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Gold-PM Conference

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Alan Tayor 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 as 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.

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• Copper	• Process Development	• Solid/liquid separation
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• Gold/Silver	• Technical & Economic Evaluations	• Electrowinning & electrorefining
• Base Metals	• Feasibility Studies	• Precipitation
	• Plant Design	• Cyanidation & CIP/CIL
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ALTA 2019 Gold-PM Proceedings Contents

Gold-PM Proceedings

Keynote Address

Gold-PM Keynote

FIT-FOR-PURPOSE PRECIOUS METALS LEACH SYSTEMS: MATCHING LEACH STRATEGIES TO SOURCE CHARACTERISTICS

By

Prof Jacques Eksteen
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ABSTRACT

The gold industry has been supporting research into alternative lixiviants over a number of decades. However, it may sometimes appear to the casual observer that the industry is no closer now than it was 20 years ago to implementing a feasible solution at multiple sites. Although one industrial calcium thiosulfate plant has been commissioned, not many new processes have progressed beyond pilot scale. Often the problem lies in the fact that one-size-fits-all lixiviants are sought and it is clear that such a panacea does not exist. Ore mineralogy and chemistry, environmental conditions and water availability, mobilisation of toxic deleterious elements and creation of toxic by-products remain challenges, over and above the general required attributes such as sufficiently fast kinetics, low reagent consumption, low reagent price, reagent and gold complex stability, and the need to recycle reagent which mostly involve expensive solid-liquid separation equipment. Moreover, as leaching is only one part of the process, and metal recovery from solution, reagent recovery and recycle, waste bleed streams and downstream recovery, refining and waste treatment processes need to be technically and economically feasible while still offering lowered environmental and safety risks. Cyanide based processing has been particularly robust given a combination of the requirement of limited (if any) piloting required, biodegradability in tailing impoundments, and a process that is well understood by engineering companies (yet complexities remains often underestimated due to poor understanding of reagent-gangue mineral interactions).

This paper will explore a few of alternative lixiviants and contrast it to cyanide leaching. It will look at the attributes that modern lixiviant systems need to have to make them technically, environmentally and economically attractive from an overall processing perspective. It will be shown that an intelligent and engineered approach is required in modern gold extraction. In many cases cyanide may still suffice, but a fit-for purpose lixiviant evaluation is required to ensure that leaching processes are optimal for the ore, the site, the environment and the process economics. One of the key challenges in modern processing engineers is the lack of understanding of the overall process chemistry, mineralogy and by-product formation and a lack of risk appetite for process chemistries that are not well understood. Often process engineers are more comfortable with changes in mechanical process technology than changes in the chemistry that underpins the process. This risk aversion to changes in process chemistry is even more pronounced amongst mining engineers, geologists and mining company executives making the selection of alternative process chemistries a hard sell up the management chain and subsequently to company shareholders where analysts' views are even more conservative.

Keywords: Alternative Lixiviants, Gold, Silver, Deleterious Elements, Recovery Processes, Lixiviant Attributes

Gold-PM Proceedings

Application of IX

GO FOR GOLD AND IGNORE CYANIDE SOLUBLE COPPER
A NEW APPROACH TO GOLD-COPPER ORES

By

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Presenter and Corresponding Author

Malcolm Paterson

ABSTRACT

The Cyanide Soluble Copper (CNsolCu) contained in gold-copper ores has often been the Achilles Heel in making these particular projects economic. It has been a headache for geologists and metallurgists alike. The copper has proven to be more than just a nuisance element, but a determinant in the projects' economic feasibility. In addition to the financial implications, directly quantifying the impact has proven to be a distraction in the assessment of what should be a gold project. The measurement of total copper in the ore is not sufficient to understand the cost impact as it is the cyanide soluble copper that is relevant. Total copper may become important if it can justify the inclusion of a flotation circuit pre or post CIL to produce profitable copper concentrate. However, this aspect should be considered separately as the true economics can be marginal.

The basis of this paper is to show that the application of a simple resin technology, the ReCYN Process, is a game changer in not only solving the cost impact of soluble copper but also in simplifying the assessment of copper/gold ores. The overall benefits are seen to extend beyond the processing costs to improved Reserve estimates[(1)].

