ALTA 2019
18 - 25 May
Perth, Australia

24th Annual Conference Proceedings

Lithium Processing Conference

Including

Novel Lithium Processes Forum

Sponsored by

OLI systems, inc.

3rd Annual Lithium Processing Event

ALTA Metallurgical Services, Melbourne, Australia
www.altamet.com.au

PROCEEDINGS OF
ALTA 2019 LITHIUM PROCESSING SESSIONS

Including

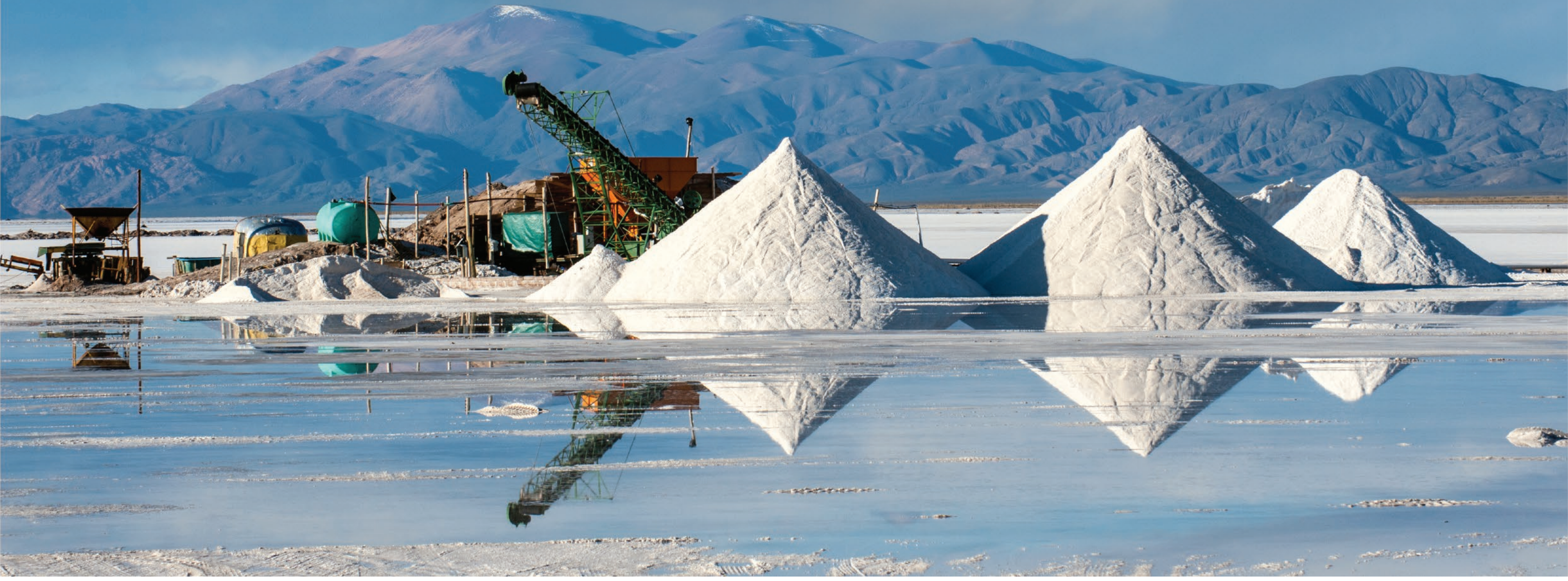
Novel Lithium Processes Forum

24 May 2019

Perth, Australia

ISBN: 978-0-9946425-9-2

REVOLUTIONIZE YOUR LITHIUM PRODUCTION THROUGH ACCURATE PROCESS MODELING AND SIMULATION



New Lithium Chemistries
Accurate chemistries critical for modeling lithium mining processes - Fundamental lithium with sulfate and chloride as well as with potash chemistry, also lithium borate systems, lithium carbonate and lithium hydroxide with key anion and cation interactions.

MSE Thermodynamic Model
Delivers rigorous and accurate chemistry simulation for the complex and interactive lithium chemistry, using a unique modeling framework capable of simulating double salts, and taking multiple ion-ion interactions into account.

In-depth Chemistry Studies
Uniquely designed for electrolyte chemistry analysis using thermodynamic modeling with new lithium and potash chemistry parameters to understand and predict the behavior of lithium and related components in either ore extraction or evaporation scenarios, OLI Studio is used in order to devise optimal extraction schemes and to provide insights to hone cost estimation and planning.

Comprehensive Process Modeling Capabilities
For applications like leaching of ores, pH control, evaporation crystallization and trace metal removal, including recycle and heat and material balance effects, OLI's Engine is available in a flowsheet environment within OLI Flowsheet: ESP as well as within other commercial flowsheet simulators for the mineral processing industry.

