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about us

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

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

Alan is Founder and Chair of the annual ALTA metallurgical conference.

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Uranium-REE Proceedings Contents

Uranium-REE Proceedings

Opening Address

Uranium-REE Opening Address

THE ROLE OF UNCONVENTIONAL URANIUM RESOURCES

By

Martin Fairclough
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International Atomic Energy Agency (IAEA) (Austria)

ABSTRACT

Uranium resources and deposits have been broadly subdivided by the Joint OECD/NEA-IAEA Uranium group[1] as either conventional or unconventional. Unconventional resources are defined as very low-grade resources from which uranium is recoverable as a minor by-product and where there has been no history of commercial production. Furthermore, by-product uranium is defined as such when it is a secondary or additional product, in contrast to co-product where one of several commodities must be extracted to make a mine economic (thus categorising uranium produced from the Olympic Dam mine as a co-product defining the deposit conventional). It is important to note that there are additional definitions regarding co- and by-product uranium that focus on the part of the processing flow sheet at which uranium is extracted, whereby by-product can be extracted from secondary mine waste material and can be defined as by-product extraction from unconventional deposits, such as uranium from phosphates and from residue, waste rock or tailings from gold or copper deposits. Recent interest in the latter is growing as part of a broader interest in the mineral extractives industry of re-mining anthropogenic resources as a means to reduce waste and environmental remediation costs, but still remains conceptual.

For economic reasons the majority of historical uranium production has been from conventional uranium resources. While the confidence in resource estimates of unconventional resources is relatively low, due to lack of data, low grades, and lower economic and technical confidence in their profitable extraction, the proportion of resources is relatively high and has geographic distributions that are different from conventional resources. Consequently, the potential impact on an individual country's domestic supply ambitions, has led to interest in extraction of uranium from unconventional resources. Not only does the extraction of unconventional resources require significant technical investment, but the degree of regulatory and environmental oversight is not any less than is required for conventional resources.

In the IAEA geological classification of uranium deposits most unconventional resources are associated with intrusive plutonic, polymetallic iron oxide‐ copper‐gold breccia complexes (IOCG-U), volcanic-related, Au-rich palaeo-quartz-pebble conglomerate, placers, lignite‐coal, phosphorite and black shale. Identified conventional resources amount to ca. 7-8 Mt U[2]. In recent editions of the Red Book, with similar amounts of unconventional resources. However, the IAEA Uranium Deposit database (UDEPO) lists several hundred unconventional deposits with limited available data (and therefore requiring significant additional work to be included in Red Book) amounting to > 50Mt U. Many of these deposits are outside of the well-established uranium centres in Kazakhstan, Canada, Australia etc and are potential important sources of domestic uranium supply for other countries. While some of these resources are currently destined to reside in mine waste (or have already done so) with no immediate plans to extract them, they remain as part of the unconventional resource inventory for possible future extraction should the economic, technical and environmental factors prove appropriate.

1. OECD/NEA-IAEA Uranium 2018 resources, Production and Demand. Paris, France (2018).

2. International Atomic Energy Agency, Uranium Resources as Co- and By-products of Polymetallic, Base, Rare Earth and Precious Metal Ore Deposits, IAEA-TECDOC-1849, IAEA, Vienna (2018).

Keywords: Unconventional uranium, uranium mining, comprehensive extraction, remining, co-product, by-product.

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Uranium-REE Proceedings

Keynote Address

REVIEW OF MEMBRANE TECHNOLOGY AS A PROCESS TOOL

By

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Contributors

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Simon Donegan, Director and Principal, BDB Process Pty Ltd, Australia

ABSTRACT

The Application of membranes to hydrometallurgical processes as a new mode of separation has now been established at commercial scale. Membranes offer a significant advance in that they represent a mode of discrimination between different ionic aqueous species quite unlike that offered by other techniques such as Resin Ion Exchange, Solvent Ion Exchange, Selective Crystallisation, or Cementation.

Nemaska Lithium Inc. is currently installing membrane electrolysis cells for the recovery of high purity lithium hydroxide. This installation involves a very different membrane application and functionality to that employed by the installations of Paladin Energy Limited.