The approach is to effectively ignore the cyanide soluble copper and focus on the gold. By incorporating the ReCYN process into the recovery flowsheet, the soluble copper no longer becomes a cost. It can be shown that the additional cyanide consumed in dissolving copper is more than balanced by the recovery of the copper and its associated cyanide by the ReCYN process. The nett cyanide cost is then exclusively related to gold recovery.

As an example, the cyanide soluble copper can increase sodium cyanide consumption to over 15kg/t ore at certain times. Without the soluble copper, the cyanide consumption could be less than 1kg/t ore. This latter figure can now be used in the project economics without reference to CNsolCu, thus simplifying the Resource, Reserve and Process cost estimation.

Cyanide soluble copper also causes downstream processing problems with adsorption onto carbon, impacting gold recovery and increasing detox costs. All these issues are able to be resolved since a higher cyanide level in the leach solution is now possible, due to the lower cost of cyanide recovered by the ReCYN process and the deletion of any detoxification costs.

There is expected to be an increase in the number of new gold projects that have ore associated with copper. Thus the challenge will grow in importance.

This paper describes three diverse examples of the application of ReCYN Technology to problematic gold-copper ores.

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

GOLD RECOVERY VIA ION EXCHANGE RESINS AND ACTIVATED CARBON – A COMPARISON OF TEST WORK METHODS

By

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Presenter and Corresponding Author

Ben Strong

ABSTRACT

Ion exchange resins, that are semi-selective for gold, have been used for gold recovery from leach solutions since the late 1960s, predominantly in the former USSR, but also in some Western operations from the 1980s. The physical and chemical properties of these ion exchange resins require a specific set of laboratory tests to be conducted in flow sheet development phases to ensure process feasibility, as well as for ongoing process monitoring during operations.

Given that CIL/CIP test work processes are generally well understood in the gold sector, this paper compares test work methods and desired data outputs from CIL/CIP test work and RIL/RIP test work, where relevant, and highlights key differences driven by the properties of the relevant adsorbant and chemical system.

This paper considers test work for major process steps, such as leaching, adsorption and desorption, as well as tests for monitoring the ongoing health and performance of each adsorbant.

Keywords: Gold Recovery, Ion Exchange Resin, Test Work

GOLD RECOVERY FROM CARBON FINES

By

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Presenter

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ABSTRACT

Resin-in-Leach (RIL) technology for gold recovery from carbon fines has been under development at Mintek for a number of years. The results of continuous pilot plant test work confirming the efficiency of gold transfer from carbon fines onto the resin were presented at ALTA in 2018 (1). In addition to the loading of gold, it was established that base metals, mercury and silver also loaded onto the resin.

During the last year, the focus has been on the development of the downstream processes, consisting of the elution of base metals, gold and silver and subsequent selective recovery of the precious metals from the resulting eluate.

Various elution reagents (NaCN/NaOH, 6 M HCl, NH_3/NH_4Cl, H_2SO_4, H_2SO_4/thiourea) at different concentrations and temperatures were tested. It was established that selective elution of the metals could be achieved with some of the reagents. It was possible to elute 100% of the copper followed by other base metals followed by gold using a mixture of NaCN/NaOH. In excess of 99% of each of Hg, Zn and Ni was eluted by 0.2 M H_2SO_4 at 60°C. Subsequent elution with 0.5 M H_2SO_4 / 0.5 M thiourea (TU) mix at 60°C yielded not only complete elution of gold and silver, but also their separation into various fractions.

A number of attempts were made at recovering gold and silver from bulk acidic thiourea eluate containing 353 mg/L Au and 828 mg/L Ag. Electrowinning and alternative options such as precipitation with borohydride, oxalic acid and sodium metabisulphite as well as re-adsorption of the gold-thiourea complex onto a cation exchange resin were evaluated. Borohydride precipitation yielded >95% of both gold and silver recovery. The product formed using borohydride exhibited a high sulphur content and contained ~12% Au and 31% Ag. Conventional electrowinning, typically considered for gold recovery from thiourea streams, resulted in the plating of 100% Au and 97% Ag.

