ALTA 2018
19 - 26 May
Perth, Australia

23rd Annual Conference Proceedings

Nickel-Cobalt-Copper Conference

Including

Hydromet Processing of Copper, Nickel & Cobalt Sulphides Forum

Sponsored by

9th Annual Nickel-Cobalt-Copper Event

ALTA Metallurgical Services, Melbourne, Australia

www.altamet.com.au

PROCEEDINGS OF
ALTA 2018 NICKEL-COBALT-COPPER SESSIONS

Including

Hydromet Processing of Copper, Nickel & Cobalt Sulphides Forum

21-23 May 2018

Perth, Australia

ISBN: 978-0-9946425-1-6

ALTA Metallurgical Services Publications

To purchase a copy of this or other publications visit www.altamet.com.au

Celebrating 32 years of service to the global mining and metallurgical industry.

ALTA Metallurgical Services was established by metallurgical consultant **Alan Taylor** in 1985, to serve the worldwide mining, minerals and metallurgical industries.

Consulting: High level metallurgical and project development consulting.

Conferences: ALTA conferences are established major events on the international metallurgical industry calendar. The event is held annually in Perth, Australia. The event comprises three conferences: Nickel-Cobalt-Copper, Uranium-REE-Lithium and Gold-PM.

Short Courses: Technical Short Courses are presented by Alan Taylor, Managing Director.

Publications: Sales of proceedings from ALTA Conferences, Seminars and Short Courses.

MetBytes: Free technical articles offering metallurgical commentary and insights.

Free Library: Conference proceedings and technical papers. The library is expanded regularly, providing a major ongoing resource to the industry.

ALTA Metallurgical Services PO Box 1211, Blackburn North, Vic, 3130, Australia
T: +61 (0)411 692 442 | www.altamet.com.au

SOLVAY

asking more from chemistry®

SOLVAY MINING SOLUTIONS

Inspired by your challenges. Driven by *innovation*.

Innovation is at the heart of everything we do. We are a market leader fueled by our clients' desire to address their increasingly complex operational challenges using our extensive industry experience.

Solvay Mining Solutions keeps your mineralogy, design and process challenges in mind. Let us show you how we innovate to support your sustainable future.

solvay.com

ALTA Metallurgical Services

Celebrating 32 Years of Service

ALTA Metallurgical Services (**ALTA**) was established by metallurgical consultant **Alan Taylor** in 1985, to serve the worldwide mining, minerals and metallurgical industries. **ALTA** offers a wide range of services and resources to the metallurgical industry.

Consulting

High-level metallurgical and project development consulting.

Short Courses

Practically-oriented short courses presented by Alan Taylor. Topics include treatment of nickel laterites, copper ore leaching, uranium ore processing, copper SX-EW, heap leaching and solvent extraction.

Conferences

ALTA conferences are one of the world's premier annual metallurgical events. **Next conference: ALTA 2019** is the 24th annual conference and will be held 18-25 May in Perth, Australia. The event comprises five international technical conferences, three short courses and an international trade exhibition. It features a highly-focused program, topical forums and presentations from key international speakers.

Publications

Proceedings and manuals from ALTA conferences, seminars and short courses.

MetBytes

Free technical articles offering metallurgical commentary and insights.

Free Library

Includes proceedings from 1995-2016 Nickel-Cobalt-Copper, Uranium-REE and Gold-PM conferences for free download (1340+ papers). The library will be expanded regularly, providing a major ongoing resource to the industry. A selection of papers from recent conferences are also available.

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

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

Extensive experience in:	...including
• Gold/Silver • Copper • Nickel/Cobalt • Uranium • Base Metals	• Leaching: atmospheric, heap, in-place, bio. and pressure • Cyanidation and CIP/CIL • Solid/liquid separation • Flotation • Electrowinning and electrorefining • Solvent extraction/ion exchange

Enquiries: allisontaylor@altamet.com.au www.altamet.com.au

ALTA 2018
19 - 26 May
Perth, Australia

Nickel-Cobalt-Copper, Uranium-REE-Lithium and Gold-PM Conference and ISR Symposium

Sharing ideas, innovations, technologies and projects

A special thank you to our sponsors, exhibitors, co-sponsors and partners.

Sponsors

EKATO
PEXGOL X-LINKED PIPING SOLUTIONS
LANXESS Energizing Chemistry
NobelClad
STEULER KCH
BASF We create chemistry
KOCH KNIGHT
SOLVAY
FLSmidth
jord IDEAS ENGINEERED
WEIR Minerals
mining3 TRANSFORMING MINING
OLI systems,inc.
Purolite

Exhibitors

EKATO
PEXGOL X-LINKED PIPING SOLUTIONS
REMA TIP TOP
TURTLE TOUGH SENSORS
SPXFLOW
CSIRO
STEULER KCH
ALS Metallurgy
KOCH KNIGHT
CGIS
THE SIMULUS GROUP
SGS
MINTEK
Diemme Filtration A brand of Aqseptence Group
SysCAD
CORE
MEXTRAL
Italmatch Chemicals
KERAMOS MINING AND PROCESSING SUPPLIES
wood.
BUREAU VERITAS
MOGAS SEVERE SERVICE BALL VALVES
AuTec INNOVATIVE EXTRACTIVE SOLUTIONS
Teck
PLA PROCESS ANALYSERS
Ausenco
Ansto Minerals
SUNRESIN
METZ
matec pacific
Department of Mines, Industry Regulation and Safety
PROCESS IQ
MPS MINING & PROCESS SOLUTIONS
Curtin University
YORK Process Systems A JOHNSON CONTROLS COMPANY
ALTA

Co-Sponsors and Partners

TMS The Minerals, Metals & Materials Society
SAIMM THE SOUTHERN AFRICAN INSTITUTE OF MINING AND METALLURGY
IAEA International Atomic Energy Agency
CSIRO
Government of Western Australia Department of Mines, Industry Regulation and Safety Geological Survey of Western Australia
XXIX IMPC 2018 SEPTEMBER, 15-21, 2018 MOSCOW, RUSSIA www.impc2018.com
MEI
International mining
AUSTRALIAN MINING MONTHLY
COPPER WORLDWIDE
PERTH CONVENTION BUREAU
Tourism WESTERN AUSTRALIA

ALTA 2018 Nickel-Cobalt-Copper Proceedings Contents

Nickel-Cobalt-Copper Proceedings

Opening Address

WHAT IS CHANGING IN THE GLOBAL MINERALS INDUSTRY - DELIVERING VALUE BY LEVERAGING RESOURCES

By

Dr Stephen Grocott
Chair, AMIRA International Ltd
and Chief Technical Development Officer, Clean TeQ Limited, Australia

Joe Cucuzza
Managing Director, AMIRA International Ltd, Australia

ABSTRACT

There have been remarkable changes in the mining industry since September 1959 when a group of mining industry executives signed the memorandum of understanding that gave rise to the Australian Minerals Industries Research Association (A.M.I.R.A.). These changes and the corresponding industry pressures span business, technology, and societal areas. They have led to the emergence of new technologies that have improved our ability to explore, that allow us to mine more efficiently and to process lower grade ores. Outcomes from AMIRA International projects have contributed to and continue to contribute to shaping our industry. Many of the solutions from these projects helped to deliver multi-million dollar gains for our members and changed work flow processes for our industry in general. These changes come hand in hand with capacity building in research institutions, resulting not only in the development of world-class international research capability but also the training of students that have gone on to become leaders in industry and academia. Of course, change is a continuous process and now our industry is at the early stages of new revolutions including large increases in energy and water costs, automation, data analytics, the emergence of “Internet of things” (IoT) and other technologies that have the potential to further disrupt and change how industry does business by addressing the immediate challenges. AMIRA International continues to work for the minerals industry, evolving to address these new challenges.

The time is right for a step-change in industry collaboration to solve our biggest challenges, and capture our most attractive opportunities. Collaboration is not easy, particularly peer-to-peer collaboration. Many of the truly difficult challenges will require the latter to be successfully addressed. It is doubtful that the types of the collaboration that are in vogue now will deliver the transformational changes that will come from addressing the long terms challenges of the industry, indeed they are really focusing on the short-term challenges. This paper is a cloudy crystal ball look at the greatest of these challenges and the collaborative effort required and how AMIRA International can contribute to capturing the value and mitigating the risks.

Keywords: Technology, Change, AMIRA

Nickel-Cobalt-Copper Proceedings

Keynote Address

FLOWSHEET OPTIONS FOR COBALT RECOVERY IN AFRICAN COPPER–COBALT HYDROMETALLURGY CIRCUITS

By

[1]Kathryn C. Sole, [2]John Parker, [3]Peter M. Cole, and [4]Michael B. Mooiman

[1]Kathryn C. Sole Consulting, South Africa
[2]Process Ideas, South Africa
[3]Peter Cole Metallurgical Services, South Africa
[4]Franklin Pierce University, USA

Keynote Presenter and Corresponding Author

Dr Kathy Sole

Kathryn C. Sole Consulting, South Africa

ABSTRACT

The price of cobalt has increased by some 450% in the past two years, mainly due to increasing demand for lithium-ion batteries, which are in widespread use in consumer electronics and increasingly required for electric vehicles. There are limited alternatives to cobalt in these batteries at present. With an official production of 64 000 t in 2017, the Democratic Republic of Congo produces more than half of the world's cobalt, which is eight times more than that of its closest competitor.

