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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.

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Nickel-Cobalt-Copper Proceedings

Opening Address

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A RESEARCH-BASED STRATEGY FOR ESTABLISHING AUSTRALIA AS A LEADING PLAYER IN THE EMERGING GLOBAL BATTERY INDUSTRY

By

Jacques Eksteen
Chief Operating Officer and Research Director
Future Battery Industries CRC (Australia)

ABSTRACT

The rapid shift to a renewable energy future is driving a global battery boom never seen before. Storage technologies will be a cornerstone of future electricity and transport systems.

As a result, many countries are competing for a larger share of the world's battery supply chain at a time when trade tensions and geopolitical issues are a growing influence.

Australia can build on its strengths in this environment to secure an expanded place as a central player in global battery value chains - an abundance of battery minerals, world class skills in mining, processing, research and regulation, and opportunities arising from growing renewable uptake in our electricity grids.

A key pathway in making the most of the opportunity is industry-led research which can help players large and small move further down the value chain in creating new investment and industries in Australia.

This presentation will provide an update on the establishment of the Future Battery Industries CRC which will put Australia at the centre of a national plan to refine, manufacture and supply materials and components for batteries. It will highlight some of the project activities being pursued to extract and refine battery metals such as nickel, cobalt and lithium from diverse resources and to produce nickel-cobalt-manganese (NCM) mixed hydroxide precursors and cathode active materials, as well as the projects involved with battery testing and environmental impact minimisation across the value chain from resources to cathode active materials.

The FBICRC represents a unique and growing collaboration bringing together industry players across the value chain in Australia and overseas, eight universities and the CSIRO, State Governments and many SMEs to further develop the battery industry eco-system in Australia and the research and workforce skills required.

The first wave of potential flagship research projects are under development and several scene setting research projects have already been commissioned.

As a six-year cooperative research centre, FBICRC is trying to rapidly build momentum as it moves into delivering industry-focused research that in turn produces real and measurable outcomes tied to economic growth, new jobs and continued investment in the sector.

With around $130M (cash and in-kind) and nearly 60 participants, we are the largest battery industry collaboration in Australia's history – though a small budget in globally terms we are committed to working with others to leverage existing research activities and resources. We remain open to new participants and supporters.

Keywords: future battery industries, research, education, jobs, investment, nickel, cobalt, lithium

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Keynote Address

Nickel-Cobalt-Copper Keynote Address

BIOLEACHING OF NICKEL AND COBALT – THE PROGRESS AND THE POTENTIAL

By

John Neale
Technical Specialist
Mintek, South Africa

ABSTRACT

The emergence of bioleaching for the processing of sulphide ores and concentrates has occurred over the past 35 or so years. The use of this technology for the extraction of nickel and cobalt has been extensively investigated over this period, and it has found commercial application in several forms, ranging from the treatment in mechanically-agitated tanks of cobaltiferous pyrite tailings just north of the equator in central Africa, to the extraction of nickel from a polymetallic black schist orebody in heaps situated in boreal conditions just outside the Arctic Circle.

In between those extremes, several other pilot, demonstration-scale and industrial operations have been implemented across a variety of dimensions, including those already mentioned (using mechanically-agitated versus heap reactors, and in widely diverse climatic conditions), but also encompassing vastly differing mineralogies and chemistries, varied microbial communities and their associated operating temperature ranges, and with a wide-ranging selection of downstream processing flowsheets for purification and recovery.

This review traces the emergence and development of nickel and cobalt bioleaching technology, focusing on the impact of mineralogy on the chemistry of the leaching processes, the important microbial factors, and how these parameters, combined with economic considerations, influence flowsheet selection. Progress is assessed by reviewing the significant advances that have occurred on a case-by-case basis, with an emphasis on those projects that have proceeded to, or are close to, industrial application.

The future potential for bioleaching of nickel and cobalt is inextricably linked to these metals' respective markets. Both are battery metals, and future demand is likely to be closely correlated with the emergence of a low-carbon economy, and the impact this is expected to have on the energy sector. Supply-side factors will also impinge on the future application of nickel and cobalt bioleaching. Most notable amongst these are the supply from non-sulphidic resources, and geopolitical issues around responsible production (particularly for cobalt).

These factors are assessed, drawing on recent reviews and up-to-date market projections, to sketch the potential for the future use of bioleaching as a primary extraction process for these two metals.

Keywords: Bioleaching, Nickel, Cobalt

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EV Implications

A METALLURGICAL EVALUATION OF THE TRANSITION TO ELECTRIC VEHICLES

By

[1]Mike Dry and [2]Bryn Harris

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[2]NMR360 Inc., Canada

Presenters and Corresponding Authors

Mike Dry

Bryn Harris

ABSTRACT

Whilst increased EV usage may or may not significantly reduce global emissions of CO_2 to the atmosphere from the whole production/usage cycle of vehicles, it will certainly improve the air quality of our cities. In this paper, we examine the impact of two scenarios (New Policies and EV30@30) recently published by the IEA (International Energy Agency), focussing on the requirements for the metals that their implementation require.

We calculate that, while it appears that reserves of the relevant metals are adequate, the advent of 130 to 250 million electric vehicles on our roads, in accordance with the two scenarios above, will increase the demand for lithium by 170-326%, Class 1 nickel by 82-156%, cobalt by 97-187% and graphite by 130-251% of current global production, just for the EV batteries needed. We calculate the increased demand for copper and aluminium to be 4-7% and 2-4%, respectively, of current world production.

We also examine the impact on the global demand for the various metals in the infrastructure required for harvesting the amounts of non-fossil energy called for by the two scenarios studied. If all the electricity required for EVs were to come from solar power using CIGS panels, the global production of gallium would need to increase two- to four-fold, that of indium five- to ten-fold and selenium four- to eight-fold. For thin-film CdTe panels, the global production of tellurium would have to increase by a factor of 38 to 66. For wind power, generating the required electricity would require the global production of neodymium to rise by over 800 percent. Nuclear power appears to be a non-fossil source that is well placed to supply the extra electricity called for in the two IEA scenarios.

The metal most likely to curtail the production of high-capacity batteries for electric vehicles is cobalt, which is a by-product of both nickel and copper production. Choosing the appropriate deposits from which to produce the extra copper and nickel could also generate the extra cobalt required.

We ignore the impact of recycling and re-processing of old tailings in our analysis of the two IEA scenarios, but we do, nevertheless, recognise that both of these are targets for the near future, and that the final full penetration of electric vehicles will require extensive recycling and the re-processing of tailings that are presently not counted as reserves.

Keywords: Batteries, EVs, CO_2 emissions, solar power, wind power, nuclear power, cobalt, nickel, lithium, rare earths

ENERGY AND EMISSION PERFORMANCE OF LITHIUM ION BATTERY POWERED VEHICLES

By

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Consultant, Australia

Presenter and Corresponding Author

Peter Jolly

ABSTRACT

The Lithium Ion Battery (LIB) is a maturing technology that is finding large scale application in electric vehicles (EVs) and in stationary storage applications, such as the Tesla Powerwall. The primary constituents of a LIB are the cathode, consisting of various percentages of Nickel, Cobalt and Manganese. the anode, consisting of graphite, and the electrolyte made of Lithium ions. All these materials are either sourced from mining and refining operations or perhaps recycling. These operations use primary energy, either in the form of fossil fuels or other sources, such as renewables or nuclear, to produce the final product.

The paper summarizes already published data on a Cradle to Grave (CTG) analysis of EV's compared to other vehicle types, including Hydrogen Fuel Cell Vehicles (H_2 FVC). The results show that EV's are attractive, both from an energy and CO_2 emissions footprint, although challenges remain to reduce the driving costs, specifically the capital cost of the EV and its associated LIB. While the data presented is for USA, the analysis could be mirrored in Australia using the analysis methods outlined in the paper.

Keywords: Lithium Ion Batteries, Nickel, Cobalt, EROI, ESoEI, GREET, Cradle to Grave, BEV, FVC, Hydrogen

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Precursor Products

MARKET OUTLOOK FOR BATTERY GRADE NICKEL SULPHATE AND IMPLICATIONS OF VARYING PRODUCT SPECIFICATIONS

By

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JordProxa Pty Ltd, Australia

Presenter and Corresponding Author

Nipen Shah

ABSTRACT

Nickel sulphate is a key battery pre-cursor material for lithium ion batteries. The rapid increase in the number of electric vehicles (EVs) and storage batteries will create a surge in the demand for nickel sulphate. Manufacturers of the lithium ion batteries used in many of these vehicles have been able to increase the energy density of the batteries by increasing the ratio of nickel contained in the cathode. Taking into account both rising vehicle numbers and changing battery chemistry, Roskill estimates that the demand for nickel sulphate will grow 25% every year for the next nine years.

The specifications for the purity of battery precursor materials such as nickel sulphate hexahydrate are very stringent, but are not well defined globally and differ significantly. These purity requirements have significant effect on the capital and operating costs of pre-treatment and crystallisation plants.

In this paper we will explore the linkages between the EV growth, nickel sulphate demand and required number of nickel sulphate plants. We will also discuss the implications of varying product purity specifications on plant design, project delivery and capital costs.

Keywords: Nickel sulphate, crystallisation, product purity, battery

NICKEL SULFATE FOR LITHIUM-ION BATTERIES – HOW ALTERNATIVE PRODUCTION PATHWAYS IMPACT GREENHOUSE GAS INTENSITY

By

[1]Sam Spencer, [2]Rob Rouwette and [1]Simon Donegan

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Presenter and Corresponding Author

Sam Spencer

ABSTRACT

Estimates of the increase in nickel production that is required to meet demand over the next decade range between 1.0 and 2.5 Mtpa. These forecasts incorporate a conservative prediction that 45 - 60% of this growth will be needed just to satisfy the projected electric vehicle market. For this market, a large part of this nickel demand is expected to be in the form of high purity nickel sulfate that is required to produce lithium-ion batteries.

