**TECHNICAL PROGRAM @ A GLANCE**

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**Poster Session**, Monday, August 16 @ Sheraton Cavalier Hotel in the Foyer. Judging from 17:30 to 18:00
Monday, August 16, 2010 AM
Room: Adam Ballroom

Co-chaired: Jerry Grandey and Engin Özberk

8:00 OPENING OF THE PLENARY SESSION
Engin Özberk, Vice President, Innovation and Technology Development, Cameco Corporation

8:10 THE FUTURE IS U
Gerald W. Grandey, Chief Executive Officer, Cameco Corporation

8:35 AREVA’S VISION IN CANADA AND THE WORLD
Roger Alexander, President and CEO, AREVA Canada Inc.

9:00 ADDRESS TO DELEGATION
Zhou Zhenxing, Chairman, CGNPC Uranium Resources Co., Ltd. of China

9:25 SASKATCHEWAN’S VISION FOR URANIUM SUPPLY AND NUCLEAR ENERGY
Honourable Bill Boyd, Minister of Energy and Resources, SK

10:00 Coffee Break

10:15 URANIUM 2009: RESOURCES, PRODUCTION AND DEMAND
Robert Vance, Nuclear Energy Analyst, OECD Nuclear Energy Agency

10:40 THE ROLE OF REGULATORY ORGANIZATIONS IN MAKING THE ‘FUTURE IS U’
M. Binder, President, Canadian Nuclear Safety Commission

11:05 URANIUM INDUSTRY
Chief Tammy Cook-Searson, President of Kitsaki Management Limited Partnership

11:30 ADDRESS TO DELEGATION
Galymzhan Pirmatov, Vice-President, Finance, National Atomic Company, "Kazatomprom" JSC
14:00 Paper 5791 - Keynote Speech
URANIUM OCCURRENCES AND EXPLORATION EXPERIENCE IN INDIA
A. Chaki
Atomic Minerals Directorate for Exploration and Research, India

The history of the uranium industry in India is briefly reviewed. The efforts of exploration in a number of important uranium provinces, such as the Singhbhum Shear zone, Cuddapah basin, Mahadek basin, Bhima basin, North Delhi Fold Belt and Kaladgi basin, are outlined. Though India had been an early starter in uranium exploration, it slightly lagged behind to cope with the emerging new technologies in mineral exploration, mainly because of the technological isolation. In the new millennium, there is a major shift in India’s uranium exploration strategy from conventional exploration techniques to “technology intensive” exploration. With the large pool of human resources along with the new technology-intensive exploration program, India will achieve self-sufficiency in uranium in the near future.

14:30 Paper 4794
ON THE BRAZILIAN URANIUM PRODUCTION AND DEMAND: SCENARIOS FOR THE NEXT 20 YEARS
R.A.S Villegas and L.A. Gomiero
Indústrias Nucleares do Brasil - Unidade de Concentrado de Urânio, Brazil

The Brazilian government announced in 2007 its plans to reactivate the nuclear program. As a result of this decision, a new nuclear power plant is already being built and there are studies dealing with, among other activities, the building of 5 to 9 new ones until the end of 2030. Such increase of the country’s uranium demand affects INB, the Brazilian state company that’s in charge of uranium supply. This paper describes scenarios predicted to impact the Brazilian nuclear industry for the next years and the INB’s plans to meet the country’s needs in terms of uranium exploration and production.

15:00 Paper 4855
AUSTRALIA’S URANIUM: RECENT EXPLORATION, RESOURCES AND MINE DEVELOPMENTS
A.D. McKay, I.B. Lambert and L.J. Carson
Geoscience Australia, Australia

Uranium exploration expenditure in Australia reached a record level of A$220.5 million in 2008, which had subsequently declined to A$179.6 million in 2009. Recent discoveries include: Ranger 3 Deeps east of Ranger open pit and Thunderball project in the Northern Territory, and Pepegoona and Yadglin sandstone hosted deposits in South Australia. Australia’s Reasonable Assured Resources recoverable at costs of <=US$80/kg uranium at December 2009 are estimated (preliminary) to be 1,224,000 tonnes of uranium, 5% higher than the estimate for December 2008. Recent developments at Olympic Dam mine, Four Mile in situ recovery project, Ranger mine, and Honeymoon, Oban and Yeelirrie projects are discussed.

15:30 Coffee Break

16:00 Paper 4872
URANIUM MINING AND MILLING IN AUSTRALIA - AN OVERVIEW
J. Battista and H. Jones
Golder Associates Pty Ltd, Australia

Uranium mining in Australia has a chequered history. This paper reviews the development of the Australian uranium production industry from the 1930s to the present day. It outlines the geology of the various deposits and the mining and metallurgical techniques used to extract the uranium. The industry is and has been profoundly affected by government policies and the paper considers the roles of the federal, state and local governments. The influence of public opinion on nuclear issues and the effects current and historical policies of various governments have had on uranium production are outlined. Despite heavy restrictions placed on it, Australia’s uranium mining industry has maintained its place as one of the world’s largest producers. This paper also provides an outline of where the industry in Australia may be headed in future.
This paper examines issues relating to the future of uranium in Canada. It outlines the need for increased base-load electrical power generation to reach Canada’s full economic potential of the resource sector. It outlines international comparisons, with emphasis on wind power generation as part of the energy mix of energy sources. It examines a broad overview of options and nuclear power; addressing the nuclear industry’s safety as well as the unfounded continuing public fear of radiation. It also addresses nuclear waste management and disposal and the environmental assessment work done, leading up to the current Nuclear Waste Management Organization (NWMO).

Phosphate rock of sedimentary origin contains on the average 0.01% uranium. At an annual world production of phosphate rock of 130 millions tons this represents a potential source of about 13,000 tons uranium. Because the mining and processing of phosphate rock is already financed by the existing phosphate fertilizer industry, the cost of the uranium as a by-product should not be great. Before the discovery of rich uranium deposits this source was developed on industrial scale. The production of phosphoric acid by sulfuric acid process is at present facing the problem of disposal of gypsum; about 1.5 tons of gypsum is produced per ton of rock processed. This material contains all the radium originally present in the rock which results from the radioactive decay of uranium. As a result, phosphogypsum contains about 0.03 mg Ra/t or 30 pCi/g. The recovery of uranium from this source and the advantages of using nitric acid are discussed. The possibility of applying in-situ, heap and vat leaching to phosphate rock is emphasized.
Demand for reliable, affordable energy will continue to grow as lesser developed countries aspire for standards of living closer to that of developed nations. Society now also realizes the environmental costs of various forms of energy and electricity production. Increasingly, nations are turning to nuclear power to contribute clean, reliable and affordable electricity. Cameco has aggressive growth plans to increase uranium supply to the nuclear industry in order to meet this growing demand. This presentation will provide an overview of Cameco’s current and future uranium supply portfolio including existing operations, projects under development and projects under evaluation.

Northern Saskatchewan comprises an area of about 350,000 km² and boasts some of the world’s largest known high-grade uranium deposits. The successful mining of these deposits, however, can not be accomplished without overcoming technical challenges. Not only is the high grade of the uranium ore challenging, but mining methods need to be developed to deal with ground water at very high pressures, and ground conditions that vary substantially from excellent to wholly unconsolidated clays and sand. This paper discusses the various mechanisms of inflows at the three of the Cameco Corporation Mines in Northern Saskatchewan. The risk of inflows is quantified in terms of unique challenges from hydrogeologic conditions, rock mass integrity, and uncertainty in geologic conditions. Mitigation strategies in case of an inflow are also briefly described. The paper concludes by addressing the impact of institutional rules (corporate standards) on minimizing, monitoring, and controlling the probability and/or impact of unexpected inflows.
In a world where underground mining is more commonly deeper than 5,000 ft., and 8,000-10,000 ft is becoming less extraordinary, new techniques and technologies are in demand to reverse the trend of increasing costs per ton mined. So when a company using their own internal engineering, project and operating resources achieve a true technical first, and moves from concept, through research and development, to successful implementation at the pace of regular production, this is an important event. While the technological details of how the inflow into the flooded Cigar Lake Mine was identified and sealed are tantalising, the value lies in reviewing the repeatability of how to achieve this kind of extraordinary result, which raises people-in-team related questions like; how were they led? How did the working environment get created and sustained that allowed the team to operate in a consistently innovative mindset? How did they maintain a pace that relegated research, development and testing to a pace which is common in a regular operating function? How was the risk of these new techniques and technologies evaluated in a timely and effective manner that was considered normal rather than abnormal, and did not retard the pace of the team progress? If repeatable in regular team project and operating environs, then challenging and improving accepted mining methods, practice and technologies could become the norm rather than the exception.
The Key Lake mill located approximately 570 km north of Saskatoon, Saskatchewan, Canada and is currently the world's largest primary producer of uranium producing 8.5 million kg U3O8/y. The feed to the Key Lake mill currently originates from the McArthur River mine, an underground mine located approximately 80 kilometres north of the Key Lake mill. The McArthur River mine, located within the Athabasca Basin, is the world’s largest high-grade uranium deposit with proven and probable reserves, as of December 31, 2009 of 152 million kg U3O8. Approximately 1,300 people are employed at Key Lake and McArthur River of which 51% of the workforce are residents of Saskatchewan’s north. The mine site and mill are remote and employees commute via air travel to and from the sites from Saskatoon, Saskatchewan as well as communities throughout northern Saskatchewan. Employees work a 7-day in/7-day out work rotation and reside in permanent camps during the work week at the mine and mill.

In 2006, SOMAIR decided to increase the uranium production by 50% using heap leaching for the treatment of low grade ores. These ores, which come from different ores with various properties, have been studied in four steps:  
- Lab tests: to compare the ores (characterization, acid consumptions, recovery).  
- Column tests on an average sample: to define significant parameters for a feasibility study.  
- Column tests on specific samples: to optimize recovery for each ore and identify problems of percolation due to the clays.  
- Pilot tests in large boxes (stalls): to validate process parameters.  
Uranium production by heap leaching started commercially in July 2009.

The White Mesa Mill (WMM) began operating in 1980 as a regional processing mill owned by Energy Fuels Nuclear, Inc. Original mill design was for 656,000 Mtpa of U ore producing 1,250 Mtpa of U3O8 concentrate. Sustained market downturns delayed facility upgrades during most of the 1980s and 1990s. The new owners of WMM, Denison Mines, elected to advance the regional mill concept in 2007 with the modernization of these facilities. This paper details the decisions taken in the plant revitalization, choice of leading-edge instrumentation, motor controls, process automation and training, with some example benefits from process control stabilization.

The Caetité-Brazil uranium facility produces about 400 tonnes/year of U3O8 from an ore averaging 0.29% U3O8. The steps of the process consist of: ore crushing, heap leaching with sulphuric acid, U separation and purification by solvent extraction with a tertiary amine followed by stripping with a sodium chloride solution and precipitation as ammonium diuranate and then product drying. A change in the milling process is being evaluated in order to increase the production as well as uranium recovery. Heap leaching will be replaced by conventional tank agitated leaching of the – 590 µm ground ore slurry in a sulphuric acid medium. The replacement of the stripping reagent is also being considered.
The modern uranium mill generates a vast amount of raw data from various sources including control systems, operator logsheets, assay results and environmental monitoring, which is frequently stored in separate databases. Implementation of software at the McClean Lake mill that includes an integrated, web-based view of these multiple and disparate data sources has provided better tools in the effort to manage this "data load", and extract the information required to enhance process understanding and support the continuous improvement and decision making processes. This paper outlines the opportunities, challenges, and milestones of this software project.