Download the OLI Systems Whitepaper on Process Modeling for Lithium mining to learn more.

Let OLI Systems help you minimize the cost of deployment and operations while maximizing product and salability. Sign up for a free applications assessment.

OLI systems, inc.

think simulation | getting the chemistry right

ALTA Metallurgical Services

Celebrating 33 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 2020 is a world-class annual metallurgical conference, **celebrating its 25th year**, and a leading platform for innovation. The event will be held 23-30 May in Perth, Australia and comprises five technical conferences, three short courses and an international trade exhibition. It features a highly-focused program, topical forums and presentations from key international speakers. What do people say about ALTA? Read our Testimonials

Publications

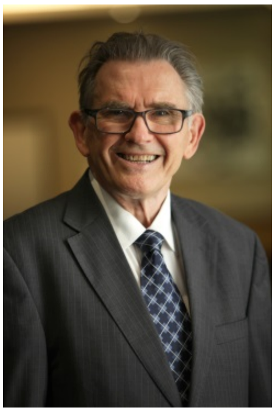
Proceedings from ALTA conferences and seminars, and technical short courses manuals.

MetBytes

Free technical metallurgical articles offering metallurgical commentary and insights.

Free Library

Includes proceedings from 1995-2017 Nickel-Cobalt-Copper, Uranium-REE and Gold-PM conferences for free download (1460+ papers). A selection of ALTA 2018 papers is also available. The library is expanded regularly, providing a major ongoing resource to the industry.



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

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

Major Commodities

- Nickel/Cobalt
- Copper
- Uranium
- Gold/Silver
- Base Metals

Areas of Experience

- Metallurgical Testwork Supervision
- Process Development
- Process Design
- Technical & Economic Evaluations
- Feasibility Studies
- Plant Design
- Project Engineering
- Commissioning
- Peer Reviews
- Client Representative for Projects
- New Technology Assessments
- Development & Presentation of Short Courses

Technical & Engineering Expertise

- Leaching – atmospheric tank, heap, pressure, bio, & in-place
- Solid/liquid separation
- Solvent extraction & ion exchange
- Electrowinning & electrorefining
- Precipitation
- Cyanidation & CIP/CIL
- Crushing, grinding & flotation
- Gravity processing

ALTA 2019
18 - 25 May
Perth, Australia

Nickel-Cobalt-Copper, Uranium-REE, Gold-PM In Situ Recovery, Lithium Conference and Exhibition

Sharing ideas, innovations, technologies and projects

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

Sponsors

EKATO
LANXESS Energizing Chemistry
NobelClad
mining3 Transforming Mining
Ausenco
SOLVAY
STEULER KCH
WEIR Minerals
Air Liquide creative oxygen
OLI systems, inc.
BASF We create chemistry
Purolite
jord proxa future focused
Brisbane Met Laboratory

Exhibitors

EKATO
matec pacific
KOCH KNIGHT
REMA TIP TOP
SPXFLOW
CGIS
TURTLE TOUGH SENSORS
SUNRESIN
MOGAS Severe Service Ball Valves
SGS
STEULER KCH
DURATEC AUSTRALIA
Bureau Veritas
CORE
METS Engineering Process + Innovation
MINTEK
CSIRO
Air Liquide creative oxygen
JENIKE & JOHANSON
SOLVAY
TITAN Metal Fabricators
Endress+Hauser People for Process Automation
Italmatch Chemicals
Diemme Filtration A brand of Aqseptence Group
AMS Technologies Advanced Membrane Separation
The Simulus Group
Outotec
SEFAR
PLA Process Analysers
AXIONIT
FLOWROX
ArrMaz
metso
wood.
MPS Mining & Process Solutions
FLSmidth
METSIM
FRIEM
Continental Engineering Services Australia
ALTA

Partners and Co-Sponsors

SAIMM The Southern African Institute of Mining and Metallurgy
IAEA International Atomic Energy Agency
COM 2019 Conference of Metallurgists MetSoc
CSIRO
Curtin University
Government of Western Australia Department of Mines, Industry Regulation and Safety Geological Survey and Resource Strategy
MEI
International Mining
Resources Review
Australia's Mining Monthly
Copper Worldwide
Perth Convention Bureau
Tourism Western Australia

Lithium Processing Proceedings Contents

ALTA 2019

Lithium Processing Proceedings

Keynote Address

INNOVATION REQUIRED TO MEET FUTURE LITHIUM DEMAND

By

Adrian Griffin
Managing Director
Lithium Australia, Australia

ABSTRACT

With a seemingly insatiable demand for lithium-ion batteries accelerating globally, we, as a wasteful society, discharge more lithium to waste than ever enters the supply chain.

