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INNOVATION IN MINERAL PROCESSING: WHERE ARE WE HEADED?

By

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Acknowledgements: sources of referenced information...

3. Tracking the trends, Deloitte, 2013. The report is available at www.deloitte.com
5. Charts from Gold Fields Mineral Services (GFMS). These charts are available at www.gfms.co.uk
Treatment of Laterites
BREAKING NEW GROUND

By

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VALIDATION OF NICKEL LATERITE DIAGNOSTIC LEACHING PROTOCOL

By
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ABSTRACT

A typical nickel lateritic ore body contains several weathered zones. The limonitic and saprolitic zones exist closest to the surface and towards the bottom of the deposit, respectively, and there may also be an intermediate zone present, composed of clays. Nickel in these deposits is expected to be hosted mainly in goethite, clays (e.g. nontronite) and serpentines (e.g. lizardite). An understanding of ore mineralogy and elemental deportment is vital for the effective processing of nickel from an ore body. Common characterisation techniques, such as Quantitative X-Ray Diffraction (QXRD) and Quantitative Evaluation of Minerals by Scanning Electron Microscopy (QEMSCAN) may be costly, time-consuming and not readily available at mine sites. Furthermore, these techniques may not be effective for nickel deportment analysis: QXRD can be used for major mineral prediction but cannot be used to identify where specifically the nickel is located, while nickel deportment analysis by QEMSCAN may be problematic if the nickel concentrations in minerals are low. A possible alternative to mineralogical analysis for determining nickel deportment is by the selective sequential leaching of nickel-containing minerals followed by the determination of nickel in solution after each leach. This approach could be a simple, accessible, cost-effective and more accurate alternative to mineralogical analysis. Previous literature research has presented sequential leach methodologies for determining nickel mineralogy, but none have targeted all zones of a lateritic ore body. A diagnostic leach for nickel laterite deportment in all three zones has been developed primarily for geometallurgical applications. However, predicted theoretical nickel recoveries by this method have not been compared to those determined from typical atmospheric or ambient leaching used in industry. Laboratory experiments have therefore been conducted to validate the theoretical model by assessing the correlation between the predicted and actual amounts of nickel leached.
UPGRADING NICKEL/COBALT LATERITES BY SIMPLE PHYSICAL MEANS

By

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ABSTRACT

The Summervale-Westlynn lateritic nickel/cobalt mineralisation, approximately 500 km NW of Sydney (NSW), has relatively high nickel (averaging 0.85% Ni) content and it is amenable to upgrading by physical means. The Summervale-Westlynn deposit, based on drilling data, is largely a saprolitic type formed by alteration of Fe-enriched harzburgites, an ultramafic rock of peridotite composition, consisting of olivine and orthopyroxene. The limonitic type mineralisation is less dominant and it has either never been developed or largely eroded. Experimental work showed that the Summervale-Westlynn ores can be upgraded by sizing, wet gravity and magnetic separations. The coarse fraction contained the least amount of nickel and cobalt. Rejection of the coarse fraction by sizing also improved the grade of the remaining ore. Regrinding the coarse fraction and subsequently repeating the gravity and magnetic separation improved the nickel recoveries to some extent. This study showed that a product containing up to 35% more nickel could be made from the Summervale-Westlynn ores. This product is expected to be suitable for ferronickel production. In this paper, the results of the bench-scale tests are discussed.
THE RKEF PROCESS
FOR THE TREATMENT OF LATERITES

By

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THE RKEF PROCESS
This stands for:

ROTARY
KILN-
ELECTRIC
FURNACE
Mineral Processing
HIGH THROUGHPUT XRF ORE SORTING OF DISSEMINATED SULPHIDES

By
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ABSTRACT

Global demand in base metals has put more pressure on mining low grade disseminated copper and nickel ores. With grades regularly sitting below 1% the removal of unwanted barren material through sensor based ore sorting would significantly upgrade the ore body and remove unwanted contaminants from the downstream processing system.

X-ray fluorescence is a technology commonly known in the mining industry. It is used in on-site laboratories to assay samples, on core loggers and at the face in the form of a handheld XRF analyser. It works on the principle of secondary x-ray emission to ascertain the elemental composition of the sample.

Outside the laboratory most XRF systems are only sensitive to elements of atomic number 20 (Calcium) and greater. Their accuracy is directly related to the homogeneity of the sample, the number of readings and the time taken for each reading.

XRF is most commonly used in the field for base metals and the heavier elements such as uranium and lead. It is thus not surprising that it has been incorporated into ore sorting equipment to sort material based on the elemental composition of each particle. The major problem with using XRF in sorting is the time required for the sensor to produce an accurate elemental composition. Tomra Sorting Solutions has been using XRF in the sorting industry for several years and is now improving the system to gear it up for high throughput machines required in the mining industry capable of many thousands of particles per second and hundreds of tonnes per hour on a single sorter.