Paladin Energy Limited installed two membrane plants in their operating facilities: one in Malawi at the Kayelekera Project which is an ambient temperature atmospheric acid leach/RIP circuit; and the second in Namibia at the Langer Heinrich Project which is an elevated temperature, atmospheric alkali leach with CCD washing and NIMCIX resin circuit. Both of these applications were the result of a clear focus by the Company on both optimisation and innovation.

Publicly available data from these two operations demonstrates the significant potential of membranes to simplify circuits, improve selectivity and reduce operating costs compared to the established alternatives.

Neither of these applications operated the chosen membranes within the recommended operating windows published by the manufacturers, but both were technically and commercially very successful and both exceeded the forecast performance used to justify the project capital expenditure. The author and contributors were all involved in both installations and comprised the technical and project management core of the design and development teams in both cases. That experience, and subsequent operating exposure has provided a window into the potential for further, more general, application of membranes in hydrometallurgical processes. It appears likely that membranes will be applied in a broad range of applications to improve process outcomes.

Keywords: Uranium, Hydrometallurgy, Ion Selectivity, Process Optimisation, Innovation

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Uranium-REE Proceedings

Technical Sessions

VANADIUM BOOM DRIVING REVIVAL OF BY-PRODUCT VANADIUM RECOVERY FROM URANIUM ORES

By

Alan Taylor

ALTA Metallurgical Services, Australia

Presenter and Corresponding Author

Alan Taylor

ABSTRACT

The vanadium price has been extremely volatile in recent years. After peaking in 2018, the price has declined due mainly to lower than expected demand in China attributed to the slow rate of compliance with China's new rebar standard for structural steel together with substitution with niobium. Another driver is the projected growth in the application of Vanadium Redox Flow Batteries for stationary energy storage for renewable power generation and electric vehicles (EVs) which could result in a long-term increase in demand and price.

The top four producing countries are China, South Africa, Russia, and Brazil from titaniferous magnetite ores. Typically the process comprises crushing, milling, magnetic separation, roasting, leaching, purification, precipitation, and calcining to produce V_2O_5. Most of the V_2O_5 is converted into ferrovanadium or nitrogen vanadium alloy which are used as additives to strengthen steel. Other uses include catalysts such as in sulphuric acid converters.

Vanadium has been previously produced as a by-product from the processing of carnotite uranium-vanadium sandstone ores in western USA. A number of existing uranium plants and developing projects are planning or evaluating vanadium production to take advantage of the projected higher demand.

The presentation outlines flowsheets used by previous commercial by-product vanadium operations and identifies developing projects.

Keywords: Vanadium, By-Product vanadium, Projects, Uranium processing, Carnotite, Redox flow batteries, Stationary energy storage.

MINERALS CRITICALITY ASSESSMENT FROM AN AUSTRALIAN PERSPECTIVE

By

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[2]RMIT University, Australia

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David Whittle

ABSTRACT

Critical Minerals Assessment (CMA) is concerned with the mineral inputs to a system (such as an economy or industry), the risks of a disruption to supply occurring, and the impacts that such a disruption would have on the system. Take for example Rare Earth Elements (REEs), which are presently considered to be critical minerals from the perspective of several sovereign entities. The current criticality of REEs is due to supply being dominated by one nation (China), and the significant impact to a sovereign entity's defence, energy and/or electronics sectors if REE supply is disrupted.

From the perspective of Australia as a sovereign entity, the main interest in CMA has historically been as a potential supplier of critical minerals to the global market. For Australia, the criticality of minerals is generally seen as an opportunity, as Australia has the potential to increase the supply of minerals that other sovereign entities deem critical. The Australian Government therefore carefully examines the CMA results produced by other sovereign entities (e.g. Japan, EU, UK, US). However, each of these sovereign entities apply their own CMA methodology and these methodologies were not established with a supplier country's perspective in mind. For Australia, this presents challenges when it comes to the consolidation and comparison of CMA results. These challenges lead to one of two question addressed in this paper: What CMA analytical framework would best suit Australia in its assessment and integration of CMA results from other sovereign entities?