Within the supply chain itself, lithium has become a disposable commodity, a large proportion of it ultimately relegated to landfill.

Meanwhile, much lithium not actually entering the supply chain is lost to inappropriate processing technologies or a dearth of meaningful attempts to recover any when it is associated with other commodities, such as tin and tantalum. And all of this occurs in the shadow of potential supply shortages.

The solution to ethical and sustainable lithium supply lies in better resource utilisation and effective recycling.

There are several elements to better resource utilisation. With respect to hard-rock sources of lithium, different styles of mineralisation can be exploited, among them greisen, clays and waste discharge streams containing lithium micas. In the case of lithium brines, yield can be improved using chemical processes that recover lithium more efficiently than via evaporation ponds.

Within the supply chain itself, lithium can be recycled by way of hydrometallurgical rather than pyrometallurgical techniques, since the latter discharge lithium to useless slag or flue gas.

Unutilised opportunities to improve efficiencies throughout the lithium cycle (as in the production of lithium-ion batteries) are outlined in this paper.

Keywords: lithium, sustainable, ethical, clay, brine, greisen, recycling, LieNA®, SiLeach®

ALTA 2019

Lithium Processing Proceedings

Production and Recycling

RECENT ADVANCES IN HYDROMETALLURGY FOR THE DEVELOPMENT OF A SUSTAINABLE PRODUCTION OF LITHIUM-ION BATTERIES

By

Alexandre Chagnes

Université de Lorraine, CNRS, GeoRessources, France

Presenter and Corresponding Author

Alexandre Chagnes

ABSTRACT

It is expected that the small world of lithium will boom due to the emergence of electric vehicles. Likewise, it is expected that the demand in cobalt and nickel will be increased by 31% and 69% between 2017 and 2030, respectively. The development of sustainable and economic processes to recover lithium, cobalt, nickel and manganese from primary and secondary resources is therefore of great importance, especially because of a huge demand of these metals to produce lithium-ion batteries. This paper gives recent advances in the development of hydrometallurgical processes for the sustainability of battery raw materials.

Keywords: copper recovery, ammonia leach, solvent extraction, electrowinning, process development, pilot plant

ALTA 2019

Lithium Processing Proceedings

Roasting and Calcination

THE NATURE OF LITHIUM MINERAL PHYSICAL PROPERTIES IN SELECTING CALCINATION AND ROASTING EQUIPMENT

By

Grant Harman

Lithium Consultants Australasia, Australia

Presenter and Corresponding Author

Grant Harman

ABSTRACT

Until recently, Talison was essentially the sole supplier of spodumene concentrate to the world. The bulk of the spodumene concentrate had a grade of 6 wt% Li_2O and still remains the bench mark for chemical grade. In addition, the combined spodumene and quartz content comprised roughly 90 wt% and other minerals only 10wt%.

The newer spodumenes being offered to the market typically have a lower amount of spodumene and quartz and behave differently in the calcination and/or roasting operations which are typically the first steps in the processing of lithium concentrate to extract the lithium. Furthermore, many of the new ores require flotation of a significant portion of the ore in order to achieve the grade and this results in a finer concentrate. Similarly, the secondary lithium mineral concentrates, such as lithium micas and clays, are also fine (compared with the median particle size of the Talison SC6.0) and contain a larger percentage of other minerals. They are generally more reactive, for example to acids at low temperature.

There are a suite of tests that can be performed on a lithium concentrate to determine which equipment is the most suitable for the calcination and or roasting of the ore. The tests that can be considered include elemental analysis, mineralogy, PSD (particle size distribution), TGA (thermogravimetric analysis), DSC (Differential Scanning Calorimetry) and the Heating Microscope Dilatometer.

Based on the physical properties a selection of the best equipment can be made for the application with the melting point and PSD of the concentrate being the two main factors to consider. Typically, the range of calciners and roasters available include rotary kilns, fluidised bed kilns, flash calciners, tunnel kilns and multiple hearth furnaces. This paper provides guidance for the selection of the most suitable equipment based on the physical properties of the lithium concentrate.

Keywords: Lithium ores, spodumene, calcination, calciner, roaster, TGA/ DSC, PSD, rotary kiln, fluidised bed kiln, flash calcination, multiple hearth furnace.