This elemental sorting system actually benefits from the disseminated nature of some of the base metal ores. XRF is essentially a surface measurement and disseminated ores produce a more homogenous particle whose surface readings have a strong correlation to the grade of the entire particle. This opens doors for sorting copper and nickel as well as options for more accurately sorting other metals such as manganese, iron, chrome, gold and uranium, but crucial to this process is the ability to do it at on a high throughput machine that makes economic sense in the mining industry.
CO-TREATMENT OF OXIDE ORE WITH NICKEL TAILINGS AT MT WINDARRA

By

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ABSTRACT

Poseidon Nickel Limited (“Poseidon”) is developing the Windarra Nickel Project located near Laverton, 260km north east of Kalgoorlie, Western Australia. A nickel sulphide concentrator been designed and a gold tailings treatment plant is also under development. The Mt Windarra deposit was previously mined and processed by WMC over an 18 year period, ending in 1994. During this time, a large amount of nickel and gold tailings were generated by the Windarra plant and other local operations.

An opportunity to further enhance the project exists in the form of historic nickel tailings and disseminated nickel ore in stockpiled waste dumps that are located within the mining lease. Poseidon has developed a hydrometallurgical process that can treat both of these materials simultaneously, as well as low grade nickel sulphide ore that is unsuitable for flotation. The flowsheet is based on a two-stage nitric acid leaching circuit operating at low acid addition rates and at atmospheric pressure The process was developed in partnership with Direct Nickel Pty Ltd. The filtered leachate solution can be sent directly to a precipitation circuit to produce a high-grade mixed sulphide product.

The oxide ore/tailings co-treatment product can be sold as a premium product or it can blended with the nickel concentrate from the main Windarra flotation circuit, increasing the nickel grade and reducing impurities. This strategy allows Poseidon to enhance flotation nickel recovery and reduce impurities, thereby maximising operational flexibility and profitability of the overall project.

A Prefeasibility Study for the combined oxide ore/tailings treatment plant is currently under development, with further pilot testwork also scheduled for 2013. The results from this will be used to supplement the Definitive Feasibility Study for the Windarra Nickel Project, moving towards operation of the combined plant in 2017/2018.
THE UNIQUE PROPERTIES OF METHANE SULFONIC ACID FOR THE MINING INDUSTRY

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- Introduction
- MSA Properties
- MSA Applications in Mining:
  - Scale Removal
  - Radionuclide Removal from Copper Concentrates
Solid/Liquid Separation
DEVELOPMENT OF THE NEXT GENERATION THICKENER
FEATURING THE RADFLOW™- FEEDWELL TECHNOLOGY

By

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Heap Leaching
THE USE OF DIAGNOSTIC TECHNIQUES TO REDUCE BACTERIAL HEAP LEACH DEVELOPMENT TIME

By

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ABSTRACT

Development of heap leach projects is highly dependent on the timing for testwork, and invariably the testwork programs tend to be quite long. BioHeap utilizes Nitric Acid Digests (NADs) to estimate optimum crush sizes, and it has been noted that 2 week NAD’s gives a good estimate of copper recovery from a Chalcopyrite BioHeap at the pilot scale and the potential exists to use the 2 week NAD test as a better estimate of liberation and copper recovery than column testing, giving the possibility of reducing development time of a BioHeap project.

Estimate of nickel recovery is also possible, and the data gathered to date indicates that NAD’s give an estimate of minimum nickel recovery.

Sample selection and representivity remains critical to relying on testwork programs in development of leaching projects.
Nickel-Cobalt-Copper Proceedings

SX/IX
RECOVERY OF ACID BY SOLVENT EXTRACTION FROM MINING WASTE AND PROCESS SOLUTIONS

By

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ABSTRACT

With a selected organic system consisting of 50% TEHA (tris-2-ethylhexylamine) and 10% Shellsol A150 in octanol, over 80% H2SO4 was extracted from a feed solution containing 200 g/L H2SO4 at an A/O ratio of 1:2 in a single contact. After 3 stages of successive extraction, nearly 99% of acid was extracted with only 2 g/L H2SO4 left in the raffinate. It is found that the extracted acid was stripped readily from the loaded organic solution using water. After acid recovery, the remaining metals such as copper, cobalt, nickel and zinc in the concentrated solution in low acidity could be further recovered, again using SX. When the concentration in mining waste and process solutions is low, membrane distillation (MD) can be used to recover fresh water and concentrate the acid and metals with low cost if waste heat is available in the mine site. A combination of MD and SX is perfect for recovering water, acid and metal values using the proposed flowsheet.
MASS TRANSFER EFFICIENCY IN SX MIXERS

By

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ABSTRACT

Mass transfer is a key issue in solvent extraction processes and may actually be a bottleneck in some plants. To achieve the necessary stage efficiency an optimum droplet size must be created. Those droplets must be maintained in a turbulent environment to ensure intensive mass transfer. Low intensity mixing does not provide sufficient turbulence or mass transfer. Mixing that is too aggressive will develop fractions that cannot be separated in the settler. Previous studies have shown that the primary reason for separation problems is the extremely non-uniform energy distribution in the mixer which leads to extremely non-uniform distribution of droplet sizes.

