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Proceedings

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



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.

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Uranium-REE Proceedings

Project Development

SO YOU HAVE FOUND A URANIUM DEPOSIT – NOW WHAT

By

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Presenter and Corresponding Author

Alan Taylor

ABSTRACT

Uranium exists in a seemingly myriad of minerals (>150 known), further complicated by different valencies. While there may be one or two dominant species in a deposit, there are often a variety of minor minerals which need to be treated in order to achieve a high recovery. On top of this, uranium minerals occur in a wide variety of host rocks.

STEP ONE MUST BE TO carry out initial thorough and systematic geological and mineralogical studies and detailed chemical analyses of drill samples in order to classify the ore deposit versus other known types of deposits and Identify ore types within the deposit with potentially different metallurgical properties.

STEP TWO – SOMETIMES OVERLOOKED - IS TO benchmark the deposit against other past and present commercial operations and/or projects attaining feasibility study level for similar deposits to gain information on successful and unsuccessful geological interpretation, resource assessment, and mining and treatment methods.

THIS LAYS A SOUND FOUNDATION FOR STEP THREE which is undertake a THOROUGH Scoping Study covering ALL aspects of the project to make a decision whether to move on to a Prefeasibility Study (PFS), undertake further scoping level work, bring in a partner, sell the project, or walk away.

If proceeding with a PFS, the recommendations should specify the preferred or short listed mining methods and treatment processes, incorporate metallurgical and mineralogical input to the procedures for the drilling program and geological model, and prepare a project development plan, schedule and cost. Sometimes there are opportunities for by-products, such as vanadium, molybdenum, base metals, REEs which may add value.

Finally, the temptation to take short cuts SHOULD BE AVOIDED AT ALL COSTS!

Keywords: Uranium Deposits, Project Development, Process Selection, Scoping Study, Prefeasibility Study, Key Steps

PROCESS DEVELOPMENT FOR THE MULGA ROCK PROJECT

By

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Vimy Resources Limited

Presenter and Corresponding Author

Chad Czerny

ABSTRACT

The history, geology and development of the Mulga Rock Project, one of Australia's largest undeveloped uranium resources is outlined with focus on the process development. The Mulga Rock Project is located approximately 240 km ENE of Kalgoorlie in the Great Victoria Desert of Western Australia. The Project will have the capacity to produce around 1,360 tpa of U_3O_8 for up to seventeen years. A Pre-feasibility Study was completed in Q4 of 2015. Vimy Resources Limited is presently engaged in a Definitive Feasibility Study (DFS) which is scheduled for completion in Q1 of 2017.

The metallurgical testwork undertaken to develop the current process flowsheet is summarised and the implications of the results for the process selection for beneficiation (by gravity separation) of uranium-bearing lignite, lignitic clay/shales and carbonaceous sands, and for downstream hydrometallurgical recovery of uranium are discussed.

The beneficiation plant proposed for ore processing comprises of a ROM ore mineral sizer, logwasher for ore slurring and attritioning, slimes removal using hydrocyclones, and upgrading of a middlings fraction by mass rejection of between 50 and 60% barren quartz sands using two stages of Upward Current Classification (UCC), to produce a uranium-enriched concentrate, and a tail containing low concentrations of uranium (typically <60 ppm U_3O_8). Upgraded ore (by a factor of 2 to 2.5) is milled and thickened to produce a leach feed slurry.

Uranium is recovered from the beneficiated ore by agitated tank sulphuric acid leaching at atmospheric pressure and temperatures of 50 to 70°C. Due to the 'preg-robbing' nature of the carbonaceous ore, uranium recovery from the acidic pulp is achieved using resin-in-pulp (RIP). The eluate obtained by resin stripping is further processed by micro-filtration/nano-filtration followed by direct precipitation using hydrogen peroxide to produce a uranyl peroxide hydrate ($UO_4 \cdot xH_2O$) intermediate.

Continuous piloting campaigns are currently in progress, and will be briefly outlined. Around 20 dry tonnes of blended ROM ores obtained from two open cut test pits excavated at Mulga Rock is being processed in these programs.

Results from this program will be supplemented by an extensive Geometallurgical program underway, aiming to capture natural ore heterogeneity and process implications with regards to beneficiation (upgrade factor and uranium recovery), deportment of chlorides to the slurry and leach variability.

KVANEFJELD REFINERY PILOT PLANT OPERATIONS

By

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Presenter and Corresponding Author

Damien Krebs

ABSTRACT

Greenland Minerals and Energy is a junior project development company which is listed on the Australian Stock Exchange (asx:GGG). It is developing the Kvanefjeld rare earth and uranium project located in the southern tip of Greenland. The project has completed a Feasibility Study and is currently in the permitting phase.

