ALTA 2014

24 - 31 May

Perth, Australia

Proceedings

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Uranium-REE

Keynote Address

URANIUM-REE KEYNOTE ADDRESS

THE SOLVENT EXTRACTION OF URANIUM WITH AN EYE TO THE FUTURE

By

Murdoch Mackenzie

Private Consultant, Australia

Presenter and corresponding Author

Murdoch Mackenzie

ABSTRACT

Solvent extraction has been a significant hydrometallurgical route for the recovery of uranium since the introduction of the process at the Eldorado Port Radium plant in 1958. Although it is most commonly used as a primary recovery process it has also been used as a purification process to treat the eluate from primary ion exchange circuits. Uranium solvent extraction is simple and robust and can deliver a high concentration high purity loaded strip solution suited to the production of U_3O_8 solids. Uranium solvent extraction is restricted to the treatment of acid leach clarified solutions but this has not prevented uranium solvent extraction from continuing to be a contender in the design of new uranium circuits. However the process faces several challenges. There are environmental problems with the disposal of chemicals such as ammonium and sodium. Recycling of raffinate containing entrained organic may be a problem for in situ leach operations. The size of the mixer settlers required to treat very low tenor leach solutions may favour the alternative ion exchange process. Although uranium solvent extraction has a long history there have not been great advances in the chemistry and the equipment since its introduction. This is in part due to the robustness of the chemistry and the fact that in recent years the relatively small number of new uranium projects has not provided an incentive for engineers to develop new equipment. The transfer of base metal solvent extraction technology has however led to some advances in the design of uranium solvent extraction circuits. Significant advances have been made in solving environmental problems and the prevention and treatment of crud.

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Project Development

CONTINUOUS LEACHING OF KVANEFJELD CONCENTRATE

By

D Furfaro and DGI Krebs

Greenland Minerals and Energy Limited, Australia

Presenter and Corresponding Author

Domenic Furfaro

ABSTRACT

Greenland Minerals and Energy Ltd is currently developing the Kvanefjeld Uranium/Rare Earth deposit located in Southern Greenland. The project has a very large resource base and will produce approximately 23,000 tpa TREO and 513 tpa U3O8. The flowsheet includes a flotation circuit which upgrades the rare earths from ~1.3% TREO to 14% TREO in the concentrate. The flotation circuit has been successfully piloted and proven in continuous operation. As part of the ongoing hydrometallurgical development a sample of concentrate was leached in a 100 hour continuous weak acid leach circuit to target a key area of process risk. A continuous test was required in order to confirm process conditions required for silica control and generate material for further downstream process evaluation. Particular attention was paid to enhancing solid-liquid separation and producing low silica leach solutions. All unit operations downstream of the weak acid leach were batch tested. These downstream unit operations included strong acid leach, metathesis, HCl releach and impurity removal. The results have substantially improved confidence in the weak acid leach and uranium solvent extraction circuits and confirmed process conditions for unit operations downstream of the atmospheric leach.

METALLURGICAL TESTING OF SURFICIAL URANIUM ORES OF CENTRAL JORDAN

By

Hussein Allaboun

Jordan Atomic Energy Commission, Jordan
Jordan University of Science and Technology, Jordan

Presenter and Corresponding Author

Hussein Allaboun

ABSTRACT

A three phase metallurgical testing program was launched to investigate the leaching behaviour of uranium ores of the Central Jordan area (CJ). Phase I was a preliminary investigation conducted on randomly selected samples produced from excavated trenches and drilled cores made by geologists in the exploration area. These samples were subjected to bench-scale leaching studies; the results of which concluded obvious amenabilities toward alkaline leaching. Moreover, the relatively soft host rocks were also deemed amenable to crushing and grinding processes.

Based on the then acquired knowledge of ore body, three bulk samples were picked and collected. Two of these samples were tested under dynamic and static alkaline leaching conditions. The third is being tested. Uranium deportment analysis on these samples revealed that uranium is distributed in all size fractions: indicating the relative value of the fines vs. the coarse fractions. Dynamic leaching tests confirmed the previous results obtained in phase I and revealed more information regarding the leaching kinetics, particle size effect on recoveries, and the maximum achievable recoveries. Static leaching experiments on 20mm crushed ore, reached average recoveries above 80%; these findings match well with those obtained by rotating bottle tests. Agglomerated ore exhibited an average of 7% overall slumping behaviour while undergoing column leaching. Ore was agglomerated with water; average water requirements were 15% and 20% for the tested two bulk samples.