TUNNEL KILN MINERAL ROASTING

By

Jeffrey K Claflin, Scott Brindley and Aaron Claflin

Ausenco Minerals, Australia

Presenter and Corresponding Author

Jeff Claflin

ABSTRACT

Use of a rotary kiln for gypsum roasting is problematic. Use of a single counter-current rotary kiln can cause the reactions to proceed too far and in the case of clay-like materials and many lithium ores, can result in vitrification and un-extractable products. A co-current rotary kiln can be used to hold the material at the reaction temperature successfully, however the capital cost becomes prohibitive because two kilns are now required. Typically, a rotary cooler is used to cool the roasted product before leaching. The result of three large rotary devices is that the feed of the first device can be many tens of meters above ground with a commensurate installed capital cost.

Rotary kilns are kept short and heat transfer is intensive (high temperature differences and/or increased gas flow) to reduce capital cost. High exhaust gas temperature results in sensible heat loss and increased operating cost. A high gas velocity in the kiln improves heat transfer, but generates dust. This dust is carried out of the kiln and must be recovered before the gas can be released to the atmosphere. In the specific case of gypsum roasting, if the reagents are not kept in intimate contact with the ore, sulphur dioxide can be released and require scrubbing. Dust recovery and gas cleaning equipment can increase the capital cost by 50%.

With respect to operating cost, shorter kilns have high exhaust temperatures resulting in larger sensible heat losses and increased fuel consumption. All high temperature rotary kilns must have cool shells for structural integrity reasons. The shells are kept cool, in part, by ambient air and intentional equipment heat losses.

Tunnel kilns are an alternative to rotary kilns. Heat can be introduced into a tunnel kiln anywhere along its length and gas temperature controlled to within 5°C anywhere in kiln – product damage is easily avoided. Thermal efficiency is high with all exhausts just above dew point and equipment surface temperatures safe to touch. The solids are stationary on the cars and the gas velocities are insufficient to generate dust. Dust removal from the off-gas is not necessary even when processing ore containing 15% clay.

This paper presents the development of a tunnel kiln for lithium ore roasting from its inception through modeling, lab and pilot testing, engineering and vender quotations for purchase. This development process is the same as that used to evaluate a tunnel kiln to process other minerals at high temperatures. The tunnel kiln roaster is shown to be a fraction of the installed capital cost of a rotary kiln roaster and far less costly to operate.

Keywords: Roasting, Gypsum, Vanadium, Lithium, Heavy Mineral, Refractory Mineral, Rare Earth Minerals, Platinum Group Metals, Mineral Heat Treatment, Tunnel Kiln, Process Development, Pilot Plant, CAPEX, Operating Parameters

ALTA 2019

Lithium Processing Proceedings

Project Development

PROJECT DERISKING: THE IMPORTANCE OF METALLURGICAL TESTING AND PILOTING WITHIN THE PROJECT LIFECYCLE

By

Pete Forakis, Dwight van der Meulen and Chad Czerny

SGS Minerals Metallurgy, Australia

Presenter and Corresponding Author

Pete Forakis

ABSTRACT

Mining and processing plant projects are very capital intensive and as such tend to follow the typical project development route of 1) Scoping Study (SS), 2) Pre-feasibility Study (PFS) and 3) Definitive Feasibility Study (DFS). This is an attempt at mitigating risk at each stage and to identify the development option(s) which will yield the highest probability of financial success. The early phases are an opportunity to evaluate the various options, to define the most viable processing route with the lowest capital and technical risks. The use of metallurgical testing is key to remove risk that can have a negative impact on capital cost as well as ongoing operating costs.

Metallurgical testing and piloting are essential to properly assessing the appropriate processing route to produce the desired end-product from variable ores which are potentially mined over many years. This enables the selection of the most appropriate flowsheet and has a direct impact on capital costs. Extended piloting campaigns at the DFS phase are also a way to minimize risks for operating costs. Changes or modifications of the flowsheet at the early stages of the project are much less costly than at later stages. In some cases, it is impossible to change the fundamental process once the project has been given the Notice to Proceed (NTP).

Metallurgical testing and piloting is of particular importance for the fast-growing market for lithium ion battery feedstock such as cobalt and nickel sulphate and lithium carbonate and lithium hydroxide. This is due to the fact that the processing methods are not tried-and-tested mature processes. The feed materials are highly complex and variable, and the end-product specifications are very tight and require careful process control and development. This makes metallurgical testing and piloting crucial in the development of a project. Case studies will be presented.

Keywords: DFS, PFS, Flotation, Comminution, Spodumene, Brine, Lithium, Process Development, Pilot Plant, Metallurgical Testing, Project Lifecycle

BRINE CHEMISTRY AND PROPERTIES PREDICTION DURING SALAR EVAPORATION TO MAXIMIZE PRODUCT YIELD

By

Diana Miller and Anthony Gerbino

OLI Systems, Inc., USA

Presenter and Corresponding Author

Anthony Gerbino

ABSTRACT

This paper outlines the use of the Mixed Solvent Electrolyte (MSE) model to predict the chemical composition and properties of salar brines during evaporation. The model has been validated using published peer reviewed experimental data of different salts containing Li-Na-K-Mg-Ca-Sr-B-SO_4-CO_3-Cl ions. The MSE model is able to predict the formation of thirty-four halides, forty-three sulfates, twenty-one carbonates, thirty-four borates, and three mixed-anion salts. This allows the simulation of the full evaporation process, from leaching to purification, of salars with different starting compositions.