New types of impellers have been developed in recent years which produce a more uniform energy distribution and more uniform droplets which reduce the entrainment of the dispersed phase in the continuous phase; even for high power inputs.

This study examines the influence of distribution of energy on mass transfer efficiency.
RECOVERY OF NICKEL AND COBALT FROM LEACH SOLUTIONS CONTAINING IRON AND ALUMINIUM USING ION EXCHANGE RESINS

By

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ABSTRACT

Recovery of Ni and Co from solutions generated by heap and atmospheric leaching with high concentrations of Fe and Al is a long-standing problem and a serious challenge. Although nickel can be recovered by ion exchange (IX), the recovery of cobalt in the Ni-depleted raffinate has not been resolved. In this study, the recovery of cobalt from a synthetic Ni-depleted raffinate using resin in pulp (RIP) with Dowex M4195 resin was investigated. To obtain high recovery of cobalt and its good separation from iron, the solution pulping or neutralisation should be conducted in a pH around 4 before addition of the resin. Using this method, the recovery of cobalt reached 92% and the iron adsorption was only 3% in a single contact. More than 95% Co was recovered by two successive RIP operations. Impurities including Zn, Fe, Al, Mn, Mg etc. reported to the eluate with cobalt could be removed by solvent extraction (SX) and precipitation to obtain pure cobalt product.
ABSTRACT

Crud is a common concern in SX processes and is formed as a complex solid stabilized emulsion of aqueous and organic\(^{(1,3)}\). Crud formation is highly dependent on the amount of solids entering the circuit and is influenced by a number of other operational factors. A common practice for crud processing is interfacial pumping, wherein crud, organic, and aqueous are pumped from the settlers for treatment and utilizes a variety of equipment. These mechanical means of crud processing are effective, however, require significant processing time and require oversight to prevent the return of contaminated organic.

Cytec has developed a unique crud treatment process utilizing both chemical and mechanical means to enhance the solid/liquid separation. The use of ACORGA CB\(^{®}\) 1000 crud busting reagent allows a rapid separation of solids from the organic phase and provides similar volume recovery to current practices. The process allows operations to return clean organic back to the plant more efficiently and may enable operations to process more crud. In addition, the organic quality of the recovered organic is higher than that recovered by typical means, which can lead to operational cost savings.
Agitation
In hydrometallurgical minerals processing slurries are often processed at very small grind sizes and high solids concentrations. This normally results in flow anomalies of such slurries. Due to flow limits or yield stress the slurry tends to stagnate close to the vessel bottom, the walls and at any internals. The main mixing task therefore generally is not suspending of the solids but the homogeneous blending of the entire vessel volume. If not considered during the agitator design only a fraction of the vessel contents will be mixed. Therefore the knowledge of the slurry rheology as well as the variations in process parameters is vital to design e.g. storage or surge tanks. The integral mixing solution considers the motor power, the choice of the impeller type and number, the impeller diameter as well as the design of the baffles and feed and discharge positions.
HIGH CURRENT DENSITY COPPER ELECTROWINNING AT TENKE FUNGURUME MINING COMPANY

By
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ABSTRACT

Tenke Fungurume Mining Company (TFM), located in Democratic Republic of Congo (DRC), an affiliate of Freeport-McMoRan Copper & Gold Inc. (FCX), began operation of a copper electrowinning tankhouse in March of 2009. Many obstacles were faced and overcome to establish a new greenfield project in rural DRC. Initial copper electrowinning results were satisfactory, but cathode quality and current efficiency decreased as copper production increased. FCX’s Technology Center and TFM personnel began operation of two bench-scale copper electrowinning cells in the Tenke tankhouse to diagnose chemistry effects occurring on the cathode and anode. The results indicated an excellent electrolyte chemistry, producing finely crystalline copper at 430 A/m² current density with 97% current efficiency. Tenke’s commercial electrolyte contained 43 g/L copper and approximately 0.7 g/L Fe³⁺ concentration. Examination of the bench-cell lead anodes by hand-held x-ray fluorescence (XRF) showed no accumulation of manganese on the anode surfaces, and lead sliming was not observed.