Twelve locations in the CJ area have been selected by specialists for bulk sampling. The samples are deemed representative to whole orebody. Phase III of testwork will be based on these bulk samples.

THE NOLANS RARE EARTH PROJECT – AN UPDATE

By

John Ganser, Andrew Napier, James Kyle, David White and Sunil Jayasekera

Arafura Resources Limited, Australia

Presenter and Corresponding Author

James Kyle

ABSTRACT

Arafura Resources flagship project and its key focus is the Nolans Rare Earth Project, one of the world's largest and most intensively explored rare earth deposits, located in the Northern Territory of Australia, close to the Stuart Highway and about 130 km by road from Alice Springs. The rare earths are associated mainly with apatite (a calcium phosphate mineral, monazite (a rare earth phosphate, and allanite (a calcium and rare earth silicate mineral.

The Project has undergone an extensive testwork program over the last 10 years aimed at developing a technically and economically viable flowsheet for the treatment of Nolans ore to produce five pure rare earth oxides as final products.

The initial development of the Project was based on a mine and concentrator to produce a rare earth mineral concentrate for transport to a Rare Earths Complex at Whyalla in South Australia for chemical processing into the final products. In this process, the apatite concentrate was pre-leached with hydrochloric acid to dissolve the calcium phosphate prior to sulphation of the rare earth minerals using a sulphuric acid baking process. The "cracked" rare earths were solubilised in water, and impurities (Fe, Al, Th removed as a solid residue prior to uranium recovery by ion exchange, and precipitation of the rare earths as a mixed carbonate precipitate. The mixed carbonate was dissolved in hydrochloric acid as feed to a solvent extraction rare earth separation process, to produce five 99% purity rare earth oxide products (Cerium Oxide, Didymium Oxide, a mixed heavy rare earth oxide, Lanthanum Oxide and a mixed Samarium, Europium and Gadolinium oxide. This process underwent extensive piloting in the period 2010 to 2012 to validate the process and to produce final rare earth products for potential customer assessment. The hydrochloric acid used in pre-leach was regenerated from a residual calcium chloride solution formed following phosphate precipitation from the pre-leach liquor to produce a calcium phosphate product.

Although this process showed strong financial returns, process development work continued to examine the potential for process improvements and to reduce the Project's capital expenditure. This development work has resulted in a substantial reduction in the estimated capital cost of the Project. This has been achieved by a number of process improvements, the major ones being the replacement of hydrochloric acid by sulphuric acid in the pre-leach stage, and the replacement of the rare earth carbonate intermediate product by a rare earth hydroxide. Major capital savings are also being realised by reconfiguring the Project, by relocating intermediate chemical processing to the mine site, and placing the rare earth separation plant into a developed chemical precinct with access to 'over the fence' supply of key reagents.

This paper will provide a technical overview of the Nolans Project, with particular emphasis on the changes to the flowsheet generated by the replacement of hydrochloric acid with sulphuric acid. It will also include a preview of further development work currently being undertaken in China.

SELECTIVE LEACHING AND ACID RECYCLE ON SONGWE HILL RARE EARTH CONCENTRATE

By

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Presenter and Corresponding Author

Gavin Beer

ABSTRACT

Mkango Resources Limited is developing the Songwe Hill rare earth project in south east Malawi. The project holds an NI 43-101 compliant mineral resource estimate comprising of an Indicated resource of 13.2 million tonnes grading 1.62% total rare earth oxides (TREO and an Inferred resource of 18.6 million tonnes grading 1.38% TREO. A mineralogical program identified the fluorocarbonate mineral, synchysite, and the phosphate mineral, apatite, as the most prevalent rare earth host minerals whilst calcite and ankerite were identified as the most common gangue minerals present. Extensive metallurgical testwork was conducted initially at Mintek in South Africa and more recently at Nagrom in Western Australia. A robust flowsheet has been developed consisting of comminution, flotation, hydrochloric acid leaching, purification, cerium rejection and rare earth precipitation delivering a product suitable as feed to a rare earth separation refinery. More recently the leach process has been enhanced to incorporate a two stage selective leach process as well as acid recycling via calcium sulphate precipitation. This approach offers innovative advantages including a significant reduction in acid costs as well as a further concentration of the rare earths providing a reduction in downstream capital and operating costs.