Considering the recent global upsurge in uranium production activity, in 2008 the IAEA re-launched its Uranium Production Site Appraisal Team (UPSAT) program with emphasis on the holistic review of uranium production cycle activities. The review is built around an international panel of uranium industry experts put together by the IAEA. Each UPSAT panel is specific to the requirements and terms of reference for its review. The Terms of Reference are drawn up jointly by those requesting the review and the relevant IAEA technical staff. In January 2010 the first UPSAT review was undertaken at Indústrias Nucleares do Brasil’s uranium operation in Caetité, Brazil. In this paper we describe the philosophy, planning, execution and outcomes of this first UPSAT review, and discuss the possible benefits of hosting a review for future potential UPSAT clients.
REFINING/CONVERSION

Monday, August 16, 2010 PM
Room: Kelsey

14:00 Paper 5605
SPRINGFIELDS FUELS – TECHNOLOGY AND CAPABILITIES
M. R. Gornall and D. G. Eaves
Springfields Fuels Ltd, UK.

This paper describes the technologies applied and capabilities of Westinghouse’s Springfields facility in the UK. The site has been involved in the front end of the nuclear fuel cycle for over sixty years yet has some of the most modern manufacturing facilities for UF6 and nuclear fuel. The current capabilities at Springfields include UO3 to UF6 conversion, natural and enriched uranium residue recovery, reconversion of natural and enriched UF6 to UO2, fuel fabrication of Advanced Gas-cooled Reactor (AGR) and Light Water Reactor (LWR) products, the export of UO2 intermediates and the potential to utilise reprocessed uranium feedstock. These processes are supported by an extensive analytical and technical knowledge base.

14:30 Paper 5576
MINIMIZING THE RISK AND IMPACT OF URANIUM HEXAFLUORIDE PRODUCTION
D.R. Clark¹ and T. W. Kennedy²
¹ Cameco Corporation, Port Hope Conversion Facility, Canada
² Cameco Corporation, Major Projects Division, Canada

Cameco Corporation’s Port Hope conversion facility, situated on the shore of Lake Ontario in the Municipality of Port Hope, Ontario, Canada, converts natural uranium trioxide (UO3) into uranium dioxide (UO2) or natural uranium hexafluoride (UF6). Conversion of UO3 to UF6 has been undertaken at the Port Hope conversion facility since 1970 and is currently carried out in a second-generation plant licensed to annually produce 12,500 tonnes U as UF6. Consistent with Cameco’s vision, values and measures of success, Cameco recognizes safety and health of its workers and the public, protection of the environment, and the quality of our processes as the highest corporate priorities. Production of UF6 in a brownfield urban setting requires a commitment to design, build and maintain multiple layers of containment (defence-in-depth) and to continually improve in all operational aspects to achieve this corporate commitment. This paper will describe the conversion processes utilized with a focus on the cultural, management and physical systems employed to minimize the risk and impact of the operation.

15:00 Paper 5380
DEPLETED URANIUM PROCESSING AND FLUORINE EXTRACTION
S.T. Laflin
International Isotopes Inc., USA

Since the beginning of the nuclear era, there has never been a commercial solution for the large quantities of depleted uranium hexafluoride generated from uranium enrichment. In the United States alone, there is already in excess of 1.6 billion pounds (730 million kilograms) of DUF6 currently stored. INIS is constructing a commercial uranium processing and fluorine extraction facility. The INIS facility will convert depleted uranium hexafluoride and use it as feed material for the patented Fluorine Extraction Process to produce high purity fluoride gases and anhydrous hydrofluoric acid. The project will provide an environmentally friendly and commercially viable solution for DUF6 tails management.

15:30 Coffee Break

16:00 Paper 4780
URANIUM REFINING WITHOUT SOLVENT EXTRACTION
A. Bhowmik, P. Shanmugavelu, D. Dhavamani, A. Agrawal, S. Sarkar and T.K.Bera
Chemical Technology Group, Bhabha Atomic Research Centre, India

Uranium Refining is the process by which undesirable neutron absorbing elements such as Boron (B), Gadolinium (Gd), Dysprosium (Dy), Cadmium (Cd), Europium (Eu), Samarium (Sm) and other metals (Fe, Ni, Co, Ca, Mg etc.) are removed from the yellow cake. Generally, uranium refining is carried out by solvent extraction process, by using organic extractant such as Tri-n butyl phosphate (TBP) diluted with Kerosene. This process generates significant volume of nitrate bearing liquid waste and degraded organic. In order to eliminate the use of hazardous organic and anhydrous ammonia for uranium refining, altogether, a new process using hydrogen peroxide for selective precipitation of uranium from uranyl nitrate solutions has been developed. The precipitate is filtered and washed with DM water to obtain product meeting nuclear purity standards as per ASTM C–753-04. The product is spray dried and calcined to obtain uranium oxide. This process is simple as it integrates refining and precipitation process together. The new process is more environment friendly.
Uranium tetrafluoride, UF4, is produced at the Port Hope conversion facility by the reaction of uranium dioxide, UO2, with hydrogen fluoride in a wet process. Two of the important parameters for UF4 quality control of this process are the water content and the unreacted UO2 content. Water content is typically measured by weight loss during heating, while UO2 content is determined by measuring the ammonium oxalate insoluble content. A procedure was developed using thermal gravimetric analyses to simultaneously determine the water content by weight loss and the unreacted UO2 content through weight gain after oxidation.
Molten Salt Reactors and Uranium: A Perfect Fit?
D. LeBlanc1,2
1Physics Department, Carleton University
2Ottawa Valley Research Associates Ltd.

Molten Salt Reactors were chosen as one of the six Generation IV reactors due to their numerous advantages in terms of overall safety, low cost potential, minimal long lived waste and superior resource utilization. These reactors are typically thought of as operating on the thorium to 233U cycle. However, all these advantages and still more are also true of simplified designs that employ no fuel processing and run off Low Enriched Uranium while requiring only a small fraction the uranium needs of LWR or CANDU designs. This paper will review the great potential of this often overlooked mode of operation and introduce new proposed designs.

Global Outlook for Nuclear Power
F.H. Southworth
AREVA NP Inc., USA

The global nuclear power forecast, the North American outlook and the effect of nuclear power growth on greenhouse gas emissions in North America will be discussed. The construction of Generation III reactors will replace aging power plants and, further, add capacity that is environmentally sustainable. The outlook for Generation IV reactors also may significantly improve the environmental balance after 2030, both in electrical markets, waste reduction, and in non-traditional markets such as process heat.

The CANDU reactor has proven to be a strong performer in both the Canada, with 22 units constructed in Ontario, New Brunswick and Quebec, as well as in Argentina, Korea, Romania and China where a further nine units are operating and two in the planning stage. The average lifetime capacity factor of the CANDU reactor fleet is 89%. The last seven CANDU projects in Korea, China, and Romania have been completed on budget and on schedule. CANDU reactors have the highest uranium utilization efficiency measures as electricity output per ton of uranium mined. The CANDU fuel channel design using on-power fueling and a heavy water moderator enables flexible fueling options – from the current natural uranium option to burning uranium recovered from used LWR reactor fuel and even a thorium-based fuel. AECL and the CANDU reactor are poised to participate in the worldwide construction at least 250 new reactors over the next 20 years.

AN OVERVIEW OF NUCLEAR LEGISLATION AND REGULATORY FRAMEWORK IN INDIA
A.B. Awati and R.B. Grover
Department of Atomic Energy, India

The centrepiece of Indian legislation that deals with nuclear energy is the Atomic Energy (AE) Act, 1962, which was enacted to provide for the development, control and use of atomic energy for the welfare of the people of India, other peaceful purposes and matters connected therewith. It lays down basic principles and provisions relevant to nuclear energy and empowers the Central Government for its administration. Major provisions include control of radioactive and prescribed substances, exploration and mining of atomic mineral resources, control over production and use of atomic energy; carrying out research and activities for the development and use of atomic energy and protection from radiation hazards. The AE Act is supplemented by rules [regulations] and orders for the implementation of various provisions. Although it is the principal legislation that deals with nuclear energy, there are other regulations in the areas of mines and minerals, environment, health and safety, foreign trade and industry, which are inter-linked with certain provisions of the AE Act. This paper presents an overview of nuclear and related legislation and regulatory framework in India.
The Australian Government policy is to ensure that uranium mining, milling and rehabilitation is based on world best practice standards. A best practice guide for in situ recovery (ISR) uranium mining has been developed to communicate the Australian Government’s expectations with a view to achieving greater certainty that ISR mining projects meet Australian Government policy and consistency in the assessment of ISR mine proposals within multiple government regulatory processes. The guide focuses on the main perceived risks; impacts on groundwaters, disposal of mining residues, and radiation protection. World best practice does not amount to a universal template for ISR mining because the characteristics of individual ore bodies determine the best practice.

Ranger Uranium Mine operates under an Authorisation issued by the Northern Territory Government. In addition, the site is regulated by a set of Environmental Requirements attached to the uranium export permit issued by the Australian Government Department of Resources, Energy and Tourism. A Heap Leach facility proposed for the site could result in a third approval being issued, in accordance with the Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act). Finding the correct balance to regulate the mine in light of these approvals will be a challenge for the range of stakeholders involved in regulation and oversight of this operation.
There are fifteen accepted types of uranium ore deposits and at least forty subtypes readily identified around the world. Each deposit type has a unique set of geological characteristics which may also result in unique processing implications. Primary uranium production in the past decade has predominantly come from only a few of these deposit types including: unconformity, sandstone, calcrete, intrusive, breccia complex and volcanic ones. Processing implications can vary widely between and within the different geological models. Some key characteristics of uranium deposits that may have processing implications include: ore grade, uranium and gangue mineralogy, ore hardness, porosity, uranium mineral morphology and carbon content. Processing difficulties may occur as a result of one or more of these characteristics. In order to meet future uranium demand, it is imperative that innovative processing approaches and new technological advances be developed in order that many of the marginally economic traditional and uneconomic non-traditional uranium ore deposits can be exploited.

Among the uranium deposits in the Karoo sandstones of southern Africa, those in the Escarpment Grit Formation at Mutanga are particularly attractive because uranium occurs as uranyl phosphate rather than refractory oxides or silicates. The fluvial Escarpment Grit sandstones unconformably overlie the late Permian lacustrine Madumabisa Mudstone and are conformably overlain by the early Triassic fluvial Interbedded Sandstone and Mudstone Formation. The Mutanga deposits contain resources of 1.99 million lb. measured, 5.82 million lb. indicated and 13.2 million lb. inferred U₃O₈ at →286 ppm. The deposits are suitable for open-pit mining, and acid heap leaching. Autunite, as pore-filling crystals, and fracture/grain coatings, is the predominant uranium mineral, with minor brannerite and coffinite. The autunite likely formed from uranyl ions, oxidized and leached from primary uranium minerals following post-Karoo fault uplift, precipitated with dissolved phosphate and possibly concentrated following the Permian-Triassic extinction.

