were characterized by a large proprietary equipment delivery from Outotec as well as the holistic design overview of the plant and the process. Changes between the plants were due to the different design fundamentals reflecting also the time when the design took place. Also new material development played an important role in the overall design of the plants.

This paper summarizes the experiences from site commissioning and presents the strong effect design phase decisions had on the commissioning stage. The most crucial elements for successful project execution are highlighted.

Keywords: Pressure Oxidation, Autoclave, Process optimization, Gold,

EXTRACT MORE OUNCES WITH THE MACH REACTOR

By

Adrian Singh

Gold Ore Pty Ltd, South Africa

Presenter and Corresponding Author

Adrian Singh

ABSTRACT

The gold industry today is beset with many challenges such as:

- The treatment of refractory and semi refractory ores which are often preg robbing as well
- The retreatment of gold tailings deposits often at low grades and low recoveries
- Process bottlenecks related to kinetics
- Increasing reagent consumptions and costs
- Pressure to reduce toxic discharge such as cyanide and arsenic onto tailings dams
- Operating plants with significantly reduced workforce owing to pandemics such as Covid 19

With the whole world having to cope with the Covid 19 pandemic, never before has there been such immense pressure to improve efficiency, reduce costs, reduce staff complements and to operate in an environmentally responsible manner. Many companies face the threat of closure and retrenchments unless novel, out of the box solutions can be found, evaluated and implemented timeously.

This paper highlights how the cutting-edge MACH reactor technology may be employed to improve kinetics and recovery and reduce cyanide consumption, against the backdrop of a gold price that has shown a steady upward trend over the past five years, to significantly improve the profitability of metallurgical operations and save jobs. The MACH reactor may be the last piece of the puzzle to ensure the economic feasibility of marginal projects.

The paper will also explain how the MACH reactor may be used to improve the performance of cyanide destruction and arsenic remediation systems in order to meet the stringent requirements of environmental discharge.

The MACH reactor is positioned at the pinnacle of shear/cavitation reactor efficiency and harnesses the incredible energy of cavitation to clean particle surfaces, break particles and improve liberation and create an environment that allows certain chemical reactions to proceed that would otherwise not be possible.

The nucleation of pico bubbles directly onto fine particles also improves flotation performance with regards to both grade and recovery with lower mass pulls to create a flotation euphoria hitherto not witnessed in the industry. The MACH reactor provides a completely new and steepened grade recovery curve for operators to work with to extract the maximum value from their ore.

Keywords: MACH Reactor, cavitation reactor, pico bubbles, semi refractory ore, tailings dam retreatment, cyanide destruction, improved recovery, improved kinetics, reduced reagent consumption, improved profitability, improved grade recovery curves

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Ion Exchange

ION EXCHANGE – BRINGING FLEXIBILITY, ROBUSTNESS, AND HIGHER RECOVERIES TO MINE WATER TREATMENT

By

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ABSTRACT

When Kirkland Lake Gold acquired the Fosterville mine, an excess mine water situation from the dewatering of underground operations was expected. Regulatory approval to treat excess mine water using a water treatment plant consisting of RO, precipitation and ion exchange processes was obtained. RO technology is now mature and the process designed so that the concentrated brine by-product from the RO could be evaporated from a new evaporation pond after accounting for seasonal rainfall. The treated water could be reused in the process to reduce the sites reliance on make-up water from outside. Excess treated mine water quality from the water treatment plant allows for it to be stored underground in an aquifer.

Much less was certain about the ion exchange process preceding the RO. Well before membranes came into today's water treatment picture ion exchange processes were used to reduce cations and ions in a 2-stage process. Sulphates and hardness can be reduced through ion exchange to raise the RO recovery and reduce the amount brine by product. Lingering doubts remained at site over the espoused performance, from the smaller footprint and reduced resin inventory that the proposed continuous ionic filtration could deliver. Is it possible for this less understood technology, to minimize brine ponds or even eliminate them altogether one day ?