One of the drivers of the projected growth in electric vehicle (EV) production is the demand for reduced transport greenhouse gas (GHG) emissions. A key contributor to lifetime EV GHG emissions is the GHG intensity of the EV lithium-ion battery pack. In turn, the major contributor to the GHG intensity of the battery pack is the GHG emissions associated with the production of metals used in the battery cathode (especially nickel and cobalt).

Nickel exhibits a wide diversity of ore types, mineralogy and processing technologies, which translates into a wide variation in environmental impacts associated with nickel sulfate production. Therefore, when studying the GHG emissions intensity of nickel used in lithium-ion batteries it is important to also understand the feed ore type, mineralogy and processing routes. Yet, despite this importance, there appears to have been little consideration of the GHG emissions footprint associated with different routes for producing the lithium-ion battery precursors (especially nickel sulfate).

To further our understanding of these issues, Clean TeQ set out to undertake a streamlined GHG life cycle assessment on the basis of the ISO 14040 series of standards, that compares the GHG emissions intensity of our proposed Sunrise process to possible alternative nickel sulfate processing routes.

Keywords: Nickel Sulfate, nickel pig iron, NPI, ferronickel, matte, Clean TeQ, Sunrise, Continuous Resin in Pulp, Ion Exchange, Electric Vehicles, EV, Lithium-Ion Battery, Greenhouse, GHG, Life Cycle Assessment, Carbon Dioxide

CRITICAL CONTROL POINTS - THE KEY TO EV CHEMICAL QUALITY AND VALUE CHAIN PRODUCTIVITY?

By

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Jenike & Johanson, Australia

Presenter and Corresponding Author

Corin Holmes

ABSTRACT

Explosive demand for electric vehicle (EV)'s and the higher premium battery grade chemicals attract has resulted in a rush to develop integrated operations that can capitalise on the opportunity. By moving downstream into the transformation of their direct ship ore or mineral concentrates (traditional endpoints), miners aim to increase their value add and profitability-worthy objectives.

Historically however only 5% of even basic Mining and Mineral Processing (M&MP) projects ever meet their self-proclaimed criteria for success. Operations involving continuous multi-step processing and chemical transformation(s) unsurprisingly fare even worse. One of the key reasons here is that these more complex operations, striving for high purity, tend to be designed and operated with a mineral processing mindset. In reality such operations are closer to pharmaceutical and food industry value chains, where a great deal of care and attention is required to design a capable operation and then sustain the quality and productivity imperatives.

Interestingly in both these manufacturing sectors they think about their value chains in terms of Critical Control Points (CCP); which are physical locations in the process line where failure could cause harm to people, the environment or the business (quality, productivity, waste); and where preventative control measures can be applied. This is useful framework that can be applied to EV chemical value chains as well.

In the context of an integrated EV chemical production value chain, CCP's can be defined as physical locations where there is a unique combination of controllable parameters viz;

- Interfacing materials -both flowing and fixed in terms of chemical and physical differences,
- Geometry, and
- Throughput.

According to this definition, every EV chemical production flowsheet contains many CCP's, mainly in the guise of material "transfers" (links between unit operations). As transfers are not within the scope of vendor packages and don't increase the embedded value of the passing material, they nearly always live in a M&MP operation "twilight zone", devoid of clear accountability for either their design or subsequent operation. Adaptation of the CCP framework changes all that by recognising the value destroying potential of transfers as control points, and in doing so establishing a process identity to which quality and performance accountability can be assigned.

This paper explores the potential of the critical control point framework in the context of integrated EV chemical production value chains and describes how the concept could be easily adopted to drive quality and productivity improvements as well as minimise process waste.

Keywords: EV, Quality, Productivity, Accountability, Critical Control Point

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Copper Process Innovation

Abstract only - no paper provided

A BRIEF HISTORY, AND FUTURE, OF PROCESS INNOVATION IN COPPER

By

Richard Macoun

Consultant, Australia

Presenter and Corresponding Author

Richard Macoun

ABSTRACT

Process innovation has been a significant driver of the decrease in the production cost of copper. This paper looks at the historical developments that have shifted the cost of copper production, with an emphasis on hydrometallurgical processes. The demand for copper is expected to increase with the increasing electrification of the global economy. Further decreases in the cost of production will be needed to utilize lower grade resources and satisfy this demand. This paper investigates collaborative research & development, innovation and implementation as a pathway to achieving this.

Keywords: copper, process innovation, hydrometallurgy, collaborative R&D

COPPER SLAG WASTE RESOURCE POTENTIAL FOR A CIRCULAR ECONOMY: A REVIEW

By

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Presenter

Tina Phiri Chanda

Corresponding Author

Aleksandar Nikoloski

ABSTRACT

The mining industry faces a number of challenges that include rapid depletion of high-grade deposits, rising demand for energy metals, and growing environmental concerns associated with waste disposal. Copper slag is one of the waste materials causing increasing concern due to the huge volumes being produced annually worldwide. These huge quantities of discarded slag not only cause environmental pollution and space problems for disposal, they also result in waste of valuable copper and cobalt. This is increasingly important due to the growing demand for these metals in new technologies, which may result in a supply deficit from conventional mining production.

To address these challenges, recycling and repurposing of copper slag waste using innovative technologies should be considered, creating a resource for a circular economy. This paper presents a review of copper slag as a potential resource for cobalt and copper metals. An overview of the chemical and mineralogical characterisation of copper slag is discussed. Finally, an example of the utilisation of the copper slag waste in the concrete industry to promote environmental sustainability is presented. This paper demonstrates that recycling and repurposing copper slag waste has benefits for a circular economy such as increasing critical metal supply, reducing the cost of disposal and environmental protection.

Keywords: Copper slag waste; review; circular economy; characterisation; environmental sustainability, cobalt

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Ion Exchange

RESIN IN PULP PROCESSING EQUIPMENT

By

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Presenter and Corresponding Author

Thomas Heinzle

ABSTRACT

Resin-in-Pulp (RIP) technology was originally developed for uranium applications over 60 years ago. The early applications in USA mainly treated dilute low solids slurries. Treatment of pulp densities of up to 50-60% solids was mainly developed in Russia, so that most installations of RIP technology for uranium and later gold have been in countries associated with the former Soviet Union (FSU). This technology is 'proven', hence overall project risk is minimised and acceptable.

The Russian adsorption technology is based on screen-mix systems developed in USA in late 1950s: Pachuca tanks to contact resin with the pulp; airlift pumps for slurry and resin transfers; external inter-stage screens to separate resin from pulp. The systems also incorporate Kazak 'U' columns for resin elution, and trommel screens for trash and resin screening duties apart from interstage transfer. It is claimed that this equipment limits costly resin attrition, however, some of these equipment items are limited in terms of maximum size, such that multiple units must be installed in parallel for large throughput and/or high mass transfer (eg Ni/Co/Cu) mineral processing plants, which limits the economies of scale and increases operational complexity.

Most resin applications in the western uranium industry are based on recovery from solution (Resin-in-Column) or dilute slurries, with only a single application of RIP for uranium recovery at Kayelekera. There have been several western applications of RIP for gold recovery, with the largest constructed by Ausenco to treat 4.25 Mt/y of autoclave discharge slurry at Goldstrike in Nevada, USA. Both of these RIP plants faced early technical challenges, and both overcame these challenges. Kayelekera has since ceased operations for non-technical reasons.

Western style RIP plants designed along the lines of a Carbon–in-Pulp (CIP) flowsheet can treat more ore in a single train using mechanically agitated tanks for contactors, in-tank screens for inter-stage screens, recessed vane centrifugal pumps for resin transfers, straight columns for elution, and linear vibrating screens or linear moving cloth screens for all other screen duties.

Both gold and uranium applications treat low grade ores so that resin cycle times are long, favouring lower resin wear. For base metal applications metal concentrations in solution are much higher, leading to much shorter resin cycle times and potentially higher resin wear.

Operating data on resin attrition was collected for both pachuca and mechanically agitated style equipment for various sized plants and commodities. There is considerable overlap in resin attrition. The data demonstrates that both pachuca and mechanically agitated plant designs can perform equally well with respect to resin attrition if the plant is well designed, but if not well designed, then the mechanically agitated plant can have greater attrition especially due to resin transfer outside the RIP circuit. The conclusion being that selecting the old US screen mix style equipment to reduce attrition is not necessary, but irrespective of equipment selection, good plant design is paramount.

This paper presents the CAPEX and OPEX opportunities and threats associated with both pachuca and mechanically agitated designed large-scale resin in pulp processing equipment. At present the pachuca technology is the only 'proven' technology with a long-established track record. Mechanically agitated CIP style processing technology for RIP is operating successfully, but is still in need of technical development, i.e. it is not fully 'proven'. Further studies and testwork are required, which will take time, but they are likely to suggest that the mechanically agitated technology is superior for large-scale operations.

Keywords: Resin in Pulp, RIP, Resin Processing, Uranium RIP, Gold RIP, Nickel RIP, Cobalt RIP, Copper RIP

ADVANCED ION EXCHANGE: SELECTIVE RECOVERY AND PURIFICATION OF ZINC SULFATE AND COBALT LEACH SOLUTIONS

By

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Presenter and Corresponding Author

Les-Lee Thompson

ABSTRACT

Two base metal streams were identified for potential value recovery and product quality improvement through the selective removal of metals prior to product precipitation using silica-based advance ion exchange resins. The focus of the test work was to establish baseline resin performance such as metals selectivity and loading capacity in the two mixed metals streams. Stream 1 is a zinc sulfate leach solution containing Cd, Al, Cu and Ni as impurities. The zinc sulfate solution is further processed to agricultural grade zinc sulfate monohydrate. Stream 2 is a cobalt leach solution containing Cu, Ni, Zn and Mg as impurities with concentrations that prevent the final cobalt product from achieving battery grade concentrations.