Attention then turned to the physical factors of the Tenke electrowinning cells, including electrode insulator geometry and performance. A demonstration cell was selected in the tankhouse and was operated with varying cathode and anode insulator geometries. Operation of the demonstration cell with a 3-side cathode edge strip, A-style anode insulators, and an improved cell furniture design increased current efficiency from 77% to 89% at 400 A/m² current density. Cathode quality was high-grade. Adoption of these improvements realized the demonstration cell performance throughout the tankhouse. Support measures were also put in place, including short circuit and no-contact correction, and regular electrode contact cleaning.
ON-LINE SYSTEMS FOR ELECTRO-REFINING OPERATIONAL EFFICIENCY IMPROVEMENT AND QUALITY CONTROL

By

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ABSTRACT

Optimizing the efficiency and produced cathode quality of an electro-refining plant requires not only the efficient use of energy and labour, but also high availability of machinery and the ability to rapidly observe and react to disturbances. With the use of innovative software now available in the marketplace, real-time measurement and monitoring systems help improve parameters such as efficiency, performance quality control and safety in electro-refining plants. Some of the systems to be discussed here include systematic surface quality and permanent cathode condition inspection. Another system monitors on-line cell performance, facilitating early reaction to critical disturbances such as short-circuiting, flow blockages, cell draining or electrolyte temperature excursion at the cells. Obviously, it is also highly desirable to integrate such abovementioned system data into one overall management system, along with other important information such as that provided by material handling machinery, process control systems and on-line analysers. Such a management system provides transparency for operations through real-time production efficiency, quality reporting and material tracking. Here, we will also discuss the practical benefits of utilising such systems and illustrate with case examples.
HELM TRACKER™ CATHODE CURRENT SENSING TECHNOLOGY

By

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ABSTRACT

Electrode current distribution problems often occur in electrowinning and electorefining operations. The detection of these problems is typically labour intensive and slow. Hatch has developed new technology, HELM tracker™, which measures the current of every cathode in the tankhouse in real time. Commercial trials have been undertaken in both electorefining and electrowinning plants, yielding positive results. The automated measurement system reduces the need for personnel exposure to the hazards such as acid mist and crane movements. Early detection of short circuits (over currents) and poor contacts (under currents) allows operators to rectify these problems more quickly, and hence giving improvements to current efficiency, asset longevity, production quality, production quantity, and power consumption.

Hatch has been demonstrating the robustness and performance of the HELM tracker system at two of Freeport MacMoran’s copper electrowinning plants. This paper describes the trial initial outcomes and learnings and the path of this technology to commercial status since it first emerged.

DESCRIPTION OF HELM TRACKER™

HELM tracker™ is a Hatch technology (patent pending) that can be installed in existing or new cell houses. The technology measures the current flow in every cathode (and/or anode) continuously and provides real-time detection and reporting of shorts, bad contacts and other current distribution characteristics. The development of this technology began more than 10 years ago and it is anticipated that by the end of Q2, 2013 it will have reached commercial readiness.

The system comprises sensors that are located in an insulated bar that runs the full length of the cell, positioned on top (or under) the header bars close to the wall of each cell. The system works by measuring the magnetic fields generated by DC currents flowing through the header bars which are processed by proprietary means to infer specific electrode currents. The theory behind the system is described in the section titled Calibration.

The basic components of the HELM tracker system are indicated in Figure 1 and include:

- The HELM tracker™ bars
- Electrical junction boxes
- Wireless communication of collected data from junction box to a server located in an office or control room near the tankhouse.
- HELM tracker™ server which collects and records electrode currents in a historian database and presents the data so that operators and plant metallurgists or managers can access live data and long term trending.
- A tablet or other display connected wirelessly that allows operators in the tankhouse to see real-time measurements and historical trends of any electrode currents in the tank house.
Hydro Processing
ABSTRACT

This paper is about computational methods that can be used to evaluate new metal extraction projects before the expenditure of substantial amounts of time, effort and money.

Simple calculations based on the broad chemistry of the envisaged process and publicly available information can be used to discern whether or not the project is potentially viable. If the project passes that gate, process modelling that generates a mass-energy balance for each option under consideration allows the variable costs to be more rigorously calculated and process options to be ranked. The mass-energy balance can then be passed electronically from the process modelling software to capital cost estimation software and preliminary capital cost and fixed operating cost estimates can be calculated and transferred to financial models to rank options and predict viability or otherwise.

The methodology is illustrated using an example based on a project in which Arithmetek Inc. has had no part, namely African Eagle’s Dutwa Nickel Project in Tanzania, because African Eagle has published sufficient information on this project to enable a rational comparison between the results of the calculations advocated in this paper and those from actual work on the project.
MILLING IN ACID-COPPER RAFFINATE AT THE MUMI OPERATION DRC

By

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ABSTRACT

The MUMI project has made use of milling in raffinate as a major part of the project water balance and process optimisation. The process utilises milling, leaching, CCD, SX and EW for copper recovery. Cobalt is recovered from a bleed stream of SX raffinate using precipitation of iron and manganese followed by two stages of cobalt precipitation using magnesium oxide and lime. The water balance for the operation is complex with many inputs from sources that are not readily controlled. As part of the water management programme milling in raffinate was chosen as a method of eliminating the water introduced from post milling solid-liquid separation. This was integrated with use of the SplitCircuit™ for maximisation of acid recycle from SX raffinate to the leach. The combination of processes has provided significant benefits in operation cost and plant complexity reduction.