As well as being a significant minerals exporter, Australia is also an importer of minerals and minerals-derived materials. Australia's economic exposure to these minerals and materials has yet to be examined. This is now being recognised as an analytical gap that needs to be filled in the interests of sovereign resilience. However, such analysis is complicated by several factors. Firstly, Australia has a relatively limited industrial sector, relying more on minerals-derived materials than the direct outputs of mining. This implies that in conducting CMA from an Australian perspective, that several stages along the minerals value chain must be considered. The methods currently in use by other sovereign entities are generally not well suited to this. There are other deficiencies in current CMA methodologies, including a general inability to deal with minerals that are produced as by-products. By-products tend to have very low price-elasticity of supply, and in addition, there is a confounding cross-price elasticity with respect to the primary mineral produced. This presents significant challenges from a modelling perspective. The abovementioned deficiencies in current CMA methodologies leads to the other question addressed in this paper: What CMA methodology will meet the needs of Australia as a minerals and minerals-derived products importer?

In addressing the abovementioned questions, we review the CMA methods that have been applied by other countries; Australian contribution to the science of CMA; and the specific needs of CMA if it is to be conducted from an Australian perspective. Based on that analysis, we make recommendations for an analytical framework for conducting CMA and provide information as to its ongoing development.

Keywords: Critical minerals, critical materials, agent-based models, rare earth elements, uranium, cobalt

RARE EARTH CONCENTRATE PROCESSING AND PURIFICATION. COMPARISON AND OPTIMIZATION USING OLI SIMULATION

By

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Presenter and Corresponding Author

Anthony Gerbino

ABSTRACT

We present a flowsheet simulation study of a three-step rare earth element (REE) hydrometallurgy processing plant. The steps consist of a sulphation kiln with water leach, counter-current-decantation (CCD), and a purification circuit. Our overarching goal was to optimize this part of the plant operations using rigorous thermodynamic modeling.

From a plant perspective, the following conclusions were made: 1) the current cooling of the kiln off gas recovers the bulk of the acid gases; 2) we were able to developed a relationship between off-gas temperature and amounts of HCl and H_2SO_4 exiting the first stage of scrubbing of the vent. This will allow better control of the scrubbing system to avoid gaseous emissions; 3) the current ratio of wash water:sludge feed entering the CCD circuit, recovers 99.9% of the dissolved REE from the leach residue, provided that fresh water used in the wash; and 4) some of the lime added in pH control may be underused because of slow precipitation, and the lime may continue to react in downstream purification steps where $Mg(OH)_2$ is used to reach the pH point of the second stage neutralizer.

We were able to achieve a mass balance of the plant operations using flowsheet simulation including chemical additive requirements and product / waste output. We also computed that Y, Gd, and Nd phosphates should precipitate in the CCD, even though they are not observed in plant operations. This is probably due to the slow precipitation kinetics associated with these phosphates. This may indicate that prolonged residence times of the pregnant leach may result in product loss.

Keywords: Rare earth, Processing, thermodynamics

SULFURIC ACID BAKING OF MONAZITE FOR RARE EARTHS

By

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Presenter and Corresponding Author

John Demol

ABSTRACT

Sulfuric acid baking is one of the main processes currently used in commercial flowsheets for rare earth ores and concentrates containing monazite, a rare earth phosphate mineral. Acid baking involves mixing of ore/concentrate with concentrated sulfuric acid followed by heating to >200 °C. The rare earth phosphates are converted to sulfates which dissolve in a subsequent water leach.

Sulfuric acid baking was first applied to rare earth ores in the early 1900's for processing of mineral sands concentrates in the United States. Early acid bakes were at 250-300 °C, which resulted in total dissolution of both rare earths and impurities including thorium. In the 1980's a higher temperature acid bake was developed in China which achieved some separation of rare earths from thorium and impurities in the bake. However, the bake reactions driving these effects are not well understood.