Batch isotherm resin tests were conducted to establish the baseline performance of various resins from PQ Corporation's AlphaSelect silica resin range. Adsorption tests were performed over a 24-hour period to establish resin selectivity and capacity. Sulfuric acid at 2M and 0.5M was used to evaluate the elution efficiency at different acid concentrations. A CdSelect resin was manufactured by PQ with two different particle sizes (60 µm and 90µm) to further test the resin size effect on loading capacity. The CdSelect resin was tested for Cd removal from the zinc sulfate solution. Duplicate samples were conducted on all batch tests for repeatability.

This paper covers the preliminary process design, mass balances and economic feasibility based on the resin performance and achievable stream compositions through the implementation of silica-based ion exchange resins in both base metal stream applications.

Keywords: Ion exchange, zinc, cobalt, purification, selective recovery

NICKEL- AND COBALT-CONCENTRATE PURIFICATION BY SOLVENT IMPREGNATED ION EXCHANGE RESINS: A CASE STUDY

By

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Presenter and Corresponding Author

Dirk Steinhilber

ABSTRACT

In this paper we present the purification of nickel- and cobalt concentrates by the use of Solvent Impregnated Resins (SIR) Lewatit® TP 272 and Lewatit® VPOC 1026. SIR are macroporous crosslinked polymeric beads with a solvent extractant adsorbed and immobilized on the surface and within the pores. These resins can be thought of as having a liquid complexing agent dispersed in a solid polymeric medium.

SIR combine the advantages of ion exchange resins (low capital cost, simple maintenance) with the unique and enhanced metal selectivity of solvent extraction.

These materials possess different characteristics from standard ion exchange resins, because of their low density (lower than water) and the physical entrainment of functional groups. As result, the resins need to be operated at acidic pH values to avoid losses of extractant.

Therefore we present in this paper a successful industrial application case of Lewatit® VPOC 1026 being used for Zinc removal from cobalt concentrates in a refinery located in Canada. (Feed composition of average 35 g/L Cobalt with Zinc concentration ranging from historical 5 mg/L to current 40 mg/L average. Handling spikes up to 100 mg/L).

Interestingly, we were able to optimize the operational parameters such as regeneration time. The reduction of regeneration time from 9.6 h to 4 h was achieved, which is crucial to design an economic process. Water wash steps were removed from the regeneration process to increase the life-span of the resin. Additionally, the acid concentration was reduced from 150 g/L to 100 g/L which allows significant savings on chemical costs. Furthermore, during preload the discharge solution is fed forward to batch PPT, with batches consistently meeting the low Zinc targets. An additional air displacement of the liquor leads to another saving.

In conclusion we show that solvent impregnated resins are well suited for the purification of base metal concentrates. We show that this resin type has been successfully operated within an industrial setup since many years. SIR resins are interesting candidates for the purification and refining of battery chemicals such as Nickel and Cobalt.

Keywords: Solvent impregnated resins, cobalt and nickel concentrate purification, case study,

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Heap Leaching

HEAP LEACH SOLUTION TRANSPORT MODELLING FOR IMPROVED PROCESS CONTROL AND PRODUCTION FORECASTING

By

Oliver Kloiber-Deane

Element Process, Australia

Presenter and Corresponding Author

Oliver Kloiber-Deane

ABSTRACT

A dynamic bulk solution transport model has been developed by Element Process and coupled with a leaching model to predict, over time, solution flows and grades in heaps, ponds, solvent extraction and the neutralisation plant of an overseas copper heap leach project.

The model takes into account the ore stacking schedule, ore leach rates, irrigation rates, rainfall and evaporation, changes to on-flow solution and off-flow destination, and chemistry in solvent extraction and neutralisation to provide a comprehensive project-level process model tracking aqueous copper, iron, zinc and free acid.

The model can be operated by project staff, and simulation results are used for medium- and long-term planning and process control.

Project mineralogy is primary and secondary copper sulphides hosted in massive pyrite and marcasite. Operators face challenging leach chemistry and extensive solution flow lag due to the topographically-constrained layout of leach pads. In medium-term planning, pregnant leach solution grade predictions by the model feed back into irrigation scheduling and give advanced warning of problems to enable remedial action.

In long-term planning, the model predicts the accumulation of iron, free acid and zinc in recirculating solutions. These results inform the implementation of engineering solutions to prevent problems and add value, and allows process change options to be explored in theory before pilot plants are built to prove the feasibility of any change.

The model's use in short-term planning continues to be explored.

Planning in heap leaching is always challenging due to its inherent semi-batch nature, significant process response lag, and exposure to the environment. As such, potential exists for similar solution models to improve production and compliance outcomes at other sites by providing a practical, site-operated tool for forecasting solution volumes and grades across the operation.

This paper details the development of the bulk solution transport model and its application in a commercial setting.

Keywords: heap leaching, heap leach modelling, dynamic process simulation, residence time distribution, solution transport modelling

ALTA 2020 25 YEARS ONLINE NOVEMBER

Nickel-Cobalt-Copper Proceedings

Tailings

DRY STACKING OF TAILINGS BY 3D PRINTING

By

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Presenter and Corresponding Author

Tim Graham

ABSTRACT

Traditional wet tailings disposal methods have been under intense scrutiny following two recent catastrophic TSF (Tailings Storage Facility) tails dam collapses in Brazil. Whilst regulators have rushed to ban upstream dam construction methods and operators are pumping slurry from high risk TSFs, these actions are addressing symptoms rather than causes.

Although centreline and downstream construction methods provide higher factors of safety than upstream methods, they fail to address the root cause of the issue: Wet tailings. Under certain conditions, including seismic or heavy rain events, wet tailings are subject to liquefaction and pore pressure release which may exceed TSF design capabilities.

The ultimate goals of dry tailings stacking systems are to provide safe storage facilities, retrieve maximum water volumes and to provide simplified regulations by removing the “dam” status, thereby promoting quicker project approval times. Most existing dry tails disposal methods are variations of processes which remove water from slurry by filter pressing and deposit dewatered tails by conveyor stacking systems. These have been successfully operated on diverse operations globally for many years but have not attracted widespread adoption by the mining industry due to complexity, high maintenance and high capital and operating costs.

Atom Minerals’ Engineering Team looked outside the mining industry for solutions to overcome the cost and complexity of current dry stacking systems, and is pursuing an entirely different methodology. The team studied large centre pivot irrigation systems with a view to transferring key elements of the technology including simplicity, control and efficiency into Atom’s own concept.

A centre pivot system irrigates a circular area of crops by transferring large volumes of water along a horizontal pipe (the boom) which rotates slowly about a central vertical pipe (the pivot). The boom, which is typically between 500 and 1,000 metres in length, is divided into approximately 15 to 30 of 33 metre spans. Each span is connected to two vertical structures with electrically powered wheel sets at either end which move the span clockwise or anticlockwise as determined by the irrigating requirements. Each span moves at the same angular speed and is fitted with regularly spaced sprinklers which deliver optimised water volumes to the crops below. A pivot typically takes up to 3 days to complete a circle with speed and flow rates being determined by variables including soil quality, terrain slope, fertilizer usage and water availability.

The Atom Minerals dry tailings stacking concept uses key centre pivot features modified to convey tails rather than water, and resembles a giant 3D printer which “prints” thickened slurry. Tails slurry is piped from the plant, under the stacking area, through a central vertical pipe and into a dewatering cyclone which is upstream of the horizontal boom pipe. The cyclone splits the incoming slurry into a dilute overflow stream (approximately 70% water) and a thickened underflow stream (30% water). The underflow is pressurised by a positive displacement pump, flows along the boom pipe and is discharged through regularly spaced remotely controlled valves. Each valve is connected to a flexible “dropper” pipe which trails on the ground behind the moving boom and “prints” a continuous bead of thickened slurry.

As the boom rotates it sweeps out three concentric circular zones. In the outer zone (70% of total area), the thickened slurry is deposited through the dropper pipes in parallel circular beads. After every revolution of the boom, the dropper pipes are moved one bead width outwards by a cable mechanism. This pattern continues until the entire outer zone is covered with thickened slurry. Concurrent to this activity, the dilute slurry from the cyclone overflow is deposited into the middle zone (25% of total area) and is able to flow easily and form a level surface between a raised bund on the outside and a coarse crushed rock filter on the inside. As the dilute slurry level increases with fresh inflows, it flows slowly through the rock filter, allowing for fine solids to drop out of suspension and settle whilst the water percolates through into the central clear water zone (5% of total area). The water in this zone is pumped back to the plant for reuse.

The key benefit of continuous slurry bead deposition is that there is sufficient time for the beads to dry below 20% moisture which allows for a second set of beads to be stacked on top the first set. Multiple levels of bead stacks can be deposited until the height nears the horizontal boom at which point an additional vertical pivot section can be added. This process can continue up to any designed height.

Atom's 3D slurry printing system is simple, controllable, inexpensive and provides an excellent return of water.

Keywords: Wet tailings disposal, Filter pressing, Dry tailings stacking, Centre pivot irrigation system, Concentric zones, Cyclone overflow, Cyclone underflow, Dilute slurry, Thickened slurry, 3D printer, Flexible dropper pipes, Beads, Coarse rock filter

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Nickel-Cobalt-Copper Proceedings

Laterites

THE ART OF HPAL

By

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ABSTRACT

In the past 25 years, ten HPAL projects from both the 2nd and 3rd generation were undertaken and seven are still in operation. Up to date, many valuable experiences with success and failure have been accumulated. Nowadays HPAL is moving toward the 4th generation by reflecting lessons learnt from the design, construction and operation and maintenance of the past HPAL projects.

The authors played key roles as owner, lender and engineering contractor, in the CBNC and THPAL projects. This paper presents considerations for success of anHPAL project. These subjects will be comprehensively discussed in the book titled “The ART of HPAL” which will be published soon. In celebrating the 25 year anniversary of ALTA, the essence of “The ART of HPAL” will be previewed.

The contents include; analysis and evaluation of the 2nd and 3rd generation HPAL projects in terms of technologies, implementation and operation and key factors for success are discussed. Visions of the owner leading to success of the project are considered and necessary concerns from the lender and the engineering contractor are also discussed. Finally, one of the concepts for success of the next generation HPAL projects is suggested.