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Heap Leaching

HEAP LEACH HEIGHT AND RECOVERY FROM COLUMN LEACH TESTS

By

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Corresponding Author

Thomas Apelt

Presenter

Simon Reveley

ABSTRACT

Macusani Yellowcake Incorporated (MYI is investigating the exploitation of its properties on the Macusani Plateau in south-eastern Peru. MYI has engaged GBM Minerals Engineering Consultants Limited (GBM to assist with the completion of a sequence of NI 43-101 compliant studies. In the recent Preliminary Economic Assessment (PEA, a dynamic on/off heap leach pad has been designed to extract uranium from the fast-leaching ore, processing the ore at 8.5 Mt/y at a U_3O_8 grade of 259 ppm.

This paper reiterates a method to determine the optimum heap height and corresponding recovery. The base case, the reference column leach test results, a relationship between leach extraction and grade, a leach extraction model, the recovery discounting applied, the financial parameters used, and the calculation sequence are described.

The paper also provides further details of the mathematical equations utilised, including relationships for leach recovery, lost revenue and pad cost by heap height. For this study, the optimum heap height is 7.8 m, the corresponding leach recovery is 87.3 % and the leach cycle is 2.1 cycles per year.

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REE Processes

SOLVENT EXTRACTION OF RARE EARTH ELEMENTS USING CYANEX® 572

By

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Presenter

Owen Tinkler

ABSTRACT

Cytec has developed a new organophosphorus based solvent extraction reagent for rare earth separations. The new product, CYANEX® 572, has been formulated to allow efficient extraction while minimizing the strip acid requirements. The optimization of formulation strength is expected to significantly reduce the operating costs of these circuits by reducing acid and base usage. Modeling capabilities (similar to those used successfully in Cu and Co/Ni SX have also been developed to aid in the design and optimization of CYANEX 572 SX circuits. Simulations will be shown comparing extractants.

SEPARATION OF RARE EARTHS FROM URANIUM AND THORIUM

By

Zhaowu Zhu, Yoko Pranolo and Chu Yong Cheng

CSIRO Process Science and Engineering
CSIRO Minerals Down Under National Research Flagship, Australia

Presenter and Corresponding Author

Zhaowu Zhu

ABSTRACT

Rare earths play critical roles in the advanced materials industry and recently, rare earth recovery from new sources attracts much interest. Radioactive elements of uranium and thorium are usually associated with rare earth deposits. Therefore, radiation contamination and safety issues are often of a great concern. Rare earths separation from uranium and thorium is very important to produce their products free from radiation contaminations. This paper summarised the technologies for the separation of rare earths from uranium and thorium including selective precipitation and solvent extraction applied in the rare earth industry, particularly in China. Some newly developed processes are also reviewed.

PROCESSING OF BASTNASITE-CONTAINING ORE

By

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Presenter and Corresponding Author

Mellodee Anvia

ABSTRACT

Bastnasite is a fluorocarbonate mineral of major economic significance which contains between 58–74% of mainly the light rare earth elements. The mineral may also contain up to 0.2% ThO_2 and can contain low concentrations of uranium. At the Mountain Pass mine in California and the Bayan Obo mine in China, bastnasite concentrate containing between 60–70% REO is commercially processed *via* a calcination/HCl leach route to recover the rare earths. Recently, there has been increased interest in processing ores of much lower grade. A process based on direct hydrochloric acid leaching of low-grade bastnasite-containing ore is the subject of this investigation. In this process, an intermediate rare earth chemical concentrate is produced *via* oxalate precipitation which is further processed to a concentrated rare earth chloride liquor of suitable purity to feed a solvent extraction rare earth separation refinery.

REVIEW OF CURRENT RARE EARTH PROCESSING PRACTICE

By

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Presenter and Corresponding Author

Simon Reveley

ABSTRACT

This paper reviews the current practice in the published sources for the production of rare earths, describing the mineralogy and beneficiation techniques employed at these plants and the underlying chemistry. GBM have reviewed and summarised over a dozen published processes from SEDAR(1 and other sources. This paper assumes the reader is familiar with common techniques in comminution and beneficiation and focusses on aspects that are unique to rare earth projects.