Air evaporation of six salar brines from several geographic sources was simulated. We documented the progression of salt types as the brine volume decreases. Twenty-seven salts were predicted to precipitate and dissolve during the evaporation pathway. Several of these salts sequester Li and B, reducing the overall yield of these salable products. The simulation also predicted, the mass of each salt and the quantitative amount of Li and B lost to the solid phases.

We also simulated the effects of chemical addition (e.g. CaO, Na_2CO_3, MgO, oxalic acid, etc.) on the specific salt formation and identify which chemical additive optimizes Li and B product yield. We did not consider coprecipitation or surface adsorption effects.

The objective of this work is to aid the engineer in maximizing Li-product yield, depending upon the composition of the brine, and to increase the yield of sub-products like B and KCl via simulation of the evaporation process.

Keywords: Lithium, Salar, Brine, Evaporation, MSE, Electrolyte

COST-EFFECTIVE USE OF DUPLEX STAINLESS STEEL FOR STRUCURAL APPLICATIONS IN HYDROMETALLURGICAL PROCESSES FOR THE PRODUCTION OF LITHIUM AND BATTERY METAL MATERIALS

By

[1]Claes Tigerstrand, [2]Duncan McLennan, [2]Con Logos

[1]Outokumpu, Sweden
[2]Outokumpu, Australia

Presenter and Corresponding Author

Claes Tigerstrand

ABSTRACT

The production of lithium ion batteries involves materials produced by hydrometallurgical processing of primary or secondary resources of lithium, nickel, cobalt, copper and manganese. These processes typically involve highly corrosive conditions due to the use of reagents such as sulphuric acid, chlorides, and in some cases high temperatures and pressures, so that the optimum selection of materials of construction for items such as pressure vessels, thickeners, process tanks, and other process items is a key issue.

Stainless steels of type 304 or 316 are often considered as too expensive to be used as a multi-purpose construction material with a price level several times higher than carbon steel. Therefore, they are only selected when it is absolutely necessary in harsh environments. Additionally, their mechanical strength is relatively low, similar to mild steel, which limits structural efficiency. Furthermore, stainless steel can also corrode if wrongly selected, they are not immune, and the way they corrode are often more unpredictable compared to carbon steel. Thus, why even consider using stainless steel as an alternative to coated carbon steel for structural applications?

There are several different types of stainless steel on the market where the austenitic type 304 and 316 are the most commonly used, however, this paper elaborates on how duplex (two-phase, austenitic-ferritic) stainless steel can provide cost-effective solutions for structural applications typically used in the hydrometallurgical processes used to produce materials for battery production. The severe conditions set a great demand on which material to select to entirely avoid corrosion. Moreover, the presence of metallic ions also has an inhibiting effect on the onset of corrosion in these environments. To assist in such complex material selection cases, there are several tools available for the designer, e.g., laboratory test data and field experience, to indicate the proper alloy which can resist corrosion but not to provide an over-specified solution. However, the best practice to pinpoint a suitable material with higher confidence for complex cases is often to carry-out a field test using a test-rack with steel samples of different rank to be exposed to the specific intended environment.

For less severe environments, such as handling of slurries in thickener components, the lower alloyed duplex stainless steels can often provide a more cost-effective solution, by utilizing their high mechanical strength together with adequate corrosion resistance and without the need for expensive protective coatings. The cost of coating a carbon steel can easily be in the same range as the alloy cost, especially if repair, maintenance and lost production cost are considered as well, and the total life cycle cost is emphasized, not only the initial investment cost. A case study for the latter using an in-house developed whole cost calculation tool will illustrate possible cost advantages of using duplex stainless steel for tank applications.

Finally, this paper will outline references cases which showcase metallurgical processing related applications where duplex stainless steels have been selected world-wide including a Lithium plant in Western Australia.

Keywords: Material Selection, Sulphuric Leaching, Duplex Stainless Steel, Process Tanks, Pressure Vessels, Thickener Components

ALTA 2019

Lithium Processing Proceedings

Safety

THE NASCENT WA LITHIUM INDUSTRY: THE MINING REGULATOR'S PERSPECTIVE

By

Martin Ralph

Department of Mines, Industry Regulation and Safety (DMIRS), Australia

Presenter and Corresponding Author

Martin Ralph

ABSTRACT

Mineralisation for lithium in Western Australia is frequently accompanied by low levels of the naturally occurring radionuclides – uranium and thorium, and the products of their radioactive decay. Collectively these radioisotopes are known as naturally occurring radioactive materials (NORM).