Last year was a busy time for the company as it completed a Feasibility Study, a mining licence application (draft submitted in December 2015) and pilot plant operations. Beneficiation pilot plant operations were completed at GTK in Finland in April 2015. This pilot plant treated approximately 30 tonnes of ore to producing almost 2 tonnes of rare earth mineral concentrate.

Later in the year a hydrometallurgical pilot plant was performed which mimicked the Refinery process. This pilot plant was performed at Outotec's Pori Research laboratories in Finland from September till October 2015. The pilot plant treated approximately 200 kilograms of concentrate over 4 split operating campaigns. Each campaign was performed to focus on the performance of a specific part of the refinery flowsheet. This allowed for full operating focus on a single unit operation to ensure that it was operating correctly.

The pilot plant operations were quite successful with no major issues with the flowsheet identified through continuous operation. Some fine tuning of conditions was required to ensure adequate removal of impurities was performed with recycle streams incorporated. Overall the leach extractions observed in the pilot plant exceeded the design assumptions in the Feasibility Study.

These programs were partially funded by the EURARE program. The EURARE program aims to encourage the sustainable development of European based rare earth projects. This has the goal of allowing Europe to become less reliant on importation of these key raw materials. The professionalism and performance of both GTK and Outotec contributed significantly to the success of the pilot plant operations.

Keywords: Kvanefjeld Project, rare earths, uranium, refinery, beneficiation, hydrometallurgical, pilot plant



Uranium-REE Proceedings

Process Development

THE EXTRACTION OF URANIUM FROM BRANNERITE

By

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Murdoch University, Australia

Presenter and Corresponding Author

Rorie Gilligan

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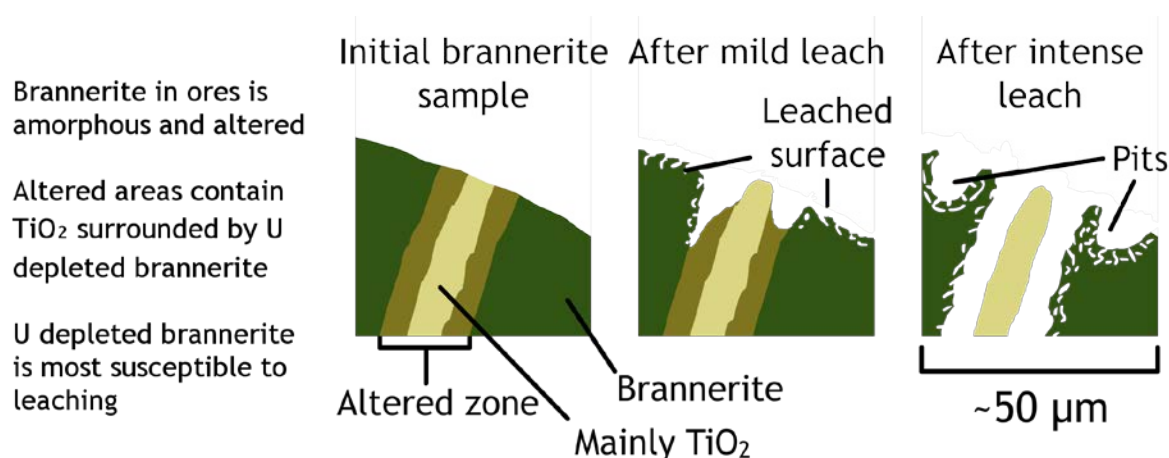
Aleks Nikoloski

ABSTRACT

Brannerite, UTi_2O_6 is the most important uranium mineral after uraninite, UO_2 and coffinite, $U(SiO_4)_{1-x}(OH)_{4x}$. It is also the most common refractory uranium mineral. Ores containing brannerite typically require intense conditions (>50 g/L H_2SO_4 , $>75^\circ C$) compared to other uranium ores for effective uranium extraction to occur. To develop an effective process for the extraction of uranium from brannerite containing ores and improve the extraction from the ores currently being processed, it is necessary to understand the chemistry of the brannerite leaching process.

As this study has shown, brannerite is typically an altered and amorphous mineral, with an extent of alteration depending on the age of the sample and the geological history of the deposit. A sample of brannerite from Cordoba, Spain, was leached over a range of conditions in acidic ferric sulphate media. The sample was filled with cracks and altered zones containing anatase (TiO_2). Process parameters studied included temperature ($25-96^\circ C$), acidity ($10-200$ g/L H_2SO_4) and the effect of adding selected gangue minerals (apatite, fluorite and ilmenite). The feed and the leached residues were characterised in detail by XRD and SEM-EDX techniques.

The results of this study showed that brannerite dissolution has a stronger dependence on temperature and lesser dependence on free acid concentration. Comparisons between the residues and the feed showed that the altered and amorphous areas of the brannerite sample are more readily leached than crystalline areas. The crystalline areas of the brannerite dissolved congruently, with titanium subsequently precipitating as anatase physically separated from the original brannerite grains.