Passing the thiourea eluate through a cation exchange resin yielded a high value-metal upgrade into the resin phase, with a loading of 40 g/L Au and 70 g/L Ag. Subsequent elution of the loaded cation exchange resin with a NaCN/NaOH mixture at 60°C resulted in 100% gold elution with a peak gold concentration of 10 g/L in the eluate. The elution of silver was incomplete probably due to precipitation of Ag compounds in the resin phase.

The following processing sequence was identified as the optimal downstream flowsheet for gold recovery from carbon fines:

- Selective removal of base metals prior to gold elution using diluted H_2SO_4 at elevated temperature (~60°C)
- Au/Ag/Cu elution with acidic TU at elevated temperature (~60°C)
- Au/Ag recovery from TU eluate using EW technology

Pilot testing of an integrated flowsheet in continuous mode is required to evaluate the impact of reagents recycling on the metallurgical performance and possible operational challenges.

Keywords: strong-base gold selective resin, selective elution, gold recovery from thiourea.

Gold-PM Proceedings

Process Optimisation

EVALUATION OF OXYGEN REQUIREMENTS OF A REFRACTORY CONCENTRATE IN A COMPREHENSIVE PRE-OXIDATION AND CYANIDE LEACHING SYSTEM

By

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Presenter and Corresponding Author

Sumedh Gostu

ABSTRACT

Oxygen demand requirements for mines are increasing due to an increase in refractoriness and complexity of ores. Present day mines contain finely disseminated Au in a refractory sulfide based matrix. Oxidative treatments prior to the cyanide leaching operations are required to liberate gold particulates for cyanidation and thereby improve gold recovery.

Out of the various pre-oxidation alternatives viz: pressure oxidation, bacterial oxidation, acidic and alkaline pre-oxidation a significant challenge remains for gold companies to estimate the oxygen demand of the ore. As a result, it is difficult to estimate the capacity for onsite oxygen supply.

An investigation of low pressure alkaline pre-oxidation and cyanide leaching of a high oxygen demand sulfidic concentrate is conducted using a custom, purpose built reactor and methodology. The effects of dissolved oxygen (DO), Free CN ppm on gold recovery kinetics, Sulfur deportation and decrease in CN and CaO consumption will be presented. Oxygen uptake rates (OUR), Total oxygen uptake determination and oxygen requirements for the tests will also be provided.

Keywords: Oxygen uptake rates, Pre-oxidation in gold cyanidation, Cyanide consumption, Gold recovery

DEVELOPMENT AND IMPLEMENTATION OF THE EKATO COMBIJET+ IMPELLER IN A BIOLEACH APPLICATION AT THE POLYUS OLIMPIADA MINE

By

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Wolfgang Keller

ABSTRACT

The core of hydrometallurgical bioleaching plants is a cascade of stirred atmospheric tank reactors. Main task of the agitators is to disperse the added gas in order to ensure a sufficient oxygen mass transfer rate. Since nowadays reactor sizes are up to 1500 m³, a cost optimization for such large reactors is fundamental to make the process profitable. Therefore EKATO has developed the Combijet+ technology which results among others in significantly reduced overall power requirements.

This impeller is characterized by its direct gas feed through one central feed pipe into a rotating distributor integrated into the impeller. The non-contacting gap between the feed pipe and the rotating gas distributer has the function of a 'pneumatic seal' that is maintenance free. The gas flows directly to the outer areas of the impeller blades where it is discharged and dispersed in zones of highest shear stress. As an advantage, the Combijet+ has an up to 20 % increased mass transfer efficiency compared to conventional impellers and gassing systems. Another big advantage applying this technology is that blockages of the usually used sparge rings can be avoided as well as the typical wear problems at the sparger nozzles.

Development work was done in a 1 m³ and 30 m³ scale in the EKATO technology center as well as with original slurry in a 30 m³ vessel. Additional CFD simulations helped to further improve impeller details. This paper outlines the development work of the Combijet+ and discusses its performance. Eight agitators using the Combijet+ were installed in 1000 m³ bioleach reactors and are successfully in operation since 2017. This successful implementation in a state-of-the-art bioleach process at Polyus Gold in its Olimpiada mine and the improvements achieved are presented as well.