African Copperbelt operations have traditionally focused on copper production; however, it has now become imperative to also consider cobalt recovery from these ores. A plethora of processing routes are possible. Most hydrometallurgical flowsheets recover cobalt from the raffinate of the low-grade copper solvent-extraction circuit, although dedicated cobalt leaching, which typically requires reductive conditions, is now considered. Downstream purification processes include sequential precipitation with a variety of reagents, solvent extraction, and ion exchange. Product choices include hydroxide, carbonate, sulphate, and metal cathode.

This review assesses technical and economic advantages and limitations of various approaches to the hydrometallurgical processing of cobalt in an African context.

Keywords: Cobalt, hydrometallurgy, flowsheet development, Africa

Nickel-Cobalt-Copper Proceedings

Main Sessions

WORLD COPPER MINE SUPPLY AND CAPACITY TRENDS; CHALLENGES FOR COPPER CONCENTRATE MINERS, SMELTERS, REFINERIES, BYPRODUCTS AND WASTE DISPOSAL

By

Carlos Risopatron

International Copper Study Group (ICSG), Portugal

Presenter and Corresponding Author

Carlos Risopatron

ABSTRACT

The objective of this document is to offer a comprehensive overview of the situation of the global copper mine supply in 2017-2018, including copper concentrates and mine refined SX-EW cathodes, and to deliver the state of knowledge on the future copper mine capacity, including expansion plans and new mines until 2025. Current challenges for copper smelters processing increasingly complex copper concentrates from domestic and imported volatile concentrates copper contents and mine ore grades trends in different regions will be discussed. The review includes a summary on the public discussion on smelting and copper sulphide processing and the regulatory environment related to the air and water emission of these plants in different regions of the world. The information sources are both technical papers discussed in copper metallurgy conferences in recent years and ICSG statistics and forecasts for the global copper mine, smelter and refinery supply and copper uses in different regions. A small discussion on the situation and role of copper and copper alloys scrap supply in the global copper industry value chain and the global perspectives of refined and scrap copper use is included.

This paper outlines the current situation of the global copper industry, focusing mainly in the quantification of upstream flows of copper from concentrates, SX-EW mine refined output and scrap supply. The discussion on current volumes of copper smelter production from concentrates and scrap is summarized, focusing on the relation between copper miners, smelters, refineries and environmental regulatory authorities in different regions. The challenges of waste disposal in the copper industry and the options to invest in different smelting and sulphide processing technologies are identified. An overview of the role of recycled copper both in the fabrication of copper products as in the production of refined copper is discussed. Finally an overview of the world industrial use of refined copper and scrap is presented to produce a picture of the global copper value chain in recent years.

Keywords: global copper mine supply, copper concentrates, mine refined SX-EW, copper smelters, copper refineries, waste and byproducts, copper scrap, recycled copper use,

USING PROCESS SAFETY MANAGEMENT TO MANAGE RISK IN MINERAL AND METALS PROCESSING FACILITIES

By

Larry J Moore, PE

FM Global, USA

Presenter and Corresponding Author

Larry J Moore, PE

ABSTRACT

Process Safety Management (PSM) as a loss prevention management system has been used in the mainstream chemical processing industries for over 50 years to limit and control risk. This evolved due to the frequency and impact of large chemical incidents which brought to the forefront regulatory codes and non-regulatory "self-governing" guidelines. PSM has not been as effectively utilized in the global mining, mineral and metals processing industries due to lack of regulatory codes and non-regulatory support organizations promoting or developing loss prevention and risk management guidelines. For example, the Mine Safety and Health Administration (MSHA) in the United States has no provision or requirement for PSM. While some larger mining companies effectively embrace and use PSM it is not yet widely or consistently applied throughout the industry.

Process Safety Management is defined as the application of management systems to the identification, understanding, and control of hazards to prevent process related incidents. A Process Safety Management System is defined as comprehensive sets of policies, procedures, and practices designed to ensure that barriers to episodic incidents are in place, in use, and effective.

In this paper elements of an effective PSM system are described. Global regulations and non-regulatory guidelines covering PSM for high hazard industries are reviewed. Case studies of several major incidents in the mining and metallurgical refining industries are presented to understand the lessons learned from failure to manage risks using a PSM system.

Finally, conclusions are drawn to adopt PSM in the mining industry as a tool for effective loss prevention and risk management.

Keywords: process safety management, mining and metallurgy, loss prevention, risk management,

Nickel-Cobalt-Copper Proceedings

Ni-Co Laterites and Scandium

THE RAMU NICKEL OPERATION: IMPROVE PRODUCT QUALITY THROUGH OPTIMIZING PROCESS CONTROL

By

[1]Gao Yongxue and [2]Peter Jolly

[1]President, Ramu NiCo Management (MCC) Ltd, Papua New Guinea
[2]Peter Jolly, Consultant, Australia

Presenter and Corresponding Authors

Peter Jolly

ABSTRACT

The Ramu project has accumulated rich experience in management, operation and system operation during its trial production and production ramp-up. In 2017, Ramu achieved its goal of annual output exceeding design capacity comprehensively. Most of the processing control performances and unit consumption control performances have been reached or exceeded the design parameters, reaching the annual target of "improving production, reducing costs and increasing efficiency." However, from a professional perspective, there is still the possibility of further optimization and improvement in the processing control of individual operating units.

This article focuses on improving operation stability of the Neutralization Section with further proposals raised to stabilize product quality.

Keywords: Ramu NiCo, HPAL neutralization, product quality improvement, HPAL, MHP

DEVELOPMENT OF A HPAL NICKEL PROJECT AND POTENTIAL SCANDIUM RECOVERY

By

Mete Yesil, Safder Iplikcioglu and Emre Ege

Egemad, Turkey

Presenter and Corresponding Author

Emre Ege

ABSTRACT

It is a challenge to develop a lateritic nickel-cobalt project and to go for a HPAL plant particularly in a country where there is no previous nickel-cobalt mining experience. There are a number of technical, social and financial issues to be addressed first.

A scoping study with a number of tests has to be carried out as a start. A prefeasibility study undertaken to choose a leaching method and process route has to be followed by a feasibility study to be able to finance the project.

One of the most important stages of a HPAL project is to get Environmental Impact Assessment approval besides project development activities such as exploration drilling, resource estimation, mine modelling, pilot plant tests and engineering.

For a HPAL project to be successful, it is important to develop an investment strategy to address four major areas; project management, engineering design and technical support, equipment selection and timely order and finally relationship with local communities.

HPAL plants can be used not only for producing nickel and cobalt concentrate but also to produce by products such as Scandium from lateritic ores.

This paper outlines important steps of a HPAL plant investment and also Scandium recovery studies. It indicates how important is to develop an effective investment strategy and effective project management as well as choosing of right solution partners for a successful HPAL plant investment and operation.

Keywords: Nickel-Cobalt HPAL, Scandium Recovery, Project Development, Project Management, Investment Strategy.

OWENDALE SCANDIUM PROJECT – PROJECT UPDATE AND METALLURGICAL TESTWORK OVERVIEW

By

[1]Boyd Willis, [2]Chad Czerny and [2]Paul Carter

[1]Boyd Willis Hydromet Consulting, Australia
[2]SGS Minerals Metallurgy, Australia

Presenters and Corresponding Authors

Boyd Willis and Chad Czerny

ABSTRACT

Platina Resources Limited (Platina) is undertaking a series of studies for the development of the Owendale laterite project, located 350 km west of Sydney in central New South Wales. The project is one of the world's highest scandium grade and tonnage laterite deposits. A Prefeasibility Study (PFS) concluded in July 2017 considered a plant treating 50,000 dry tpa of ore to produce 42.3 tpa scandium oxide. In September 2017 Platina announced a maiden Mineral Reserve of 3,990 kt grading 550 ppm scandium for a total in-situ content of 3,359 tonnes of scandium oxide, reported at a cut-off of 400 ppm scandium. At a plant feed rate of 50,000 dry tpa of ore, the average scandium head grade to the process plant is 645 ppm Sc over the first 35 years of mining high grade ore, and 475 ppm Sc for the following 45 years of mining medium grade ore.

The results of a metallurgical testwork program undertaken by SGS to determine the optimal conditions for extraction of scandium from Owendale ores using HPAL are reported. Test parameters evaluated include: leach temperature, residence time, sulphuric acid to ore ratio, use of additives such as NaCl, staged acid additions and mixed lixiviants. The relationships between these variables and metal extractions are discussed. The testwork provides the basis for the selection of process conditions for continuous pilot-plant testing to generate solutions for proving of the downstream scandium recovery flowsheet.