The first such mill in raffinate at Sepon was used as a model for the installation engineering. With the recent advent of low cost duplex stainless steels, it became possible to construct the mills completely from acid resistant stainless steel. All mill components were examined in detail to ensure that corrosion risk was eliminated. Significant focus was also made on corrosion resistance of the peripheral structures; with layout minimising these in the corrosive area; and selection of resistant materials for those that could not be removed. Acid mist generated in the mills is removed and treated in a scrubber to remove both acid and sulphur dioxide gas.

Mill operations have been successful after some commissioning issues were resolved. The mills are performing better than expected. A further installation using the same process and similar mill technology is being constructed on site, with nearly three times the capacity. Large stainless mills are now a reality and growing in use and size.
TECK’S CESL NICKEL PROCESS: ADVANCING TOWARDS A COMMERCIAL READY HYDROMET SOLUTION FOR LOW GRADE DISSEMINATED NICKEL SULPHIDES

By
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ABSTRACT
Disseminated nickel ore bodies are widely distributed around the world and are found in most of the known nickel sulphide districts. Teck has developed a novel hydrometallurgical process for treating low-to-high grade nickel concentrates and polymetallic nickel-copper-cobalt sulphide concentrates with high magnesia content without the need for separation at the milling stage. This paper will focus on the metallurgical components of the CESL hydrometallurgical process and then examine a business case which utilizes data compiled by a third party engineering company.
ABSTRACT

Canadian-based Prophecy Platinum Corporation (Prophecy) is considering options for on-site production of copper cathode and a value-added nickel-product at their Lynn Lake operation, located in northern-Manitoba, Canada. An experimental testwork campaign, followed by flowsheet development and economic modelling was undertaken to evaluate the various options open to Prophecy.

It was established experimentally that 90 percent of both copper and nickel can be recovered to a bulk concentrate of the Prophecy Resources Lynn Lake ore. Various flowsheet options have been considered consisting of either moderately thermophillic or extremely thermophillic bioleaching, combined with copper cathode production followed by nickel recovery either as hydroxide precipitate, sulfide precipitate or cathode. The economically optimal approach would be bioleaching at 70°C, followed by production of both copper and nickel in cathode form, yielding an IRR(10y) of 17 percent (rising to 24 percent with a 13 percent rise in metal prices). Various recommendations can be made to achieve further improvements to the economics.

A graphical method is provided whereby the profitability of other similar projects can qualitatively be determined very simply from knowledge of only (a) the Payable Contained Value and (b) Opex associated with mining plus administration.
ABSTRACT

Société D'Exploitation de Kipoi SPRL (SEK) is a joint venture established between Congo Minerals SPRL, 100% owned by Tiger Resources Ltd, and Gecamines. SEK’s aim has been to economically and responsibly exploit the copper resources at the Kipoi site.

In 2011 an open cut mine with a Heavy Media Separation plant (HMS) was established at Kipoi. In 2012 the operation operated at above design capacity producing 36,966t of contained copper in concentrate. This operation is planned to run until Q4 2014.

Following positive result of exploration during 2012 Tiger/SEK conducted a Definitive Feasibility Study (DFS) for the Stage II development of the Kipoi Project. Stage II consists of the phased development of a 50,000tpa integrated Agitated Leach, Heap Leach, Solvent Extraction-Electrowinning (SX-EW) plant.

This paper focuses on the development and description of the 50,000tpa integrated Agitated Leach, Heap Leach SX-EW. It is believed this final process flowsheet provides the optimal capital and operating cost outcome with greatest flexibility for future expansion of the project.

The Definitive Feasibility Study indicated both a technically and economically robust project with an initial Capital Cost of $161M and Life of Mine (LOM) Capital Cost of $384M. LOM Operating costs average $1.13/lb producing 377,000t of copper over the 9 year project life. The project delivers an NPV at 8% after capital expenditure of $378M and an IRR of 44% with an initial project payback of 16 months. The Phased development will be funded from cash flow from the existing operation. Tiger/SEK have commenced development of the project with production planned from mid 2014.
NICKEL RECOVERY USING CONTINUOUS COUNTER-CURRENT ION EXCHANGE