The Mines Safety and Inspection Act 1994 and Mines Safety and Inspection Regulations 1995 outline specific provisions in relation to worker safety. Importantly the Act emphasises the requirement to identify hazards and the manner in which they will be managed. This forms part of the formal Project Management Plan (PMP), which must be approved by the Department before operations can commence. Radiation doses arising from exposure to NORM is a hazard which is expected to be identified as part of the PMP process.

Part 16, Division 2 of the Regulations apply broadly to the management of radiation exposures resulting from NORM and in many cases will apply to lithium exploration, mining, and processing activities, unless demonstrated otherwise.

The requirements of Part 16, Division 2 place an obligation to implement a systemic management approach to identifying, assessing, monitoring and reducing radiation doses, and minimising the potential impact on the environment.

The presentation will provide an outline of the expectations for compliance with the legislation, and highlight some of the challenges posed.

Keywords: DMIRS, lithium, safety, regulators, western australia

ALTA 2019

Lithium Processing Proceedings

Purification and Recovery

THE USE OF SELECTIVE LEWATIT® RESINS WITH SMALL PARTICLE SIZE IN LITHIUM BRINE PURIFICATION

By

[1]Dirk Steinhilber, [1]Stefan Neufeind, [2]Lydia Tang and [2]R. Bhavaraju

[1]LANXESS Deutschland GmbH, Liquid Purification Technologies, Germany
[2]LANXESS Pty Ltd, Australia

Presenter and corresponding author

Dirk Steinhilber

ABSTRACT

The growing demand for high purity battery grade lithium compounds requires efficient methods for the purification of lithium concentrates, to meet the high purity specifications of battery producers.

There is evidence that conventional purification methods such as precipitation might be insufficient in many cases to achieve the required high grade lithium.

Selective chelating ion exchange resins, functionalized either with iminodiacetic acid (IDA) or aminomethylphosphonic acid (AMPA) functional groups, have been already successfully used for more than three decades in the chloralkali industry for the softening of saturated NaCl brines.

In this paper we describe the use of Lewatit® ion exchange resins for the purification of lithium brines for the removal of residual quantities of contaminants such as calcium and magnesium. We particularly investigated the influence of the ion exchange resin bead size of monodisperse small (MDS) resins and monodisperse resins (MonoPlus) on the purification efficiency.

Interestingly, when MonoPlus type resins are replaced by MDS resins, a significant increase in operating capacity was achieved. As a result, less regeneration steps are required, which allows savings on regeneration chemicals. Additionally, hardness leakage from the ion exchange filter can be reduced significantly when MDS type resins are used, resulting in lithium concentrate brines which are well suited for the production of high quality batteries. Also we describe selection criteria for ion exchange resins used for the purification of various lithium brines, such as LiCl, LiOH and Li_2SO_4 based solutions, which are important lithium sources. Key aspects of ion exchange resins such as their physical and chemical characteristics, and the process and operating parameters, which have an influence on the overall performance of the ion exchange resin purification systems, shall be discussed.

Keywords: Ion Exchange, Impurity Removal, Lithium Brine Purification, Calcium and Magnesium Removal

SELECTIVE RECOVERY OF LITHIUM USING MEMBRANE TECHNOLOGY

By

[1]Ilya Krougly, [1]Johannes Herrmann and [2]Les-Lee Thompson

[1]AMS Technologies, Israel
[2]Chimerical Technology, South Africa

Presenter and Corresponding Author

Les-Lee Thompson

ABSTRACT

The use of membranes for separation of monovalent (Li, Na, K, OH, HSO4, H, etc.) and multivalent (Mg, Mn, Fe, Co, Cu, etc.) components is an established process in the mining industry whereas the application in lithium processing is a relatively new development.

This paper summarizes the benefits of the lithium membrane system through implementation of the following sections:

- Pre-treatment using ceramic microfiltration/ultrafiltration membranes;
- Purification using nanofiltration membranes to reject impurities;

Case studies are presented on the implementation of membranes for the processing of lithium from various sources to prove the efficiency in recovery n and purification of lithium:

- 2 x synthetic solutions to simulate brines
- 3 x petalite/spodumene hard rock ore solutions

The operational and economic benefits of the implementation of membrane systems in lithium processes targets the rejection of multivalent impurities, reduction of front-end processing volumes, concentration of lithium and selective separation from monovalent impurities such as sodium and potassium.