Keywords: Book, The ART of HPAL, High Pressure Acid Leach, Laterite Nickel, Projects, Success, Failure, Technologies, Implementation, Operation, Management, Owner, Lender, Engineering Contractor, CBNC, THPAL

UPDATE ON THE PERFORMANCE OF THE RAMU NICKEL OPERATION IN PAPUA NEW GUINEA

By

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Presenter

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ABSTRACT

The Ramu Nickel project in PNG has been in commercial production since March 2012 and reached consistent nameplate capacity of 32,600tpa contained Nickel in the last quarter of 2016 and has consistently exceeded this rate since that time. The operation produces an MHP product that is sold to several Lithium ion battery manufacturers as well as refineries producing battery grade materials.

The paper will provide an overview of the unique features of the Ramu Nickel project, including the issues of mining in a wet tropical environment and the logistics and community relations aspects of managing such a large project in Papua New Guinea. The paper will include a discussion of the operating costs, thus providing a focus on the key areas for successful operation of a HPAL plant in a wet tropical environment.

The Ramu laterite deposit has proven to have a low degree of grade variability consistent with the original Mineral Resource model. This has been an important factor in the development of the successful operation, along with several key innovations pioneered by Ramu, such as hydro sluicing.

Keywords: HPAL, Hydro Sluicing, MHP

IMPROVED PASTE PUMPING TO HPAL STORAGE TANK AT MURRIN MURRIN OPERATIONS

By

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ABSTRACT

Thickened slurries with elevated viscosities are increasingly being pumped through pipelines in mining and mineral processing industries because of the need for reduced water consumption and water dilution in processing circuits. Transporting a concentrated/thickened slurry, however, can be problematic due to increased friction loss in the pipe, which may exceed the pumping capacity.

In 2014, Murrin Murrin Operation (MMO) raised this problem with CSIRO in relation to pumping concentrated feed slurry to their HPAL autoclaves, where Ni/Co laterites are leached. The slurry, which is thickened to paste prior to leaching, showed a high viscosity and yield stress. The motor amps for the pump system approached overload when operating with a solids concentration at the design duty. Operators had to dilute the slurry with water - approximately 15-25 m^3/h water was added into the slurry through a T-section at the inlet of the pump to maintain the HPAL Paste thickener underflow of ~500 m^3/h.

CSIRO Drag Reduction technology (DR) is designed to reduce the pipe friction by providing lubrication on the internal surface of a pipe or other conduits through injecting lubricating material such as water or other suitable fluids. Unlike conventional injection or dilution practices for slurries, this technology typically uses a fraction of the water (e.g. one third) used in conventional systems (e.g. single point injection) due to its novel uniform flow design.

MMO agreed in 2015 to trial DR in their operation. Initially, a prototype DR unit was developed and tested in CSIRO's laboratory. The device was delivered and became operational at MMO in early 2016. After many months of operation, MMO concluded that the DR only used ~5 m^3/h water dilution, ~25% of the original amount, to maintain the required production flow. This paper summarises DR technology and the operational experience at MMO.

Keywords: Pipe flow, drag reduction, thickened slurry, HPAL, pumping, lubrication

PULSATION REDUCTION SYSTEM FOR AUTOCLAVE FEED PUMPS

By

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ABSTRACT

Autoclave feed pumps as used for HPAL applications are a crucial part of the entire process of a Nickel/Cobalt facility. Any pump down-time or un-planned maintenance directly affects the productivity of the entire plant. Therefore, increasing the reliability of the autoclave feed pumps leads to a more stable process.

When operating autoclave feed piston diaphragm pumps, the oscillating movement of the pump pistons results in asymmetrical volume flows, both in the suction side and at the discharge side of the pump. These asymmetrical flow rates lead to pressure pulsations and to vibrations in the pump itself and the adjacent piping system, having a negative impact on the pump operation. In the suction side of the pump, these pulsations can cause cavitation, that reduce the pump reliability and pose a risk for damages, not only for the pump, but also for the entire system.

The paper will present a new pulsation reduction system (PRS) invented by MHWirth. This PRS is - in contrast to conventional pulsation dampers - suitable to eliminate high-frequency pulsation of reciprocating diaphragm pumps.

Brief description of functionality:
The new damper is connected to the propelling fluid chamber of the diaphragms. The propelling fluid, a hydraulic oil, is used as a damping medium, converting the pulsation energy described above into heat by throttle effects. This effect is similar to a shock absorber.

The paper will also explain the PRS effects, present operational data from field application and address the following benefits by using it in the HPAL process:

- Elimination of pressure surges and water hammer effects
- Minimum vibration at highest stroke rates
- Cost-value ratio
- Retrofitting of existing autoclave feed pumps

Keywords: autoclave feed pumps; high-temperature nickel laterite slurries; HPAL; pulsation; cavitation; water hammer effect

THE CASE FOR A CHLORIDE-BASED PROCESS FOR THE TREATMENT OF NICKEL LATERITES

By

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ABSTRACT

It is widely believed that if both nickel and cobalt production is to keep up with their projected demand due to the electric vehicle (EV) revolution, then there has to be a significant increase in commercial projects based on the processing of, in particular, nickel laterites, since approximately seventy percent of known land-based nickel reserves are contained in laterites. Over the past twenty-five years, apart from some nickel pig iron (NPI) operations wherein the cobalt is not recovered, and the nickel produced is not suitable for battery production because that requires Class 1, the predominant method of processing laterites has been High Pressure Acid Leaching (HPAL). Of the ten plants that have been commissioned since the mid-1990s, only seven are still operating, and none of these have been what could be described as a major success. This paper will delineate why it is believed that HPAL is a fundamentally flawed technology, not only being very expensive, but also requiring twice the stoichiometric acid addition, generating up to 1.5 tonnes of residue for every tonne of ore mined, having exceedingly difficult solid/liquid separation issues and a multitude of equipment reliability problems.

It is a fact that three of the world's major nickel refineries, those at Kristiansand in Norway (Glencore, formerly Falconbridge), at Niihama in Japan (Sumitomo) and Sandouville in northern France (Eramet) are not only chloride-based, but have been in successful operation for many years, well over half a century in the case of Kristiansand. This fact, therefore, dispels the widely held mis-conception (myth) that chloride plants cannot be successfully operated because of corrosion and a lack of suitable materials of construction, something that is consistently still voiced at major conferences, as it was in the panel discussion at ALTA 2019. Given the current climate, and the lack of true success of HPAL, it is surely time now to marry front-end processing with the established back-end refining and have the whole process carried out in a chloride medium.

The many advantages of working in chloride are highlighted, from smaller equipment to much simpler metal separation strategies and a wider range of products. The key unit operations in any chloride-based circuit are the ability to control iron and recycle the chloride lixiviant, and a description of the novel process developed and patented in this respect is given, together with where it is going to be deployed.

Keywords: chloride, nickel, cobalt, laterite, High Pressure Acid Leaching (HPAL), EV revolution.

TOWNSVILLE ENERGY CHEMICALS HUB - THE 'TECH' PROJECT

By

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Presenter and Corresponding Author

Boyd Willis

ABSTRACT

Queensland Pacific Metals (QPM) is developing the Townsville Energy Chemicals Hub (TECH) project in North Queensland, Australia and a Prefeasibility Study (PFS) was completed in December 2019. High grade nickel laterite ore mined in New Caledonia will be sea freighted 2,100 km to the Port of Townsville, formerly used by Queensland Nickel (QNi) for importation of ore. The project will produce high purity nickel and cobalt sulphate products along with high purity alumina (HPA) for the battery chemicals market.

A treatment plant employing the DNi Process™, based on a proprietary nitric acid flowsheet, will leach 566,000 wet tonnes per annum of ore grading 1.60% Ni and 0.18% Co, to produce a Mixed Hydroxide Precipitate (MHP) along with magnesium oxide, a hematite product and aluminium hydroxide. The MHP will be transferred to a co-located refinery to produce 26,400 tpa of nickel sulphate hexahydrate crystals and 3,100 tpa of cobalt sulphate heptahydrate crystals, and the aluminium hydroxide will be refined to produce HPA. Whilst the DNi Process™ flowsheet can treat a range of ore types, most of the development work to date has targeted ore blends with a magnesium to iron ratio of 0.8 or higher. The TECH limonitic feed ore has a high iron content, with a magnesium to iron ratio of just 0.065. Consequently, the successful treatment of this feed requires careful consideration of the magnesium to iron ratio, particularly in the Iron Hydrolysis circuit and offgas handling systems.

This paper discusses the preliminary metallurgical testwork, outcomes of the PFS and project economics. The process flowsheet is introduced, and innovations for dealing with high iron feed to facilitate stable operation and energy optimisation in the Iron Hydrolysis circuit are outlined.

Keywords: Ore Import, New Caledonia, Townsville, Battery Chemicals, Nickel Sulphate, Cobalt Sulphate, Nitric Acid, DNi Process, Limonite, Iron, Iron Hydrolysis, Economics, Energy Optimisation

NEXT GENERATION LATERITE PROCESSING

By

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ABSTRACT

Nickel laterites are hydrometallurgically processed by HPAL or atmospheric direct leaching. Both methods have issues with technical complexity and feasibility. A development of a novel nickel laterite processing method is presented by Metso Outotec. The process offers efficient extraction of nickel and cobalt from a laterite ore utilizing superheated steam treatment in a hydrometallurgical flowsheet. This paper introduces the process and presents laboratory scale testing results.

Process principles include agglomeration of ground laterite with sulphuric acid, superheated steam treatment of the agglomerates in elevated temperature and water leaching of the steam treated material. The process concept is based on conversion of goethite to hematite and sulphation of nickel and cobalt during steam treatment. In the water leaching, nickel and cobalt dissolution is rapid due to their sulphation and iron dissolution is minimized by the conversion of iron from goethite to hematite. Sulphuric acid consumption of the process is moderate.