In this work, a combination of chemical analysis, XRD, SEM-EDS, IR and TG-DSC was used to identify reaction processes occurring during sulfuric acid baking of a monazite concentrate between 200 and 800 °C. The effects of these reactions on the leachability of the rare earths, thorium and phosphate were also examined. It was observed that the sulfation reaction of monazite with acid was virtually complete after baking at 250°C for 2 h, resulting in >90% solubilisation of rare earth elements, thorium and phosphate. After baking at 300°C, a thorium phosphate type precipitate was formed during leaching, leading to a sharp decrease in extraction of thorium and phosphate, but the leaching of rare earth elements reached nearly 100%. The EDS and FT-IR analyses of this precipitate were indicative of a thorium pyrophosphate. As the bake temperature was further increased to 400-500°C, extraction of thorium, phosphorus and the rare earth elements decreased due to formation of insoluble thorium-rare earth polyphosphates. The formation of these polyphosphates is thought to be related to dehydration of orthophosphoric acid produced in the initial reaction of monazite with sulfuric acid. Between 650 and 800°C, monazite was partially re-formed, leading to a further decrease in rare earth extraction to 55%. The re-forming of monazite appeared to be due to a reaction between the thorium-rare earth polyphosphates and rare earth sulfates.

The improved understanding of sulfuric acid baking chemistry gained in this work is potentially of significant value to the development of economic acid bake processes for rare earth ores.

Keywords: Monazite; Rare earth; thorium; Sulfation roasting; Characterisation; Acid bake

GREENLAND RARE EARTHS

By

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Presenter and Corresponding Author

Presenter

Damien Krebs

ABSTRACT

Greenland Minerals is developing the world class Kvanefjeld rare earth project in Southern Greenland. The project hosts one of the largest deposits of rare earths globally while also containing by-product uranium, zinc and fluorspar. The project is well advanced with an updated Feasibility Completed in 2016 and optimised in 2019. The Feasibility Studies show the project consists of a mine, concentrator, refinery and new port facility. Rigorous metallurgical testwork has been completed which has produced a low cost and relatively simple process. The process has been well tested with pilot plant operations completed with assistance from the EURARE project. GML has completed pilot plant operations on the concentrator and refinery processes. Metallurgical testwork has also been completed examining the variance in metallurgical behaviour of ore across the deposit.

Extensive environmental baseline surveys have been completed to produce a comprehensive environmental impact assessment for permitting. A vast array of environmental studies and laboratory examinations have been performed to produce a comprehensive and rigorous environmental impact assessment. Other permitting aspects such as social and marine transport assessments have been completed.

Access to downstream processing for the rare earth product has been secured through co-operation with Shenghe Resources. Shenghe are a leading producer of rare earths elements based in China and with sales throughout the world. Rare Earths produced in Greenland will undo separation and further value adding with Shenghe Resources to provide a path to market for the main rare earth product. Other by-products produced by the project will include uranium, zinc and fluorspar. The project is currently in the permitting phase with public consultation expected in 2020 with the mining licence awarded in 2021. From this point, development plans will be finalised through detailed design and bankable studies.

A combination of favourable metallurgy, location and by-products will result in Kvanefjeld being a large, low cost and sustainable long term producer of rare earths.

Keywords: Greenland Minerals, Kvanefjeld, Sustainable Rare Earth Production.

A GUIDE FOR TESTING OF ION EXCHANGE RESINS

By

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Dirk Steinhilber

ABSTRACT

Ion Exchange Resins are crosslinked polymer networks equipped with functional groups, that are utilized to load and concentrate target ions onto the separation medium. These resins typically possess a spherical bead shape with a mean size between 0.3 – 0.8 mm. The porosity of ion exchange resins can be fine-tuned over a wide range, generating microspores (gel-type, 5-200 Å) and macropores (100 Å – 1 mm). Since ion exchange resins exhibit charged polar groups as active sites, the polymers need to be chemically crosslinked in order to prevent dissolution of the beads. The degree of crosslinking is a crucial parameter for the selectivity of the resin beads and it provides the required accessibility to the functional group. Traditionally ion exchange resins are prepared by suspension polymerization, that yields a broad bead size distribution. As a result, very often low operating capacities and low mechanical- and osmotically stability due to inhomogeneous crosslinking are obtained. Lanxess therefore developed a unique technology to produce monodisperse beads that is based on encapsulation on monodisperse drops. Interestingly, these resins have superior mechanic-, osmotic stability and exchange kinetics due to the homogenous polymerization within monodisperse drops.