CSIRO is undertaking advanced mineralogical and elemental characterisation studies of low-grade and refractory Australian uranium deposits. Of particular interest are the calcrete-type uranium deposits of Western Australia. These deposits are found in playa lake sediments and channels which drain a uranium-rich source. The primary uranium mineral is carnotite. The ore is highly friable and is usually found in association with clayey and calcareous minerals, such as gypsum, dolomite and halite. This paper aims to provide a better understanding of the characteristics and formation of these calcrete-type uranium deposits to assist in the development of new and improved processing routes.

The Uranium Province of Lagoa Real is located in the mid-south region of Bahia State, Brazil. Uranium, occurring mainly in the form of uraninite, is the only economic mineral commodity. The region has been explored for uranium since 1971 and 35 anomalies were detected, distributed over 1200 km². Seven are classified as deposits, accounting for reasonably assured resources of 100,000 tonnes of U₃O₈. This paper describes the geological aspects of the area, the exploration and mining activities done so far by the state company INB and the perspectives for the near future, when an increase in the country’s uranium demand is expected.
10:30  Paper 5532
NON-TRADITIONAL URANIUM EXPLORATION TARGETS IN SOUTH AUSTRALIA
M.C. Fairclough1, T. Wilson1, T. Dhu1, G. Gouthas1, P. Heath1, S.A. Bosman2 and C.D. Card2
1Geological Survey Branch, Primary Industries & Resources, South Australia
2Saskatchewan Ministry of Energy and Resources, Canada

South Australia hosts two of Australia’s three operating uranium mines with another two anticipated to begin production in the near future. Traditionally exploration has largely focused on Iron oxide copper gold + uranium (c.f. Olympic Dam style) or sandstone-hosted (c.f. Beverley style) uranium targets. However, due to the ubiquitous uranium anomalism through the Mesoproterozoic crystalline basement in eastern South Australia, process-driven target generation indicates high potential for contemporary hybrids of different types, as well as younger unconformity-related or calcrete-hosted deposits. Translation of key mineralising processes into mappable criteria allows innovative targeting strategies to be developed for explorers in Greenfield areas.

11:00  Paper 5077
AGPAITIC NEPHELINE SYENITES FROM THE ILIMAUSSAQ COMPLEX, SOUTH GREENLAND; AN IMPORTANT NEW URANIUM ORE TYPE
J. L. Mair
Greenland Minerals and Energy Limited

The Ilimaussaq Intrusive Complex in south Greenland is a layered alkaline igneous body that is predominantly comprised of agpaitic nepheline syenites. The Complex is now recognized as containing vast resources of uranium in polymetallic ores that are also strongly enriched in rare earth elements (REEs) and zinc. Uranium and REEs are dominantly hosted in phosphate minerals with a minor proportion hosted in zirconium silicate minerals. Equivalent ores are yet to be mined for uranium anywhere in the world; however, studies are well advanced in confirming a process route to economically extract uranium. The Ilimaussaq Complex is considered the world’s type-locality for agpaitic rocks. Formation of the complex is attributed to four successive pulses of magma. Resources defined to date include 192 million lb. of U3O8 at 350 ppm within an overall resource of 282 million lb. of uranium oxide at a grade of 280 ppm. With scope for several other similar sized resources within complex, the overall potential resource is of immense global significance. Metallurgical studies to date indicate that uranium can be successfully extracted from black lujavrites via an alkaline pressure leach method. There is also scope to beneficiate ores as uranium and REEs are hosted in specific mineral groups. Phosphate minerals can be effectively concentrated by froth floatation and uranium-bearing silicate minerals can be concentrated by gravitational methods. Studies indicate that REEs can be extracted from the residue following the alkaline leach process by a dilute hydrochloric acid wash, with REEs then precipitated in the form of a REE concentrate.

11:30  Paper 5350
DISSOLUTION-PRECIPITATION PROCESSES ON THE SURFACE OF URANYL-MINERALS
M. Schindler
Department of Earth Sciences, Laurentian University, Canada

Understanding dissolution-precipitation processes on the surface of uranyl minerals is crucial for predictive modeling of U mobility in the subsurface. In order to understand how pH and type of cation in solution may affect these processes, dissolution experiments were performed on mainly single crystals of seven different uranyl-minerals. Uranyl mineral basal surface microtopography, micromorphology, and composition were examined prior to, and after dissolution experiments on micrometer scale specimens using Atomic Force Microscopy, Scanning Electron Microscopy, and, X-ray Photoelectron Spectroscopy. Surface precipitation of the following phases was observed: (a) a highly-hydrated uranyl-hydroxy-hydrate in ultrapure water; (b) a Na-uranyl-hydroxy-hydrate in Na2CO3 solutions (pH = 10.5); (c) Ba- and Pb-uranyl-hydroxy-hydrates in Ba-HCl and Pb-HCl solutions of pH 2; (d) a (SiOx(OH)4-2x) phase in solutions of pH 2 (only on silicates) and sulfate-bearing phases in solutions of pH 2 (only on sulfates). These results suggest that thin coatings form on the surface of almost all uranyl minerals independent of pH and composition, affecting hereby the dissolution of the underlying mineral and thus the release of U and other radionuclides to the environment.
Tuesday, August 17, 2010 AM
Room: William Pascoe

8:00 Paper 5938 - Keynote Speech
AREVA’S URANIUM MINING BUSINESS
V. Martin
AREVA Resources Canada Inc., Canada

In 2009 AREVA became the world’s 1st uranium producer. Historically, since the closure of all uranium mines in France, AREVA’s production was essentially coming from Canada and Niger. Most recently intense development in Kazakhstan contributed to AREVA’s ascension to its current leading position. AREVA’s production will continue to increase in Kazakhstan, in Canada and in Niger and preparations are under way for the launch of production in Namibia. AREVA plans to remain a major player in the long term, with its aggressive exploration program across the world. This is particularly true here in Canada with world-class projects such as Shea Creek in the Western Athabasca Basin and Kiggavik in Nunavut that will add during the coming decades to AREVA’s flagship state of the art uranium mill at McClean Lake and its participation in the two world largest uranium high-grade projects, the McArthur River mine and the Cigar Lake project scheduled for start-up in 2013.

9:00 Paper 4751
BOXHOLE MINING AT MCArTHUR RIVER
H. Goetz, V. Madenga and J. Callin
Cameco Corporation, McArthur River Operation, Canada

Raisebore mining is the current production method at Cameco’s McArthur River Operation. This mining method requires access development both above and below the ore zone. In areas of the mine, where access above the mining block is difficult, it is proposed to extract the ore by Boxhole mining from below. A test mining program commenced in 2009 at McArthur River to demonstrate the viability of this new mining method. This paper provides a description of the Boxhole mining method and summarizes the results obtained during the first year of testing.

10:00 Coffee Break
10:30  Paper 4901
A RELIABILITY-BASED DESIGN PROCEDURE FOR MINE DEWATERING SYSTEMS
R. Bashir 1,2, S.A. Imran3 and J.F.A. Hatley4
1 Golder Associates Ltd.
2 Department of Civil & Geological Engineering, University of Saskatchewan
3 Water Quality Modeling & Monitoring, NRC Center for Sustainable Infrastructure Research
4 Cameco Corporation

The presence of groundwater in the form of large aquifers can have an important influence on investment decisions for underground mines. The design for such mines requires development of special mining methods, and mine dewatering infrastructure to avoid hazards during shaft sinking and underground development. The costs associated with mine drainage control and mine dewatering systems (MDS) are relatively small compared to the huge consequential losses that can occur in case of an uncontrolled inflow and subsequent flooding of the mine. The design of MDS needs consideration of accurate prediction of the maximum uncontrolled inflow rate, availability of the system during an uncontrolled inflow while the inflow is mitigated, and decision on pumping system technology to have capability to operate under water. The research presented in this paper provides a theoretical framework for a reliability-based design procedure which takes into account the uncertainty in the estimate of the maximum uncontrolled inflow, performance of the system during the period of an uncontrolled inflow and a methodology to decide on appropriate pumping technology considering the reliability of the system and available underground storage. The reliability-based mine design procedure integrates the ideas of Effective Reserve and Hydraulic Reliability Index to come up with a unified methodology for design of Mine Dewatering Systems.

11:00  Paper 4838
GEOMECHANICAL ASSESSMENT FOR DRIFT AND CHAMBER DEVELOPMENT IN THE ATHABASCA BASIN
S. T. Yameogo
Cameco Corporation, McArthur River Operation, Canada

Much has been said about the methodology of geomechanical design in underground excavations. However, the geological, hydrogeological and geotechnical complexities encountered at the production horizons in the Athabasca Basin commanded a novel approach in geomechanical assessment and the design of underground openings. Geologists and mining engineers at Cameco McArthur River have been able to establish a practical methodology that goes beyond conceptual approaches. In this paper, the author describes the original challenges and unique approach in the geomechanical assessment for access drift and extraction chamber development.
Joint Venture Inkai, owned by Cameco Corporation and KazAtomProm, is located in Kazakhstan and represents one of the world’s richest uranium deposits that would be suitable for extraction by in-situ recovery methods using a strong acid leach. This property has undergone the transition from exploration to development to fully operational as of late 2009, with the completions of surface processing facilities with a capacity of 2000 tU per year, and the further development of wellfields. This presentation will highlight the history of the test leach results at Inkai, the early experiences of wellfield development and performance improvement, and the design, construction, commissioning and operations of the processing facilities.

Aurora Energy Resources Inc. is proposing to build and operate a 10,000 t/d process plant to produce 97 million pounds of U3O8 over a seventeen-year project life from deposits in coastal Labrador. This paper summarizes the testwork, generally done by SGS Mineral Services in Lakefield, Ontario, and the economic studies that support flowsheet selection. The selected flowsheet includes SAG and ball milling, acid leaching using air/SO2 as an oxidant, and resin-in-pulp (RIP) extraction of uranium from the leached slurry. Other unit operations examined include ore sorting, heap leaching, liquid-solid separation, solvent extraction, and nanofiltration for eluate upgrading. We also review the extensive programs of environmental testwork and studies that were completed.

Midwest is a unique uranium deposit with exceptionally high arsenic content. The ore body is located 17 km west of the McClean Lake operation. The McClean Lake mill will be modified to process Midwest ore and handle solid wastes from the Midwest water treatment plant. This paper describes the modifications required of the McClean Lake mill, process challenges associated with treatment of the arsenic, and the possibility of recovering nickel and cobalt as a by-product. It also reviews the complexity in the design of the Midwest water treatment facility which incorporates reverse osmosis technology with conventional physical-chemical water treatment.
Toro Energy Ltd. has identified a resource of 20.2 million tonnes at a grade of 548 ppm U3O8 at Wiluna, Western Australia. Calcrete and clay delta formations host the uranium mineral carnotite. Initial studies indicate a mining operation is technically, environmentally and commercially viable. Increase in demand for uranium and a change in State Government policy on uranium mining have lead Toro to proceed with a bankable feasibility study and commence approvals with State and Federal Governments. This paper discusses how Toro arrived at the decision to utilise alkaline heap leach, a process not widely used, and how it is being developed.