To overcome the hurdle other prospective scandium producers have encountered in securing product offtake agreements in support of project funding, activities since the PFS have focused on a smaller first stage production capacity. A Definitive Feasibility Study (DFS) is scheduled to be completed in late 2018 based on approximately 20 tpa scandium oxide production. This paper reports on the Mineral Reserve, and provides updates on the ongoing process development activities, continuous pilot plant, the selection of plant capacity and the configuration for the DFS.

Keywords: Platina, Owendale, SGS, feasibility, scandium, scandium oxide, laterite, mineral reserve, testwork, HPAL, leaching, extraction, production, tailings.

USE OF PREDICTIVE MODELLING TO OPTIMISE THE SOLVENT EXTRACTION PROCESS DESIGN FOR CLEAN TEQ'S SUNRISE NICKEL-COBALT PROJECT

By

[1]Simon Donegan, [1]Sunil Jayasekera, [1]Stephen Grocott, [2]Andrew Bekle and [3]Bill Szolga

[1]CleanTeQ, Australia
[2]Solvay, Australia
[3]Solvay, USA

Presenter and Corresponding Author

Simon Donegan

ABSTRACT

CleanTeQ's Sunrise Project comprises a lateritic nickel-cobalt resource located 350 km WNW of Sydney in NSW, Australia. As at 20/9/16 the total Sunrise mineral resource was 109 Mt at 0.65% Ni and 0.10% Co. The project is currently the subject of definitive feasibility evaluations.

Sunrise is being designed to produce battery-grade nickel and cobalt products with co-production of scandium. The process design integrates pressure acid leaching (PAL) and resin-in-pulp (RIP) for primary recovery of nickel, cobalt and scandium. Sulfuric acid is used for resin elution generating an eluate containing ~50 g/L nickel-cobalt together with copper, zinc, manganese, magnesium and calcium. The eluate is then refined using a neutralization circuit followed by three sequential solvent extraction (SX) circuits that further purify and concentrate nickel and cobalt prior to crystallisation as hydrated sulfates.

Two of the designed SX circuits use extractants produced by Solvay, namely DEHPA® and CYANEX® 272. DEHPA® is first used to extract zinc, calcium and manganese whilst rejecting cobalt (and nickel) to the raffinate. CYANEX® 272 is then used to extract cobalt whilst rejecting magnesium (and nickel) to the raffinate. Process design of these circuits has been assisted by both batch and continuous testwork, as well as the predictive modelling capability of Solvay's Minchem software.

This paper will outline the SX design optimisation process.

Keywords: Nickel, cobalt, solvent extraction

A HOLISTIC APPROACH TO PRE-CONCENTRATE NICKEL IN LATERITE ORES

By

[1,2]Saeed Farrokhpay and [1]Lev Filippov

[1]Université de Lorraine, GeoRessources, France
[2]University of Queensland, School of Chemical Engineering, Australia

Presenter and Corresponding Author

Saeed Farrokhpay

ABSTRACT

Nickel is an important metal with the total global consumption of about 2 million tons per year. It is sourced from both sulfide and laterite deposits. While the majority (i.e. 70%) of the nickel resources are contained in laterites, these ores are often complex and expensive to treat using conventional methods. Today, laterites are becoming more attractive for nickel production due to the depletion of high grade nickel sulfide ores. Laterites are generally processed by hydro or pyro-metallurgy and therefore, pre-concentration of nickel before such processes is very important. In fact, upgrading the nickel content in laterite ores ahead of any recovery processes is economically desirable.

In this paper, the effect of different physical methods on the pre-concentration of nickel in laterite ores will be discussed. Nickel was upgraded using methods such as magnetic separation, density separation, flotation, and sizing. Flotation is not always considered to recover nickel from laterite ores because of the fine-grain mineralogy, and often low grade nickel. However, in this work it was possible to obtain 40% upgrade in the nickel content (at 70% recovery) for a saprolite ore sample using flotation. Magnetic separation could be also beneficial in upgrading nickel in laterite ores if the magnetic component contains nickel. Therefore, the mineralogy of laterite is very important. Furthermore, the findings of this project will help to unlock a substantial volume of nickel with significant value from laterite ores.

Keywords: nickel; laterite; preconcentration; flotation

LATERITE AND THE COMMODITY PRICE CYCLE

By

Mike Dry

Arithmetek Inc., Canada

Presenter and Corresponding Author

Mike Dry

ABSTRACT

In spite of recent commercial failures involving HPAL processing of laterite, the extraction of nickel and cobalt from laterites is inevitable if supply is to meet demand into the future. The commercial failures have been attributed, largely, to insufficient process development and excessive optimism in scaling up the autoclave and other technology. Additionally, there is a commodity price cycle that affects both input costs and revenues.

This paper examines the impact of the commodity price cycle on the economics of a hypothetical laterite project using HPAL technology to produce a mixed hydroxide precipitate containing nickel and cobalt.

Almost a century's worth of commodity price data, converted into inflation-adjusted currency, is used to examine the cash flows associated with the construction, commissioning and operation of the project for 20 years. The project is assumed to begin at various points in the commodity cycle and the resulting cash flows are examined.

The commodity price cycle was found to strongly affect the 20-year process economics.

The results of this exercise indicate that 2018 and the coming years might well be very propitious for new laterite projects.

Keywords: Nickel, Cobalt, HPAL, Economics, Commodity cycle

Nickel-Cobalt-Copper Proceedings

Filtration

DEWATERING AND WASHING OF NICKEL LATERITE TAILINGS

By

[1]Andrew Hawkey, [2]Francesco Kaswalder and [2]Davide Cavalli

[1]Diemme Filtration (Aqseptence Group), Australia
[2]Diemme Filtration (Aqseptence Group), Italy

Presenter and Corresponding Author

Andrew Hawkey

ABSTRACT

The first section of the paper presents and discusses the benefits of pressure filtration of mineral tailings, after examining the conventional and alternative technologies currently available for such large solid-liquid separation duties.

The second section of the paper introduces the concept of in-filter cake washing and, where appropriate, the filter-repulp-filter process as attractive alternatives to counter-current decanting thickener trains (CCDs). CCDs are the conventional equipment used for recovering valuable products or removing contaminants from mineral slurries. The paper proposes that the selection of specially-configured pressure filters over CCDs to recover product (or remove contaminants) for greenfield hydrometallurgical (including nickel laterite) projects can result in significant economic benefits. Similarly, the paper recommends the consideration of CCD replacement at brownfield sites.

Case studies are used to demonstrate the success of this technology. The paper concludes with the suggestion that this approach could be beneficial for new and existing nickel laterite operations for the recovery of product and acid from the leach residue.

Keywords: Nickel Laterite, Tailings, Product Recovery, Contaminant Removal, Filtration, Dry Stacking

MANAGING ULTRAFINE SOLIDS AT POSEIDON NICKEL'S MT WINDARRA MINESITE

By

[1]Mark Mullett, [2]David Ralph and [3]Michael Rodriguez

[1]Veolia Mining and Metallurgy, Australia
[2]Murdoch University, Australia
[3]Poseidon Nickel Limited, Australia

Presenter and Corresponding Author

Mark Mullett

ABSTRACT

The quality of the water within an underground mine at Mt Windarra in Western Australia was impacted by the presence of ultrafine solids. This presented two problems, which were investigated by Poseidon Nickel Limited (PNL). The first issue was associated with the drilling system used in the mine, which required a water supply that was sourced from a sump in the mine's lower levels. This supply source proved problematic as fine suspended solids repeatedly blocked filters protecting the drilling equipment after short operating times. The second problem became apparent after aerial surveillance of the mine water discharge site, which showed a discoloration appearing in the discharge zone. After a series of investigations, it became apparent that suspended solids were not the primary cause and both problems arose because the water entering the mine was supersaturated with respect to a number of solid mineral phases. The pattern of precipitation of these supersaturated phases is complicated by the gradual loss of sulphide, due to atmospheric exposure, as the mine water moves around the reticulation system.

A strategy to deal with both problems was constructed. Initially a polishing filter with a fibre-based media was commissioned, however the mass of solid materials pumped from the shaft rapidly blinded the media and the back-wash requirement was too frequent for operational efficiency. A sand filter was subsequently commissioned, which produced a filtrate that was initially clear but fine black solids developed within the matrix after a relatively short period of time. Characterisation of the water from the mine shaft, and of the associated entrained solids, were conducted to assist in the interpretation of the observations. The chemical data, observations and anecdotal information from site was used to develop the hypothesis that chemical supersaturation was apparent in the water and the most significant parameter controlling the reactions was the redox potential of the solution.