Keywords: Gold, Bioleach, Biooxidation, BIONORD®, Agitation, Combijet, Combijet+, Agitation Process Development

DEMONSTRATION AT SCALE IN THE FIELD OF A NON-TOXIC REAGENT SYSTEM TO RECOVER GOLD

By

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Paul Breuer

ABSTRACT

Alternative lixiviants to cyanide have been researched for several decades and have received much attention in recent years largely driven by the health, safety and environmental risks associated with the use of cyanide. Despite this, there remains little commercial uptake due to several barriers. The first commercial operation using thiosulfate commenced in 2014 at Barrick's Goldstrike Mine in Nevada, U.S.A. CSIRO, in partnership with Barrick, made a significant contribution to this commercial application of thiosulfate. However, the leach reagent system adopted at Goldstrike has not been proven successful for other gold ores.

CSIRO has separately developed a thiosulfate-based reagent system for gold leaching that has excellent stability and shown broad applicability in the laboratory. The 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, 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 stamp battery site uses a low capex vat leach process to recover gold from ores having good gold liberation at a p80 greater than 300 microns.

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 gold doré bars. The demonstration plant processed up to 30 tons of ore per day by vat leaching and has operated successfully for more than 6 months to validate the reagent performance and stability. The leach reagent consumption for the optimised demonstration process was 1.6 kg/t, the majority of this being entrained loss with the tails.

This paper outlines the successful validation in the field at scale which has paved the way for commercial application of the technology.

Keywords: Gold Recovery, Thiosulfate Leach, Process Development, Demonstration Plant.

CARBON CIRCUIT HEALTH CHECK

By

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Presenter and Corresponding Author

Ben Strong

ABSTRACT

If the solution tailings go up, the stop-gap response is usually to add more carbon to the carbon circuit… then what do you do?

Gold ore feed grades are dropping. Improving, and then maintaining, the efficiency of gold recovery is becoming increasingly important to plant operation.

The carbon circuit is typically composed of carbon-slurry contactors, carbon slurry transfer pumps, carbon-slurry separators, acid wash and elution columns, a high temperature carbon reactor, and occasionally sand and trash removal circuits. Each unit operation must perform its function adequately if the overall circuit is to recover gold optimally.

The following tests are readily available, though often not done well enough or often enough to be of much use. When done well, they provide a snapshot of aspects of the carbon circuit.

- Gold solution tails indicates overall carbon circuit performance
- Gold solids tails indicates gold not leached into solution
- Gold loading indicates adsorption and elution performance
- Carbon particle size distribution indicates degradation due to handling and the kiln
- Inorganic contaminant loading on the carbon indicates acid washing performance
- Carbon activity indicates overall kiln, adsorption, acid washing, and elution performance.

Chemistry of the carbon circuit is reasonably well defined and, given the results of the above tests and unchanged operation and good maintenance of the carbon circuit, gold recovery can be modelled, e.g. SIMCIL modelling. However, over time, contaminants build up, carbon degrades, operation of the equipment changes, and the equipment itself may fall into disrepair. In isolation, the above tests and modelling do not indicate WHY an individual piece of equipment is not performing adequately, only that it isn't performing. Combining results and performing ancillary, inexpensive tests (including TGA), fill in the picture.

This paper summarises the science of the individual unit operations used in the carbon circuit, what can go wrong in each unit operation, the symptom that can be observed, and what to do when that symptom is observed.

Periodically checking the health of the carbon circuit in terms of both chemistry and equipment operation provides a big return for a small expenditure. You can't just keep adding fresh carbon!