Keywords: Uranium, Titanium, Brannerite, Leaching, Kinetics, Mineralogy

DEVELOPMENTS IN URANIUM EXTRACTION AND RECOVERY TECHNOLOGY

By

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Presenter and Corresponding Author

Alan Taylor

ABSTRACT

This presentation highlights a range of technologies at various stages of development and commercialisation.

Process technology for the extraction and recovery of uranium continues to develop driven by the need to reduce capital and operating costs, the move towards lower grade and more difficult ores, the need to improve the processing of saline leach solutions and the increasingly stringent environmental regulations.

Developing areas include preconcentration, solvent extraction/ion exchange and product recovery. Technologies highlighted in this presentation are Ablation, U-pgradeTM process, nonfiltration, strong acid strip SX/IX, strong acid strip/SX, basic aluminium sulphate strip, SX for high chloride solutions, alkaline SX, Wintray SX contactor, and fluid bed precipitation.

Some other developing areas, not included highlighted in this presentation include in-situ leaching, heap leaching, solid-liquid separation, IX resins and systems, and by-product uranium recovery. Process development is likely to accelerate as uranium demand increases to supply the projected expansion of nuclear power generation.

Keywords: Uranium, technology development, preconcentration, solvent extraction, ion exchange, product recovery

EVOLUTION OF STRUCTURAL AND PHYSICAL PROPERTIES OF URANIUM-ORE AGGLOMERATES DURING HEAP LEACHING

By

¹Emerence Hoummady, ¹Fabrice Golfier, ¹Michel Cathelineau, ¹Laurent Truche, ²Nicolas Durupt,
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ABSTRACT

Heap leaching is commonly used to process low grade ores. However, ores containing fine particles and clays cause often clogging problems within heaps. To solve this problem, copper, nickel and uranium extractive industries use agglomeration. This process consists in gathering fine particles in order to adjust the ore particle size distribution. This allows improving the heap permeability and reducing fine migration during leaching. As agglomerates quality influences heap leaching efficiency, many quality tests have been performed. However they mostly focus on a column of agglomerates, and the influence of agglomerates structure on heap leaching remains poorly understood. The current study is an attempt to characterise the structure and the porosity of agglomerates and their evolution during leaching.

For this study, a low grade uranium ore from Niger has been used for agglomeration. The ore has been agglomerated using sulfuric acid as binder. Then, agglomerates have been leached during 10 days with sulfuric acid at 10g/L. Evolution of structural and physical properties of uranium-ore agglomerates during heap leaching has been investigated for different operating conditions: agglomerates size, flow rate or acid concentration.

Prior to heap leaching, X-ray tomography and SEM analysis highlighted that agglomerates are composed by the coalescence and layering of micro-agglomerates. These are composed by phyllosilicates (especially muscovite and kaolinite) coating a nucleus (mostly quartz or feldspar). One can also observe an aluminous silicate matrix phase around some nuclei. This might come from the reaction between phyllosilicates and the binder. Moreover, such a structure is the cause of the initial low connected porosity of the agglomerates (between 3 and 7%) which can be measured by mercury intrusion porosimetry (MIP). A positive correlation between the porosity and the agglomerate sizes has been exhibited.

A combined MIP–SEM analysis carried out on agglomerates after 10 days of leaching revealed that the process improved the connected porosity of agglomerates by creating new mesopores. These are mostly located around micro-agglomerates, as showed with SEM analyses and they may come from the leaching of the aluminous silicate matrix phase during the process. X-ray tomography corroborates these observations and the increase of connected porosity by about a factor 2. This allows a better diffusion of the leaching solution within the agglomerates.

Keywords: Heap leaching, uranium, agglomerates, SEM, X-ray tomography, mercury intrusion porosimetry

DEVELOPMENT OF ROASTING PLANT CONFIGURATIONS TO IMPROVE ECONOMICS AND OPERABILITY OF RARE EARTH ROASTING CIRCUITS

By

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Project and Process Development, Australia

Presenter and Corresponding Author

Louis de Klerk

ABSTRACT

Rare earth minerals are often not leachable at atmospheric conditions without first having to crack the mineral matrix at elevated temperatures with or without the presence of strong acids. Leachability of Rare Earth minerals normally require laboratory test work to determine optimum conditions of temperature, acid type and addition rate and residence time for a particular mineral. Laboratory test work generally starts in small scale muffle furnaces and progresses to larger scale muffle furnace test work, laboratory scale rotary kilns before possibly demonstrating on small scale kilns that are available in commercial metallurgical laboratories. Feasibility studies and even commercial plant designs then copy not only the process conditions but also the piloting or demonstration plant equipment designs.

Paying more attention to the configuration of commercial roasting equipment and the physical properties of the roasting chemicals and minerals by comparing alternate equipment types and configurations can significantly improve the operating and capital costs, operability and the overall financial viability of the finally selected flow sheet.