The uranium deposits of Elkon district are located in the south of Republic of Sakha Yakutia. Deposits contain about 6% of the world known uranium resources: 342 409 tonnes of in situ or 288 768 tonnes of recoverable RAR + Inferred resources. Most significant uranium resources of Elkon district (261 768 tonnes) were identified within five deposits of Yuzhnaya zone. The uranium grade averages 0.15 %. Gold, silver and molybdenum are by-products. Principal resources are proposed to be mined by conventional underground method. Location, shape and dimensions of uranium orebodies are primarily controlled by NW-SE oriented and steeply SW dipping faults of Mesozoic age and surrounding pyrite-carbonate-potassium feldspar alteration zones. Country rocks are Archean gneisses. Deposits are of metasomatic geological type. Principal mineralization is represented by brannerite. The Yuzhnaya zone is about 20 km long. It was explored by underground workings and drill holes. Upper limit of orebodies is at a depth of between 200 m and 500 m. Depth persistence exceeds 2,000 m. Uranium mining enterprise Elkon was established in November 2007. It is a 100% Atomredmetzoloto (ARMZ) subsidiary. The planned producing capacity is up to 5000 Mt U/year. It will perform the entire works related to uranium mining, milling, ore sorting, processing and uranium dioxide production. Technology of ore processing assumes primary radiometric sorting, thickening, sulphide flotaton for gold concentrate extraction, subsequent autoclave sulphuric-acid uranium leaching from flotation tails and uranium adsorption onto resin, roasting and heap leaching for uranium from low grade ores, cyanide leaching of gold. Due to a considerable abundance of brannerite, the ore is classified as refractory. Elkon development include 4 main stages: feasibility study and infrastructure development (2009-2011), mine and mill construction (2012-2015), pilot production (2013-2015), mine development and achieving full capacity production (2016-2024).
Uranium process plant design offers a wide variety of potentially feasible options that include equipment, processes and procedures used in the past, in use now, and that could be considered for future use. Process design options should be selected to reduce costs, improve efficiencies, effect safer operations, and lessen environmental impacts. This paper suggests concepts for consideration in selecting equipment, processes and procedures for uranium process plant design through the whole operation from ore intake to final product preparation.

The effects of leach parameters to determine the variability of reagents consumption on a uranium ore was investigated in this work. The effects of time, temperature, sulphates, and acid consumption on the rate of dissolution of the comminuted uranium ore samples were also studied. It was found that 77% dissolution of uranium was achieved after 8 hours at temperature 30°C. The addition of ferric sulphate at 30°C showed a decrease in acid consumption from 79.32 to 32.32 kg/t as well as decrease in the MnO₂ consumption from 21.03 to 15.06 kg/t. At elevated temperature of 60°C a higher acid consumption of 100 kg/t was realized and this is attributed to the fact that other acid consuming minerals were leached at this temperature. Maximum uranium dissolution of 89.37% was achieved after 24 hours and the acid consumption was 31 kg/t with a MnO₂ addition of 24.26 kg/t.

Cameco Corporation is in the process of revitalizing the mill at its Key Lake operation in northern Saskatchewan. The current Key Lake process employs ammonia stripping and ammonia precipitation. As part of the revitalization, the company is considering installing strong acid stripping in solvent extraction as used at its Rabbit Lake operation. This change would lead to using hydrogen peroxide for uranium precipitation. As part of the process evaluation, tests were carried out to study how changes in the temperature of an indirect fired dryer affected the properties of uranium peroxide [yellowcake] precipitate. This paper discusses the results of the test work, including the relationships between drying temperature and the following:

Uranium plants are generally located quite far from conversion plants, resulting in high transport costs. One way of reducing such costs involves putting more uranium in each drum by increasing the final product’s bulk density, which can be achieved via mechanical compaction of the powder and/or improved precipitation. For most of its plants, AREVA has adopted the latter approach, involving a new precipitation process applicable to all kinds of yellowcake produced (via uranates, uranium peroxide, etc.) that achieves bulk density of 3 for soda urinate, for example, instead of the 1.5-2 density available via conventional processes. At present, this process is being undertaken on an industrial scale and will become the norm for precipitation processes at all AREVA U plants. In addition to producing dense yellowcake, the process also delivers a product with no fines, a spherical particle shape (which allows for high-quality powder flow) and superior post-precipitation filterability.
Engineered Membrane Separation® (EMS®) technology has been applied successfully in the nuclear industry for many years for both processing and environmental applications. Radionuclides do not harm polymeric UF membranes or Thin-Film Composite membranes. In addition, these polymeric membranes are stable in both strong acid and strong base solutions, and are therefore well suited to concentrate radioactive nuclides effectively from process or waste water applications. The range of specific applications for EMS® technology include separating uranyl sulfate and nitrate from acids, fractionation of radionuclides from boron in reactor moderation water, and the removal of radionuclides from contaminated ground water sources.

Bioleaching, the microbial dissolution of minerals, is potentially useful in exploiting a variety of ore deposits, including the lower-grade uraniferous quartz-pebble conglomerate beds of the Quirke Syncline, Elliot Lake, Ontario. The metabolism of chemolithotrophic bacterium Acidithiobacillus ferrooxidans is dependent on its ability to derive energy and reducing power from the oxidation of ferrous iron. The characteristics of this bacterium, in particular the ability to oxidize both iron and sulphur with an associated high tolerance of low acidity, allow the organism to contribute significantly to bioleaching processes. Under ideal conditions, A. ferrooxidans promotes the oxidation of iron-containing sulphide ore materials, breaking their crystal structure and promoting the dissolution of iron, base metals, as well as uranium, rare earth elements and associated elements of toxicological interest such as arsenic and selenium. The current study documents an overview of the recovery of uranium and rare earth elements to solution, plus investigates the acid generating potential of the solid residues from a series of environmentally controlled, biologically-mediated uranium ore extraction experiments. The findings will be used in the design of larger scale bioleaching experiments to further assess the potential for success of bioleaching as a metallurgical extraction technique potentially leading to minimum maintenance decommissioning strategies for the ore deposits of the Quirke Syncline.
Nuclear power is experiencing a renaissance and stable growth all over the world and is emerging as one of the leading options for meeting the ever increasing demand for electricity, avoiding greenhouse gas emissions and global warming. Presently, some 437 Nuclear Power Reactors are in operation in 30 countries with total installed power of ~370 GWe, generating ~14.5% of global electricity. According to the projection of the International Atomic Energy Agency (IAEA), the installed nuclear power is likely to be in the range of 748 GWe by 2030.

Natural Uranium is the basic raw material for nuclear fuel. It contains U235, the only fissile isotope in nature, and U238 which could be transmuted in a reactor to man-made element Plutonium, which has Pu239 and Pu241 fissile isotopes. Light Water Reactor (LWR) system is most common and account for nearly 90% of the operating nuclear power reactors, followed by the Pressurized Heavy Water Reactor (PHWR) system which contribute to some 6%. The LWRs and PHWRs use Low Enriched Uranium (LEU) containing up to 5% U235 and natural uranium (0.7% U235) as fuel respectively, in the form of high density uranium oxide pellets. Nuclear power reactor and fuel cycle activities go hand in hand. The front end of uranium fuel cycle consists of exploration and mining of uranium ores, their milling, purification and refining to UO3, conversion to natural UO2 powder for fabricating PHWR fuel and to UF6 followed by U235 enrichment (up to 5%) and conversion to LEU di-oxide powder for LWR fuel. The UO2 powder is subjected to pelletization, sintering and center less grinding to obtain fuel pellets which are encapsulated in zirconium alloy cladding tubes to form fuel pins that are subsequently clustered to form fuel assemblies. The major challenges in front end of uranium fuel cycle are meeting the growing annual demand of uranium, increasing fuel burn up and ensuring high performance and zero defect of fuel.

The present paper summarizes the recent development in the front and back end of uranium fuel cycle, highlighting the fuel development activities for thermal and fast reactors.
density functional theory is used in this calculation. The total energy technique is implemented to investigate changes in the lattice constants. The ab-initio calculations predict a 36-38% increase in the volume per uranium atom when transforming from UO2 to U3O8, which agrees very well with experimental data. The implication of this prediction on the linear expansion and fragmentation of fuel is discussed. The calculated elastic constants of urania are in good agreement with experiments. The predicted mechanical properties of UO2 and U3O8 are compared.

10:00 Coffee Break

10:30 Paper 4864
**MODELLING OF THE TETRAVALENT URANIUM OXALATE PRECIPITATION IN A VORTEX REACTOR AT STEADY STATE**
*M. Bertrand, E. Plasari, N. Lamarque, O. Lebaigue, F. Ducros*

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Oxalic precipitation is usually applied to process radioactive wastes or to recover actinides from a multicomponent solution. Precipitation reactions being highly sensitive to many operation parameters, the computer simulation appears to be a very effective tool to forecast the evolutions of the system subjected to various operating conditions. This study focuses on the tetravalent uranium oxalate precipitation modelling which combines population balance and hydrodynamics. The objective of this work is to show how flow pattern inside the precipitator can have a noticeable effect on the precipitate properties.

11:00 Paper 5925
**FUEL FABRICATION ACTIVITIES FOR POWER REACTORS IN INDIA – PRESENT AND FUTURE PROSPECTS**
J. Raigiri Narayana
Nuclear Fuel Complex, India

Based on the initial developmental works and pilot plant studies carried out at Bhabha Atomic Research Centre (BARC), Mumbai, the Nuclear Fuel Complex (NFC) was established as an industrial unit during early 1970s to manufacture fuel assemblies and reactor core structural for PHWRs and BWRs. The Plants consisting of Uranium and Zirconium streams process raw materials in form of Magnesium Di-Uranate (MDU) and Zircon Sand respectively to fabricate finished fuel assemblies. Presently, 17 PHWRs and 2 BWRs are operating in India, generating about 4340 MWe of electricity. The reload fuel assemblies for all these Reactors are manufactured at NFC in addition to the reactor structural use of Coolant Channels and Calandria Tubes. In tune with the decision of the Department of Atomic Energy to set-up twelve PHWRs of 700 MWe capacity, NFC has embarked on expansion programme to manufacture fuel for all these Reactors. In addition, the plans are afoot to set-up fuel fabrication facilities for catering to the needs of large number of imported Light Water Reactors (LWRs), in collaboration with the fuel manufacturers abroad. The Paper highlights the present scenario and the future plans for fabrication of nuclear fuel assemblies for both indigenously built and imported Reactors.