Thus if a new ion exchange application or a new ion exchange resin is developed it is important to have a set of resin testing procedures available in order to develop an efficient resin for the required application.

In this paper we present guidelines on how to quantify the abovementioned resins parameters. We present test procedures case from product development over application development to the upscaling to full scale plants. Protocols for determination of resin stability such as osmotic shock and chatillon force measurement are presented. Additionally resin evaluation by isotherm testing and breakthrough experiment will be presented. This paper shall help the end users to develop their application in the lab.

Keywords: Ion exchange resin testing, osmotic stability, mechanic stability, chatillion force measurement, isotherm and breakthrough testing

Uranium-REE Proceedings

Application of Membranes Forum

DEVELOPMENT OF THE TIRIS URANIUM PROJECT, MAURITANIA

By

Will Goodall

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Presenter and Corresponding Author

Will Goodall

ABSTRACT

The Tiris Uranium Project is a greenfield calcrete uranium project first discovered by Aura Energy in 2008. It represents the first development in a significant new global uranium province in Mauritania with 52Mlbs U3O8 in JORC Resources and considerable exploration upside. The mineralisation is naturally suited to low capital cost development and low operating cost extraction of uranium, presenting an opportunity for near term development of the Project.

The Resource is a shallow flat lying uranium bearing calcrete extending from surface to a depth of 5m. Located in Mauritania, West Africa the Tiris Project is deep in Sahara Desert 680km from iron ore mining centre of Zouerat. In July 2019 AEE published Definitive Feasibility Study with positive results, demonstrating a low cost project utilising efficient mining and processing techniques.

Tiris was a greenfield discovery by Aura Energy in 2008. The Project has since been extended with Measured and Indicated Resources of 17.1Mlbs U_3O_8 and Proven and Probable Ore Reserves of 10.1Mt at average 336 ppm U_3O_8. The uranium mineralisation is calcrete hosted within 5m of surface and the principle uranium host mineral is carnotite. The mineralisation is located at surface and is naturally free digging, resulting in simple mining with low mining costs.

The nature of mineralisation allows for highly efficient beneficiation due to the fine-grained nature of the carnotite. Upgrade of leach feed material results in 90% uranium recovery to ~10% of beneficiation feed mass. The proposed flowsheet includes a remote beneficiation circuit, with centralised conventional carbonate leaching circuit at 90C and atmospheric pressure. The pregnant liquor is concentrated by Ion exchange and membrane separation prior to precipitation and calcination.

The completion of the Definitive Feasibility Study for the Tiris Uranium Project presented attractive fundamental characteristics. Low CAPEX of US$63M and AISC of $29.8/lb U_3O_8 make the Tiris Project ideally placed to take advantage of the upward trajectory of the uranium market. The 15 year mine life represents a fraction of Resources, with considerable opportunity to both expand production and extend the life of mine. Mauritania is a favourable mining jurisdiction with significant existing infrastructure and skilled workers.

We will provide a summary of the project and the status of development. In addition, we will explore opportunities to further improve the project technical and economic returns and how we have leveraged partnerships to efficiently develop the Tiris Uranium Project.

Keywords: Tiris, Uranium, Carnotite, Calcrete, Alkaline Leaching, Mauritania

COMMERCIAL APPLICATION OF MEMBRANES AT KAYELAKERA AND LANGER HEINRICH

By

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Presenter and Corresponding Author

Darryl Butcher

ABSTRACT

Both the Kayelekera and Langer Heinrich uranium mines (both mines developed and operated by Paladin Energy Limited) incorporated innovative process technology in their original design. Kayelekera incorporated continuous RIP extraction and Langer Heinrich incorporated alkali leach and RIX. These two mines were the only new mines to be successfully developed by a non-state operator in the last uranium price boom (post 2000 and pre Fukashima). Both operations incorporated some sub-optimal design issues that increased operating cost and reduced operability. One of the assigned rolls of the Paladin Technical and Project Development team was to develop cost effective resolutions for such issues.