Keywords: Mine water; Mine water discharge; Mine water chemistry

Nickel-Cobalt-Copper Proceedings

Pressure Leach Equipment

DYNAMICS OF PISTON DIAPHRAGM PUMPS IN AUTOCLAVE FEED APPLICATIONS

By

Erik Vlot

Weir Minerals, Netherlands

Presenter and Corresponding Author

Erik Vlot

ABSTRACT

Piston diaphragm pumps are used worldwide to transport slurries against high discharge pressures in the mining and minerals processing industry. The application includes feeding of autoclaves with high temperature slurries in High Pressure Acid Leach (HPAL) circuits. Since the introduction of the piston diaphragm heat barrier technology in the late 1980's, significant improvements have been made in understanding the dynamic behaviour of these pumps, in this application. This has enabled a continuous increase in capacity of heat barrier pumps while maintaining a high reliability of the installation. In this paper, the dynamics phenomena which are important to consider in designing and selecting piston diaphragm pumps for autoclave feed applications are discussed. These include pressure pulsations in and around the pump, vibration of the pump assembly, pump cavitation and diaphragm deformation. Experimental and numerical approaches used for obtaining an understanding of these phenomena will be discussed, as well as improvements on the pump and system design and its operation based on this understanding.

Keywords: piston diaphragm heat barrier pumps, pulsation dynamics, diaphragm reliability

PROTECTIVE SURFACE TREATMENT AND TECHNOLOGY ROADMAP FOR HPAL AND POX APPLICATIONS – VELAN UPDATE

By

[1]Fadila Khelfaoui, [1]Luc Vernhes, [1]Craig Bekins, [1]Nicolas Lourdel, [1]Duke Tran, [2]Fabrice Pougoum, [3]Dominique Poirier, and [4]Gary Lantzke

[1]Velan, Canada
[2]Polytechnique Montreal, Canada
[3]National Research Council of Canada, Canada
[4]Callidus Welding Solutions, Australia

Presenter and Corresponding Author

Fadila Khelfaoui

ABSTRACT

Although thermal sprayed ceramic oxide coatings are being successfully employed to enhance equipment performance in High-Pressure Acid Leach (HPAL) and Pressure Oxidation (POx) applications, significant development has been made over the past 15 years to categorize these coatings for different plants. These achievements in protective surface treatments have enhanced the life span of in-service equipment, including metal-seated ball valves (MSBV's) in Hydrometallurgy, especially in HPAL and POx services.

Velan, a pioneer of engineered valve solutions, has 25 years of experience in the development and manufacturing of severe-service valves for critical isolation applications around the autoclave. Leveraging the field experience, Velan's service provider Callidus Process Solutions presented a paper at ALTA 2006 considering fully fused surface treatment to meet severe conditions of HPAL and POx.

A detailed literature review was undertaken by Velan to assess commercially available protective surface treatments, including the most recent advancement in nanostructured ceramic materials and metallurgically bonded solution. In addition, the review features the latest developments with respect to both the Velan, patented nano-TiO_2-Cr_2O_3 APS-deposited ceramic, compatible with a wide range of substrates, and a field-tested commercially-ready metallurgically bonded hardfacing. This paper details the results of the in service trials, presents the current state of the art, a view on existing field-service issues and provides an optimized solution and a metallurgically bonded surface layer.

Keywords: High Pressure Acid Leach (HPAL), Pressure Oxidation (POx), Severe-service valves, Nanostructured coatings, nano-TiO_2-Cr_2O_3, Tribo-mechanical and corrosion properties, Acoustic emission method.

IMPLEMENTING AN SSV STANDARD PRACTICE FOR THE HYDROMETALLURGY INDUSTRY

By

G. R. Waters

CGIS, Canada

Presenter and Corresponding Author

Ross Waters

ABSTRACT

The Manufacturers Standardization Society of the Valve and Fittings Industry (MSS) has spearheaded an initiative to determine the minimum requirements a valve needs to be able to perform to when faced with extreme conditions, whether from pressure, temperature, toxicity, solids, or usage. The result will be a Severe Service Valve Standard Practice, which will provide industry with objective principles and parameters on how to define and subsequently identify Severe Service Valves, and the applications they must be used in.

This process serves to benefit the hydrometallurgy industry by providing lessons learned during the examination and definition of SSVs, and the global collection of operating data. Future and current practitioners of hydrometallurgy, especially pressure hydrometallurgy, stand to benefit from the collective knowledge being acquired. The Standard Practice involves the cooperation of many sources of knowledge and experience, all passed on through open source. By defining and describing the minimum industry recommendations for service, hydrometallurgy applications such as autoclave block, let-down and vent control, utility isolation and non-return will now have a specific and trustworthy guideline to consult when selecting the right valve for the situation.

This paper serves to explain the Severe Service Valve Standard Practice in further detail, and how it will be used by the hydrometallurgy industry. It will draw on five decades of industry experience from one of Canada's leading valve experts.

Keywords: Autoclave Block, Let-down and Vent Control, Utility Isolation, Non-Return

Nickel-Cobalt-Copper Proceedings

Nickel Sulphate

THE PRODUCTION OF HIGH PURITY NICKEL SULFATE HEXAHYDRATE SUITABLE FOR LITHIUM ION BATTERIES BY EVAPORATIVE CRYSTALLISATION

By

John J. Warner, D. Stuart Bradbury and Nipen Shah

Jord International, Australia

Presenter and Corresponding Author

John Warner

ABSTRACT

Until recently the priority when designing a nickel sulfate plant was to achieve high product recovery at low energy consumption in a plant of reasonable cost. Bradbury described a state of the art solution in a paper presented at ALTA 2007. Today, however, the desire to supply nickel sulfate hexahydrate to the rapidly expanding makers of lithium ion batteries has added a new priority: achieving near absolute purity, typically better than 99.95% w/w.

Achieving such purity, often with strict limits on individual metal ions, requires that the process design of the crystalliser system considers multiple factors including: the rate of liquor purge; the entrainment of mother liquor on the crystals; and the efficiency of washing the crystals as they are discharged from the centrifuge.

This paper describes how a proper balance for purity can be reached without sacrificing the process achievements reported earlier, such as high product recovery and low energy use. Indeed, recent advances in MVR technology have allowed us to further lower energy use.

Keywords: Nickel Sulfate, Crystallisation, Product Purity, Draft Tube Baffle, MVR

Nickel-Cobalt-Copper Proceedings

Cementation / SX/EW

CLEANMETALS PRESENTATION OF METALS CEMENTATION IN AN AGITATED FLUIDIZED BED – (COPPER EXAMPLE)

"One waste stream, copper for 3'600 Toyota Prius lost forever! Not acceptable!"

By

Guillaume Lefort and Dominique Richon

Cleanmetals SA, Switzerland

Presenter and Corresponding Author

Guillaume Lefort

ABSTRACT

Cleanmetals has developed a versatile, reliable, highly efficient and easy to operate cementation reactor with no moving parts allowing for direct and financially viable production of metals from low grade and/or low volume Pregnant Leach Solution ("PLS").

The reactor operates at 25m^3/h. The lowest concentration being put through our reactor was 0.45g/l and the highest was 20g/l. In all cases a minimum of 95% extraction rate was achieved in one passage through the reactor. Each g/l produces 17t of copper per month.

The PLS goes into the reactor from the bottom, flows through the reactor and an agitated fluidized bed of iron shots and exits at the top whereby it is fed into a magnetic filter removing the residual iron and through a filter press recovering the copper cement. The role of the specific agitation is to regenerate the surface of the iron shots used as a sacrificial metal, thus allowing for the contact area between the iron and the PLS to always be optimal.

Selectivity between some metals can be achieved by modifying operational parameters. As an example, a client was cementing 65% of the arsenic (As) content in his copper PLS producing a noxious cement with salability and value implications. We managed to reduce the As content by a factor of 20 (not noxious) while increasing the extraction rate by 18% thus adding in excess of 108t of copper cement per annum. This extra recovery represents the copper need for 3'600 Toyota Prius. The goal of our reactor is to offer the metallurgical and mining industry a technico-economic solution to process any kind of secondary streams and gain value from the contained metals in only one process, thus reducing the amount of metal disposed of and the environmental impact of our industry.

This paper outlines what type of various solutions Cleanmetals has treated with the attached performance and results of such production or pilot campaigns.

Keywords: Copper Recovery, Metals Recovery, Secondary Streams, Remediation, PLS, Waste Streams, Acid Mine Water Drainage

AMELIORATING THE IMPACT OF COLLOIDAL SILICA ON COPPER SX – THE MMG SEPON EXAMPLE

By

[1]Liz Brown, [1]Jimmy Lim, [1]Leonardo Paliza, [2]Kevin Rees, [2]Nigel Thiel, [3]Sasha Boskovic and [3]Andrew Coveney

[1]MMG LXML Sepon, Laos
[2]MMG Limited, Australia
[3] Huntsman Performance Products, Australia

Presenters and Corresponding Authors

Kevin Rees

Sasha Boskovic

ABSTRACT

Colloidal silica, formed in the leaching process from the dissolution of Si containing gangue minerals, can pose a number of operational challenges in hydrometallurgical processing. Colloidal silica can lead to issues with poor flocculation and settling in thickeners, and it can also significantly impact the operation of Solvent Extraction (SX) processes, by increasing phase disengagement times, reducing extraction kinetics, causing unwanted continuity flipping, significantly increasing CRUD generation, and solvent losses.