11:30 Paper 5367
**PLUTONIUM ROCK-LIKE OXIDE FUEL (ROXF) SYSTEM, THEIR ONCE-THROUGH BURNING AND USAGE**
A. E. Mohamed
Brno University of Technology, Czech Republic

The ROXf is a kind of inert matrix fuel U238-free matrices, it has a high plutonium transmutation capability. The ROXf consists of chemically stable phases of fluorite stabilized ZrO2 or ThO2 and spinel MgAl2O4. In this fuel, PuO2 is solidified in a fluorite phase. With U238-Free matrices, a large part of the plutonium can be burned after irradiation in conventional LWRs. The spent ROXf consists of natural analogous geologically stable phases, and is disposed directly as high level wastes ‘HLWs’ after about 50 years cooling. From the high plutonium burn up rate and the high stability of the fuel, the ROXf-LWRs system has proliferation resistance and environmental safety. Characteristics of two types of ROXf, Zr-ROX and Th–ROX with weapons-Pu, in an LWR core arrangement are evaluated by cell burn up calculations and 2-D core calculations using the SRAC code system and JENDL-3 nuclear library. In an LWR of moderator to fuel volume ratio = 1.9, which corresponds to current PWRs, Pu transmutation rates with the two types of ROXf are large enough and more than 80% and 99% of Pu and Pu239, respectively, can be burned. The calculated kinetic parameters indicate less moderate characteristics of ROX cores, especially with Zr-ROX. The fertile Th232 in Th-ROX works like U238 in the UO2 fuel, making kinetic parameters more moderate and reactivity drop due to burn up smaller than that Zr-ROX. The neutron capture of Th232 to generate U233, causes the safeguards problem. Thus, the characteristics of Zr-ROX as a typical example, were investigated in this study.
URANIUM EXTRACTION HISTORY USING PRESSURE LEACHING
*K.S. Fraser and K.G. Thomas
1HATCH, Canada
2Kinross Gold Corporation, Canada

Over the past 60 years of uranium process development only a few commercial uranium plants have adopted a pressure leaching process in their flowsheet. The selection of acid versus alkaline pressure leaching is related to the uranium and gangue mineralogy. Tetravalent (U+4) uranium has to be oxidized to hexavalent (U+6) uranium to be soluble. Refractory tetravalent uranium requires higher temperature and pressure, as practised in pressure leaching, for conversion to soluble hexavalent uranium. This paper chronicles the history of these uranium pressure leaching facilities over the past 60 years, with specific details of each design and operation.

THE EFFECT OF OXIDATION-REDUCTION POTENTIAL AND FERRIC IRON CONCENTRATION ON LEACHING OF URANIUM ORES
M. Maley, S. Burling and R. Ring
ANSTO Minerals, Australia

The many number of uranium deposits around the world vary significantly in their mineralogy, grade and textural characteristics. Therefore, information from traditional or conventional sources regarding the fundamentals of leaching the uranium and gangue minerals is not always applicable when studying particular ores. Empirical studies on particular ores can be effective in understanding leach systems and can lead to improvements in process design, but there remains a lack of fundamental understanding which is necessary for ongoing process optimisation as ore bodies continue to vary. ANSTO Minerals has undertaken a program of work to address some of the fundamental questions of uranium leaching, including the unexpected impact for some ore types of leaching at high oxidation potential.
9:30 Paper 4857
THE EFFECT OF VARIOUS HALIDES ON THE DISSOLUTION OF SYNTHETIC URANIUM DIOXIDE (UO2)
R. Ram, F. Charalambous, J. Tardio and S. Khargava
Advanced Materials and Industrial Chemistry group, School of Applied Sciences, RMIT University, Australia

The naturally occurring mineral tetravalent uraninite (UO2) is one of the major raw products used to produce nuclear fuel grade uranium. Increasing demand for uranium has led to significant interest in improving the efficiency of UO2 dissolution, particularly from complex, low grade uranium ores. In this study the influence of F- and Cl-, [Fe3+] and oxidation reduction potential on UO2 dissolution were investigated. F- was found to have a significant effect on UO2 dissolution under the conditions studied, with a significant decrease in UO2 dissolution occurring with increasing F- concentration. [Fe3+] also was found to have a significant effect on UO2 dissolution. The mechanism of UO2 dissolution under different conditions is also discussed.

10:00 Coffee Break

10:30 Paper 4906
CHARACTERISATION AND DISSOLUTION STUDIES ON VARYING FORMS OF BRANNERITE
F.A. Charalambous, R. Ram, J. Tardio and S.K. Bhargava
Advanced Materials and Industrial Chemistry group, School of Applied Sciences, RMIT University, Australia

Brannerite is commonly referred to as refractory uranium mineral as it is usually highly resistant to acid leaching. There is however widely varying literature data on brannerite leaching, with some studies reporting that brannerite leaching can be achieved under relatively mild conditions. The differences observed for brannerite leaching are most likely due to the high degree of variation in the composition and structure observed in natural brannerites. These aspects of brannerite chemistry however are not very well understood due to a lack of fundamental research. The aims of this study were to investigate and develop methods for synthesising brannerites of varying composition and to investigate the effects of composition on brannerite leaching in acidic conditions.

11:00 Paper 4841
THE DETERMINATION OF SELENIUM AND MOLYBDENUM DISTRIBUTION IN URANIUM ORE AND MILL SOLIDS
G. Heinrich1, K. Kyser2, D. Chipley2 and E. Lam1
1Innovation & Technology Development – Research Centre, Cameco Corporation
2Department of Geological Sciences and Geological Engineering, Queen’s University

The distributions of molybdenum and selenium in solid compounds in uranium ores and mill streams were studied. The methodology consisted of LA-ICP-MS analysis of mineral grains and of physical sample separation and subsequent characterization of the mineral concentrates by chemical analyses and X ray diffractometry followed by correlation of the assay data. Results of the study indicated that selenium and molybdenum in the ore samples were not only present in sulphides, but to an even greater extent in phyllosilicates and uraninite, whereas in mill solids, they were absent in gypsum and likely adsorbed on iron hydroxides.

11:30 Paper 4800
BIOMINERAL PROCESSING OF HIGH APATITE CONTAINING LOW GRADE INDIAN URANIUM ORE
Abhilash1, K.D. Mehta1, B.D. Pandey1, L.Ray2, P.K.Tamrakar3
1MEF Division, National Metallurgical Laboratory (CSIR), India
2FTBE Dept., Jadavpur University, India
3CR&D Dept., Uranium Corporation of India Limited, India

Microbial species isolated from source mine water, primarily an enriched culture of Acidithiobacillus ferrooxidans was employed for bio-leaching of uranium from a low-grade apatite rich uranium ore of Narwapahar Mines, India while varying pH, pulp density (PD), particle size, etc. The ore (0.047% U3O8), though of Singhbhum area (richest deposit of uranium ores in India), due to presence of some refractory minerals and high apatite (5%) causes a maximum 78% recovery through conventional processing. Bioleaching experiments were carried out by varying pH at 35°C using 20%(w/v) PD and ≤76 μm size particles resulting in 83.5% and 78% uranium bio-recovery at 1.7 and 2.0 pH in 40 days as against maximum recovery of 46% and 41% metal in control experiments respectively. Finer size (<45 μm) ore fractions exhibited higher uranium dissolution (96%) in 40 days at 10% (w/v) pulp density (PD), 1.7 pH and 35°C. On increasing the pulp density from 10% to 20% under the same conditions, the bio-recovery of uranium fell down from 96% to 82%. The higher uranium dissolution during bioleaching at 1.7 pH with the fine size particles (<45 μm) can be correlated with increase in redox potential from 598 mV to 708 mV and the corresponding variation of Fe(III) ion concentration in 40 days.
Joachimsthal in Saxony was an important silver mining district since the Middle Ages when around the 1770s production started to decrease and the mining town was about to become a ghost town. It was at that time that Martin Heinrich Klaproth (1743-1817), a pharmacist in Berlin who later became a professor of chemistry at the Royal Mining Academy, discovered that the black mineral in the ore can be used to give glass a brilliant yellow color with green fluorescence when added to the molten batch. He was also convinced that this mineral must have contained a new metal. This discovery coincided with the discovery in 1781 of a new planet in the solar system by his compatriot William Herschel who had immigrated to England in 1757 and called the planet Uranus. Hence Klaproth named the new metal "uranium" to honor his compatriot. In 1789 he was able to isolate a black heavy solid from the ore which he thought to be the new metal. Since that time uranium started to play a dominant role in the history of civilization that will be told briefly.

The IAEA’s programmes encompass all aspects of the uranium production cycle, (UPC). The IAEA collaborates with member states to organize training activities, workshops and technical meetings that promote good practices in UPC. The present paper presents an international, interactive and web based initiative, UPNET, Uranium Production Network for Education and Training. Ramp-up of uranium production to 2030 will see new mines starting with lower grade resources after 25 years of UPC stagnation. Many emerging operations are based in countries with limited skills and experience. Constraints with people who can teach, train and consult are expected. Good practices in UPC by qualified personnel can help develop economically viable operations and avoid environmental legacies which have characterized many uranium mining projects in earlier times. Creation of an international network for training and education in UPC would be a substantial step forward in resolving the rising demand for skilled personnel. Developing contacts with potential participants and contributors has begun. A meeting of specialists is planned to promote a vision, framework and structure of the network; meanwhile development of the systems at IAEA that will carry the network has begun and these will be configured to suit UPNET as well as other networks that serve topics across IAEA’s Nuclear Fuel Cycle program.

Uranium production is cyclic and for most of the past 25 years it has been at a low point. The price increase that began in 2003 has steadied now after reaching record values in 2007; but exploration is now surging ahead – in 2009 we saw at least three new mines commence production. But the personnel to support all these activities, both operators and regulators, are a dwindling and ageing group with few replacements available and few young people entering the industry over the past 25 years. The skills shortages we are experiencing cover a wide variety of disciplines. How is the global uranium industry going to cope with the staff needs for the expansion that is happening? Both operators and regulators face a crisis. This paper examines the current situation and discusses options for the future.

RMIT University has recently introduced new teaching and research training programs on uranium processing technology at both undergraduate and postgraduate level. These programs have been implemented to improve young scientists and engineers’ awareness of Australia’s uranium processing industry, and to help provide future employees with improved background knowledge to the industry. The teaching program involves joint course development and lectures delivered by the leading scientists from ANSTO (Dr Suzanne Burling and Dr Chris Griffith) and Rio Tinto (Dr Stephen Grocott). This lecture series, which is offered to final year applied science and chemical engineering students, covers a range of topics and issues related to uranium processing including uranium mining, methods for characterising uranium ores, extraction of uranium, the nuclear fuel cycle, waste and safety. The research training program involves honours and PhD students undertaking research projects on uranium mineralogy and uranium
extraction. Research students are also provided with extensive training on how to conduct research safely using radioactive materials. The research programs are undertaken in RMIT’s new EPA approved, low level radiation laboratory which has been dedicated to research projects on uranium processing. An extended overview of both of these new programs will be presented. This program is unique in Australia and is designed to address the issue of skill shortage in the ever growing Uranium industry world wide. International collaborators in this program will be most welcomed.

16:30 Paper 4750
CANADA’S MMP (MAINTENANCE MANAGEMENT PROFESSIONAL) EDUCATION AND CERTIFICATION PROGRAM
Norman Clegg¹ and Vince Rae²
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²Fuel Services Division, Cameco, Canada

PEMAC (Plant Engineering and Maintenance Association of Canada) is a national not for profit association providing global leadership, education and certification in world class maintenance, reliability and physical asset management practices. This presentation will introduce the MMP (Maintenance Management Professional) education and certification program and its 8 Modules. You will see the learning elements and learning outcomes of each of the 8 Modules which are delivered through selected colleges, institutes and universities across Canada using in-class, on-site and live, on-line formats in both official languages.