By

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PRESENTATION

• INTRODUCTION TO CONTINUOUS COUNTER-CURRENT ION EXCHANGE TECHNOLOGY FOR NICKEL RECOVERY AND PURIFICATION

• COMMERCIAL PLANT OPERATING DATA
THE AUSENCO COPPER PROCESS

By
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ABSTRACT

The Ausenco Copper Process has been designed to mitigate changes in the copper grade in ore bodies and provide mines with a way to produce a high copper content concentrate or ‘super con’. Copper ore bodies often show supergene enrichment of the copper minerals, with weathering leading to conversion of chalcopyrite (‘CuFeS₂’) to iron-depleted copper minerals such as bornite (‘Cu₅FeS₄’) and chalcocite (‘Cu₂S’). As a mine gets deeper into the deposit the copper content of the copper minerals typically declines and the iron content increases as the mining transitions from the supergene zone to the sulfide zone. A concentrate rich in the supergene minerals typically has a higher copper content than a chalcopyrite concentrate. Additionally, as mines age, the ore grade tends to decline, because operators typically mine the best ores first to pay back the invested capital. To maintain copper output, concentrator throughput is often increased by staged plant expansions. The decline in final grade of the copper concentrate is offset by a higher tonnage output, which also compensates for the decline in copper recovery to the concentrate.

The throughput of modern copper smelters is frequently constrained by the capacity of the acid plants used to capture the sulfur dioxide they produce. Thus, the copper/sulfur ratio is an important consideration. A smelter so constrained might be interested in purchasing some concentrate with a higher copper/sulfur ratio to blend with lower-grade concentrates to increase total copper output. Availability of super con grade material allows a smelter to increase copper production for a given feed tonnage or have something to blend with lower-grade concentrates to maintain copper production.

The Ausenco Copper Process conceived by Grenvil Dunn and Peter Bartsch, (Australian patent 2008200206) involves a two-stage hydrometallurgical process. It has the twin advantages of producing a higher-grade concentrate for sale while increasing total copper recovery for the miner. Recovery to saleable concentrate is increased by recovering copper from a lower-grade concentrate fraction, in addition to the conventional concentrate. The lower-grade fraction is treated by pressure oxidation (‘POX’) to generate an acid copper sulfate solution. This is then used in a non-oxidizing pressure leach to leach iron out of the high-grade fraction, producing a super con final product.

The process is also able to reduce the content of some deleterious species, such as uranium and certain base metals, in the concentrate. In addition, excess acid and ferric oxidant from the POX stage is available for leaching other fractions of the ore. It may also have application to certain copper-gold ores that do not respond well to flotation, provided they are low in pyrite.
Chloride Processing
FURTHER DEVELOPMENT OF THE CHLORIDE PROCESS FOR BASE AND LIGHT METALS: RECENT MINIPLANT AND FIRST PILOT PLANT DATA

By

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ABSTRACT

Neomet has been updating the chloride processing flowsheet for nickel laterite ores and other feeds over the past few years. This paper reviews the more recent developments in the flowsheet, with particular emphasis on the key acid recovery and iron precipitation unit operation. Results of a miniplant campaign leaching composite laterite ores are presented, together with the latest developments and initial results from the pilot scale operation of the acid recovery circuit. The deportment and behavior of impurities, notably aluminium, magnesium and manganese, all major components of laterite ores, are demonstrated, and the implications of these data discussed in the context of the overall flowsheet.
INNOVATIVE PROCESSES FOR THE RECOVERY OF GOLD AND BASE METALS

By

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ABSTRACT

Chloride metallurgy is emerging as an alternative process for the production of base metals. Process Research ORTECH Inc. (PRO) has been at the forefront of technological development of chloride metallurgy. PRO’s patented mixed chloride technology has been applied to the recovery of several products including titanium dioxide from ilmenite ores, REE from alumino-silicate ores, base metals and PGM from sulfide ores, gold from refractory ores and base metals from laterite ores. This paper will describe the application of PRO’s mixed chloride technology for the recovery of gold from refractory ores and base metals from lateritic ores. PRO process uses mixed chloride lixiviant (HCl+MgCl₂) to bring base metals in solution. The HCl leaching system provides the opportunity to regenerate the acid by pyrohydrolysis, while the presence of MgCl₂ in the lixiviant enhances the activity of the hydrogen ion by orders of magnitude, making the lixiviant very aggressive. This results in high recoveries of base metals. Base metals are separated from pregnant leach solution (PLS) successively using innovative solvent extraction steps. Overall, the process flowsheet is efficient, environmentally friendly and economically attractive.
DEVELOPMENT OF CHLORIDE BASED METAL EXTRACTION TECHNIQUES
ADVANCEMENTS AND SETBACKS

By
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ABSTRACT
The expected depletion of ore bodies conveniently amendable to orthodox, technologically and energetically relatively effortless refining practices may sooner or later cause serious disturbances in the supply of industrial metals such as – but not limited to – Nickel, Cobalt, Titanium and Vanadium. In parallel the producers of Aluminum and Gold face increasing opposition by environmentalist movements and regulators, who rightfully question the sustainability of production methods that yield undesirable long-term liabilities such as red mud ponds or depend on the use of toxic chemicals in substantial quantities.