This paper reviews the deleterious role colloidal silica can play in hydrometallurgical processes, and provides a "How To" on diagnosing and then ameliorating these issues by coagulating colloidal silica with polyglycol ether based coagulants. Specifically, the paper will focus on the recent operational benefits seen in Copper SX at MMG Sepon's operation in Laos by using Huntsman's POLYSIL® RM1250 coagulant, a polyglycol ether based coagulant, in the solid liquid separation circuit. POLYSIL® RM1250 coagulant was able to substantially reduce silica and colloidal silica concentrations in the clarifier overflow PLS. In this case, colloidal silica was contributing to emulsification of the aqueous and organic phases in SX and long phase disengagement times. The laboratory testing, which was a pre-cursor to the plant trial and the subsequent plant trial approach and results are also reviewed. Huntsman's POLYSIL® RM1250 coagulant was effective in restoring normal phase disengagement times and solvent extraction operation at Sepon.

Keywords: Copper, Solvent Extraction, Colloidal Silica, Coagulation, Polyglycol Ether Coagulants

THE IMPACT OF POLYMERIC CLARIFYING AGENTS ON THE PHASE DISENGAGEMENT AND KINETICS OF SOLVENT EXTRACTION

By

Jack Bender, Mitchell Catling, John Milligan, and Brenda Delgado

BASF Mining Solutions, USA

Presenters and Corresponding Authors

Jack Bender and Mitchell Catling

ABSTRACT

Solvent extraction (SX) processes are typically quite robust. However, the presence of chemical species in the aqueous phase can have a substantial negative impact on the extraction of metals or the stability of the emulsions formed. The addition of flocculants and coagulants to pregnant leach solutions (PLS) upstream of the extraction stages of SX, can be a concern depending on the chemical structure of these polymers. In some cases, the addition of polymers to PLS in copper mines has resulted in obvious negative impacts on phase disengagement or copper extraction kinetics. These polymers fall into three categories of charge; cationic, anionic, and non-ionic. In addition, the molecular weight of the polymers, typically measured as an intrinsic viscosity, has an influence on the behavior of the flocculant or coagulant.

A screening of polymers with varying molecular weight and charge versus a modified aldoxime and a ketoxime/aldoxime blend has been undertaken to determine the effect on extraction kinetics and phase disengagement times. Even at relatively low concentrations, 25 ppm polymer using synthetic or plant PLS, a reduction in the rate of copper extraction and/or an increase in phase disengagement time was noted. As a result of this work, it was determined that the structure of the polymer has a definite impact on the SX system.

DEVELOPMENT, DESIGN AND IMPLEMENTATION OF OUTOTEC'S VSF®X SOLVENT EXTRACTION TECHNOLOGY

By

[1]Tuomas Hirsi, [1]Rami Saario and [2]Mark Weatherseed

[1]Outotec (Finland) Oy, Finland
[2]Outotec Pty Ltd., Australia

Presenter and Corresponding Author

Mark Weatherseed

ABSTRACT

Outotec's VSF®X modular mixer settler solvent extraction technology has its foundations in the industry-proven VSF® solvent extraction technology. This groundbreaking modular design provides a new way to efficiently deliver and construct solvent extraction plants.

As per previous VSF® (vertical smooth flow) plants, VSF®X plants comprise separate Outotec DOP Pumps and SPIROK Mixers to produce and sustain dispersion and settlers with Outotec DDG® Fences for phase separation. These technologies deliver validated process results and are utilized in some of the largest solvent extraction plants in the world.

The challenge for Outotec was to develop a system where the VSF®X components are modular to allow great flexibility in project implementation, while maintaining the process performance benefits that are achieved with the VSF® technology.

The VSF®X product development target was to produce a design that is efficient to manufacture, and when ready can be transported with container transportation equipment to the installation location and easily installed. There were strict guidelines to avoid any negative performance compared to VSF® process performance. The operational efficiency and fluid behavior inside the equipment was tested by CFD calculations before proceeding with mechanical design. The innovation and design process was recognized with an International Mining Metallurgy Hall of Fame award 2014.

The Outotec VSF®X plant has now been delivered to five locations with one more project presently in manufacture. These installations have shown that the development targets have been met with a high degree of success. The modular delivery showed that high manufacturing quality can be achieved in workshop conditions with a high degree of safety. The safety aspect is further extended to the site installation work, where modular installation procedures enable safe and efficient work.

In this paper, we present the successful Outotec VSF®X design process, stating the targets agreed for the product development at the start and assessing development results against these targets. Examples of the benefits achieved in recent projects are identified and discussed.

Keywords: Solvent extraction, Modular delivery, Product development, VSF®, VSF®X.

DESIGN AND MATERIAL SELECTION CONSIDERATIONS FOR SOLVENT EXTRACTION AND ELECTROWINNING PLANTS

By

[1]Bernadette Currie and [2]Graeme Miller

[1]Ausenco, Australia
[2]Miller Metallurgical International Limited, Australia

Presenter and Corresponding Author

Bernadette Currie

ABSTRACT

Equipment service life and corrosion management are major considerations in the design of solvent extraction and electrowinning plants for base and industrial metal extraction. Material selection for vessels, piping, equipment, valves and infrastructure is directed by the need for resistance from chemical attack, compatibility with the solvent, and properties of electrical conductivity and combustion resistance. Finding the correct balance of these attributes makes for unique requirements and may rule out many typical mineral processing material selections, especially for minor components and ancillaries.

Several trends in the solvent extraction industry have put even greater demands on these criteria.

- Use of sea water or hypersaline water for process and makeup duties.
- Deliberate introduction of lixiviants with increased chloride concentration to boost recovery.
- Concentrate leaching processes feeding existing solvent extraction facilities for copper cathode production.

This paper outlines the special considerations, challenges, and costs for selecting materials suitable for continuous use in an organic phase that are able to provide long service life when exposed to low pH, high chloride, aqueous solutions. The focus will be on the specifications for vessel materials and minor ancillary components. Special metallic alloys, plastics, elastomers and other compatible composite alternatives are covered.

Keywords: Hydrometallurgy, Solvent Extraction, Electrowinning, Materials of Construction, Corrosion, Sea Water, Leaching, Water Consumption, Material Compatibility, Acid, Composites

APPLICATION OF LAGRANGE ENERGY METHODS TO DEVELOPMENT OF ACID MIST CONTROL TECHNOLOGIES IN BASE METALS ELECTROWINNING

By

Sabdiel Mella, Jorge Mella, Randy Vergara, Zeryan Guerra and Fernando Guerrero

SAME S.A., Chile

Presenter and Corresponding Author

Randy Vergara

ABSTRACT

In electrowinning of base metals, an electrolyte solution mist is generated, consisting of nanometric drops of water, sulfuric acid and sulfates of dissolved metals. This aerosol is formed during bursting of oxygen bubbles on the surface of the electrolyte, generated in the hydrolysis reaction that takes place at the anode. This phenomenon is known as "acid mist". The generation of acid mist is a limiting factor for electrowinning because its performance is enhanced at higher current densities and electrolyte temperatures, but in this condition solubility of oxygen in aqueous solutions decreases and evaporation rate increases, promoting generation of acid mist.

There are several technologies for control of acid mist, which allow plant operators to reduce or extract emissions in electrowinning cellhouses. Acid mist reduction systems reduce generation of bubbles, increasing their size and/or mechanically interfering with aerosol dispersion process; chemical surfactant agents, titanium anodes and floating mechanical barriers, such as balls, discs or plastic beads, are included in this category. Acid mist extraction systems capture aerosol in suspension after its formation, in order to evacuate it from the cellhouse and/or to condense it and recirculate it to the electrolytic solution; Extractor hoods, local cell ventilation, washers, brushes, mesh panels, filters and cross-flow ventilation systems are examples of extraction technologies.

By applying Lagrange Energy Methods it is possible to study acid mist problems by understanding them as a high energy density emission that must be converted into a low energy fluid, depriving it of its ability to transport pollutants. A simplified mapping of areas with high and low energy density allows engineers to visualize the problem and design a basic system, at the level of conceptual engineering, which is able to control acid mist with a minimum external input of energy; then, by using CFD modeling, is possible to optimize recovery rates and energy efficiency of the system, modifying its geometry and/or incorporating complementary devices.

In the early 1990's, this methodology was applied to analyze traditional acid mist extraction hoods in electrolytic cells, that use forced ventilation for the extraction of polluted air, revealing that high internal pressure and air velocity result in more leaks, suboptimal recovery and high operating costs. As result of this analysis, a new acid mist extraction hood was designed. The new technology was able to maintain mist concentrations below 0.6 mg/m^3, allowing electrowinning operators to work at higher current densities (up to 426 A/m^2), and to abate and recover up to 98% of the mist. This patented system was named "High Energy Hood" and currently is the most effective technology for acid mist control available in market.