Metso Outotec has successfully tested this process in laboratory scale. Efficient nickel and cobalt extractions were achieved with minimal dissolution of iron in the solution. Nickel and cobalt containing PLS is suitable feed for traditional further treatment. By facilitating the sulphation in the steam treatment with superheated steam from sulphuric acid plant, the process offers a potential way to treat nickel laterites.

Keywords: Outotec, Laterite, Leaching, Nickel, Cobalt

CONTINUED DEVELOPMENT OF NIWEST NI LATERITE PROJECT – NIWEST SOLUTION NEUTRALISATION, FE/AL REMOVAL AND DIRECT SOLVENT EXTRACTION CONTINUOUS PILOTING

By

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David J Readett

ABSTRACT

GME's NiWest Ni Laterite Project is currently in its Pre-Feasibility Process Development stage. The NiWest Ni Laterite project 30km from Leonora in Western Australia contains 100Mt of +1% Ni Laterite in resource (JORC 2012).

The proposed Heap Leach, Solution Neutralisation and Fe/Al Removal, DSX (Direct Solvent Extraction) to pure Ni product process flowsheet has been going through a series of continuous pilot plant testing phases. The most recent pilot program has been the NiWest Process DSX circuit. Following extensive small-scale batch and batch/continuous testing, and mass balance based metallurgical modelling, a single stage neutralisation circuit was defined followed by a Versatic10 based DSX circuit.

The neutralisation circuit consisted of a preliminary re-leach circuit, where incoming pregnant leach solution (PLS) was contacted with recycled neutralised solid precipitates. The slurry was then neutralised using calcrete. & the neutralised slurry then thickened, with the resulting clear supernatant called "neutralised" PLS suitable for processing via DSX. The DSX circuit consisted of a preloading stage followed by a three-stage extraction, two-stage wash and three-stage stripping circuit. The high purity, high concentration Ni electrolyte was then contacted with Cyanex 272 to recover the valuable Co prior to generation of a pure Ni product of choice.

The paper summarised results from the 2017 continuous pilot plants that were operated at Nagrom Brisbane. The neutralisation circuit treated PLS generated from NiWest Project's Mt Kilkenny ore resulting in the removal of 99.5% of the Fe and 99% of the Al from solution with only 2% Ni losses. The resultant "neutralised" PLS was the feed to the DSX pilot circuit. The DSX circuit generated an electrolyte that, after Co removal, produced pure Ni sulphate electrolyte with 98% recovery of the Ni. The electrolyte was used to generate pure Ni sulphate crystal, Ni carbonate and electrowon pure Ni cathode. An intermediated strip stage was utilised to generate a pure Ni chloride product.

The continuous piloting has generated the necessary process information to allow for the successful completion of a Preliminary Feasibility Study for the NiWest Project based on the process flowsheet described.

Keywords: Ni Laterite, Heap Leach, Acid Neutralisation, Fe/Al Removal, Direct Solvent Extraction, Electrowinning, Process Development, Pilot Plant

JERVOIS' NICO YOUNG NI LATERITE PROJECT: DEVELOPMENT OF A NI LATERITE HEAP LEACH

By

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Presenter and Corresponding Author

David Readett

ABSTRACT

In 2019, Jervois Mining completed a Technical Study(1) on its 100% owned Nico Young. The NiCo Young project 25km north west of Young in central New South Wales has a mineral resource of >90Mt of 0.63% Ni and 0.05% Co Laterite (0.5% Ni cut-off), JORC 2012).

Over the past years, Jervois had investigated a number of options for the development of a NiCo Young project. In 2017, with a revitalised management team, Jervois focussed on development of the project based on a heap leach operation. Heap Leach was chosen as it has materially lower capital costs and is operationally simpler than alternate process routes such as high pressure acid leach (HPAL). Additionally, members of the Jervois team were responsible for the design, construction, commissioning and operation of the Ni laterite heap leach circuit at Glencore's Murrin Murrin Operations in Western Australia, where heap leaching was technically and commercially successful on ores similar to Nico Young.

The heap leach based flowsheets investigated have the capability of producing either a Ni/Co mixed hydroxide product or can be taken through to a pure Ni sulphate and Co sulphide.

During 2017/18, Jervois completed significant metallurgical testwork using targeted drill core from the Ardnaree deposit. The metallurgical testwork consisted of materials characterisation, geometallurgical evaluation, geotechnical and hydrodynamic testing, bottle roll and column leach testwork.

This paper summarises the positive results achieved from the metallurgical testwork program, summarised in Table 1, which provided confidence in the technical viability of heap leaching.

Table 1: Scaled-up 4m Heap Leach Process Design Criteria based on Metallurgical Testwork

Ore Type	Leach Cycle (days)	Ni Dissolution (%)	Co Dissolution (%)	Acid Consumption (kg/t)
Limonite	309	43	85	400
Saprolite	350	73	85	550
Weathered Serpentinite	368	81	85	400

The resultant Technical Study was conducted to a degree of accuracy consistent with a pre-feasibility study and was titled as such by its authors; however, the Mineral Resource was insufficient to support the estimation of ore reserves or to provide an assurance of economic development. For ASX reporting purposes, the Technical Study therefore could not be classified or referred to as a "pre-feasibility study" as defined by JORC Code (2012 Edition) clause 39.

Comprehensive pre-feasibility level mining study work was undertaken. This work included, amongst other key areas, agglomeration, stacking, and feed leaching analysis along with process waste stream determinations.

Keywords: Ni Laterite, Heap Leach, Metallurgical Testwork

IN-SITU RECOVERY – EMERGING TECHNOLOGY FOR THE EXTRACTION OF NICKEL AND COBALT FROM LATERITE DEPOSITS

By

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Maxim Seredkin

ABSTRACT

In-situ recovery (ISR) transfers hydrometallurgical processing of mineralised bodies to the subsurface to directly obtain solutions of commodities. As a result, there is little daylight surface disturbance. For ISR to be successful, however, deposits need to be permeable. Furthermore, commodities need to be readily amenable to dissolution by leaching solutions over a reasonable period, with an acceptable consumption of leaching reagents.

Modern processing of nickel-cobalt ores generally involves pyrometallurgical / smelting and hydrometallurgical methods. Hydrometallurgical methods include AAL, HPAL and heap leaching technologies. All these methods are not economic however for deposits in the Urals and Kazakhstan. Nickel pyrometallurgical plants of the Urals are currently closed, and AAL and HPAL test work did not demonstrate viable economic parameters.

The Ural-Kazakhstan province hosts Mesozoic nickel-cobalt laterite deposits with Mineral Resources containing 0.2 to 3 Mt of nickel metal. The deposits occur within zones of ultramafic massifs of various ages and genesis. These deposits were silicified in Cenozoic time under cover of younger sediments and are mainly represented by silicate mineralisation with quite low nickel and cobalt grades: Ni 0.3–1.3%, Co 300–500 ppm.

ISR has never been used for nickel-cobalt laterite deposits at the industrial scale. Successful laboratory and field pilot ISR tests have been completed in the past years however at several Urals deposits including Tochilnogorskoe (Lipovskaya group), Kungurskoye and Rogozhinskoe (Cheremshanskaya group), and Ekibastuz-Shiderty[(9)(10)].

The most successful and complete ISR test was completed at the Ekibastuz-Shiderty deposit where sulphurous acid was used as the leaching agent. The nickel grade in pregnant solutions (PS) reached 120 mg/l and nickel was extracted in the form of nickel cathode. Nickel grades in PS in laboratory column tests reached 500–2,000 mg/l. The liquid to solid ratio is 12–15. These values are comparable with heap leaching at the Murrin-Murrin project[(1)].

Hydrogeological conditions at the Ekibastuz-Shiderty deposit are quite favorable. Permeability is 0.1–0.3 m/day and higher in fractured and fault zones, comparable with uranium deposits in Wyoming. The ISR process will be applied above and below the water table with collection of PS from the water table in fractured serpentinite.

Clean TeQ[(4)] has developed a process for the treatment of Ni-Co PS using a complex hydrometallurgical method (a combination of IX, SX and neutralisation of pregnant solutions after HPAL). This method is applicable for Ni-Co deposits in the Urals and Kazakhstan with some improvements for the treatment of PS after ISR.

CSA Global and UGTC prepared an ISR process based on a combination of available modern technologies to support the Scoping Study for the Ekibastuz-Shiderty deposit in 2019. This technology is potentially amenable to other deposits in the Urals and Kazakhstan and maybe even more favorable for laterite deposits in tropical zones (such as Indonesia).

Keywords: in-situ recovery, nickel, cobalt, technology, laterite, deposits

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Solvent Extraction

COMMERCIALIZATION OF ACORGA® CR60 CRUD MITIGATION REAGENT IN NORTH AMERICA AND CENTRAL ASIA

By

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Bravo Mbao

ABSTRACT

Crud, sometimes referred to as gunk, is a stable emulsion of aqueous, organic, air and fine solid particles. In spite of the many technological advances in the hydrometallurgical industry, it appears that the formation of crud in a Solvent Extraction (SX) operation is unavoidable. Crud formation in SX plants has been an unsolved problem for decades. Without intervention, crud builds up in the settler and can eventually spread throughout the SX plant, causing higher rates of organic loss, higher aqueous in organic entrainment (leading to cathode quality issues or increased electrolyte bleeds) and downtime for the operation. Unfortunately, many current techniques for managing crud in SX plants are reactive

Taking a radically different approach, Solvay developed a new PLS additive (ACORGA® CR60) to prevent the crud formation process and in some cases reduce organic into aquoes entrainment. The results from laboratory-scale, larger-scale on-site tests, commercial plant trials and comercial application have demonstrated that crud formation can be dramatically reduced without impacting SX plant performance, leaching or electrowinning. Commercial results are discussed to demonstrate the benefits to the SX circuits and compatibility with upstream and downsteam processes.