17:00 Paper 4752
THE IAEA ACTIVITIES SUPPORTING IMPLEMENTATION OF BEST PRACTICE IN URANIUM PRODUCTION CYCLE
J. Slezak
International Atomic Energy Agency, Austria

Since the International Atomic Energy Agency’s foundation in 1957, the Agency has had an increasing interest in uranium production cycle (UPC) developments. Recent activities cover tasks on uranium geology & deposits, exploration, mining & processing including environmental issues. The two projects titles are (1) Updating uranium resources, supply and demand and nuclear fuel cycle databases and (2) Supporting good practices in the UPC in particular for new countries. Based on the recent experience, one of the new activities is focused at human resources development to improve application of best practice called Uranium Production Cycle Network (UPCNet).
This paper presents a brief outline of the uranium industry in India. In particular, the mining, ore processing and tailings management technologies used in operations of the Uranium Corporation of India Ltd. (UCIL) are described. Challenges to meet the increasing demand of uranium and to expand the nuclear energy sector are outlined. Future prospects, including indigenous efforts and overseas opportunities, are explored.

Until the mid-nineties of the last century, uranium mining belonged to important industries in the Czech Republic and, the Czech Republic occupied a leading position in the world in the production of uranium concentrate. A considerable phasing out of this industry in the first half of the nineties in the last century led to the closure of almost all underground uranium mines; at present they are decommissioned and flooded. Mining operations are performed in only one underground mine in the deposit of Rožná with the expected cessation of mining by the year 2015. The present-day home production of uranium meets only 45% of the demand of the Czech nuclear power industry and is secured from three sources, namely from the production of the deposit of Rožná, from the treatment of mine waters flowing from closed underground uranium mines and from the remediation of the rock environment of the deposit of Stráž. With the proven reserves of more than 100,000 t of natural uranium not mined at present, the Czech Republic still represents a potentially significant uranium producer.

The Eagle Point Mine is part of the Cameco Rabbit Lake Operation. The mine produces uranium ore using the long-hole, vertical and horizontal retreat mining method. The majority of the mine workings are under Wollaston Lake and cementitious grouting is used as one of the water control measures. Historical groundwater table in the mining area was close to ground surface. The Lower 163 Zone encompasses an estimated 4.2 million pounds U₃O₈ geological resource that was not considered feasible to mine due to the expected groundwater flows in the area. Cross-hole testing was conducted to better understand the groundwater flow through various geologic units. A local depressurization test was conducted to assess the potential for lowering the water table. Following testing an active depressurization was conducted to lower the groundwater table below the planned mining areas. This resulted in safe and drier mining conditions and allowed for the successful extraction of the ore body.
Many methods of geohazard risk management have been developed for various applications, including for mining industries and protection of highway infrastructure. The most common instrumentation used for management of geohazards is vibrating wire piezometers, slope inclinometer casings, strain gauges, and weather stations (a partial list). Monitoring requirements for instrumentation typically depend on the potential risk of a monitoring site. Alternatives for monitoring vary from occasional manual monitoring to sensors connected with near real-time monitoring capability and alarms that automatically distribute notifications to defined individuals. This paper describes a few common geohazard risk management methods used in the mining industry, the monitoring options that are available, and some considerations when developing monitoring plans.
14:00 Paper 4885
THE PAREX CODE: A POWERFUL TOOL TO MODEL AND SIMULATE SOLVENT EXTRACTION OPERATIONS
C. Sorel, M. Montuir, V. Pacary, H. Roussel, B. Dinh, P. Baron
CEA, Nuclear Energy Division, Radiochemistry & Processes Department, Chemistry of Separation Processes Service, Recycling Processes Modelling Laboratory, France

The PAREX code has been developed since the 1990s by CEA and AREVA to describe the PUREX process implemented in the French fuel reprocessing plants. It enables the calculation, either in steady or transient states, of the behaviour of the different elements of interest at each process step. The highly customized structure of the software allowed the implementation of various phenomenological models describing solvent extraction systems dedicated to uranium purification from crude ore to spent fuel. After qualification of the implemented models, the code was used to perform the design of flowsheets, for safety demonstration analysis or for operational assistance.

14:30 Paper 4846
ON STREAM ANALYZER, ONE MORE TOOL IN OUR TOOL BOX
B.A. Just and M.J. Galbraith
AREVA Resources Canada Inc. Canada

The AREVA Resources Canada Inc. McClean Lake uranium processing facility experienced serious operational challenges in handling crud formation. In order to assist in troubleshooting the performance of the Solvent Extraction circuit, the company purchased and installed an On Stream Analyzer (OSA). This presentation will share the benefits and challenges encountered with the commissioning of the OSA. It will also elaborate on unexpected benefits beyond solvent extraction.

15:00 Paper 4888
THE SIMPLE SOLUTIONS CONCEPT: A USEFUL APPROACH TO ESTIMATE DEVIATION FROM IDEALITY IN SOLVENT EXTRACTION
C. Sorel and V. Pacary
CEA, Nuclear Energy Division, Radiochemistry & Processes Department, Chemistry of Separation Processes Service, France

The solvent extraction systems devoted to uranium purification from crude ore to spent fuel involve concentrated solutions in which deviation from ideality can not be neglected. The Simple Solution Concept based on the behaviour of isopiestic solutions has been applied to quantify the activity coefficients of metals and acids in the aqueous phase in equilibrium with the organic phase. This approach has been validated on various solvent extraction systems such as trialkylphosphates, malonamides or acidic extracting agents both on batch experiments and counter-current tests. Moreover, this concept has been successfully used to estimate the aqueous density which is useful to quantify the variation of volume and to assess critical parameters such as the number density of nuclides.

15:30 Coffee Break

16:00 Paper 5885
URANIUM SOLVENT EXTRACTION CIRCUITS: OPERATIONAL CHALLENGES AND ADJUSTING TO UNIQUE PROCESS CONDITIONS
J. Bender1, M. Virnig1, A. Nisbett1, P. Crane2, M. Mackenzie3 and K. Dudley4
1Cognis Corporation, Mining Chemicals Technology, USA
2Cognis Australia Ltd., Mining Chemicals Technology, Australia
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4Consultant, KDHC Pty Ltd, South Australia

Uranium solvent extraction (USX) is a mature technology that was first successfully employed in the 1950s. It involves the use of a tertiary amine in a diluent to extract uranyl sulfate anions. USX processing and the quality of the product can be affected by impurities in the leach liquor. These impurities can also interfere with the chemical or physical aspects of the SX process. Ore mineralogy will dictate the quantity and type of impurities that will be present in the resulting leach liquor. While the transfer of the majority of impurities into the final product is undesirable, an additional concern is that they can negatively affect routine plant operations. Because the extraction mechanism is a simple ion-pairing, there is a competition between any anions for protonated amine. The relative selectivity of an anion and its concentration in the pregnant leach solution (PLS) dictate the degree of extraction. For a plant to run optimally, it is essential that the composition of the incoming feed is determined. It is important to acknowledge that each operation is somewhat unique, and that the pregnant leach solution generated from leaching will be influenced by the ore and gangue mineralogy, site water quality, and water balance issues specific to that site. Therefore, the information and philosophy outlined in this article serve to provide a generic approach that can be potentially applied and adapted to any site or project.
Mined uranium (U) ore often contains relatively high concentrations of elements (other than uranium) that may be deleterious to the environment. These include molybdenum (Mo) and selenium (Se), which are liberated from uranium oxides and associated sulphide minerals during milling processing. A critical environmental concern in the U mining industry is the possibility of long-term mobilization of elements such as Mo and Se from tailings deposited in in-pit tailings facilities to regional groundwater systems. In this study, x-ray absorption spectroscopy (XAS) was used to study the molecular speciation of these elements of concern (EOC) in samples from the Deilmann Tailings Management Facility (DTMF) at Key Lake in northern Saskatchewan, Canada. An understanding of Mo and Se speciation will help to characterize their long-term stability and evolution in the mine tailings. Results indicate Mo exists mainly as molybdate (+6 oxidation state) and Se exists mainly as selenite (+4 oxidation state). Linear combination fitting (LCF) analysis of the Mo K-edge XANES spectra on tailings samples using standard reference compounds suggests various proportions of NiMoO₄ and CaMoO₄ complexes as well as molybdate adsorbed onto ferrihydrite.
URANIUM FUEL MANUFACTURE II

Tuesday, August 17, 2010 PM
Room: Kelsey

14:00  Paper 5368
LICENSING APPROACH FOR LOW ENRICHED URANIUM
P. Desiri
GE Hitachi Nuclear Energy Canada Inc., Canada

The newly designed Advanced CANDU© Reactor technology utilizes enriched uranium as the fuel source. GE Hitachi Nuclear Energy Canada Inc (GEH-C) has partnered with AECL to develop and manufacture this enriched fuel. As part of this program, GEH-C required a licence to manufacture low enriched uranium fuel. A project description for the manufacture of low enriched uranium fuel bundles was first submitted to the CNSC in May of 2007. The hearing for both the licence amendment and environmental assessment was held January 13, 2010 and an amended licence was granted Feb 15, 2010. Several challenges were encountered during the licensing process, particularly in regards to the public consultation aspects of the project. This paper will summarize the approach taken to obtain a licence to produce low enriched uranium fuel at enrichments up to 5%. It will include the technical requirements, as well strategies to overcome various licensing challenges.

14:30  Paper 5403
TRANSITIONING TO LARGE VOLUME ENRICHED FUEL MANUFACTURE
A. Pant¹, M. Longinov² and W. Newmeyer²
¹Cameco Fuel Manufacturing, Canada
²Nuclear Safety Associates, Canada

Cameco Fuel Manufacturing (CFM) has a long history of low enriched uranium (LEU) fuel manufacture for development and specialty applications. The recent LVRF initiative necessitated extending the protocols used for small scale manufacture so that large volume production of the ~ 1% enriched material could be safely deployed in accordance with regulatory guidelines. This paper will discuss some of the technical and cultural changes that were initiated in order that a successful transition could be effected. In particular, the unique manner in which criticality safety principles were developed and embedded in the mind-set of the personnel as well as the robustness of the engineering design will be discussed.

15:00  Paper 5377
DESIGN AND DEVELOPMENT OF AN AUTOMATED URANIUM PELLET STACKING SYSTEM
B.S. Riess and S.B. Nokleby
University of Ontario Institute of Technology, Canada

A novel design for an automated uranium pellet stacking system is presented. This system is designed as a drop-in solution to the current production line to enhance the fuel pellet stacking process. The three main goals of this system are to reduce worker exposure to radiation to as low as reasonable achievable (ALARA), improve product quality, and increase productivity. The proposed system will reduce the potential for human error. This single automated system will replace the two existing pellet stacking stations while increasing the total output, eliminating pellet stacking as a bottleneck in the fuel bundle assembly process.

15:30  Coffee Break

16:00  Paper 5378
AUTOMATED FUEL INSPECTION
J. Vanderlaan and S.B. Nokleby
University of Ontario Institute of Technology, Canada

A proposed method of applying high-speed, non-destructive testing (NDT) technologies to the inspection process of UO2 (uranium dioxide) fuel pellets is presented. The scanning process examines each pellet individually for correct surface roughness and any surface imperfection or defects. Three inspection technologies are investigated: laser scanning of surface roughness, 2D laser scanning, and vision systems. The complete circumferential surface inspection of the pellet can be achieved using a combination of these three technologies.