Since the reports used are preliminary in nature, the processes detailed within are subject to change as more advanced test work is carried out. Despite this, the reports do show that the processes have the ability to economically extract rare earths from their minerals.

Of the thirteen projects reviewed, the most common processing methods are:

- Physical beneficiation by flotation (used in eight projects).
- Acid or alkali cracking of the concentrate at elevated temperatures prior to leaching (used in eight projects).
- Leaching to separate the rare earths from their host mineral. All thirteen projects use leaching. Seven projects use a water leach following an acid or alkali crack, with the remainder using an acid or alkali leach.
- Precipitation from solution. The rare earth elements are then most commonly precipitated from solution as carbonates, via addition of sodium carbonate (used in seven of the thirteen projects).

Despite these common unit operations, no two flowsheets are identical, highlighting the variations required to accommodate site specific mineralogy.

Membranes

THE APPLICATION OF AMS MEMBRANES IN URANIUM ORE PROCESSING

By

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Presenter and Corresponding Author

Johannes Herrmann

ABSTRACT

AMS Technologies is a commercial membrane manufacturer that specializes in the treatment of in-process and wastewater streams. Following a decade of cutting edge research, our team of scientist developed a unique line of highly durable **nanofiltration** membrane products enabling the treatment of aggressive industrial streams with great benefits to clients

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Radiation Control

RADIATION CONTROL IN DESIGN AND OPERATION OF PLANTS FOR PROCESSING URANIUM, RARE EARTHS & OTHER RADIOACTIVE ORES

By

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Presenter and Corresponding Author

Mark Sonter

ABSTRACT

Most attendees will know that radiation protection of workers and of nearby ('critical group' members of the public is an essential ‘social licence’ requirement which imposes constraints in the design and operation of plants which treat uranium ores. It is not quite so well known that these same constraints apply to a greater or lesser extent also to Rare Earths plants, due to the usual association of REE with thorium in its ores. In particular, the handling of ‘thorium waste’ requires attention to radiation control.

This paper dissects plant design and operational radiation control requirements, by describing the several different 'dose delivery pathways' (being exposure to gamma shine; inhalation of airborne radioactive ore, product, or tailings dusts; inhalation of airborne radon or thoron decay progeny ('daughters'; and ingestion of radionuclide-bearing dusts; then going on to discuss how they are (a monitored in practice, and (b controlled by design, and in operation.

An additional aspect of radiation control, which comes to the fore particularly in REE extraction, and in plants where uranium is present only as a minor contaminant, is the need for adequate rejection of all (parent and daughter radionuclides from your non-radioactive product stream(s, to ensure acceptability/saleability. This has become an issue for exporters of copper concentrate containing contaminant uranium, with the growing use of a default 'rejection figure' by purchasers (or port authorities of '1 Becquerel per gram' U in the concentrate, the complete story being more complex. For REE producers, there is (depending on U content of the ore the need to ensure rejection of Actinium from the Lanthanum stream, and possibly Protactinium from Praesodymium product

The metallurgist's conceptual tools for tackling these issues include an understanding of the uranium and thorium decay chains; of radionuclide decay and ingrowth, and hence secular equilibrium; and how to carry out 'Activity Balance', analogous to mass balance. We discuss some radionuclide buildup situations as examples.

OPTIONS FOR REMOVING URANIUM & THORIUM FROM ZIRCON MINERAL SANDS

By

Damian Connelly

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Presenter and Corresponding Author

Damian Connelly

ABSTRACT

Australia is a major world producer of zircon currently supplying 45% of the world's production. A number of these resources are high in radioactivity (uranium & thorium and this makes them commercially unattractive and more difficult to market.

Zircon is used for foundry sand, refractories, ceramics and glazes and zirconium chemicals. There are radiation limits on the sale and transport of zircon in countries such as China.

This has created a challenge to reduce the radioactivity and greatly improve the marketability of the product. There are a number of patents and proprietary technologies available for reducing radioactivity in zircon. A number of these options were tested and results were mineralogically controlled and the efficiency varied depending on the source of the zircon sand.

In addition there were issues with OPEX and design of process plants to achieve such reductions. Whilst a number of companies have evaluated a number of these technically challenging process options, no commercial plants have been built to date.