During 2014, a similar research was carried out to study traditional cross-flow ventilation systems, concluding that, as an effect of the separation between air injection and mist extraction devices installed in opposite walls of the cell, induced pressure and velocity fields are not homogeneous, resulting in dead zones where there is no acid mist removal and turbulent areas in which the polluted air recirculates, wasting energy and decreasing acid mist extraction rate. A new crossflow ventilation system was developed and patented in 2015, considering a homogeneous system of fresh air injection and mist extraction systems, installed in opposite walls of the electrowinning cellhouse, generating a vertically-confined cross-flow layer, minimizing dispersion of pollutant with minimal energy consumption. Acid mist is recovered in a washing chamber, located before exhaust fans that evacuates remnant treated air to the atmosphere.

This article describes the proposed methodology and analyzes acid mist emissions from a Lagrangian perspective, in order to detect opportunities for improvement and present design guidelines for new control systems. Practical cases of technologies developed by SAME® are discussed.

Keywords: Acid mist, electrowinning, cross flow ventilation, extraction hood, energy methods.

Nickel-Cobalt-Copper Proceedings

Hydrometallurgy

THE FEASIBILITY OF LEAD METAL PRODUCTION AT LEADFX'S PAROO STATION LEAD MINE

By

[1,3]David Dreisinger, [2]Ken Baxter, [2]Mario Di Cristofaro, [2]Hermann Scriba, [3]Nick Waters, [4]Andrew Worland, [4]Tom Cooper, [5]Neil Bourne, [5]David Potts and [5]Roy Hampson

[1]InCoR Technologies Limited, Canada
[2]SNC-Lavalin, Australia
[3]InCoR Energy Materials Limited, Australia
[4]LeadFX Inc, Australia
[5]ALS Global Metallurgical Services, Australia

Presenter and Corresponding Author

David Dreisinger

ABSTRACT

The Paroo Station lead mine, located in Western Australia and owned by LeadFX, has historically produced a lead flotation concentrate from a predominantly lead carbonate (cerussite) orebody. The shipment of the cerussite concentrate from the minesite to smelters is subject to strict environmental controls and high product handling, logistics, treatment and refining charges due to the concentrate containing 67% lead, the transport distance and the lack of intrinsic fuel value and by-product elements. LeadFX needed to implement an innovative solution in order to process the concentrate on-site, therefore reducing environmental risk and cost.

InCoR Technologies, with SNC-Lavalin, has completed a Definitive Feasibility Study (DFS) for the construction and operation of a Hydrometallurgical Facility at Paroo Station, which will allow LeadFX to process the concentrate on site and produce LME grade lead metal ingots for shipment. The process technology, accessed via an exclusive license to InCoR Technologies from BASF SE and the University of British Columbia (and now exclusive sub-license to LeadFX Inc.), uses methane sulphonic acid as the lixiviant for leaching and electrowinning of lead. The feasibility study included a drill program and an extensive bench scale and pilot scale flotation and hydrometallurgical testwork and development program at ALS Global Metallurgical Services laboratories in Perth.

The DFS concluded that the construction of the process plant was technically feasible and financially viable. Importantly, the construction of the Hydrometallurgical Facility will result in value added production of lead metal in Western Australia and significantly improved mine economics. The highlights of the study were:

- 15 year Mine life - a 3.3 times increase [1]
- 1.19 million tonnes contained lead in Ore Reserves (JORC 2012) – 2.5 times increase [1]
- >85% conversion of Mineral Resources to Ore Reserves
- Hydrometallurgical Facility capital cost estimate: US$151.1 million
- Acid leaching, electro-winning and melting flowsheet to produce up to 70,000 tpa of lead metal ingots
- Life of Mine C1 cash cost: US$1,254/t Pb (US$0.57/lb Pb)
- NPV of US$191 to 303 million and IRR of 23.5 to 31.3%pa at long-term LME lead price of US$2,250[2] to 2,575/t Pb (US$1.02 to 1.17/lb Pb)

LeadFX is progressing to Front End Engineering Design (FEED), environmental permitting and financing and has a final investment decision target of Q3 of 2018.

Keywords: lead recovery, methane sulphonic acid, leach, electrowon, pilot plant, feasibility study

[1] Compared to the Company's last Technical Report dated March 10, 2015

[2] Wood MacKenzie – Lead long-term outlook Q4 update, December 2017

CORROSION PROTECTION IN HYDROMETALLURGICAL ORE PROCESSING PLANTS: MATERIALS – APPLICATION – MAINTENANCE

By

Dave Barnett

TIP TOP Oberflächenschutz Elbe GmbH, Germany

Presenter and Corresponding Author

Dave Barnett

ABSTRACT

Efficient and effective Corrosion Protection is the key factor to guarantee long service lifetimes of processing plants throughout the world and throughout the various industries which are handling aggressive slurries, liquid or gases. Especially in ore processing plants, for example the high pressure acid leach process for Nickel we are facing a variety of challenges for corrosion protection.

Starting from an autoclave with high temperature, high pressure and hazardous chemicals the residual abrasive slurries are transported via pipes to different equipment such as storage tanks, reactors, counter current decanters, thickeners and many other pieces of equipment.

This presentation summarizes the different methods of corrosion protection which are applied in ore processing plants worldwide, the parameters which determine the type of system to be used such as chemicals involved, concentration, temperature and life expectancy.

The presentation also summarizes further influences such as abrasion, pressure and UV radiation which can have a large influence on corrosion protection linings. One major cause of failure of such corrosion resistant linings is permeation and this paper addresses the factors which influence permeation and subsequently the life expectancy of such a lining and explains the parameters which can be optimized to increase the life expectancy of the lining.

In this presentation an overview of the items which should be observed during the design and engineering of a corrosion protection lining will be given and further the importance of factors such as climatic conditions, health and safety and surface preparation during the application of such products as well as the repair and maintenance will be addressed.

Keywords: Corrosion Protection, Abrasion, Chemical Resistance, Permeation

AUTOGENIC REAGENT GENERATION FOR PURIFICATION OF PROCESS LIQUORS: CASE STUDIES

By

Bonginkosi Nkosi and Conny Sehlola

Mintek, South Africa

Presenter and Corresponding Author

Bonginkosi Nkosi

ABSTRACT

The direct addition of a precipitation reagent such as sodium hydroxide or lime to value metal-containing process liquors results in the introduction of impurities to the process stream. A process has been developed for the purification of value metal-containing solutions by chemical precipitation using autogenic reagent generation concept. The process is aimed at minimising the introduction of impurities and value metal losses by replacing the conventional precipitating reagent with an autogenic reagent containing the value metal. The process involves drawing a split stream from the impure process stream and generating an autogenic reagent from it by precipitation using a hydroxide, sulfide or carbonate. The autogenously generated value metal-bearing reagent is then used to raise for example the pH in the process stream to precipitate impurities such as iron (Fe), aluminium (Al), and others according to their solubility or metathetically remove for example Copper (Cu) as a sulfide.

The autogenic reagent generation concept was applied to the purification of a nickel sulfate stream to prove its viability. The nickel sulfate stream containing Fe and copper (Cu) as major impurities was purified by hydroxide and sulfide precipitation with nickel hydroxide ($Ni(OH)_2$) and nickel sulfide (NiS) respectively. Complete removal of Fe and Cu was achieved by hydroxide precipitation, with over 99% (m/m) precipitation efficiencies obtained. Copper sulfide (CuS) precipitation resulted in complete Cu removal at high NiS excess of ~300%. Therefore, the autogenic reagent generation concept is viable for the purification of a nickel sulfate stream. The process in principle could also be applied to the recovery of several metals including cobalt (Co), titanium (Ti), rare earth elements (REE) and others.

Keywords: Autogenic reagent generation, precipitation, value metal, impurities

THICKENER DESIGN, CONTROL AND DEVELOPMENT

By

Mike Miller

SNC-Lavalin Australia

Presenter and Corresponding Author

Mike Miller

ABSTRACT

The common thickener underpins the performance of most hydrometallurgical facilities. Thickeners are simple, reliable, effective and efficient – under the right conditions. For the rest of the time, however, thickener performance (or lack of it) seriously affects the rest of the operation. In many plants, thickener problems are a regular, day-to-day operational event. So much so, in fact, that these issues seem to be accepted as a normal part of doing business. Given recent developments in thickener design and modelling, this should not be the case.

The purpose of this paper is to present a generalised understanding of the various inputs that combine in the design, control and operation of a modern thickener. This paper does not seek to provide all the answers in thickener design and control, but hopes to give the reader a greater understanding of the questions that need to be asked in the course of preventing or controlling thickener problems.

Starting with the basics of thickener theory, key elements of the sedimentation process and options for thickener selection are explored, as well as testwork requirements and the features of critical thickener components. Thickener control strategies and shortcomings in current thickener operations are discussed, including the strengths and weaknesses of the given field instrument options and their application in the overall control strategy. Many of these can be considered as “growing pains”, associated with changes introduced by process improvements in other areas.

Finally, options for design and operational improvements (for both greenfield and brownfield operations) are discussed.

Keywords: Hydrometallury, Sedimentation, Solid-Liquid separation, Thickening, Thickener, Clarifier, Flocculation, Rheology, Process Design, Process Operation, Trouble-shooting, Control.