Alternative, seemingly more versatile, cleaner processes for the refining of minerals, which start with a leach in hydrochloric acid, have been proposed and discussed for decades in various academic and industrial circles but consistently failed to win the approval of project sponsors and investors – not unlikely because it has remained a fairly difficult exercise to make an ultimately compelling case for their technical viability and commercial feasibility throughout project related due diligence.

In the present paper, we shall showcase a selected segment of the state of the art in this field, outlining why the subject is of industrial interest and commercial importance, what – to the best of knowledge of the authors – could theoretically be achieved and what may not unlikely remain out of reach for the foreseeable future.

Advancements, that have been made, and encouraging insight, that has been collected during the development of a certain class of more or less promising flow sheets and techniques, are showcased and discussed.

Further we elaborate on some perceived major road blocks, highlight some present ideas to improve the status quo and outline a road map for future research and development.
NICKEL EXTRACTION FROM LATERITE ORES BY LEACHING WITH HYDROCHLORIC ACID

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ABSTRACT

For the extraction of nickel from laterite ores, the following flow sheet is proposed: Leaching with hydrochloric acid, preconcentration of the brine, oxidation of ferrous (if present) to ferric chloride, hydrolysis of ferric chloride leading to the precipitation of hematite and evaporation of hydrochloric acid, and crystallization of non-hydrolysable metal chlorides by means of sparging hydrogen chloride into the solution. Hydrogen chloride required in the latter step is produced internally by super-azeotropic distillation of regenerate. The process has a closed water balance, as water driven off in the preconcentration step is used for tailings and hematite rinsing or is released if brought in by the ore into the process. Nickel can be finally recovered from a solid chloride mixture containing only minor amounts of ferric chloride.

Based on experiments regarding the leaching, the hydrolysis, and the crystallization section of the flow sheet, a rough mass and heat balance is calculated as a part of ongoing work.

During hydrolysis of artificial oxidized leachate, a rather pure hematite with approx. 0.5 wt% Al, 0.3 wt% Cr, and 0.5 wt% Cl and minor amounts (i.e. < 100 ppm) of other nonferrous metals can be separated in hydrolysis. Hydrochloric acid with 20-40 wt% HCl can be evaporated at 180°C. In the crystallization experiment, a filter cake containing all of the nonferrous metals and 0.4 wt% FeCl₃ is collected.

According to the mass and heat balance, the thermal energy consumption for the flow sheet is estimated to be in the order of 12 GJ/t of the laterite ore used for this study. This value has to be considered as preliminary result of ongoing work and is expected to go down by refining experimental conditions.
PAL Forum
HOW TO MITIGATE COSTS OF TITANIUM REPAIRS ON REMOTE MINE SITES

By

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ABSTRACT

Cost effective planning and consideration is required when outsourcing specialized titanium welding contractors to perform both planned and emergency on-site maintenance, repairs and modifications on titanium pressure equipment and piping. There are many facets to consider to organizing specialized weld repair teams ready to commence work upon arrival on a work site. Plant maintenance managers who outsource titanium repair scopes should consider the following: Leaching plants using titanium and other high-end corrosion service materials should develop a core relationship with the group of specialized, experienced contracted service to develop a seamless work flow during critical path activities; This includes early involvement of the specialized welding contractor to define the effective scope of work and confirm repair outcomes; knowing there are often multiple disciplines (contractors) involved in most tasks and how crucial to identify and harness any experience within the nominated contractors during the remedial assessment. Longer term relationships can benefit by involving contractors in the plants’ routine inspections and more importantly during any failure assessment. A contractor must become familiar with each plant’s staff, the process circuit, operations systems and facilities to become an integral part of the plants’ reliability team. The plant managers should tap into the valuable information an experienced titanium repair team can offer when defining and forecasting effective maintenance strategies.
NANOSTRUCTURED AND CONVENTIONAL CR$_2$O$_3$, TiO$_2$ AND TiO$_2$-Cr$_2$O$_3$
THERMAL SPRAYED COATINGS FOR METAL SEATED BALL VALVE APPLICATIONS IN HYDROMETALLURGY

By

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ABSTRACT

Thermal sprayed ceramic coatings are successfully employed to enhance the load carrying capacity and the tribological performance of the base material in order to extend the in-service life of equipment, including metal-seated ball valves (MSBV's) in Hydrometallurgy service. Ceramic coatings are vital to protect machines in the harsh abrasive conditions encountered in corrosive processes such as Pressure Oxidation (POx) and High Pressure Acid Leach (HPAL).