The effect of different flow sheet configurations on costs have been investigated by process modeling and consideration of the physical and thermodynamic properties of the minerals, chemicals and roasting products for the case of sulphation roasting of a rare earth concentrate.

Comparison of a conventional directly fired rotary kiln process with alternate flow sheets are used to demonstrate the improvements that are possible in the capital and operating costs leading to an improved and more robust flow sheet.

Keywords: Rare Earth Minerals, Roasting, Sulphation, Leaching, Process Development, Rotary Kiln



Uranium-REE Proceedings

Scandium Recovery

RECOVERY OF RARE EARTH ELEMENTS AND SCANDIUM FROM EUROPEAN DEPOSITS BY SOLVENT EXTRACTION

By

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Corresponding Author

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Presenter

Şerif Kaya

ABSTRACT

Solvent extraction methods are being developed for the separation and purification of Rare Earth elements (REE) as part of the EC funded EURARE project. Following initial laboratory batch test work, the mission was to construct and operate a flexible solvent extraction purification and separation mini-pilot plant capable of testing the process developed and producing high purity REE products and scandium of high purity. So far, the work performed has resulted in the separation of heavy (HREE), medium (MREE) and light (LREE) Rare Earths elements, and the separation of yttrium from the HREE fraction and Nd from the LREE fraction. Scandium purification will follow using a separate flowsheet.

Keywords: EURARE, Rare Earths, Scandium, Solvent Extraction

RECOVERY OF SCANDIUM FROM BAUXITE RESIDUE BY SELECTIVE PRECIPITATION FROM LEACH SOLUTIONS

By

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Presenter and Corresponding Author

Bengi Yagmurlu

ABSTRACT

As a member of EU H2020 ETN Red Mud Project which aims to recover all constituents of bauxite residue (BR) and adopts a zero-waste valorisation point of view, this study focuses on maximized recovery of Scandium in the BR. The red mud investigated was obtained from Aluminium of Greece and contains 130ppm of Sc in its composition which makes it a valuable Sc resource. Previous studies showed that a remarkable amount of Sc (~90%) could be extracted by direct acidic leaching of BR and in this study selective precipitation was investigated on obtained pregnant leach solution (PLS) from BR. Three different approaches; (a) direct precipitation with selected agents from highly impure PLS obtained directly from red mud, (b) pre-purified and enriched PLS in terms of Sc by solvent extraction and (c) cascade type continuous precipitation process to reach various Sc products will be compared and assessed. Advantages and drawbacks of those mentioned approaches will be discussed in cooperation with experimental results.

Keywords: Scandium, Bauxite Residue, Precipitation, Recovery

SYERSTON SCANDIUM PROJECT: LONG TERM SUSTAINABLE SCANDIUM SUPPLY USING CLEAN TEQ'S CONTINUOUS RESIN-IN-PULP TECHNOLOGY

By

John Carr

Clean TeQ Metals Pty Ltd, Australia

Presenter and Corresponding Author

John Carr

ABSTRACT

Clean TeQ is developing its Syerston Scandium Project in New South Wales, Australia. The Syerston ore body hosts the richest known natural concentration of scandium at scale in the world.

Scientists and metallurgists have known for decades that scandium has a range of unique properties, notably as an alloying agent for aluminium. Aluminium-Scandium (Al-Sc) alloys have remarkable strength, corrosion resistance and welding characteristics. As such, they hold the promise of lighter weight and more energy-efficient solutions in mainstream economic activities ranging from transportation (aerospace, rail, marine, automotive) to construction to power distribution. More recently, the substitution of scandium for yttrium in solid oxide fuel cells (SOFCs) has been critical to the emerging commercial success of these distributed power systems.

Until now, the world has derived limited benefit from scandium's unique potential because of a largely dysfunctional global supply chain. Scandium has only ever been recovered as a by-product of other mining or metal processing activities, from sources with low starting scandium concentrations. The available supply has been limited, unreliable and costly; the market has been opaque and distorted by political forces.

Clean TeQ is changing this paradigm, by combining Syerston's grade and unique hydrometallurgical processing technology to provide large-scale, low cost scandium to the market. At the core of the process is Clean TeQ's Continuous Resin-In-Pulp (cRIP) technology, which provides a simple highly efficient process route for recovery of scandium, as well as other by-product metals.

Keywords: scandium, aluminium alloys, Syerston, continuous ion exchange, resin-in-pulp, aerospace, automotive.



Uranium-REE Proceedings

Lithium Processing

THE SILEACH™ PROCESS - LITHIUM RECOVERY FROM SILICATES, WITHOUT ROASTING

By

Adrian Griffin

Lithium Australia, Australia

Presenter and Corresponding Author

Adrian Griffin

ABSTRACT

Lithium Australia NL initially developed the hydrometallurgical Sileach™ process specifically for the digestion of spodumene, a mineral only commercially processed by roasting and leaching. The conventional processing mechanisms are energy intensive and require high-grade ore for a positive commercial outcome whereas competitive lithium production processes recovering lithium, as carbonate, from brines, generate the final product for about half the cost.