Keywords: Gold recovery, carbon circuit, carbon activity, organic fouling, regeneration, reactivation, kiln, inorganic fouling, acid washing, elution, adsorption, stage efficiency

REAL-TIME MONITORING OF PRECIOUS GOLD IN SLURRIES

By

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Presenter and Corresponding Author

Yves Van Haarlem

ABSTRACT

Real-time, on-stream analysis of the metal content of process slurries is an essential prerequisite for process monitoring and advanced control of mineral processing circuits. On-stream X-Ray Fluorescence (XRF) sensors for base metal applications are available commercially and form the basis of many plant monitoring circuits. To date, these commercial technologies have been insufficiently sensitive to measure precious metals such as gold and platinum group elements, typically present at part-per-million (ppm) and sub ppm levels.

CSIRO has developed a novel X-ray based technology, called UltraGold, which enables detection of gold in slurries on a real-time basis with a precision below 30 parts-per-billion. This technology is based on the use of advanced X-ray optics, extensive Monte Carlo computer modelling for analyser design and high accuracy X-ray spectrum fitting where the X-ray intensities are matrix corrected.

In this paper, we will introduce this technology and discuss the results of a proof of principle study performed in the laboratory with plant slurries (tailings and tailings spiked with concentrate) from an Australian beneficiation plant.

As projected grades in (gold) mining around the world fall and several large-scale mines approach the limits of their economic reserves, this method can enable significantly reduced operating costs by rapid analysis to improve circuit efficiency and hence improve recovery significantly.

Keywords: Gold in slurries, real-time process control, gold recovery, XRF

Gold-PM Proceedings

Fit-for-Purpose Leaching Systems Forum

GEOMETALLURGY AND PROCESS MINERALOGY OF GOLD ORES: METHODOLOGIES AND APPLICATIONS IN PROCESS SELECTION AND PLANT OPTIMIZATION

By

Joe Zhou and Jing Li

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Presenter and Corresponding Author

Joe Zhou

ABSTRACT

The mining industry is a business full of risks, requiring large and long term investment. One of the risks is the technical risk associated with project evaluation, process selection, mine planning and plant performance. Understanding the variability in an orebody is extremely important for project development and process optimization, particularly for precious metals ores. Due to the variability of grade, metal deportment and bulk mineralogy, recoveries of valuable minerals and concentrate grade may vary from time to time during the mine life and impact the plant performance and project economics. The objective of geometallurgy and process mineralogy is to reduce and minimize the technical risk in project evaluation, process selection, mine planning and plant operation through systematic geological investigation and ore characterization by (1) documenting variability within an orebody and (2) quantifying and evaluating the impact of the variability on grinding, flotation, leaching and metal recovery processes.

This presentation introduces the methodologies of geometallurgy and process mineralogy, with a focus being on application in mineral processing and extractive metallurgy of gold ores. Case studies will be provided from a variety of processing options such as gravity concentration, flotation, cyanidation and pre-oxidation..

Keywords: Geometallurgy; Process mineralogy, Mineral processing; Extractive metallurgy; Gold ores

CYANIDE-FREE FUTURE OF GOLD PROCESSING – PROCESS SIMULATION AND KNOWLEDGE MODELLING

By

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Presenter

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ABSTRACT

Consideration of new methods for evaluation of development stage processes is essential in pursuing to find a replacement process for cyanidation. While cyanidation is generally an efficient and low-cost process, it has some restrictions treating low-grade and complex ores, from which a higher portion of the world's gold production derives. In addition, in some areas the legislation drives development of more environmentally friendly processes; thus, the research of environmental impacts in the development stage is crucial. In the Research Group of Hydrometallurgy and Corrosion in Aalto University, sustainable development of cyanide-free gold processing is an essential part of the group's research focus. The current study presents the resent results of (i) process modelling and life-cycle-assessment of an alternative gold leaching process using halogens and (ii) knowledge modelling by a case-based reasoning tool for retrieving information from scientific articles concerning cyanide-free gold leaching.

The sustainability, overall operation, and impacts of new metallurgical processes need to be assessed to fulfil the principles of green mining and metal production. In addition, the consumption of chemicals, characteristics of waste waters, and carbon dioxide formation in gold leaching plants need to be addressed. Simulation and life cycle analysis are tools which can be used to evaluate the development stage processes. In the current study, leaching of refractory gold ore in a chloride/bromide-based process is simulated using HSC-Sim 9 and the life cycle assessment of the process is built using GaBi.