Velan, a leading designer and manufacturer of industrial valves, has 20 years of experience in the engineering of severe service MSBV’s for critical isolation applications around the autoclave. The National Research Council of Canada (NRC) in Boucherville and Polytechnique Montreal have world recognized know-how on coating engineering and characterization, in particular for wear.

A detailed characterization project was undertaken by Velan in collaboration with the NRC and Polytechnique Montreal to perform mechanical and tribological resistance evaluation of the most promising ceramic coatings potentially suitable for this service, including a novel blend of n-TiO$_2$-Cr$_2$O$_3$. Hardness and shear strength were evaluated using micro-hardness indentation testers and universal tensile testing equipment. Wear resistance of the coatings under different conditions such as sliding wear, abrasion and galling were measured by standard pin-on-disc tests, abrasion tests and custom-design galling tests.

It was found that TiO$_2$-Cr$_2$O$_3$ offers superior tribological performances compared to n-TiO$_2$, mainly due to the presence of Cr$_2$O$_3$. Optimized balance between the hard and brittle Cr$_2$O$_3$ phases and the soft and ductile TiO$_2$ phases yields to higher abrasion, sliding and galling resistance. In parallel, the novel mix of n-TiO$_2$ and Cr$_2$O$_3$ is considered as a promising evolution of the current TiO$_2$-Cr$_2$O$_3$ blend.
POTENTIAL FOR CO₂ SEQUESTRATION AS MINERAL CARBONATE WITHIN NI LATERITE PROCESSING

By

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ABSTRACT

Worldwide there is a large research effort into technologies for the sequestration of CO₂ due to the overwhelming concern of what might happen if there is a runaway greenhouse effect. One potential technology being pursued examines whether the enormous reserves of magnesium silicates in the earth could be converted to magnesium carbonate which is considered to be a safer option than the storage of supercritical CO₂ deep underground. But a viable technology has not been found because the use of acid and base, in the traditional processing sense, is prohibitive due to the scale and need for both low energy and low cost. One idea that might circumvent this problem is to use a regenerable buffer to enable both low pH for Mg dissolution and high pH for MgCO₃ carbonation.

Given that the magnesium silicate reserves of interest also contain significant levels of Ni, it could be worthwhile to combine the CO₂ sequestration pursuit with the pursuit of Ni extraction, whereby a symbiotic relationship exists and the two operations can assist each other to achieve technical, environmental and economic process goals.

This paper presents our work to date on the use of a tertiary amine as a regenerable buffer, including a process concept. We have found that both tripropylamine and triethylamine are capable of raising the pH of an acidic solution to over 8 and therefore able to precipitate MgCO₃ when added to the extract solution from the treatment of serpentinite with HCl while low pressures of CO₂ are also sparged into the solution. Precipitation of the carbonate was found to occur within minutes. It has been found that the amine can be regenerated through heating to over 80°C. Preliminary work has shown that the pH can be decreased to 3.4. The precise mechanism for regeneration is still being established, however, it appears that when heated, the miscibility of triethylamine in water decreases dramatically and that phase separation of it might be the driving force for the dissociation of protons from the amine.

Future work is focused on: Potential for amines to be regenerated such that the corresponding acid concentration is capable of dissolving both Mg and Ni from serpentinites in a reasonable timeframe; evaluation of technical feasibility of each unit operation needed for the overall process; determination of potential for selective precipitation of Mg and Ni carbonates; identification of optimum amine and acid counter ion. If the process is successful with a sulphate counter ion there is also the potential to treat Mg sulphate tailings to regenerate sulphuric acid.
THE GORO PROCESS
AN OUTSIDERS PERSPECTIVE

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Overview

- Location
- History
- Process Overview
- Incidents
- Concluding Remarks

(Drawn from a variety of published sources)
ABSTRACT

The precipitation of mixed hydroxide is increasingly being considered as an intermediate step in the hydrometallurgical processing of nickel and cobalt. Producers currently receive roughly 75% of the value of the contained nickel and zero value for contained cobalt. In this paper, a new selective leach process for refining the mixed hydroxide is described that allows for recovery of the majority of the nickel as final metal product and realizes value for the cobalt. The features of the new process are compared with two other alternative routes (1) acid leaching followed by solvent extraction of the cobalt and (2) ammonia leaching followed by solvent extraction of the nickel. The outcomes of a process simulation for the selective acid leaching process are presented along with capital and operating cost estimates. The operating and capital costs of the process are estimated to be ±50%. For the processing of 50,000 t-Ni/y in the form of MHP, the operating cost is estimated to be $93 million AUD ($0.87 per lb of Ni contained in MHP) and the capital cost as defined for this study is estimated to be $287 million AUD. A new 20 year plant processing MHP would have a payback period of less than 2 years, an IRR of over 60% and an NPV of greater than $1.5 billion AUD. Over 94% of the total value (nickel and cobalt) contained in the MHP is extracted by the new process.