Development of Sileach™ was aimed at reduced operating costs to make lithium chemicals from spodumene competitive with chemicals from brines. The process has been further successfully tested on other lithium minerals, including a wide range of micas. More recently it has been used on refractory gold slags to remove mineral coatings that blind the gold particles from cyanide solutions.

Keywords: Lithium, Processing, By-products, Roasting, Hydrometallurgy

BENEFICIATION OF SPODUMENE ORE INTO A CONCENTRATE AND FURTHER PROCESSING TO PRODUCE BATTERY GRADE LITHIUM CARBONATE

By

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Presenter and Corresponding Author

Damian Connelly

ABSTRACT

The demand for high purity battery grade lithium carbonate is expected to grow significantly in the future.

The mining and processing of spodumene involves a number of challenges in order to achieve a high grade and recovery with minimal impurities. This paper discusses the value adding beneficiation step of processing spodumene and challenges.

This spodumene concentrate is then processed through the traditional sulphuric acid route and the challenges involved in achieving battery grade lithium carbonate are discussed. In addition, the evolving new alternative process routes are listed as options for consideration.

The lithium-ion battery sector is one of the largest consumers of lithium, currently estimated to be at approximately 26% of total global lithium demand. Originally used in computing and mobile communication devices, lithium-ion batteries are being increasingly used to power electric bicycles (e-bikes), vehicles and mass energy storage devices. Lithium-ion batteries have superior energy density, are more efficient and environmentally friendly than traditional acid batteries.

Keywords: Spodumene beneficiation, sulphuric acid processing, production of battery grade lithium carbonate



Uranium-REE Proceedings

Ion Exchange

ACID RECOVERY FROM URANIUM ELUATES USING ION EXCHANGE RESIN

By

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Jaco Bester

ABSTRACT

An experimental study using ion exchange resin for acid recovery from sulfuric acid uranium eluates is described in this work. Commercial grade chromatographic particle size anion and cation resin of the Dow Chemical company was used to investigate whether uranium and sulfuric acid could be separated and recovered by the principle of ion retardation. Results demonstrate the possibility to recycle acid and recover uranium from the eluate by an ion exchange mechanism rather than by ion retardation (patent application filed).

POLYAMINE FUNCTIONALISED CHELATION ION EXCHANGE RESINS FOR URANIUM EXTRACTION

By

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ABSTRACT

Ion exchange (IX) techniques are ubiquitous in industrial processes throughout the world, being used in areas such as desalination, mineral extractions and the nuclear fuel cycle. In the nuclear fuel cycle IX has been implemented at the front end for the extraction of uranium from pregnant leach liquors, chemical control of the coolant water within reactors and also at the back end in spent fuel reprocessing and waste treatment^{1,2,3}. Though there is a major competitor to this technology in solvent extraction (SX), IX has always been a major workhorse technology in the nuclear industry. This is due to IX not having some of the drawbacks of SX such as the lower ability for preconcentration, potential for solvent loss, phase disengagement in multiple contact stages, third phase formation and the generation of large volumes of liquid aqueous and organic waste streams.

Chelation is a thermodynamic effect inferring an enhanced stability for a multidentate ligand and metal complex when compared with a complex containing the same metal ion and a group of similar monodentate ligands. Chelation IX resins have also been shown to resist uptake suppression due to the ionic strength of uptake media⁴. This effect can aid in potentially producing selective extractants which could be tailored to specific metals in a range of aqueous feeds. N-donor functional groups (ethylenediamine (EDA), diethylenetriamine (DETA) and pentaethylenehexamine (PEHA)) have been grafted onto the Merrifield resin (chloromethylated polystyrene). Soft N-donor ligands are well known to bind to uranium⁵, with N-donor functional groups being commonly used at the front end of the nuclear fuel cycle for uranium extraction from pregnant leach liquors³. These IX resins are classed as weak base resins, which are commonly found to be effective when sulphuric acid leach conditions have been used⁶. There are reports of like resins being used in the literature^{7,8,9}, however, a comprehensive analysis of uptake (loading isotherms, pH dependence) and direct comparison between the homologous functional groups has not been published.

The three synthesised resins and a commercial resin, Purolite S985, have been assessed for their uptake behaviour towards uranium (as UO₂SO₄) in sulphuric acid media. Purolite S985 is also a polyamine resin, which was designed for the selective removal of heavy metals. It has been shown to extract platinum, palladium, rhodium, nickel, copper and zinc^{10,11,12} under varying conditions, but its uptake towards uranium is relatively unknown. Uranium loading isotherms have been performed at constant pH, as well as studies to explore the effect of pH and SO₄²⁻ concentration. Isotherm models have been derived using data from extended x-ray absorbance fine structure (EXAFS) data and compared with well known isotherm models such as Langmuir and Dubinin-Radushkevich. Elution methods will also be investigated.