Keywords: Mine water treatment, softening, AMD, acid mine drainage, desalination, RO, ion exchange, zero liquid discharge, minimum liquid discharge, water recycling, water treatment, wastewater

EVALUATION OF ION EXCHANGE TECHNOLOGY FOR AU RECOVERY FROM COMPLEX ORES CONTAINING CU AND PREG-ROBBING MATERIAL

By

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ABSTRACT

The presence of copper-containing minerals in gold (Au) ore is quite common and this can present processing challenges because copper (Cu) forms stable complexes with cyanide (CN). Additionally, carbonaceous material in gold deposits causes preg-robbing whereby soluble gold is adsorbed and thereby lost to the residue. The combined presence of preg-robbing material and copper results in poor gold recovery in conventional Carbon-in-Leach (CIL) processing. Resin-in-Leach (RIL) technology is considered an attractive option for processing of preg-robbing ores containing high Cu, since the ion exchange resins offer the advantage of selectivity for Au over Cu. This means that the resin can compete with the carbonaceous material for the soluble Au cyanide complex.

Mintek recently conducted a study to evaluate the performance of various available gold selective resins for Au recovery from Au/Cu solution with and without the presence of extremely preg-robbing material in the form of 5 g/l fine carbon. The effect of temperature on the gold recovery by the resin was included in the study. Test work involved adsorption equilibrium isotherms conducted on synthetic solution and resins with tri-butylamine (TBA), guanidine and bis-picolylamine (BPA) functional groups.

Resins with the TBA functionality resulted in the best performance with higher Au loading and higher Au/Cu selectivity whereas the resin with BPA functionality had relatively low Au loading but co-loaded lesser quantities of Cu. The presence of the preg-robbing material adversely affected the performance of all resins. However, at elevated temperature (60˚C) efficient Au recovery (>90%) at relatively high Au loading was achieved with the TBA resins. Cu co-loading was high as it was not affected by the presence of the pre-robbing material and this aspect will have to be resolved in the elution strategy.

RIL with either TBA or BPA resin can be considered for processing of Au/Cu ores. RIL using TBA resin at elevated temperatures would be required for processing material with a high level of preg-robbing effects.

Keywords: gold, copper, preg-robbing, resin, RIP

IMPROVE SILVER REFINING QUALITY AND QUANTITY: REGENERABLE ION-EXCHANGE RESIN FOR HIGHLY SELECTIVE PALLADIUM CAPTURE IN NITRIC ACID

By

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ABSTRACT

Most precious metals refineries produce silver by electrorefining. In the electrolysis process, silver anodes may contain palladium, which is prone to transfer to the electrolyte and the fine silver. The intensity of its transfer is directly dependent on the palladium content and current strength. This represents a loss of valuable palladium and limits the capacity of an electrorefining installation, increasing the lead time of the silver purification process.

In this paper, we show that the use of selective ion-exchange resin and sorption technologies makes it possible to selectively remove Pd from the Ag-electrolyte and, consequently, increase the current of silver electrolysis. In this system, the palladium is recovered for separate refining and resale.

Krastsvetmet's silver electrorefining was upgraded with such ion-exchange purification Upon installation, the electrolyte has become free of palladium increasing quality of the refined silver and increasing the throughput of the installation. The eluted palladium has been treated in the palladium refining flow-sheet for a full recovery. This paper will cover the practical results from Krastsvetmet's operations with industrial-scale skid, integrated into silver refining flowsheet.

Keywords: Axion, Krastsvetmet, Silver, Palladium, Ion-exchange, Electrorefining, Electrowinning

THE APPLICATION OF ORE SORTING TECHNOLOGY TO UPGRADE OF GOLD ORES

By

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ABSTRACT

Sensor-based automatic ore sorting technologies are used in the minerals industries to efficiently remove waste and sub-marginal grade material from crushed and screened run of mine (ROM) ore, producing a coarse (typically >10mm) upgraded pre-concentrate at an early stage in the mineral processing circuit. This can result in a significant uplift in ROM grade while maintaining a high recovery, thereby avoiding additional energy intensive downstream processing of this rejected component of the ROM feed.

In greenfields projects ore sorting which achieves significant levels of gangue rejection opens the possibility of a reduction in downstream processing plant capacity, leading to lower capital expenditure, potentially reduced unit operating costs, reduced water consumption and reduced environmental impact through reduced tailings disposal volumes.

Waste rejection through ore sorting can also enable:

- 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.

This paper provides an overview of ore sorting technology and the status of ore sorting in gold mining and processing operations. A review of some of the factors that may influence uptake of the technology is discussed.

Keywords: Sensor Ore Sorting, Single Particle Sorting, Preconcentration, Mine Expansion, Low-Grade Stockpiles, Ore Trucking.