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A NOVEL PROCESS TO RECOVER URANIUM FROM SOLVENT EXTRACTION CIRCUITS

By

Mark Urbani and Gary Johnson

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Presenter and Corresponding Author

Mark Urbani

ABSTRACT

A new chemical process to recover uranium from loaded amines is described. A provisional patent has been lodged. The process is suitable for the recovery of uranium from acidic leach liquors by solvent extraction with amines and is potentially a viable alternative to the ammonia and strong acid strip processes. Stripping of uranium is achieved without pH control, which eliminates the risk of uranium precipitation in mixers. This issue is prevalent with ammonia stripping. The process generates loaded strip liquor that is suitable for uranium recovery by conventional precipitation using hydrogen peroxide, albeit without pH control.

The process requires the use of a relatively benign matrix solution which provides the hydroxide ions necessary for stripping and precipitation. Expensive and/or hazardous reagents, such as ammonia, strong sulfuric acid or sodium carbonate, are not required. The main reagent consumed is limestone, which allows for sulfate removal from the strip solution bleed stream via the precipitation of gypsum.

FACTORS INFLUENCING THE EFFECTIVENESS OF FIREWALL DESIGNS FOR METALLIFEROUS SOLVENT EXTRACTION PLANTS

By

Adrian MacHunter

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Presenter and Corresponding Author

Adrian MacHunter

ABSTRACT

The process of metalliferous solvent extraction for the recovery of uranium, copper, nickel and some other precious metals is more than 50 years old; however, the technology is continuously changing and improving. From 1999 to 2004 the solvent extraction industry suffered four very significant fires in large commercial plants, resulting in high capital and production losses. Many of the implemented fire risk mitigation solutions in metalliferous solvent extraction plants have been a ‘knee jerk’ reaction to these devastating fires. Many of these solutions have been derived from misguided information and limited technical and fire risk knowledge. Metalliferous solvent extraction plants, like many industrial processes, are most efficient if the process equipment is installed close together to reduce piping lengths. Shorter piping lengths will reduce frictional losses, thermal losses and the head required to pump liquids, which in turns reduces the energy required for the process and the capital costs. However, the reduction in plant footprint means a reduction in the separation distances between fire hazards and therefore a potential fire could spread throughout the entire plant. Firewalls are needed to provide a positive isolation between settlers.

The purpose of this study is to investigate some key factors that influence the effectiveness of firewall designs in metalliferous solvent extraction plants. The study will then derive a simplified design correlation for engineers and designers to estimate the firewall height required to adequately isolate settlers from each other and achieve separation between fire zones in solvent extraction plants in the conceptual and feasibility phases of a project.

A series of computational fluid dynamics simulations involving a theoretical solvent extraction plant with varying settler sizes, firewall heights, separation distances between the settlers and the firewall and varying wind velocities were modeled. The Mudan equation for the thermal radiation intensity experienced by an element outside the flame envelop under wind and no wind conditions was then used to compare the results from the simulations.

The following factors were studied and found to influence the effectiveness of firewall designs for metalliferous solvent extraction plants:

- The Settler on fire surface area had minimal effect;
    - Increasing surface area by 125% (400m^2 to 900m^2);
    - Increased the maximum radiant heat transmitted to Settler 2 by 0.4kW/m^2 and the average radiant heat by 0.1kW/m^2;
- The separation distance between the settlers and the firewall had significant effect;
    - Increasing the separation distance from 0m - 1m, reduced the radiant heat transmitted to Settler 2 by 40% - 80%;
    - Further increasing the separation distance from 1m - 2m, reduced radiant heat by an additional 25% - 40%;
- The prevailing wind had significant effect;

URANIUM RECOVERY FROM SULPHATE LEACH SOLUTION CONTAINING CHLORIDE USING A MIXED SYSTEM OF D2EHPA AND CYPHOS IL-101

By

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Present and Corresponding Author

Zhaowu Zhu

ABSTRACT

Uranium recovery from its sulphate leach solution containing high chloride concentration is a great challenge because traditional solvent extraction using tertiary amine suffers from low uranium extraction efficiency. A new solvent system consisting of D2EHPA and Cyphos IL-101 was studied to solve this problem.