Keywords: Uranium Recovery, Chelation, Ion Exchange, EXAFS, Polyamine, S985

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Solvent Extraction

NEW SOLVENT EXTRACTION SYSTEM FOR URANIUM RECOVERY FROM LEACH SOLUTIONS USING SEAWATER

By

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Zhaowu Zhu

ABSTRACT

Uranium resource processing using seawater is highly demanded due to the shortage of underground water. Currently there is no solvent extraction (SX) system suitable for uranium recovery from leach solutions containing high chloride concentrations comparable to seawater.

In order to develop a suitable solvent extraction system for uranium recovery from leach solutions using seawater, a number of SX systems were studied in terms of uranium extraction and separation from impurities, especially iron(III). A new SX system has been developed with which >99% uranium was extracted from a synthetic leach solution using seawater, while only about 10% iron(III) was extracted, leading to the separation factor of uranium over iron(III) >1000. With the new SX system, uranium was almost completely extracted (>99%) in a pH range of 0.5-1.5 tested. Therefore, no pH adjustment may be needed for uranium extraction. Uranium maximum loading in 1% (v/v) of the organic system was >1.3 g/L. The kinetics of uranium extraction was fast, reaching equilibrium within 3 min. Except for vanadium, all other commonly associated impurities could be readily separated from uranium. After uranium extraction, the discharged raffinate solution can be recycled to the leach step due to the high chloride tolerance of the new SX system. This can significantly reduce the water usage and the environmental concern as well. Scrubbing with 0.5 M H₂SO₄ is efficient to remove the co-extracted iron. In a single contact, uranium stripping was 80% with 4 M H₂SO₄ solution, and almost complete (>98%) with 0.5 M Na₂CO₃ or (NH₄)₂CO₃ solution. A process using the new SX system has been proposed.

Keywords: Solvent extraction, New system, Uranium, Seawater-leaching, Chloride.

APPLICATION OF MIXED PHOSPHONIC/PHOSPHINIC ACID REAGENTS FOR SEPARATION OF RARE EARTHS

By

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James Quinn

ABSTRACT

The separation of rare earth elements from each other is commonly achieved by solvent extraction, using EHEHPA (2-ethylhexyl phosphonic acid 2-ethylhexyl mono-ester, also known as P507, PC-88A and Ionquest 801). In recent years, mixed reagents containing EHEHPA and Cyanex 272 (a weaker, phosphinic acid reagent) have been put forward for this task. This work examines the extraction and separation of rare earths by EHEHPA, Cyanex 272, Cyanex 572 (a commercially available phosphonic/phosphinic acid reagent) and mixtures of EHEHPA and Cyanex 272.

We present results of a detailed study on the effect of pH and extractant concentration on distribution ratios of mixed reagents. The observed antagonistic impacts of mixed phosphonic/phosphinic reagents were studied by the method of continuous variation and supported by ³¹P NMR and electrospray ionization-mass spectrometry (ESI-MS).

In this presentation we discuss the pros and cons of using these reagents for the production of high purity rare earths.

Keywords: rare earths, solvent extraction,

PROCESS DEVELOPMENTS FOR THE RECOVERY OF URANIUM AND MOLYBDENUM IN KAROO SANDSTONE DEPOSIT VIA SULPHURIC ACID LEACHING

By

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Presenter

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ABSTRACT

Low grade uranium deposits such as the Karoo Sandstone deposit in South Africa have remained unexploited to date, due to the low uranium price and high OPEX associated with the extraction of the uranium. The Karoo Sandstone deposit contains relatively high concentrations of carbonates which contributed to the high acid consumption in the sulphuric acid leach step. In order to reduce the OPEX, flotation of carbonates was investigated. Significant concentrations of molybdenum found in the deposit can cause cruds and third phases in the uranium solvent extraction unit operation which is problematic. Molybdenum removal was required prior to uranium solvent extraction and was thus considered as a potential by-product.

Laboratory test work done at Mintek showed that innovative combinations of flotation and solvent extraction process routes, resulted in promising reductions in processing costs. In order to quantify the impact of these improvements on the viability of exploiting the Karoo Sandstone deposits, a laboratory test work programme was undertaken to produce data for high level OPEX and revenue estimations.

The removal of calcite by flotation prior to leaching, had shown to reduce the acid consumption by >50% in the leach step, while still resulting in a uranium recovery of greater than 85%. Selective extraction of molybdenum from the leach liquor by the oxime extractant showed that greater than 98% of the molybdenum could be recovered without significant uranium co-extraction.