Keywords: Solvent Extraction, Crud Formation, Copper, Emulsion, ACORGA® CR60, Commercial application

SILICA ISSUES VERSUS COPPER SOLVENT EXTRACTION PLANT DESIGN

By

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ABSTRACT

Most of the copper in the Democratic Republic of Congo (DRC) is currently produced as cathodes via the leaching of copper oxide ore (or concentrates) followed by solvent extraction (SX) and electrowinning (EW). One of the major challenges faced by many copper solvent extraction plants is the disturbance of mixer stability associated with the presence of colloidal silica in aqueous phases. The magnitude of the impact which the silica has upon the solvent extraction process is dependant upon several factors including the physical form or forms in which the silica is present, the particle size distribution of the silica particles, the chemistry of the pregnant leach solution and the magnitude of the pH shift in the mixer as protons are exchanged for copper. Changes in the physical form of the silica can result in increased process disruption without a large change in total silica concentration of the PLS. This can make management of the situation problematic as crud runs are not easily predicted. In most plants where silica is present in the PLS, there are issues with increased crud formation and slower phase disengagement resulting in increased transfer of undesirable impurities to the electrowinning circuit, significant increases in reagent losses to raffinate and in some cases transfer of electrolyte to extraction further reducing extraction efficiency due to reduced pH in the PLS. Phase disengagement in aqueous continuity tends to be most severely impacted and crud formation in aqueous continuity can occur in very large volumes. Unfortunately, it can also be very difficult to maintain organic continuity in the mixer boxes when silica is present in high concentrations. As a consequence of the surface-active nature of the silica colloids mixer stability is not maintained, the emulsion flips to aqueous continuity and massive crud runs through the plant can occur very quickly. Production losses in both quantity and quality are almost unavoidable in this case.

Depending on the design of the SX plant, silica related issues were mitigated so far in two ways in the DRC: The addition of a coagulant to reduce silica content in the leach solution, and the increase of organic to aqueous (O/A) ratio above standards values. The addition of a coagulant for silica removal has the advantage of being virtually applicable to all plants. It has an impact mostly on the operating cost. Coagulants have been tested in various DRC plants. They were successful at lab scale, but the first few plant trials were disastrous and caused many plant staff to lose confidence in the use of coagulant for silica removal. The first successful coagulant plant trial in the DRC was achieved at MMG Kinsevere in the second quarter of 2019. From December 2018 to May 2019, the Cu production lost because of crud runs associated with high colloidal silica in the leach solutions at MMG Kinsevere was evaluated at 850 tons. The plant design (and construction) could not allow an increase of mixers O/A above 1.5 without affecting copper production targets. Experience from MMG Kinsevere's sister company Sepon in Laos has indicated that the addition of BASF Magnafloc® 9000 coagulant in the clarifier was successful fin reducing silica content in the leach solution and improving mixer stability. To reduce the risk of potential downstream effects, MMG Kinsevere decided to move the addition point ahead of the post leach thickener, without compromising neither the dose nor the performance. The mitigation of colloidal silica related issues by running at higher than standard O/A values had variable levels of success in DRC potentially high capex plants. In March 2017, Ruashi plant lost 470 tons copper and 45 tons cobalt due to colloidal silica related issues in the leach solution. The problem was mitigated by running with mixers' O/A ratios above 2, but an increase of the transfer of impurities from the leach solution to the electrolyte was noticed. This was a consequence of running towards the high limit of the specific flow recommended for settlers. At Chemaf Usoke, copper production targets are easily achieved with the settlers running at a specific flow below 3 $m^3/h/m^2$. O/A ratios close to 3 are achieved without impacting significantly the transfer of impurities from the leach solution to the electrolyte.

Keywords: BASF, Democratic Republic of Congo, Chemaf Usoke, Ruashi, MMG kinsevere

SILICA MANAGEMENT IN A COPPER SOLVENT EXTRACTION PLANT – MMG KINSEVERE CASE STUDY

By

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Presenter

Laeticia Tartibu

ABSTRACT

Severe phase continuity instability was observed at the Kinsevere Solvent Extraction (SX) plant since December 2018, resulting in reduced plant operating capacity, increased crud formation, increased reagent consumption and reduced current efficiency at electrowinning (EW) with deterioration of the copper quality. The symptoms were postulated to be colloidal silica and this was confirmed by analyses, which indicated a significant increase of silica in the solution feeding SX.

MMG Kinsevere reviewed the experience of other plants to mitigate the silica impacts on the SX operation. The actions taken were mainly: (i) running the SX plant with high organic inventory and (ii) maintaining higher than normal organic to aqueous (O:A) ratio in all the stages, with at least a ratio above 2. This assisted in mitigating the silica impacts to a certain extent. But some design limitations, such as limited capacity of the organic pump and the absence of the organic recycles on the mixer-settlers, did not allow the O:A to be maintained above 2.0 without compromising copper production; thus, sporadic instabilities were still observed and SX could not be operated at its required maximum capacity.

MMG Kinsevere successfully achieved efficient silica removal without adverse effect on the SX by dosing Dehscofix® SC12 coagulant (supplied by Protea Chemicals) into the leach discharge slurry. A week after the start-up of the coagulant dosing trial, the silica in solution dropped from >1500 ppm to within 500 ppm range. The SX recovered its stability and was again operating at maximum capacity. In addition gradual improvement was observed on current efficiency and copper cathodes quality at the EW with use of the coagulant.

Keywords: Colloidal silica, solvent extraction, phase continuity, phase continuity stability, coagulant.

COPPER AND COBALT RECOVERY FROM TAILINGS LEACH PLANT SOLUTIONS-A CASE OF A LEACH PLANT ON THE COPPERBELT OF ZAMBIA

By

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Milton Simukoko, Leonard Kabondo

ABSTRACT

Tailings leach plant final tailings solution phase contains typically 0.5 gpl Copper and 0.05 gpl Cobalt. Depending on the ore treated, it may contain other impurities such as Nickel, Manganese etc. in varying concentrations. All these are neutralized using quick lime and or rock lime along with the acid and disposed off. However, if part of the solution component is recovered, it is possible to recover the metallic components and subject the product to beneficiation processes in an economically viable manner.

Hence, the solution component was recovered from the tailings leach plant on the Copperbelt of Zambia and subjected to precipitation where the solution was reacted with three precipitation reagents i.e. Quick lime, Sodium Carbonate and Sodium Hydroxide. In the first instance, pH was varied between 5 and 10, residence time between 1 and 7 hrs, and reagent concentration between 10 – 50 gpl to establish the optimum operating conditions for the process. The optimum pH, residence time and reagent concentration obtained were 8.5, 2 hrs and 40 gpl respectively. At the optimum operating conditions, tests were conducted and financial evaluation carried out to determine the most economical reagent.

The results obtained showed recoveries higher than 80 % for both Copper and Cobalt for the three reagents with precipitate Copper grade ranging from 12 - 25 % and Cobalt 1 - 2.5 % depending on feed grades in solution. It is worth noting that the precipitate produced is amenable to the Smelter Process and or Cobalt Plant for both Copper and Cobalt recovery.

Financial evaluation shows that this process is viable with NPV over five years for Lime at $ 68 million, Sodium Carbonate at $ 51 million and Sodium Hydroxide at $ 55 million at LME Cu $ 6,000/t and Co $ 30,000/t. To fully implement this work, the capital expenditure required is $ 10 million for installation of paste thickeners, precipitation vessels, filtration equipment and pumps. Hence, from the NPV values obtained, it can be concluded that Lime gives the highest NPV of the 3 reagents. Other than Copper and Cobalt recovery from tailings leach plant final tails, this method can be used in treatment of various waste water streams for metal recovery.

Keywords: tailings, recovery, precipitation, precipitate, NPV (Net Present Value), LME (London Metal Exchange)

ACID REMOVAL BY SOLVENT EXTRACTION FOR USE IN ELECTROLYTE TO NEUTRAL AQUEOUS SYSTEMS

By

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Jack Bender

ABSTRACT

BASF has developed a solvent extraction reagent system that can extract various acids; nitric, hydrochloric, sulfuric, perchloric, etc. ranging in concentration from 300g/L to neutral. The reagent is so effective, that the aqueous solution can reach a pH of ~9 by a standard liquid-liquid solvent extraction process. The reagent is readily available and affordable and is diluted in a standard diluent. Lab work has been completed and a pilot trial at a customer is ongoing. Since the reagent is very stable and does not extract according to a typical pH isotherm, it is capable of being activated at extremely high acid concentrations. Thus, acid is readily removed from electrolyte solutions. As an anion extractant that extracts both the proton and the conjugate base of the acid, the extraction of cationic metals is not possible and thus the extractant will not have extractive competition from an aqueous with cationic metal speciation. However, in systems with non-conjugate base anions, the reagent selectivity will have to be determined. Both the lab work and details of the pilot plant operation will be covered, focusing on the application for copper leach plants with high pyrite concentrations that lead to an ever-increasing acid concentration. Kinetics, acid loading capacity, and phase disengagement will also be discussed. Given the extremely fast kinetics of the reagent, the solvent extraction process is not limited to conventional mixer settlers but could be accomplished in columns which increases the flexibility of the process.

Keywords (use Keywords style): Acid Removal, Solvent Extraction, Electrolyte

ALTA 2020 25 YEARS ONLINE NOVEMBER

Nickel-Cobalt-Copper Proceedings

Deep Sea Nodules

DEEP-SEA POLYMETALLIC NODULE MINING AND PROCESSING

By

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Presenter and Corresponding Author

Alexander Sutherland

ABSTRACT

Lithium ion batteries (LiBs) are a critical tool for electrifying our technologies in the face of climate change. The most prominent LiB-dependent technology is the electric vehicle, the demand for which is expected to reach 25% of all vehicle sales by 2030.

DeepGreen Metals is developing a means to source the metals for EV batteries from polymetallic nodule deposits on the ocean floor of the Clarion-Clipperton Zone (CCZ). Leveraging a combination of this resource's intrinsic benefits, responsible project development and Hatch's process engineering expertise, DeepGreen's solution presents a 75% reduction in emissions compared to terrestrial mining operations, and produces zero solid waste, liquid waste or tailings.