The organic system consisting of D2EHPA and Cyphos IL-101 formed an internal compound with two molar D2EHPA and one molar Cyphos IL-101. The mixed organic system performed well in uranium extraction and its separation from Fe(III in sulphate solutions. The mixed organic system demonstrated high tolerance to chloride up to 12 g/L in terms of uranium extraction and its separation from iron. More than 83% U was extracted with the organic system consisting of 0.05 M D2EHPA and 0.05 M Cyphos IL-101 in Shellsol D70 while less than 10% Fe(III was extracted within the pH range of 0.5-1.25, resulting in high separation factor of U over iron. Almost all co-extracted iron could be scrubbed using 0.5 M sulphuric acid. The co-extraction of vanadium was significant, but less at low pH of <0.5. The extraction of other metals including Al, Cu, Mn, Mg and Ca was insignificant, resulting in ready separation of uranium from them. Effective uranium stripping was achieved with 4 M H_2SO_4 or higher using multiple stages. The kinetics of uranium extraction and stripping was fast and good phase separation was observed.

HONEYMOON MINE AUSTRALIA: COMMISSIONING AND OPERATION OF THE PROCESS PLANT USING A NOVEL SOLVENT EXTRACTION REAGENT MIXTURE IN A HIGH CHLORIDE ENVIRONMENT

By

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Presenter and Corresponding Author

Simon Ballestrin

ABSTRACT

The Honeymoon Uranium Project is wholly owned by Uranium One Incorporated. The operation uses in-situ leaching to extract uranium from uranium-bearing sandstone aquifers underground and the resultant pregnant leach solution (PLS is pumped to the surface for processing. Uranium is extracted from the PLS using a unique reagent suite in the solvent extraction (SX circuit. After scrubbing and stripping, uranium is precipitated to a uranium peroxide product and dried for despatch.

The PLS is targeted to contain about 50 – 70mg/L uranium with up to 10 g/L chloride and 0.5 g/L ferric iron. However, during the initial operations the PLS achieved ranged between 50 – 55 mg/L. The low uranium concentration coupled with the high chloride level and the presence of iron provide difficulties for a conventional SX reagent suite, thus requiring the development of a unique reagent blend of di-2-ethyl hexyl phosphoric acid, tertiary amine and tri-butyl phosphate. An iron removal process is installed after SX before uranium is precipitated as a hydrated uranium peroxide product.

The plant was commissioned in August 2011. Some of the challenges during and after commissioning included low uranium leach tenors, the appearance of crud deposits in the extraction columns, optimisation of the scrub circuit, the formation of a third phase in the strip circuit, high phase disengagement times in strip, and carry through of organic into the precipitation area. Strategies developed to mitigate and solve these issues are discussed.

EVOLUTION OF MIXER-SETTLER DESIGN FOR USX

By

Alan Taylor

ALTA Metallurgical Services, Australia

Presenter and Corresponding Author

Alan Taylor

ABSTRACT

The early USX mixer-settler designs in the late 1950s and 1960s were adopted from the nuclear industry. Inter-stage transfer was by gravity, airlifts or pumps. During the 1960s, pump-mix type mixer-settlers of various designs were increasingly favoured. The advent of copper SX in the late 1960s led to the development of what became known as the conventional mixer-settler which was designed to minimize entrainment losses of the more expensive organic extractant and to keep organic out of the associated copper EW facility. A number of new designs were developed and applied for USX. Objectives included reduction in footprint, especially for indoor operations, and reduction in capital cost, organic inventory and entrainment losses. The USX designs included the use of trays or baffles in the settlers, a launder for primary phase disengagement, and static in-line mixers. Relative few USX plants have been built since the uranium price decline beginning in the early 1980s and continuing through to fairly recent times, and only the Krebs and conventional mixer-settlers have continued to be applied along with pulsed columns which have found increasing favour. In the meantime, there have been further developments in copper SX mixer-settler design which are available for application for USX. These include reverse flow settlers, Outotec VSF mixer-settlers, MMS side-feed mixer-settlers and MC process mixer-settlers which features a new mix box and pump-mixer design. Possible future developments could involve improvements to current designs, revisiting earlier commercial designs, further development of previously piloted designs, and new innovations. The main objectives are opex related - to reduce entrainment losses and power consumption, and capex related - to reduce footprint, settler area and organic inventory.