16:30  Paper 5458
ROLE OF CRYSTAL MISORIENTATION IN THE FORMATION OF THE INTERLINKED HYDRIDE CONFIGURATION IN ZIRCALOY-4
W. Qin¹, N.A.P. Kiran Kumar² and J.A. Szpunar¹
¹Department of Mechanical Engineering, University of Saskatchewan, Canada
²Department of Metals and Materials Engineering, McGill University, Canada

The formation of δ hydride in Zircaloy-4 has been studied using electron backscatter diffraction. Both intra-granular and inter-granular hydrides were observed. The intra-granular hydrides platelets prefer to interlink each other and form a chain-like configuration. Based on thermodynamic model, the formation mechanisms of the interlinked structure were analyzed. We found that the misorientation of two adjacent grains and the tensile stress near the tips of hydride platelets are the key factors affecting the appearance of the interlinked structure.
TEXTURE INHOMOGENEITY IN ZIRCALOY-4 AND Zr-1%Nb CLADDING TUBES

N.A.P. Kiran Kumar¹, J.A. Szpunar²
¹Department of Metals and Materials Engineering, McGill University, Canada
²Department of Mechanical Engineering, University of Saskatchewan, Canada

Re-orientation of hydrides platelets along the radial direction during reactor operation adversely affect the mechanical properties and may lead to failure of the cladding tube. Until now many factors have been reported as being responsible for the hydride re-orientation along the radial direction. In the present study, texture inhomogeneity along radial direction is investigated and is considered as one of the main factors responsible for hydride reorientation. Texture of the top and bottom layers of Zircaloy-4 and E110 alloy was measured using X-ray diffraction and electron back-scattering diffraction (EBSD) techniques. Texture results obtained by X-ray diffraction technique was used to compare the texture inhomogeneity in Zircaloy-4 and E110 alloy. Kearns’ f parameter was used to calculate differences in thermal expansion coefficients at different thickness layers in both alloys. The stress generated by differences in thermal expansion can contribute to hydride re-orientation and cracking of the fuel cladding. Zircaloy-4 texture is more inhomogeneous than E110 alloy texture.
Tuesday, August 17, 2010 PM
Room: Terrace

14:00 Paper 5027
DESIGN AND LICENSING OF A NEW URANIUM TAILINGS MANAGEMENT FACILITY IN THE UNITED STATES
K.F. Morrison1 and F. Filas2
1Golder Associates Inc., USA
2Energy Fuels Resources, USA

Strategically located within the Uravan Mineral Belt District of western Colorado, the Piñon Ridge Project is the first new uranium mill being proposed for construction in the United States in over 25 years. In 1992, dramatic changes to the US regulatory environment for uranium ore processing occurred making regulatory compliance an increased challenge for a new facility. Proposed as a uranium and vanadium milling operation with an ultimate capacity of 6.3 million tonnes, the mill will receive ore from a number of mines in the region. The project includes design and licensing of a uranium/vanadium processing facility, tailings cells, evaporation ponds, and ore stockpile pads. The focus of this paper is to provide an overview of the current US regulations, how the regulations have evolved in the recent past, and how these regulations were applied to design of the mill facilities. A status update on the project is also provided, with the mill license application submitted to the Colorado Department of Public Health and Environment (CDPHE) in November 2009.

14:30 Paper 4908
CANADIAN REGULATORY PROCESSES AND PRACTICES FOR ENVIRONMENTAL PROTECTION IN URANIUM MINING
F. Ashley1 and M. McKee2
1Canadian Nuclear Safety Commission, Saskatoon, Canada
2Canadian Nuclear Safety Commission, Ottawa, Canada

The Canadian Nuclear Safety Commission (CNSC), under the Nuclear Safety and Control Act (NSCA), regulates all nuclear facilities and nuclear related activities in Canada. The enhanced environmental protection mandate under the NSCA has led to reassessment and subsequent requirements for significant process changes to effluent treatment systems at existing uranium mining and milling operations. Waste rock and tailings from the mining and milling operations must also be carefully managed to minimize potential adverse environmental effects during operations and for the long term. This paper will review the regulatory processes used in Canada for uranium mining and milling operations and the design practices used and specific examples of effluent treatment and tailings and waste-rock management systems in Saskatchewan.

15:00 Paper 4909
THE REGULATORY PERSPECTIVE ON RADIATION PROTECTION IN CANADIAN URANIUM MINES
D. Schryer
Canadian Nuclear Safety Commission, Saskatoon, Canada

The Canadian Nuclear Safety Commission (CNSC) is the principal nuclear regulator in Canada. The CNSC is empowered through the Nuclear Safety and Control Act (NSCA) and its associated regulations to regulate uranium mining and milling. Radiation Protection is one of the main safety and control areas mandated under the NSCA and its regulations. Radiation Protection measures are required to manage the risk to the public, the workers and the environment and are considered in all our licensed activities at uranium mines and mills. The CNSC expects its licensees to demonstrate a healthy respect for radiation protection and look for this behaviour in the managed systems. Confirmation that this has been adopted as part of the licensee’s safety culture is obtained through our inspection and verification activities. This paper will describe the regulatory controls and explain how they are applied by using best practices of current uranium mines and mills.

15:30 Coffee Break

16:00 Paper 4911
LICENSING URANIUM MINES AND MILLS: PREDICTABLE AND EFFICIENT
C. Gunning and G. Schwarz
Canadian Nuclear Safety Commission, Ottawa, Canada

The Canadian Nuclear Safety Commission (CNSC) is striving to develop an effective process for reviewing licence applications for new uranium mines and mills. This paper reviews the documented framework that the CNSC has developed to ensure that regulatory requirements and the licensing process for new uranium mines and mills are effective and efficient, and are also fair, transparent and predictable. The framework encompasses an information document describing the licensing process; a licence application guide, application assessment plans and staff review procedures. Adherence to the information and advice provided in these documents will ensure that proponents submit good quality, comprehensive applications. Elimination of delays caused by incomplete or poor quality submissions will increase the efficiency of the licensing process.
The Saskatchewan Ministry of Environment recognizes uranium mining as an important contributor to Saskatchewan’s economy. The environmental performance of the industry is closely monitored, often with significant process. The Saskatchewan Ministry of Environment has embarked on a visionary restructuring of its regulatory framework from conventional command and control to a result-based regulatory framework. This new regulatory framework will provide for: establishing clear environmental protection and resource management objectives; the streamlining of the environmental acts and regulations; development of an environmental code; reliance on qualified persons; enhanced compliance and enforcement tools; the elimination of many permits; and greater certainty in environmental assessment decisions. Results-based regulation promises to deliver enhanced environmental protection with less process.
LESSONS FROM THE PAST: A LITERATURE REVIEW OF THE RESIN-IN-PULP PROCESS FOR THE URANIUM INDUSTRY
B. McKevitt and D. Dreisinger
University of British Columbia, Department of Materials Engineering, Canada

In the 1950s, the resin-in-pulp (RIP) process was a hot topic for uranium research around the world. Several design methodologies were tested, and a few were implemented on a commercial scale. Many thought that RIP would dominate as the process of choice for uranium recovery; however, in the Western World, other processing routes replaced RIP. Recently, RIP is once again being proposed as a potential processing option for uranium. This paper provides a literature review of the development of the RIP process from the 1950s to today.

THE RECOVERY OF URANIUM FROM ACID LEACHED ORE USING RESIN-IN-PULP TECHNOLOGY
S. Leung, L. Heymann and D. King
1Aker Metals, a Division of Aker Solutions Canada
2Aker Solutions Australia Pty Ltd., South Australia

Ion exchange resins have been used extensively in the past to extract uranium from aqueous solutions. This was done by contacting relatively clean solutions with resin beads in a conventional resin column. An expensive liquid-solid separation step ahead of the ion exchange circuit is required to provide the clean solutions. When dealing with uranium ores that are difficult to filter or settle, it has been found that resin-in-pulp (RIP) provides a more economical treatment path. Aker Metals, a division of Aker Solutions Canada Inc. has been involved in the design of two such plants and, in each case, has found RIP to be an acceptable low cost solution to these difficult ores. This paper will compare the Capital and Operating costs of a 3500 tonne per day acid leach uranium plant using the more conventional CCD-SX route with those for a RIP circuit. Treatment options designed to mitigate resin loss by breakage and fouling will be discussed. An overview of current projects using this approach will be given.

RIP STUDIES AT AREVA: R&D AND APPLICATIONS FOR NIGER AND CANADA PROJECTS
Yuanbing Ling, Nicolas Durupt and Nicola Banton
1AREVA-SEPA [Service D’études de Procédés et Analyses], France
2AREVA Resources Canada Inc., Canada

Cominak in Niger owns a large stock of high grade fines which cumulated originally from underground mining discharge water. This ore is too fine to be treated with the current process because it readily blocks the cloths of the belt filters. Cominak plans to build a Resin-In-Pulp (RIP) plant. The RIP technology permits to recover U values without filtration. Some bench scale studies (at AREVA-SEPA) and two trial campaigns (on site) had been successfully conducted to implement the RIP process, which further allows, from economic point of view, a positive feasibility evaluation. As part of the Kiggavik Project managed by Areva Resources Canada (ARC), AREVA-SEPA is also being actively involved in developing a practical, cost-effective and environmentally sound process flowsheet. RIP technology has drawn significant attention due to the relatively low water consumption and capital cost. SEPA’s experience with RIP technology together with the newer and better-performance resins makes this technology a viable choice. Three pilot campaigns have been accomplished at SEPA, which is believed to be of great help to reduce technical risk as well as capital risk in the decision making for Kiggavik project.
A significant expansion project is under way at KATCO’s Torkuduk In Situ Recovery (ISR) operation to increase uranium production to about 4000 tU/year. Higher flows and lower uranium concentration are expected in the rich solutions coming from the well fields. Therefore, extra adsorption and elution columns and modified operating conditions are required to deal with the increased demand for uranium transfer from the ISL solutions to the eluate solution, which goes to the uranium precipitation section. Resin adsorption and elution performance have been interpreted and projected by using Mc-Cabe-Thiele equilibrium diagrams. The resin load, the adsorption mass transfer coefficient, the adsorption zone height and the eluate concentration have been estimated for the expected changing operating conditions associated to the future mine plan. This information has allowed to improve the present operation results and to define the main process design criteria for the expansion project.

In-situ leach uranium mines frequently extract other metals of value from the ore body. Some mines in Texas and New Mexico extract substantial quantities of moly and rhenium, while Colorado plateau and Wyoming mines may co-extract vanadium in the leach solutions. In many cases, the recovery of the secondary metal oxoanions could add significantly to the revenue of the mine. The opportunity to add secondary metal values to the top line of operating mines is limited by the availability of effective ion capture resins that will recover molybdenum, rhenium, or vanadium from in-situ leach solutions. Ion exchange columns that are manufactured with interstitial polymer networks (Spiderwebs) suspended between silica particles have enhanced rates of equilibration with solutions flowing through the Spiderweb. When the Spiderweb-like polymer networks are modified with metal-selective chelating agents, highly metal-selective columns are prepared that strongly bind uranium and the secondary metals of interest. We report tests of enhanced uranium and molybdenum extraction from both pregnant and barren ISL solutions. The captured metals can then be separately eluted from the columns with a variety of acidic or basic reagents.
While regulatory licensing guidance for uranium mine licensing has not been updated to specify high-density gamma radiation characterization of a site, such technology is in current use. For example, gamma scan maps are incorporated in recent U.S. in situ recovery license applications. In the long run, a site with thorough pre-operational gamma mapping will encounter a smoother license termination process. An understanding of exposure rates can also inform radiation protection planning. We present pre-licensing and remedial action examples from a number of our projects worldwide. Our purpose is to encourage uniform and updated site characterization procedures.