At the Kayelekera Uranium Mine (Malawi), acid demand for uranium leach and resin elution was throughput limiting, so a strategy to improve this situation was sought. The solution selected was to introduce a nano filtration circuit into the concentrated eluate processing section. Through nano filtration, a significant portion of the acid used for resin elution was able to be recycled back to the process without material accompanying recycle of uranium.

The Langer Heinrich Uranium Mine (Namibia) utilises RIX for uranium extraction and impurity rejection. Resin ageing in the presence of alkali process liquors was a material issue, leading to the gradual decline of resin adsorption capacity and effective loaded resin uranium tenors. This necessitated a gradually increasing resin advancement (and elution) rate. Loaded resin in this process is eluted with 1M sodium bicarbonate, which ultimately leads to a gradual increase in sodium carbonate concentration in process liquors, to the point that sodium carbonate becomes a circuit poison. Nano filtration was again able to be used to recycle a significant portion of the elution sodium bicarbonate back to barren eluate make-up without material accompanying uranium.

In both the above cases, process operating costs were reduced materially, especially so in the case of the Langer Heinrich mine, where total process operating costs were reduced by over 50% (cost per pound U_3O_8 basis).

Keywords: Uranium, Hydrometallurgy, Ion Selectivity, Process Optimisation, Innovation

APPLICATIONS OF MEMBRANES IN URANIUM AND LITHIUM PROCESSING

By

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Presenter and Corresponding Author

Adrian Manis

ABSTRACT

Applications of membranes within the process for recovery of uranium, lithium and other metals have been slowly emerging. There are many potential advantages such as the ability to recover and recycle reagents. Special attention needs to be paid to key challenges such as high acidities which can attack membranes and the presence of saturated salts such as gypsum which can foul membranes.

In the area of uranium recovery, new and existing applications of nanofiltration will be covered. The main focus in the area of uranium processing will be a case study of a new application involving the treatment of alkaline uranium leach solution to concentrate uranium and decrease reagent usage. A key challenge in developing this application was to overcome the potential for membrane fouling due to the presence of saturated salts in solution.

In lithium recovery, applications will be presented involving the use of both nanofiltration in the treatment of lithium brines and electrodialysis in downstream processing of refined lithium.

Keywords: Nanofiltration, hydrometallurgy, acid recovery, electrodialysis, uranium, lithium

CASE STUDY: CONCENTRATION OF URANIUM ELUATE USING NANOFILTRATION ON AN ISR PLANT IN KAZAKHSTAN

By

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Presenter and Corresponding Author

Les-Lee Thompson

ABSTRACT

The low uranium market position and decrease in in-situ leach recovery production concentration over the life of the mine, drives continuous optimization and process improvements in order to maintain operational profit margins. The application of nanofiltration membranes was evaluated on two process streams, namely (1) pregnant leach solution and (2) eluate post IX. Membrane systems were also investigated at various positions in the operating circuit in order to target concentration of uranium and simultaneously reduce the volume of eluate to be transported by road for further processing. Nanofiltration membranes produce two value streams by not only concentrating uranium but also recovering and recycling reagents, as permeate, back to the leach section.

The application of new technology in the mining industry follows rigorous technical and commercial evaluation to prove viability prior to major capital investment. This paper follows this process from the initial baseline feasibility calculations, modelling plant data and performance, through to synthetic and process solution laboratory studies and eventual pilot plant deployment and integration into the process plant.