OPEX estimations indicated that the main cost component was the leach unit operation. A significant reduction (62%) of OPEX was achieved due to the removal of acid consumers by flotation. The cost of molybdenum solvent extraction (0.04 USD/tonne) was low as compared to the revenue (6 USD/tonne) generated for molybdenum recovery. This was an indication that the recovery of molybdenum as a by-product was favourable. The increase in molybdenum recovery by leaching at a lower pH value of 1.2 did not enhance the potential profit due to the higher acid consumption. Uranium recovery is thus the primary target for processing of the Karoo Sandstone deposit. Hydrometallurgical data and economic estimations based on the test work done have shown that the recovery of high purity uranium and molybdenum from the Karoo Sandstone deposit was favourable.

Keywords: Uranium, molybdenum, flotation, leaching, solvent extraction

COMMISSIONING OF A MINI REE SX PILOT PLANT AT SGS MINERALS SERVICES – LAKEFIELD SITE

By

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ABSTRACT

SGS Minerals Services commissioned an internal R&D program to develop in-house expertise in the design, setup, and operation of a REE separation pilot-plant at its Lakefield, Canada site. A mini pilot scale SX circuit of 120 stages was designed, constructed and operated to separate Pr and Nd from La and Ce contained in a synthetic REE chloride stream simulating the raffinate from an initial La-Nd|Sm-Lu+Y separation.

Two pilot campaigns were run totalling 25 days of 24/7 operation with 99.4% plant availability in the final 20 day campaign. Purities of >99.9% in the PrNd strip liquor and >99% in the LaCe raffinate were achieved and simultaneously sustained for prolonged periods. Key to controlling and adjusting the circuit was the rapid assay turnaround (as low as 1-2 hours) provided by the on-site SGS analytical laboratory. This permitted the operating team to modify conditions and observe the effect of changes relatively quickly considering the large number of stages. A portable XRF analyser was also used to monitor progressive assay trends. A MS Excel-based model was developed to simulate the SX plant behaviour and allow future circuit design.

This paper discusses the design of the circuit, operating conditions, some of the key operating factors and controls, and results obtained.

Keywords: Rare Earth Elements, REE Separation, Solvent Extraction, Process Development, Pilot Plant, Hydrometallurgy



Uranium-REE Proceedings

Membranes in Uranium Ore Processing Forum

PROCESS MEMBRANES APPLIED IN THE MINING INDUSTRY

By

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ABSTRACT

With the growing demand for water and increasing water scarcity the mining industry is challenged to reuse water and recover process streams to meet environmental regulations. Using reclaimed treated effluents in the mining industry has enormous potential. Crossflow Membrane Filtration economically addresses the challenges facing the mining industry. The membranes provide separation from 2 microns (Microfiltration) to < 5 angstroms (Reverse Osmosis). The most common technologies used in the mining industry are Nanofiltration (NF) and Reverse Osmosis (RO). This presentation will address the fundamentals of how membranes work with a brief overview of the various commercial applications including ultra-low energy RO membranes to address reclaim and meet environmental discharge limits and acid stable NF membrane to recover valuable metals from process streams.

Keywords: Water reuse, Reverse Osmosis, Nanofiltration, Process Recovery

PALADIN ENERGY LTD – NANO-FILTRATION TECHNOLOGY FOR REAGENT RECOVERY

By

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ABSTRACT

A membrane-based acid recovery plant has been successfully installed and commissioned at Paladin Energy's Kayelekera Uranium Mine in northern Malawi. This Acid Recovery Plant (ARP) is believed to be the first commercial-scale operation of its kind in the world. The design has successfully demonstrated that a uranium-containing acid stream can be separated into a clean, uranium-depleted acid stream containing the majority of the acid and a low-volume, concentrated uranium stream. Apart from the significant acid savings (circa 40 t/day 98% sulfuric acid), the ARP also resulted in significant savings in neutralising chemical requirements downstream of the ARP.

Continuous operation over a six month period has demonstrated the success of the design and the long-term sustainability of membrane performance and cost savings. At a capital cost of US\$5M, the net operating cost savings of approximately US\$3 per lb U₃O₈ resulted in a simple payback period of 7 months. The project has been successful from both a technical and financial perspective. Despite the success of the ARP in reducing operating costs, Kayelekera Uranium Mine has since been placed on care and maintenance due to sustained low uranium prices.

Uranium can be stripped from ion exchange resins using a variety of acid and alkaline eluants. At Kayelekera, the eluant is sulfuric acid, while at Paladin's flagship operation, Langer Heinrich in Namibia, the eluant is sodium bicarbonate. Both eluants strip adsorbed uranium from ion exchange resins to produce Concentrated Eluate (CE). The acid or alkali component of the CE can be recovered using the nano-filtration technology developed by Paladin Energy and BMS Engineers. Paladin Energy has recently been granted a patent for this technology. Based on the success of the first membrane plant at Kayelekera, a second plant has been designed, installed and commissioned at Langer Heinrich. This plant, designed to recover sodium bicarbonate from the CE stream, was successfully commissioned in March 2015 and continues to perform above design expectation.