EVALUATION OF THE CHANNELLING EFFECT OF GRAVITY DOMINATED PACKED BEDS PERTAINING TO HEAP LEACHING HYDRODYNAMICS

By

W. Ashane M. Fernando and I.M. Saman K. Ilankoon

School of Engineering, Monash University, Malaysia

Corresponding Author

I.M. Saman K. Ilankoon

Presenter

W. Ashane M. Fernando

ABSTRACT

Heap leaching is a well-known mineral processing technique, whereby crushed and run-of-mine ores are used for valuable metal extraction from low grade ores. It is primarily applied for the recovery of precious metals (gold) and base metals, such as copper from secondary sulphide and oxide ores. However, this hydrometallurgical technique typically results in lower recoveries compared to conventional mineral extraction techniques, such as froth flotation followed by smelting, and there is a lot of scope for improvement. Potential sources of improvement are not only in the leaching kinetics of industrial heaps, but also in the hydrodynamics of the heaps. This paper addresses heap hydrodynamics, especially liquid channelling, which causes lower recovery efficiencies in industrial heaps, and the strategies to minimise the adverse effects. Heaps are complex unsaturated systems, where the application of unsaturated fluid dynamics is required. This paper will cover the distribution of liquid within heap systems, as it has a strong effect on the transport of both leaching reagents and dissolved metal species. When the heap systems are modelled using unsaturated hydrodynamics, such as using Richard's equation, the liquid distribution profile around a drip emitter follows a Gaussian distribution. In this paper a 2-D column packed with ore particles was employed and the horizontal spread of liquid in the vicinity of drippers was ascertained within the packed bed system. The results show wetting profiles within the bed with severe flow channels between the particles. Even though intermittent liquid addition in industrial heap leaching is supposed to increase metal recoveries by removing dissolved species efficiently, its effect on flow paths development and associated liquid channelling has not been explicitly discussed in the literature. This aspect will also be investigated in this work in order to distribute liquid flow paths evenly and thus maximise low grade based metal extraction efficiencies.

Keywords: Channelling, Intermittent leaching, Liquid flow features, Low grade copper ores, Heap Leaching

Nickel-Cobalt-Copper Proceedings

Hydromet Processing of Copper, Nickel & Cobalt Sulphides Forum

COMPARATIVE ANALYSIS OF LIXIVIANT/OXIDANT SYSTEMS FOR CHALCOPYRITE LEACHING FROM COARSE SAMPLES AT ELEVATED TEMPERATURE

By

[1,2]Tania Hidalgo, [2]Laura Kuhar, [1]Andreas Beinlich and [1]Andrew Putnis

[1]Curtin University, Australia
[2]CSIRO, Australia

Presenter and Corresponding Author

Tania Hidalgo

ABSTRACT

Chalcopyrite ($CuFeS_2$) is the most common copper-bearing mineral and represents more than half of global copper mineral reserves(1). Refractory chalcopyrite requires the addition of an oxidant and lixiviant for dissolution. Although lixiviants have been evaluated in previous studies for conventional mining, limited information is available regarding their behaviour during the leaching of coarse samples at high temperatures, including their stabilities and what secondary products may form. We compared the thermal stability of a variety of lixiviants and their ability to leach copper from chalcopyrite with oxidant addition at set temperature, pressure and pH conditions. Tests were conducted at 170°C for 120 to 576 hours using solid cubes (4-mm sides) to simulate coarse samples found in heap leaching and in-situ recovery. Sealed batch reactors (closed-system conditions) were used to simulate an anaerobic environment that may be experienced in a subterranean application (such as an in-situ recovery environment). Lixiviants, including sulfuric acid, hydrochloric acid and glycine, and oxidants, including iron (III), copper, dichromate and hydrogen peroxide were screened for their suitability to leach copper from hard rock copper-sulphide deposits.

This paper presents the findings from this study and includes a comparison of the leaching systems at high temperature based on an identification of products and passivation phenomena, and an analysis of surficial textures. Conclusions are provided on the possible suitability of the systems for use in high-temperature copper in-situ recovery processing based on the laboratory performance of the chosen systems.

Keywords: Copper Recovery, Chalcopyrite Leaching, Hydrometallurgy, Surface Passivation, Mineral Replacement

THE USE OF ADDITIVES IN THE LEACHING OF PRIMARY COPPER SULFIDES IN ACIDIC FERRIC SULFATE MEDIA UNDER RECYCLE SOLUTION CONDITIONS OBSERVED IN HEAP LEACHING

By

Aleksandar N. Nikoloski and Glen P. O'Malley

School of Engineering and Information Technology, Murdoch University, Australia

Presenter and Corresponding Author

Aleks Nikoloski

ABSTRACT

The present account summarises some of the main findings of a research program carried out at Murdoch University that has investigated the effects of common leaching process control parameters, major species present in the leach system, and additives on the rate and extent of copper extraction from low-grade ores in which chalcopyrite ($CuFeS_2$) was a dominant copper source mineral, under heap leach recycle solution conditions. The primary aim of this paper is to demonstrate the benefits of certain additives on the leaching of chalcopyrite under these conditions.

Determining an effective, low cost extraction process for copper from chalcopyrite is important, as chalcopyrite is the most abundant copper mineral in the earth's crust and most of the reserves are of low grade and not suitable for conventional flotation/pyrometallurgical processing. The current research focus for the treatment of these low-grade chalcopyrite ores is hydrometallurgical processing, with the most viable option from a cost perspective being heap leaching with the aid of bacteria in a sulfate media. However, it is well known that chalcopyrite is refractory under those conditions, with slow leaching kinetics and poor overall extraction due to passivation of the chalcopyrite surface. Extensive research has demonstrated that the addition of certain additives can significantly improve the copper extraction. Yet there has been little research into how these additives affect the extraction of copper under recycle leach solution conditions, or the mechanism of copper extraction. Investigating this process under recycle leach conditions is important because in heap leaching, many of the low-grade deposits require long treatment periods to liberate the copper from a coarsely ground feed so the leach solution is recycled multiple times and it has very high activity with respect to many species.

The studies at Murdoch University consisted of batch leach tests, detailed structural and mineralogical characterisation of samples and thermochemical modelling. The results demonstrate that silver has a strong catalysing effect on the extraction of copper from chalcopyrite ore under leach recycle conditions, and at a high enough dosage can effectively overcome surface passivation, enabling almost complete extraction of copper. The addition of activated carbon, chloride ions or wetting agent was also shown to promote the extraction of copper. Varying the concentration of additives and other process conditions has enabled the critical concentration of each additive for effective treatment to be determined. The data from the study informed the development of a theory for the reaction mechanism through which silver promotes copper extraction, enabling the identification of (secondary) synergistic additives that should significantly reduce the required silver dosage and make this treatment cost effective in practice.

Keywords: Chalcopyrite; Additives; Heap Leaching; Acidic Ferric Sulfate; Recycled Solution.

REVIEW OF SEQUENCE ASSAY SCHEMES FOR COPPER SPECIATION AND ITS USE IN GLYLEACH™

By

Frank Trask

Mining and Process Solutions, Australia

Presenter and Corresponding Author

Frank Trask

ABSTRACT

A general description of the GlyLeach™ leaching technology will be given, with a broad view of results from a number of different ores. Advantages and disadvantages of the method are discussed.

The classical method for simple copper mineral speciation via assay is presented and reviewed in detail. Problems between objective and subjective tests are reviewed, and the reason for them explained. There is a radical difference between a mineralogical assay and a sequence assay.

A graphical chart useful for interpretation of the normal sequence assay is presented and its use discussed.

A new sequence assay sub group is proposed to deal with arsenate and antimonides that are soluble is sodium sulphide.

Lastly, examples from real data are examined and compared with the actual response of several oxide and sulphide ores to Cu extraction using both GlyLeach™ and classical acid leaching.

Keywords: Glycine, sequence assays, leaching data

COPPER COBALT GOLD PROJECT FLOWSHEET DEVELOPMENT

By

Damian Connelly, Brett Morgan and Josh Brown

Mineral Engineering Technical Services Pty Ltd (METS), Australia

Corresponding Authors

Brett Morgan

Josh Brown

Presenter and Corresponding Author

Damian Connelly

ABSTRACT

Cobalt is present as cobaltite, copper is present as chalcopyrite and the gold is predominantly associated with the sulphide minerals. The similar nature of the sulphide minerals, together with the gold association, has allowed a very simple beneficiation process and production of a bulk concentrate. These results suggest excellent potential for the production of a concentrate for hydrometallurgical processing.

Testwork was conducted on a composited sample of drill core from the Company's recently completed drilling program at the Cobalt Ridge prospect. Mineralisation tested included grades representative of what is considered the "background" grade for the main lode within the cobalt deposit. The assayed grade of the sample was 0.14% cobalt, 0.32% copper and 0.09 ppm gold, providing a variation to the previously tested high-grade mineralisation.

Simple bench scale rougher flotation tests yielded excellent recoveries of 93.6% cobalt and 98.45% copper. A large scale rougher-regrind cleaner flotation circuit achieved 78.7% cobalt and 91.6% copper recoveries in 2.92% of the rougher feed mass. The cleaner concentrate graded 3.31% cobalt, 9.28% copper and 2.73 ppm of gold. This concentrate was used for the downstream testwork.