The membrane systems performance parameters that were critical in the development of the feasibility models were as follows:

- System recovery affects permeate production and volumetric concentration factor
- Uranium rejection affects permeate quality
- Acid passage affects ammonia water consumption
- Operating pressure which is a limiting factor on feed concentration changes from site

The membrane performance data from all the previous studies are compared with pilot plant results and resulting effect on the payback period as initially calculated.

Keywords: Uranium, nanofiltration, membranes, acid recovery

PREVENTING GYPSUM SCALING OF MINEWATER RO/NF/UF MEMBRANES

By

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Presenter and Corresponding Author

Stephen Chesters

ABSTRACT

Reverse Osmosis (RO), Nano-Filtration (NF) and Ultra-Filtration (UF) membranes are capable of treating mine waters to produce a concentrate stream and a pure water stream. The concentrate can be used for enhanced precious metal and leaching solution recovery. The product stream of permeate water can be reused in mine process make-up water, dust suppression or further treatment for domestic use. In this paper the authors have researched and identified 389 membrane plant in mines worldwide using RO, NF and UF membranes of which 69% are in gold and copper mines. In precious metal mines, waste water can be concentrated using a membrane plant so additional metals can be recovered from barren liquor. Leaching solutions and acid can also be recovered in the membrane plant concentrate. Acid mine drainage (AMD) is increasingly treated and then reused or sent off site as a valuable resource for domestic and agricultural use. The wholesale adoption of membrane technology is hampered by the potential for rapid membrane fouling and calcium sulphate (gypsum) scale deposition.

The authors have embarked on a research project to investigate calcium sulphate scale formation at varying pH and in the presence of a variety of soluble metals. New antiscalant formulations have been tested with supersaturated simulated mine waters. Initially beaker threshold tests were conducted to establish the effectiveness of antiscalants at preventing gypsum crystal growth under different conditions. The more promising antiscalants were then tested using a membrane sample on a flat sheet test rig. The scaling solution is circulated over the membrane surface under pressure and normal operating conditions with and without antiscalant present to assess performance. Some key results are presented focussing on a new antiscalant that can inhibit gypsum scale formation in membrane plants using acidic mine water as a feed source and in the presence of high levels of soluble metals. This means the window of potential application of membrane technology is significantly broadened as the current practice of neutralising acidic mine waters and incorporating expensive soluble metal removal techniques prior to feeding the mine water to the membrane plant is not required.

The research team conducted a large number of experiments and collated enough data to establish windows of operation of various antiscalants with differing chemistries and conditions. This data has been incorporated into algorithms and a mine water specific scaling prediction software. This tool can be used to quickly assess the suitability for RO/NF/UF membrane plant use in a mine.

Keywords: Mining, open pit, precious metal, heap leaching, pregnant liquor concentration, calcium sulphate scale, gypsum, reverse osmosis membrane, nano-filtration membrane, antiscalant, acid mine drainage, water treatment, enhanced metal recovery, leaching solution recovery, water balance.

CLEANING CALCIUM SULFATE IN MINE WATER MEMBRANES

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ABSTRACT

Mining industries continue to use large volumes of water to facilitate the extraction of precious metals from rock; resulting in large quantities of waste water. Membrane technologies are capable of producing clean permeate water for reuse onsite, and the concentrate stream can be used for precious metal recovery. Acid mine drainage (AMD) is a problem in most mines due to high levels of pyrite (FeS_2) within the embedded rock. These AMD waters are often very acidic and have high levels of metals, which if untreated will lead to rapid fouling and scaling of the membrane plant. Calcium Sulfate (Gypsum) scaling is prevalent and can cause catastrophic failure of the membranes. In this paper the authors have investigated the chemistry of $CaSO_4$ scaling. Flat sheet test rigs and 2.5” membranes were deliberately scaled with simulated mine waters and then different cleaning reagent formulations used to try and remove the calcium sulfate scale. Some new cleaning product formulations, termed Cleaner A and Cleaner B have shown promise in their ability to remove $CaSO_4$ scale with the results presented herein.

Keywords: Calcium Sulfate, Mining, Acid Mine Drainage, Reverse Osmosis, Pyrite, Gypsum, Flat Sheet Rig, Membrane Cleaning