This presentation describes DeepGreen's solution and breaks down its substantial life cycle benefits in contrast to terrestrial operations.

Keywords: Battery chemical production, Circular economy, Cobalt sulfate, Cobalt sulphate, Deep-sea minerals, Environment, Manganese Nodules, Nickel sulfate, Nickel sulphate, Polymetallic nodules, Sustainable, Zero discharge, Zero waste

HARVESTING NODULES FROM THE SEABED SURFACE AND EXTRACTING COBALT NICKEL COPPER AND MANGANESE

By

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Colin Seaborn

ABSTRACT

Seabed manganese nodules containing Co-Ni-Cu-Mn are important resources for the future, particularly to support the move to electric vehicles. While these nodule resources are generally around five kilometres under water, they sit on the surface of the seabed. These nodules can be harvested without pre-stripping, drilling, and blasting and are pumped to a vessel on the water surface. No concentration or beneficiation is proposed at sea. The nodules will be shipped to onshore processing plants.

The technology of harvesting and processing the nodules was demonstrated at a pilot scale in the 1970s, and economic assessments indicated nodules would be competitive with lateritic nickel deposits being explored at the time. Despite these advancements, deep-sea nodule mining was never commercialized because the areas of interest were beyond national jurisdiction. The 1982 Law of the Sea Treaty (UNCLOS) declared these minerals “the common heritage of mankind”. The treaty set conditions for access that were too onerous for investors, and all commercially driven exploration and development underway at that time ceased. Only more recently has interest been rekindled although challenges related to regulation remain.

In contrast, Ocean Minerals (OML) has resource areas reserved for exploration within the Cook Islands (CI) Exclusive Economic Zone. The Cook Islands is a sovereign commonwealth country with deep-sea mining legislation providing a clear path to harvesting. Cook Islands nodules are primary cobalt resources (0.5% grade) compared to nodules in international waters, which are primarily nickel resources.

This paper will outline the outcomes of the December 2019 research cruise in the Cook Islands undertaken by OML. These outcomes will include initial metallurgical testing of sub-samples from around 250 kgs of nodules recovered.

This paper will provide:

- a short history of pilot projects for harvesting seabed nodules since the 1970s;
- an overview of seabed nodules resources in Ocean Minerals reserved areas;
- a summary of the status of seabed harvesting and environmental regulations in the Cook Islands;
- a brief status on Ocean Minerals proposed seabed nodule harvesting and recovery systems;
- processing options for the CI nodules, based on previous research by others on other nodule deposits within other areas of the Clarion Clipperton Zone (CCZ) in the NE Equatorial Pacific (Cook Islands nodules have not undergone process testing previously, and have higher cobalt (0.5% vs. 0.2%), lower nickel (0.2% vs. 1.3%) and copper (0.1% vs. 1.2%) grades and a lower Mn/Fe ratio (0.8 versus 3.7) compared to the CCZ nodules, so metallurgical testwork is required); and
- the current status of the project, including sample collection and initial process testing on Cook Islands nodules.

Keywords: Manganese nodules, harvesting and processing, cobalt, nickel, copper, manganese, Cook Islands

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Nickel-Cobalt-Copper Proceedings

Filtration

HOW VERY LARGE FILTER PRESSES SUCH AS THE GHT5000 WILL INFLUENCE THE CAPEX AND OPEX OF TAILINGS FILTRATION PLANTS

By

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Andrew Hawkey

ABSTRACT

The scale of mining operations has been increasing over the last twenty years (at least), particularly in the copper sector. The adoption of pressure filtration and dry stacking as a reliable and safe method of managing mine tailings has driven the filter press suppliers regularly servicing this market to design and build larger machines to appropriately satisfy this increasing scale.

Filter presses currently used in mine tailings applications are typically already very large. However, as demonstrated in previous papers, the number of filter trains (each train consisting of a filter press, drip tray, cake discharge chute, cake feeder/conveyor, slurry feed pump(s), associated piping and electrical wiring, etc.) has a significant effect on capital cost and operating cost. Limiting the number of trains to the minimum (allowing for appropriate standby capacity) for a particular duty is desirable from an economic point of view. At least in the case of Diemme Filtration, this was the justification for designing and building the filters currently used in tailings applications. These are already large machines and have been in operation for at least ten years.

The copper tailings sector includes mines that require the management of huge amounts of tails. Filtration and dry stacking of these tails has been selected as the most desirable management technology, particularly for safety and water recovery. The amount of tails from a single copper mine can be more than 50,000 tonnes per day (dry basis) but for the very large mines it can even range to more than 200,000 tonnes per day (dry basis). For this scale, the number of even the largest filter presses currently available is very high and results in a complex and expensive installation. There is now a need for the development of a significantly larger filter press.

Diemme Filtration has been working on a new filter press design with approximately three times the chamber volume and filtration area of its existing fast filter press currently used for tailings applications (already very large). The new machine is the ‘GHT5000’ and this paper presents some of the features of this filter press but focuses on how the increased capacity favourably affects the CAPEX and OPEX of a tailings filtration plant with a very high processing duty, typical of those found in the copper sector.

Keywords: Copper, Tailings, Filter Press, Filtration, Dry Stacking, Dewatering, Water Recovery, CAPEX, OPEX

PERFORMANCES IMPROVEMENT WITH HIGH PRESSURE PLATE AND PRESS FILTERS

By
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Presenter and Corresponding Author

Edoardo Sommacal

ABSTRACT

This study aims to analyse the use and performance improvement of high-pressure filters in the treatment of slurry resulting from mineral processing.

Brief case studies on copper concentrate and tailings are used to demonstrate the success of this technology as well as different test work studies will be presented to report on the improved efficiency of high feed pressure plate and press filters.

The current practice brings some challenges especially when it comes to the increasing industry requirement to process lower grade and ultrafine material, water scarcity and energy efficiency.

The paper proposes that the installation and use of specialized high-pressure filters can result in significant process optimization with capital and operational cost savings.

The paper concludes with the suggestion that this approach will be beneficial for new and existing process applications and shows the flexibility of integration of the technology in new and existing mining infrastructure regardless of the sophistication and process environment implemented.

Keywords: Tailings, Concentrate, Filter Press, Silt Management, Dewatering, Separation, Risk Mitigation

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Nickel-Cobalt-Copper Proceedings

Hydromet Processing of Ni-Co-Cu Sulphides Forum

COMPARISON OF METHODS FOR SULPHIDE PROCESSING IN NICKEL LATERITE HPAL PLANTS

By

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Presenter and Corresponding Author

Hermann Scriba

ABSTRACT

Expectations of high growth rates in the Electric Vehicle (EV) market and associated battery production has resulted in predictions of nickel and cobalt supply deficits in the near future, thereby calling for higher production capacity.

Existing Nickel Laterite HPAL plants are well positioned to respond to these increases in demand, however, the production rate is typically limited by the feed grade of the nickel laterite ore being processed and PAL circuit capacity, necessitating construction of additional leach trains to increase capacity. Co-processing of higher grade oxide and/or sulphide feed materials is another option that can be considered to increase capacity and this practice has been applied at Western Australian operations on a limited scale. Particularly the processing of nickel and/or cobalt bearing sulphide concentrates presents an opportunity for synergistic co-processing while increasing the production capacity of such HPAL processing complexes.

At ALTA 2019 Linico's RoastPAL Process was introduced as a means to synergistically combine sulphide processing with conventional nickel laterite HPAL processing. It was proposed that bulk sulphide concentrates with nickel and/or cobalt content can be considered for generation of sulphuric acid and steam for use in the HPAL leach while simultaneously sweetening the feed to the PAL autoclaves. It was demonstrated that this can potentially result in significantly improved productivity and profitability compared to a laterite HPAL operation on its own. The process is suitable for greenfields and brownfields application.

While the RoastPAL Process is versatile enough to be considered for a range of different sulphide concentrates, a number of alternative, mainly hydrometallurgical, processing methods can also be considered for incorporation of synergistic sulphide processing into a HPAL processing plant. This paper explores potential alternative flowsheet arrangements that can be considered for this purpose and compares the merits of these flowsheets as applied to sulphide concentrates of various characteristics. It is shown that selection of the processing approach depends largely on the location of the project, and the characteristics and availability of metal sulphide resources and competing processing avenues available for such resources.

Keywords: Nickel, Cobalt, Laterite, Sulphide, HPAL, PAL, Pressure Leach, POX, Leaching, Synergy, Pentlandite, Cobaltite, Pyrite, Pyrrhotite, Roasting, RoastPAL

RE-TREATMENT OF TAILINGS USING CHLORIDE-BASED PROCESSING

By

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Presenter and Corresponding Author

Bryn Harris

ABSTRACT

Climate Change and the Electric Vehicle revolution, Sustainability and Environmental Compliance, all in the face of dwindling resources, pose a major significant challenge for the extractive metals industry. Several common, everyday metals such as gold, silver, zinc, copper, nickel and especially cobalt, with known reserves and current consumption rates will be mined out within our current generation. Where are new reserves going to come from? The “sexy” answers such as deep sea mining and asteroid mining are a very long way off being practical possibilities, and the former faces immense environmental and political obstacles before it can become a reality. Yet, there is one resource which is rarely considered, and is not included in the many calculations of reserves. This resource comprises the many old and current tailings dumps around the world, which because of the inefficiencies in early and even current processing methods, still contain significant amounts of these critical metals.

This paper reviews briefly methods of re-treating these old dumps, and concludes that chloride processing, especially of pyrrhotite-based tailings, offers by far the most effective, efficient and environmentally-sound method for re-treatment. Laboratory and pilot data, together with process modelling, and a ballpark financial analysis are presented to support this thesis.

Keywords: Carbon footprint, Chloride, Climate change, Cobalt, Electric vehicles, Nickel, Pyrrhotite, Tailings

Note: This paper was also presented at CIM COM 2020.