Keywords: Membranes, Nanofiltration, Ceramic, Lithium, Impurity rejection.

Lithium Processing Proceedings

Novel Lithium Processes Forum

SUSTAINABLE PLANT DESIGN – CASE STUDY FOR LITHIUM PRODUCTION FROM SPODUMENE

By

Dylan van den Berg, Lachlan Wright and Greg Sheehan

Hatch, Australia

Presenter and Corresponding Author

Dylan van den Berg

ABSTRACT

Lithium-based batteries are a key ingredient in the green revolution to electrify vehicles and transform energy usage through installation of large and small-scale energy storage. This new enabling technology reduces emissions from internal combustion engines from our cities and, through the use of energy storage, allows for higher levels of renewable energy supply to be incorporated into electricity grids. These changes will make society more sustainable and ensure a better quality of life for future generations. While lithium producers are enabling this revolution, historical designs have not focused on minimising the environmental and social impact of the processing operations. With the tighter environmental regulatory framework in China and elsewhere, lithium operations now being designed are responding to these challenges.

This paper benchmarks the sustainability of spodumene processing operations using Hatch's Four-Quadrant Analysis (4QA) tool. It considers process design configurations for improving the sustainability of spodumene lithium processing against identified metrics of water usage, power usage, fuel usage and waste generation. The tool compares each option on both an economic and weighted sustainability scale.

Keywords: Sustainability, spodumene processing, design, 4QA, lithium hydroxide, spodumene, concentrator, conversion plant

TECHNICAL OPTIONS FOR PROCESSING A LITHIUM CLAY ORE AND ACHIEVING HIGH PURITY LITHIUM CARBONATE

By

Damian Connelly

METS Engineering Group Pty Ltd (METS), Australia

Presenter and Corresponding Author

Damian Connelly

ABSTRACT

Lithium production is dominated by brines and the hard-rock minerals such as spodumene, petalite, lepidolite and amblygonite. With lithium batteries powering the lithium mining sector the commercial development of lower grade resources is gaining traction. Lithium clays are a large low grade source of lithium and cannot be processed by standard hard-rock processes. The poor beneficiation characteristics and high energy requirements of these processes are not economically feasible. Recent research and advances into the extraction of lithium from clays has resulted in new projects advancing towards production. Acid leaching is particularly promising although there is also considerable merit to roasting lithium clays in the presence of gypsum.

Impurity elements that are leached from the lithium clay are of particular importance to processing as they can have a significant impact on the viability of producing a high purity lithium carbonate product. Recent advancements in lithium clay processing technologies have improved the selective extraction of lithium over impurity elements. Progress has also been made on the separation of impurity elements after they are dissolved in solution.

Recent advances in the extraction of lithium from clays are discussed here with a focus on hydrometallurgical processing and purification of the leach solution.

LITHIUM FROM CLAY VERSUS LITHIUM FROM SPODUMENE

By

Mike Dry and René LeBlanc

Arithmetek Inc., Canada
Lithium Americas, Canada

Presenter and Corresponding Author

Mike Dry

ABSTRACT

Interest in lithium for lithium-ion batteries for electric vehicles and other applications continues to drive interest in the extraction of lithium from various sources. Two sources already commercially exploited are lithium-bearing brines and hard rock deposits containing spodumene. A third source of lithium is lithium bearing clays.

This paper presents a comparison of the extraction of lithium from clay against the extraction of lithium from spodumene. The chemistry is examined and process modelling is used to calculate reagent and utility consumption and costs for the two routes.

The finding of this study is that the reagent/utility costs are very similar for the two routes.

Keywords: Lithium, clay, spodumene, sulphate, processing, variable costs

A REVIEW OF LITHIUM HYDROXIDE PRODUCTION METHODS

By

Chris Griffith and Adam Roper

ANSTO, Minerals Business Unit, Australia

Presenter and Corresponding Author

Chris Griffith

ABSTRACT

Integral to the production of cathode materials and electrolytes for Lithium Ion Batteries (LIB) is the availability of suitable lithium chemical concentrates. The most commonly referred to concentrates include lithium carbonate (Li_2CO_3, LC) and hydroxide mono hydrate ($LiOH.H_2O$, LH). Although chloride, sulfate and phosphates are employed to varying degrees, each of these can be easily accessed using either LC or LH and the appropriate inorganic acid.

Industrial production of LH has historically been conducted in a number of ways including: 1) Direct α-spodumene conversion with slaked lime; 2) LC reaction with slaked lime and rejection of $CaCO_3$; and 3) Causticisation of Li_2SO_4 and rejection of Glauber salt. The latter is the preferred method for LH production from spodumene mineral concentrate and is that which will be employed by Tianqi, Albermarle and SQM/Kidman for the refineries under construction or planned for Western Australia.