When relying on public information of the processes, the search of required information for building simulation models is challenging. This can be assisted by an efficient utilization of existing knowledge through automated information retrieval. This study presents the latest version of a case-based reasoning application for comparing and ranking scientific articles about cyanide-free gold leaching. The structure of the tool is built based on expert interviews, conducted partly in ALTA 2016.

Keywords: Gold Processing, Gold Leaching, HSC Chemistry, Life-cycle assessment, Case-based Reasoning

TECHNOLOGY OPTIONS FOR PROCESSING A GOLD ORE WITH VARIABLE REFRACTORY CHARACTERISTICS

By

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Presenter and Corresponding Author

Damian Connelly

ABSTRACT

The treatment of gold ores is dependent on the mineralogy and is unique to each deposit. Free milling gold is gold that can be recovered by concentrating methods without resorting to roasting, pressure leaching or chemical treatment. Refractory gold ores are ores that have gold associated with sulphides, carbonaceous matter or gold in solid solution with other minerals. Refractory ores require pre-treatment steps to liberate gold for the cyanidation step. Gold ores may also be double refractory. Double refractory gold is associated with both sulphides and carbonaceous matter. Typical free milling gold circuits consist of a gravity concentration process which typically has low recovery but produces a high grade 'heavy' concentrate and a low grade 'lighter' fraction. The low grade fraction is processed by carbon in pulp/carbon in leach (CIP/CIL) circuits and the high grade fraction is processed through an intensive leaching process. For refractory sulphide ores an additional process step is required to improve the availability of gold for cyanide leaching.

There are a number of process technologies capable of this of which several are discussed here. This paper summarises the various technologies that can be applied in the treatment of gold ore from free milling gold to double refractory gold with a focus on recovery of free milling and mildly refractory gold ores.

DEVELOPMENT OF MIXED CHLORIDE PROCESS FOR GOLD RECOVERY

By

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Yeonuk Choi

ABSTRACT

For gold ore bodies with more complex mineralogy, it is challenging to extract the gold with the conventional process. The chloride process has advantages to treat complex ore bodies but downstream processing after leaching has been challenging, especially recovering gold from the PLS. Therefore, innovation to recover the gold now plays a major role in metallurgical processes as established technologies have challenges in treating the types of ores that are available while meeting the increasingly stricter environmental regulations.

Alternative chloride based processes have been developed that can be used to recover the value elements from the available feed stocks with potentially lower environmental impact. Chloride-based hydrometallurgical processes have several advantages, including higher leachability of complex ores/tailings and relative stability of chloro-complexes of the metals. Process Research ORTECH Inc. (PRO) has developed mixed-chloride process flowsheets, where an innovative solvent extraction process step is used for the separation of gold from their respective chloride solutions. This paper will discuss the potential aqueous chloro-chemistry of the gold and separation reaction mechanism involved in the solvent extraction process.

Keywords: Gold Recovery, Mixed-chloride, Atmospheric Leaching, Solvent Extraction

EVALUATION OF VARIOUS OPTIONS TO MINIMISE THE IMPACT OF COPPER ON GOLD ELECTROWINING IN AN ACACIA GRAVITY GOLD PROCESSING PLANT

By

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ABSTRACT

A Consep Acacia gold processing plant is used by Katavi Mining to treat high copper-bearing gravity concentrates. The resulting high copper concentration in the pregnant leach solution (up to 40 g L^{-1}) caused some serious problems in the downstream gold electrowinning process: 1) very low gold electrowinning efficiency; 2) cathode product containing >90% copper and; 3) reduced / blocked solution flow through the cathode mesh due to the fast growing copper deposit.

At the request of Katavi Mining, CSIRO Mineral Resources investigated various process options to minimise the impact of copper on the gold electrowinning process. The options investigated included: 1) removal / separation of copper from the pregnant leach solution prior to electrowinning using SART (sulfidisation, acidification, recycle and thickening), activated carbon or ion-exchange resins and; 2) optimisation of the electrowinning conditions to enable preferential deposition of gold (over copper), followed by optional copper removal and cyanide recovery by SART. A couple of viable process options were established through this investigation. Katavi Mining has adopted a CSIRO recommended process which has been in operation for a couple of years with excellent results.