EFFICIENT RECOVERY OF COBALT FROM PYRITE - UPDATE ON COB PROCESS DEVELOPMENT

By

Andrew Tong

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Presenter and Corresponding Author

Andrew Tong

ABSTRACT

Cobalt is known to be hosted in pyrite orebodies, often as a result of cobalt substitution for iron atoms inside the pyrite crystal lattice, leading to low cobalt recovery to date. Minerals processing options for pyrite ores have generally been limited to roasting, pressure oxidation leaching, or bioleaching, as practised for example in the gold and copper industry. Cobalt Blue has developed and tested on bench pilot scale an efficient process for treatment of the cobalt-pyrite ore for the Broken Hill Cobalt Project. The new process has two key steps: firstly decomposition of the pyrite to pyrrhotite and elemental sulphur under inert thermal processing; and secondly rapid leaching of the pyrrhotite in a low temperature and pressure oxidation leach. Laboratory testwork has achieved reliable extractions of >95% of the cobalt from the initial pyrite concentrate, the data and associated Broken Hill costs for production of cobalt sulphate crystals are summarised in the PFS completed in 2018. Cobalt Blue is currently constructing a demonstration plant to test the process on up to 3000 t of ore. The demonstration plant will develop the Cobalt Blue process at larger scale and inform the design criteria for completion of the Broken Hill Cobalt Project Feasibility Study.

Keywords: cobalt extraction, sulphur extraction, pyrite ore, process development, decomposition of pyrite, leaching of pyrrhotite

FLOWSHEET DEVELOPMENT FOR THE CONVERSION OF NICKEL CONCENTRATE TO NICKEL SULPHATE – IGO'S PROACTIVELY GREEN APPROACH TO PRODUCE CRITICAL MATERIALS FOR THE CLEAN ENERGY REVOLUTION

By

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Presenter and Corresponding Author

Chris Ward

ABSTRACT

With the lithium ion battery industry growing at unprecedented rates, IGO is progressing strategies to become an integrated supplier in the renewable energy value chain. A key initiative in this strategy is the development of downstream nickel sulphate production capability, and to be involved in the supply chain of high-quality metals for the lithium ion battery market. The market for lithium ion batteries across all end-use applications was reported by Roskill to have reached 114 GWh in 2017, growing at 27% per year since 2000. What used to be an industry driven by demand for small batteries in portable electronics, is now an industry experiencing rapid demand growth from large-scale applications such as electric vehicles (EVs)[1].

IGO identified the potential value of downstream processing in late 2017 and, following scoping and proof-of-concept studies, initiated a pre-feasibility study during 2018 on the technical and financial merits of converting nickel sulphide concentrate from Nova into high quality nickel sulphate. As IGO's goal is to be a significant participant in the "green" energy market the Company targeted the development of flowsheets that were sustainable and could readily demonstrate that the product was produced from processes that had substantive "green" credentials.

IGO explored a range of flowsheet options which included minimising waste streams by maximising by-products, and optimising scale and capital efficiencies. The process undertaken to select the preferred flowsheet to meet IGO's purposes will be discussed in this paper.

The paper will then present findings from the Prefeasibility Study that demonstrates the technical feasibility of The IGO Process™ for converting nickel sulphide concentrate directly to battery grade nickel sulphate without the need for an intermediate product step. This will include details from the extensive pilot and continuous plant testwork completed on The IGO Process™ that achieved high metal extractions and recoveries for both nickel and cobalt[2].

The IGO Process™ has a smaller carbon and environmental footprint compared with traditional methods for nickel sulphate production due to significantly lower emissions, power consumption and waste generation[3]. Using this process, and complemented by renewable energy initiatives at the Company's Nova Operation IGO has successfully demonstrated that the "Clean Energy Revolution" can be achieved at the mine and extended further upstream to include the raw material processing that are necessary to drive this global change for our future.

Keywords: nickel sulphate, downstream processing, clean energy, electric vehicles

VERSALITY OF METSO OUTOTEC'S BIOX® PROCESSES – POSITIONING OF THE MESOTHERM™ TECHNOLOGY FOR BASE METAL SULPHIDE APPLICATIONS

By

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Presenter and Corresponding Author

Craig van Buuren

ABSTRACT

Metso Outotec's MesoTHERM™ biooxidation technology has over the last few years been developed and expanded to provide a cost-effective and efficient solution for base metal extraction from base metal sulphide deposits. The MesoTHERM™ biooxidation technology leverages on the well-established and commercialized BIOX® process and has been further developed for the treatment of base metal sulphides (including primary and secondary copper sulphides as well as cobalt sulphides).

The unique feature/characteristic of the MesoTHERM™ process is the addition of a novel thermophile stage (60-70°C) to the conventional mesophile (38-42°C) train of bio-reactors – and this circuit configuration has shown it is possible to effect near complete (>97%) metal solubilization in the thermophile stage without compromising the process simplicity and robustness. The thermophile stage specifically targets the minerals chalcopyrite, enargite and carrollite, which are not oxidized fully in conventional mesophile biooxidation.

This paper provides the performance data derived from the MesoTHERM™ biooxidation treatment of various base metal sulphide feed concentrates and discusses the various process flow sheets which may be considered for this technology application. For the various concentrates considered, each with its own sulphide mineralogical compositions and gangue constituents, corresponding flowsheets are presented to demonstrate how the MesoTHERM™ technology can be landed to cater for the split and proportion of primary and secondary copper sulphides. Moreover, the respective circuits are modelled using Metso Outotec's HSC Simulation software to show how various process streams can be integrated to optimize the overall circuit configuration which includes downstream solvent extraction, and for copper gold ores, the cyanidation leach plant.

Metso Outotec is a globally established mining technology and equipment supplier across multiple commodities. The utilisation of the requisite Metso Outotec proprietary equipment in the MesoTHERM™ circuit allows for both process and mechanical performance guarantees and provides for ongoing technical support throughout the lifetime of the project.

Keywords: Base Metal Sulphides, MesoTHERM™, BIOX®, Chalcopyrite, Carrollite, Bornite, Thermophile

COPPER NICKEL SEPARATION CHALLENGES AND FLOWSHEET DEVELOPMENT

By

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Presenter and Corresponding Author

Damian Connelly

ABSTRACT

The nickel-copper-cobalt sulphide deposits at Lynn Lake were mined continuously between 1954 and 1976 (in that time processing more than 20 million tonnes), and it was one of Canada's major nickel mining centres of its time. Substantial resources remain and further extensive drill defined mineralisation also exists within the mining centre. The feasibility of selling a bulk concentrate is not considered economical on the basis that the value of either copper or nickel is not reimbursable when selling to a nickel or copper smelter. When considering that the economics of selling a bulk concentrate is poor, it is clear that this option would not be economical. There are limited smelters or facilities who could process this concentrate. This paper describes the testwork undertaken to produce separate copper and nickel concentrates and flowsheet options including downstream processing.

This is an example of modern metallurgy delivering a major technical breakthrough, producing separate high-value and high-purity nickel and copper concentrates. This work will enable the determination of value for the large historical mining centre, at a time when there is an expectation of future increased demand for metals.

ATMOSPHERIC LEACHING OF COPPER PRESSURE LEACH RESIDUE

By

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Presenter and Corresponding Author

Nico Groenewald

ABSTRACT

Anglo American Platinum's Rustenburg Base Metals Refiners (RBMR) in Rustenburg, South Africa, produces a Copper Pressure Leach Residue (CPLR) containing some nickel with copper. Toll refining is traditionally used to recover these metals.

Laboratory leach studies aimed at recovering specifically copper and nickel using the existing hydrometallurgical leach circuit to produce a suitable leach residue for internal recycle back to the Smelter Complex and to reduce the mass and volume of toll refined concentrate was initiated.

Previous testwork have shown that similar copper and nickel extractions for the unground and fine-grind CPLR were achieved under typical pressure leach conditions. This is attributed to the porous nature of the synthetic covellite (CuS) produced during the leach process, which greatly assists with copper metal extraction. Only 4% additional copper extraction benefit was derived from supplementary milling of CPLR to produce a fine grind feedstock for leaching.

To benchmark the degree to which copper and nickel is extracted from CPLR under atmospheric leach conditions compared with pressure leaching, several atmospheric leach tests were performed to determine the effect of pulp density, lixiviant composition, temperature, leach time and the background lixiviant iron tenor. Under the optimum conditions tested, a 99% copper extraction, 87% nickel extraction and a total mass loss of 92% from unground CPLR was achieved after 144 hours.

By comparison with a leach at pressure, similar levels of copper and nickel extraction could be achieved atmospherically regardless of the grind, simply by extending the leach time. However, it is concluded that at the required 5 g/L Fe in the leach lixiviant, the proposed atmospheric leach process would not currently complement current processes at the RBMR.

Keywords: Atmospheric Leaching, Nickel Extraction, Copper Extraction, Fine Grinding, Unground

GLOBAL COPPER VALUE CHAIN TRENDS AND COMPLEX CONCENTRATES PROCESSING CHALLENGES 2020-2025

By

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Presenter and Corresponding Author

Carlos R. Risopatron

ABSTRACT

This presentation starts analysing the positive impacts of an increasing global electric use on different copper end uses, and includes a detailed discussion on the less positive trend of an increasing energy usage. Fabrication and global copper demand drivers, including reallocation of plants in Asia and the slowdown in copper use in developed economies are discussed.

Recent data on energy use in the copper mining industry, related in part to lower copper ore grades and the need to include seawater desalination plants is presented. Then the presentation discusses the 2018-2021 trends of new copper mines and expansions, and new smelter and refinery capacity. Latest data available for the global trade of copper concentrates and blending is introduced, revealing how the copper content looks stagnated and the minor metals share is increasing, not only in the concentrates but also in the anodes and in the electrolyte in refineries. A review of the current situation of the global trade of recycled copper scrap and copper alloy scrap is followed by an overview of the new Chinese copper smelters technologies and the challenges of more smelting and refinery capacity in an environment of limited supply of copper concentrates and the reallocation of recycled copper in the scrap outside of China.

Some challenges for the evolution to a more environmentally friendly copper smelting industry are finally discussed and some conclusions on the global trends identified are summarized.