The success of these methods in producing high purity LH suitable for LIB manufacture varies considerably. This is in part to the ability to purify the Li-containing feed adequately prior to LH crystallization, as well as the amount of impurities introduced with the reagents required in the different methods. Although LH crystallization and refining (re-crystallisation) offers significant scope to cope with such introduced impurities, eventually a bleed of LH, either back up-stream or away from the process completely, to manage those impurities is required and can be a key issue for certain impurities.

Emerging alternative LH production technologies involve electrolysis and/or electrodialysis of highly purified LiCl or Li_2SO_4 solutions. The details of processes developed by Nemaska Lithium, POSCO and Neometals' are slowly coming into the public domain, but for most part there is little data on the impact of impurities, membrane life, membrane fouling and power consumption, and how this compares to more conventional LH production.

In this presentation, we intend to provide an overview of LH production methods, highlight the significant challenges that one needs to understand and overcome in order to produce LH suitable for LIB production, and demonstrate the importance of the emerging electrochemical-based technologies.

Keywords: Lithium, Lithium Hydroxide, Process Development, Process Review

EXTRACTION OF LITHIUM FROM SPODUMENE CONCENTRATE

By

[1]Goutam Kumar Das, [1]Robbie McDonald, [1]Karl Bunney and [2]Yatendra Sharma

[1]CSIRO Mineral Resources, Australia
[2]Consultant to Neometals Pty Ltd, Australia

Presenter and Corresponding Author

Goutam Das

ABSTRACT

Lithium extraction from spodumene has employed various techniques in either its alpha or beta form. However, approaches used for lithium recovery directly from the alpha form are limited. Most of studies reported to use β-spodumene either at high temperature chemical treatment followed by aqueous leaching or direct leaching. The direct leaching approaches referred in the literature generally involve high temperature (100-250°C) alkaline leaching using an autoclave or low temperature (<100°C) leaching using hydrofluoric acid. Recent studies at CSIRO were performed for direct leaching of β-spodumene in acidic (HCl and H_2SO_4) and alkaline ($Ca(OH)_2$) environments at moderate to high temperatures. More than 95% leach efficiencies were obtained in these acidic/alkaline systems using various temperatures and reaction times. The test results indicate that temperature is an essential factor for lithium release from the β-spodumene structure and this is inversely related to the reaction time.

Keywords: Spodumene leaching, hydrochloric acid, sulfuric acid, lime, lithium extraction

OUTOTEC LITHIUM HYDROXIDE PROCESS - A NOVEL DIRECT LEACH PROCESS FOR THE PRODUCTION OF BATTERY GRADE LITHIUM HYDROXIDE MONOHYDRATE FROM CALCINED SPODUMENE

By

Marika Tiihonen, Liisa Haavanlammi, Sami Kinnunen and Eero Kolehmainen

Outotec (Finland) Oy, Finland

Presenter and Corresponding Author

Marika Tiihonen

ABSTRACT

.
This paper outlines a novel development: **Outotec Lithium Hydroxide Process,** a proprietary technology for spodumene concentrates refining. The new process offers a fast throughput, direct leach process for spodumene concentrates to produce battery grade lithium hydroxide monohydrate product. The process is also environmentally sustainable. The process leach residue is a readily neutralized and inert mineral residue. The leach process is totally sulfate and acid free and the refining process does not involve any crystallization of unnecessary by-product salts.

The process concept is based on an alkaline leach process in two stages. Lithium is first extracted from the silicate mineral in a pressure leaching stage by soda ash. The leach reaction involves formation of sparingly soluble lithium carbonate and mineral component analcime ($NaAlSi_2O_6 \cdot H_2O$) as main components. In the second leach stage, lithium carbonate is solubilized in a conversion reaction, producing lithium hydroxide solution and solid calcium carbonate, which will report together with other mineral residues. Lithium carbonate formed in hydrothermal leaching has proven to be converted to lithium hydroxide in a fast reaction with high yields. Overall lithium leaching extraction yield from concentrate typically exceeds >90 %.

The alkaline hydroxide and carbonate processing milieu ensure very low solubilities of all the main impurity elements and compounds: Fe, Al, Si, Mg, Ca, B, P, etc. No additional impurities removal or precipitation stages are needed. Lithium hydroxide PLS is suitable feed for polishing (IX) and further crystallization of the final LiOH monohydrate product.

Outotec has successfully tested and piloted the process. Battery grade products (>56.5% $LiOH \cdot H_2O$) have been produced from clients' spodumene concentrate raw materials.

Keywords: Outotec, Lithium Hydroxide, Spodumene