Keywords: Gold Electrowinning, Copper Cyanide, Activated Carbon, Ion-exchange Resins, Acacia Plant, Gravity Gold

DEVELOPMENT OF A GLYCINE-CYANIDE LEACH PROCESS FOR GOLD-COPPER CONCENTRATE

By

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ABSTRACT

The GlyCat™ process offers a simple and effective method to reduce cyanide consumption caused by the presence of copper in gold ores and concentrates. Reusable glycine is added to the leach to enable a 5-to-10-fold reduction in cyanide usage for the same copper feed concentration in order to yield similar gold extractions. Copper is recovered by either sulphide precipitation or resin ion exchange. Gold is recovered by conventional carbon adsorption or alternatively using gold-selective resins.

The process is being developed for potential implementation at Telfer Gold Mine to facilitate a change in circuit design that would then allow for increased concentrations of soluble copper. This paper examines why GlyCat™ is preferred over alternative processes and describes the process development activities conducted over the past 2 – 3 years.

An extensive program of batch testwork has defined the optimum leaching chemistry and proved the effectiveness of downstream processes. 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.

Glycine consumption is anticipated to be less than 3 kg/t concentrate, while the resulting saving in cyanide is at least 30 kg/t if the same concentrate were treated using cyanidation leaching alone.

Keywords: Gold Recovery, Copper Recovery, GlyCat™, Process Development, Pilot Plant

OPTIONS OF GOLD AND COPPER RECOVERY FROM GLYCINE AND GLYCINE-CYANIDE SOLUTIONS

By

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ABSTRACT

The glycine based technology for gold and copper leaching was invented and patented at Curtin University in 2013. Leaching gold in starved or low cyanide solutions in the presence of glycine and an oxidant significantly improved the gold recovery and reduced the cyanide consumption (GlyCat™ Process). The glycine-only system (GlyLeach™) can also effectively leach copper and other base metals such as nickel, cobalt, zinc and lead.

The downstream processing of solutions from the leaching of copper and copper bearing gold ores in different glycine leach systems is critical for the successful implementation of the new leach system at an industrial scale.This paper outlines the successful options for copper and gold recovery from both glycine and glycine-cyanide solutions. The use of solvent extraction, sulfide precipitation, and ion exchange resins for copper recovery were tested, while activated carbon and ion exchange resins were used to evaluate the gold recovery from glycine solutions.

More than 99% of copper was recovered as covellite by sulphide precipitation. Solvent extraction results showed that copper glycinate at alkaline pH (pH 10.0) can be easily loaded onto LIX84 extractant followed by sulphuric acid stripping. Chelating ion exchange resins efficiently and selectively adsorbed the cupric copper over gold complexes from alkaline glycine solutions. After the copper recovery by sulphide precipitation, ion exchange or solvent extraction, it was shown that the complexed glycine with the cupric ions was released back to the leach solutions and does not adsorb onto the extractants or precipitates.

It was also seen that the activated carbon had a high adsorption tendency towards gold over copper from glycine-cyanide solutions. The gold and copper adsorption on carbon from a cyanide-glycine solution containing 2 mg/L gold, 300 mg/L copper, pH 11, 5 g/L glycine, Cu:CN of 1:1 (123 mg/L CN) and 8 g/L carbon in 24 hours reached 99.0% and 52.8% respectively. Activated carbon was found to be very selective for gold glycinate over cupric glycinate from glycine only solutions. More than 99.0% gold was adsorbed in 24 hours and less than 15% copper was adsorbed at the same time under optimum conditions from a glycine solution containing 7.5 g/L glycine, 2 ppm gold and 40 ppm copper.

The optimum process for copper and gold recovery from glycine-cyanide solutions was found to be an initial copper recovery by either sulphide precipitation or ion exchange resin followed by gold recovery with activated carbon.

Keywords: Copper Recovery, Gold Recovery, GlyLeach™, GlyCat™, Solvent Extraction, Sulfide Precipitation, Ions exchange