The Bicarbonate Recovery Plant (BRP) at Langer Heinrich recovers sodium bicarbonate from the CE and produces a clean, uranium-depleted sodium bicarbonate stream and a low-volume, uranium-rich stream. The sodium bicarbonate stream is recycled and fortified with fresh sodium bicarbonate to be reused as fresh eluant for further resin stripping in the ion exchange circuit, resulting in significant sodium bicarbonate and fresh water savings. At a capital cost of US\$7M and net operating cost savings of circa US\$6 per lb U₃O₈, this project has demonstrated a simple payback period of 3 months.

Keywords: acid recovery, membranes, nano filtration, Kayelekera, BMS Engineers, Paladin Energy

APPLICATIONS OF NANOFILTRATION IN HYDROMETALLURGY

By

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Presenter and Corresponding Author

Adrian Manis

ABSTRACT

Due to its ability to separate mono-valent and multi-valent ions, nanofiltration has potential to improve the main metallurgical recovery process in a number of commodity areas. Thus far, however, only a few such applications have been commercialized. Most nanofiltration applications in hydrometallurgy are related to waste water treatment where the concentrations of metals and acid are low.

This presentation reviews commercial and potential applications of nanofiltration that are central to the metallurgical recovery process and considers the issues that impact the suitability of nanofiltration in this field. Issues include the chemical resistance of the membranes and the potential for scale (esp. gypsum) formation and fouling.

Applications will be presented from a range of commodity areas, including uranium, zinc, lithium, gold, vanadium and nickel. Examples include reagent purification and recovery (esp. acid), the concentrating of target metals and the removal of impurities from target metals.

Keywords: Nanofiltration, hydrometallurgy, acid recovery



Uranium-REE Proceedings

Not Presented

Not Presented

NANO-FILTRATION TECHNOLOGY IN OPTIMIZING URANIUM PROCESS EFFICIENCY

By

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ABSTRACT

Following the fall of uranium prices after the Fukushima Daiichi nuclear disaster and the volatility of acid prices, uranium mining companies are facing strong incentives to increase extraction efficiency and optimize reagents consumption. Nanofiltration membrane separation, which is based on the difference in rejections of solution components, is gaining attention from uranium miners to resolve the issues. This paper aims to provide support for potential of using polymer nanofiltration membranes, which, given minor capital and low operational costs, allow to increase uranium extraction and decrease eluant consumption.

In cooperation with a top uranium mining company, a series of tests with nanofiltration membranes was conducted to treat 1) productive leach stream from sulphuric acid heap leaching process, U = 810 mg/L, 2) raffinate stream after ion exchange resin extraction U = 4.6 mg/L and 3) uranium mine drainage waters, U = 14.6 mg/L. Aim of the tests was to concentrate uranium in retentate and recover sulphuric acid in permeate, which can be re-used. Research has proven that the rejection of uranium reaches 99%. Due to the high concentration of dissolved solids in streams 1 and 2, the volumetric concentration factor was 1.5, which allowed increasing the uranium concentration in the retentate up to 1.5 times for the productive leach stream and raffinate stream. Mine drainage solution, which is poorer in total dissolved solids, exhibits 99.9% rejection and 20 times concentration increase.

Further, the separation process confirmed low sulphuric acid rejection of up to 10%. This rejection value allows to recover acid in the metal-poor permeate that can be reused at the prior stage of the process.

The ability to effectively separate solution into uranium-rich retentate and metal-poor permeate brings an opportunity to reduce mine operating costs and increase extraction efficiency.

Keywords: nanofiltration, membranes, uranium, acid recovery, productive leach solution, extraction raffinate, mine drain waters

Not Presented

EGYPTIAN MONAZITE DIGESTION BY SULPHURIC ACID PROCESS; SEPARATION OF THORIUM

By

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ABSTRACT

The major factors that affect the digestion the monazite mineral obtained from the Egyptian black sand deposits on Rosetta area and the along Mediterranean coast using sulfuric acid were investigated experimentally. The results reveal that digestion temperature of 220°C, acid/monazite ratio of 1.6/1, digestion time of 2.5 hrs and acid concentration of 93% verifies the maximum digestion efficiency for the studied monazite sand, which reached to 93.7%. Precipitation of thorium, rare earths and uranium from the filtrate sulfate solution was carried out using ammonium hydroxide, as a neutralizing agent. The precipitation efficiency of thorium at pH 1.1 was 99.1 % with only 1% of the rare earths co-precipitated. Further precipitation of uranium at pH of 6.5 verifies almost complete precipitation.

Keywords: Thorium Recovery, Leaching, Sulfate Digestion, Monazite, Process Development