The concentrate was subjected to pressure oxidation (POX) followed by solvent extraction to recover copper and cobalt. The residue was cyanide leached to recover gold. Solvent extraction shake tests were conducted to recover cobalt and copper. A flowsheet was developed tailored to the ore characteristics to recover cobalt sulphate, copper sulphate and gold.

Keywords: cobalt, copper, gold, POX, solvent extraction, cyanide gold recovery, hydrometallurgy of cobalt.

CESL COBALT PROCESS DEVELOPMENT – COMPARISON OF COBALT PRODUCT ECONOMICS

By

Justin Wu

Teck Resources Limited, Canada

Presenter and Corresponding Author

Justin Wu

ABSTRACT

To contribute to industry-wide efforts to meet the growing demand for cobalt, CESL has reviewed process know-how and extensive flowsheet test work previously developed by CESL to deliver a customizable flowsheet to produce a variety of cobalt-bearing products. Included in the overall effort to date, CESL has examined the value that can be generated for several cobalt products which previously had not been studied in detail. This paper summarizes results from a comparative study on the most economically suitable cobalt product for CESL's nickel-copper (cobalt) flowsheet using Teck's Mesaba (Cu-Ni-PGM, Au-Ag-Co) project as a study basis.

Keywords: cobalt recovery, CESL, process development, pilot plant, Mesaba, cobalt products, economics comparison

LEACHING OF COBALT BEARING NICKEL SULFIDE AND FURNACE CONVERTER MATTES WITH ALKALINE GLYCINE, AND SUBSEQUENT SX AND IX

By

Jacques Eksteen, Elsayed Oraby, Lurika Lombard and Lauren Di Prinzio

Western Australian School of Mines, Minerals, Energy and Chemical Engineering,
Curtin University, Australia

Presenter and Corresponding Author

Jacques Eksteen

ABSTRACT

The paper presents the outcomes of exploratory research relating to the leaching of nickel and cobalt from Western Australian nickel-cobalt sulfide concentrates and smelter mattes, and the subsequent recovery and separation using solvent extraction (SX) and ion exchange (IX) using alkaline glycine solutions in mildly oxidizing environments. The results set an important foundation for direct leach approaches, particularly if upstream opportunities are considered (heap leach, in-situ leach, or vat leach, or bulk ore leach) from low grade Ni-Co resources. The results for cobalt are particularly exciting given the low recovery of cobalt in most smelting operations and the loss of cobalt to converter slags in conventional approaches.

High extractions (90% for nickel and 83% for cobalt) from concentrates containing around 15% Ni and 0.3% Co were possible at room temperature using conventional bottle rolls over a 20 day period. Extractions of nickel and cobalt was around 60% and 55% after 48 hours. The concentrate contained cobalt-bearing pentlandite as the predominant Ni-Co mineralization, with pyrrhotite, pyrite, mica, garnet and talc as the predominant gangue minerals. It was found that running at milder alkaline pH (pH of 9) gave significant better leach extraction than operating at higher pH's (pH of 11) which is opposite to the behavior of copper sulfides (such as chalcopyrite, which tend to show improved leach kinetics at pH 10-11). This is convenient, given the difficulty of operating at high pH in Western Australia where high and hyper salinity leads to pH buffering around a pH of 8.9. It was also found that preoxidation of the concentrate proved to be detrimental (again opposite behavior to copper sulfide concentrates) and that the milder oxidizing conditions in a conventional bottle roll appeared to be optimal. The long leach times to achieve good recoveries implies that the leach approach is more suitable for an alkaline heap leach environment (assuming sufficient exposure of the cobalt bearing pentlandite) rather than a tank leach of the concentrate. Should concentrates be targeted, a concentrate coated gravel heal leach may be considered (compare with GEOCOAT® technology). Excellent extractions were also achieved of Ni and Co from furnace matte and converter matte. Direct leaching of granulated furnace matte has the potential of eliminating many of the logistical challenges around the converting aisle in the smelter and the batch nature of running converters with associated fugitive emissions and unsteady state SO_2 gas evolution. In all cases (concentrates and mattes) the dissolution of iron, magnesium, silicon, manganese and other impurities were insignificant (low ppm range), significantly simplifying downstream recovery from solution and base metals refining. This is particularly important for iron removal which would normally have posed a significant solid-liquid separation and waste disposal cost.

Excellent recovery from solution and separation of cobalt from nickel were achieved in both solvent extraction and ion exchange to produce the metals as concentrated nickel sulfate and cobalt sulfate solutions (using a conventional acidic strip).

The bench scale results provides a basis to investigate nickel and cobalt recovery from various sulfide resources using a benign alkaline leach technology using non-toxic, non-volatile and cost effective reagents, where the reagents can be recycled to the leach after resetting the pH.

Keywords: Nickel Recovery; Cobalt Recovery; Alkaline Glycine Leach; Nickel Sulfide; Solvent Extraction; Ion Exchange; Pentlandite

PROCESS UPDATE ON DYNAMIC HEAP BIOLEACHING OF A BLACK SCHIST ORE

By

Sarita Ahoranta, Harri Natunen and Antti Arpalahti

Terrafame, Finland

Presenter and Corresponding Author

Sarita Ahoranta

ABSTRACT

Terrafame mine located in Sotkamo, Finland utilises heap bioleaching to extract metals from black schist ore. The ore leached at the mine is a complex sulphide ore with pyrrhotite and pyrite as the main sulphides (5-15 w-% each). In addition, the ore contains 5-10 w-% of graphite. The ore deposit contains valuable metals nickel, zinc, copper and cobalt that are present in the ore as pentlandite/pyrrhotite, sphalerite, chalcopyrite and pyrite, respectively.

The heap leaching process is divided into two steps: dynamic primary leaching and multi-lift secondary leaching. Currently the residence time on primary leaching pads containing a total of 24 to 28 million tons of ore is approximately 1.5 years, after which the ore is reclaimed and restacked to permanent secondary heaps to continue the bioleaching process. Operation of the dynamic primary pads started in 2008 and reclaiming of the ore from primary to secondary pads was first commenced in 2010. The fifth round of operation on the primary leaching pads will start in 2018. In 2017, 20 864 tons of nickel and 47 205 tons of zinc were produced and the net sales of Terrafame more than doubled from the previous year to EUR 218.8 million. In addition, a new quarterly record of 13 772 tons was achieved in zinc production and the first commercial deliveries of copper were made at the end of 2017.

Heat formation in the heaps has considerably increased over time due to the improved leaching process, with e.g. outlet temperatures of the primary heap solutions increasing by more than 30% between 2016 and 2017. Temperature increase and subsequently increased soluble calcium content in the irrigation solutions has led to gypsum formation in the irrigation pipelines and thus, solutions for controlling precipitate formation in the process are currently being investigated. This paper gives an update on the current process developments at Terrafame mine, ongoing production and operation ramp-up, and future production plans including battery chemical production and the recovery of uranium and rare earth elements.

Keywords: Heap Leaching, Bioleaching, Black Schist, Dynamic Pad, Nickel, Zinc, Copper, Cobalt, Heat Formation, Irrigation, Gypsum

MONDO MINERALS NICKEL SULFIDE BIOLEACH PROJECT: MAXIMISING VALUE THROUGH GOLD RECOVERY

By

[1]Arto Laukka, [1]Janne Seppälä, [2]John Neale, [3]Pieter van Aswegen, [4]Stephen Barnett, [5]Antti Taskinen and [5]Krista Koistinen

[1]Mondo Minerals Nickel Oy, Finland
[2]Mintek, South Africa
[3]P Met. Consulting cc., South Africa
[4]Consultant, United Kingdom
[5]Geological Survey of Finland, Finland

Presenters and Corresponding Authors

Arto Laukka and John Neale

ABSTRACT

Mondo Minerals (Mondo), the world's second-largest talc producer, has mining operations located at two sites in Finland: Sotkamo and Vuonos. A by-product of the talc mining operations at both sites is a sulfide concentrate that contains a valuable quantity of nickel and cobalt, but also a small but significant quantity of arsenic, gold and platinum group metals.

In 2015 and 2016, Mondo successfully commissioned the world's first nickel concentrate bioleaching plant to recover the nickel and cobalt as a mixed hydroxide product, which is sold for the production of battery-grade nickel sulfate.

In 2017 Mondo successfully developed and piloted a process to recover gold and platinum group metals from the bioleach residue. These metals, which remain insoluble during the bioleaching process, can successfully be recovered to a high-grade concentrate suitable for sale to refiners. The process, developed with the Mineral Processing Laboratory of the Geological Survey of Finland (GTK Mintec), utilises Knelson concentrators and a strong acid wash.

This paper provides a brief update of the current status of the sulfide treatment operation, and describes the development of the gold recovery process.

Keywords: nickel sulfide bioleaching, iron/arsenic precipitation, mixed hydroxide precipitation, nickel production, gold recovery