CLIMATE CLASSIFICATION AND QUANTIFICATION FOR COVER DESIGN IN COLD ENVIRONMENTS
J. Stianson, D.G. Fredlund and T. McArthur
Golder Associates Ltd., Saskatoon, Canada

The decommissioning of uranium tailings facilities often requires the design of a suitable cover system. In cold climatic environments there is a portion each year that can be considered to be “inactive” while the remainder of the year can be considered to be “active”. There are numerous engineering design assumptions required when analyzing both the “active” and the “inactive” portions of the year. Cover systems are subjected to complex boundary conditions and are comprised of materials with highly nonlinear soil properties. This paper describes the challenges associated with the preparation and the analysis of a multi-year climatic database for the design of a cover system in cold environments. The paper also explains how climate can be classified and how observed variations from one year to the next can be taken into consideration in cover design. The results of climatic records at mine sites are used to illustrate conditions that need to be taken into consideration when designing soil cover systems.

In order to assist operators, regulators and other experts involved in the planning, performance, control and termination of decommissioning activities, the International Atomic Energy Agency (IAEA) launched in November 2004 an international project on “International Project on Evaluation and Demonstration of Safety for Decommissioning of Facilities Using Radioactive Material” (DeSa). On completion of the DeSa project, the IAEA revised the International Action Plan on Decommissioning of Nuclear Facilities in September 2007. The revised Action Plan envisages the “establishment of a forum for exchange of experience and harmonization of approaches to development and review of safety case [decommissioning plan] for decommissioning (DeSa follow-up project), including recommendations for the application of the graded approach”. The FaSa project was started in November 2008 to fulfil this purpose, and will be completed in 2011. It aims to build on the DeSa project outcomes; to review international experience, and to develop agreed recommendations on:

(i) The use and application of safety assessment in the development and review of decommissioning plans and safety related documents through the life cycle of nuclear facilities and other facilities that use radioactive material;
(ii) The implementation of the safety assessment results in the conduct of decommissioning activities (e.g., optimization, defense in depth, technical feasibility, safety functions and controls);
(iii) Application of the graded approach in the application of safety assessment;
(iv) Update of safety assessment, the operators/regulators review of safety assessments and the implementations of its results during planning and conduct of decommissioning (e.g., single and multi-facility sites);
(v) Demonstrate the application of these recommendations on selected real facilities planned for or undergoing decommissioning.

This paper will present an overview of the FaSa project, progress to date with the mining and mineral processing test case and how the DeSa methodology may influence the decommissioning of uranium mining and mineral processing facilities.
Some of the past uranium production operations have caused extensive environmental problems. The lack of appropriate regulatory framework in addition to the fact that environmental issues were not conveniently addressed in the operations contributed to this situation. Nowadays, this situation has changed dramatically and lessons learned from the past have led to the implementation of responsible operations from both environmental and social perspectives. Involvement of different stakeholders in the decision making process turned out to be a mandatory issue in many countries. With the so called “Renascence of Nuclear Power” new production sites will come into play. The sustainability of the uranium industry will depend on the adoption of good practices in these operations under a life-cycle perspective. The recently launched IAEA initiative – the ENVIRONET is aimed at contributing to expedite the transfer of experience amongst its members. It brings together private and state-owned companies, research institutes, and governmental organizations providing a forum for information and experience exchange. Sharing of practical experience is to be addressed by means of training courses and workshops. In addition to this long distance training and educational material will be made available. This paper will present the ENVIRONET and describe how networking can contribute to the implementation of sustainable and responsible uranium production operations worldwide.
Under the oxidizing conditions of the McClean Lake Tailings Management Facility (TMF) hydrocarbons entrained on the surface of tailings material from mill processes are gradually converted to soluble bicarbonate ion. This has been observed to be a process occurring over approximately three years likely encouraged by the presence of a microbiological community within the tailings mass and in the water column. A recent tailings sampling campaign has provided evidence that bicarbonate ion is participating in the conversion of gypsum to calcite. In older tailings, equilibrium with calcite appears to be controlling the terminal bicarbonate ion concentration.

Arsenic is a major contaminant in a number of high grade uranium ores mined in Northern Saskatchewan. Upon processing of these ores by hydrometallurgical processes, arsenic reports to aqueous waste solutions from which arsenic(V) is removed by co-precipitation with iron(III). This process results in the generation of a mixture of poorly crystalline arsenate-bearing phases and gypsum. Based on laboratory investigations there exists the potential upon reaction of the disposed iron(III)-arsenate phases and gypsum to lead to Ca-Fe(III)-AsO4 association resembling the mineral yukonite. In this paper the laboratory synthesis, characterization and solubility investigation of yukonite is reviewed and the implications of its formation in U-mill tailings as an arsenic control phase are discussed.
samples and reference compounds indicate the dominant oxidation states of As, Fe, and Ni in the mine tailings samples are +5, +3, and +2, respectively, largely reflecting their deposition in an oxidized environment and complexation within stable oxic phases. Backscattered electron [BSE] images of the tailings from the electron microprobe indicate the presence of gypsum/lime nodules surrounded by metallic rims mainly consisting of As, Fe, and Ni. \(\mu\)XRF elemental mapping confirms these EPMA results. \(\mu\)XAS collected within the metal-bearing rims indicates As and Fe is present mainly in the +5 and +3 oxidation state, respectively.

10:00 Coffee Break

10:30 Paper 4907
ARSENIC CONTROL IN PROCESS TAILINGS: CONTINUOUS CO-PRECIPITATION OF AS(V) WITH IRON SULPHATE MEDIA
R. Daenzer, R.J. De Klerk and G.P. Demopoulos
McGill University, Department of Mining and Materials Engineering, Canada

Arsenic constitutes a serious environmental problem for the mineral processing industries. The removal of high concentrations of arsenic in the case of uranium milling process effluents is done by adjusting the iron to arsenic molar ratio to four (\(MF_{\text{tot}}/M_{\text{As}}=4\)) and subsequently neutralizing with slaked lime in a continuous coprecipitation (CCPTN) circuit. This paper investigates the production of arsenic-bearing phases though CCPTN from simulated waste process effluents and their long term stability at accelerated conditions. In particular, special attention is given to a two stage continuous reactor set-up. Moreover, the effect of a fraction of total iron as ferrous iron and the presence of co-ions such as nickel and aluminum on the stability of the products was investigated.

11:00 Paper 5502
AGING OF REDUCED ARSENIC MINERALS IN URANIUM MILL TAILINGS AT THE McCLEAN LAKE OPERATION
C. Rinas, J. Rowson, R. Frey and K. Hughes
AREVA Resources Canada Inc., Canada

The primary arsenic minerals in the uranium ore processed at the McClean Lake Operation are rammelsbergite, niccolite and gersdorffite. During processing, a large fraction, typically (80 - 95%), of these reduced minerals is oxidized and dissolves primarily as As\(_5^+\) in the leachate solution. In the tailings preparation circuit the dissolved As\(_5^+\) is precipitated as a poorly crystalline form of the mineral scorodite. Following subaqueous deposition in the tailings management facility, a temporal rise and fall in arsenic pore water concentrations has been observed. This is due to the oxidation of the residual quantities of reduced arsenic minerals initially present in the tailings sediment. The XANES (x-ray absorption near edge spectrometry) technique has shown that As\(_1^-\) is gradually oxidized to As\(_3^+\) and then finally to As\(_5^+\) in the tailings sediment. This oxidation process results in a temporary accumulation of As\(_3^+\) in solution and is the source of the rise and fall in arsenic concentration observed.

11:30 Paper 5522
IDENTIFICATION OF POORLY CRYSTALLINE SCORODITE IN URANIUM MILL TAILINGS
R. Frey\(^1\), J. Rowson\(^1\), K. Hughes\(^1\), C. Rinas\(^1\) and J. Warner\(^2\)
\(^1\)AREVA Resources Canada Inc., Canada
\(^2\)Canadian Light Source Inc., University of Saskatchewan, Canada

The McClean Lake mill, located in northern Saskatchewan, processes a variety of uranium ore bodies to produce yellowcake. A by-product of this process is an acidic waste solution enriched in arsenic, referred to as raffinate. The raffinate waste stream is treated in the tailings preparation circuit, where arsenic is precipitated as a poorly crystalline scorodite phase. Raffinate neutralization studies have successfully identified poorly crystalline scorodite using XRD, SEM, EM, XANES and EXAFS methods, but to date, scorodite has not been successfully identified within the whole tailing solids. During the summer of 2008, a drilling program sampled the in situ tailings within the McClean Lake tailings management facility. Samples from this drilling campaign were sent to the Canadian Light Source Inc. for EXAFS analysis. The sample spectra positively identify a poorly crystalline scorodite phase within the McClean tailings management facility.
Wednesday, August 18, 2010 AM
Room: Battleford

8:00  Paper 5119
INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION: RECOMMENDATIONS RELEVANT TO THE URANIUM INDUSTRY
C.H. Clement
International Commission on Radiological Protection, Canada

The International Commission on Radiological Protection (ICRP) is an independent, international organization that advances for the public benefit the science of radiological protection, in particular by providing recommendations and guidance on all aspects of protection against ionizing radiation. This presentation touches on aspects of The 2007 Recommendations of the ICRP, a fundamental document that lays out the system of radiological protection for all exposure situations and types, and focuses on other recent publications relevant to the uranium industry. Of particular relevance are the 2009 ICRP Statement on Radon and the accompanying report on lung cancer risk from radon.

8:30  Paper 5158
UNIQUE RADIATION PROTECTION DESIGN FOR PROCESSING HIGH GRADE URANIUM ORES AT THE MCCLEAN LAKE MILL
K.Stewart
AREVA Resources Canada Inc., Canada

Rich uranium deposits in northern Saskatchewan are coming into production and will last for the next few decades. The combination of high ore grades and increasingly stringent radiation protection regulations require complex mill design features far different from those for conventional uranium mills. The McClean Lake mill, which has operated since June 1999 with production rates averaging 4 million lbs of U3O8 annually, has been expanded to receive uranium ore slurry with nominal feed grades up to about 20% U3O8 and production rate of up to 24 million lbs annually. The mill design ensures that workers are separated from radioactive ore being processed through the use of slurry handling and processing systems that are enclosed and has several state-of-the-art shielding and ventilation features that protect workers against external gamma radiation and airborne radioactive materials (radon progeny and radioactive dusts). This paper discusses the unique design of the AREVA’s McClean Lake mill.

9:00  Paper 5176
RISKS FROM EXPOSURE TO RADON AT HOME OR AT WORK
Douglas B. Chambers and Ronald H. Stager
SENES Consultants Limited, Canada

This paper examines the risks associated with exposure to radon decay products through estimation of lifetime excess absolute risks (LEAR) per WLM for selected epidemiological risk projection models from miner studies and pooled residential radon studies applied to the ICRP 103 reference populations. The mSv per WLM was calculated using the total detriment per Sv factor. The effect of smoking was considered based on application to Canadian mortality data by smoking status. There was a large variation in the risk per WLM and dose conversion factor depending on the smoking histories which vary substantially between individuals and over time.

9:30  Paper 5501
EPIDEMIOLOGICAL EVIDENCE AND RADIATION PROTECTION
R. Lane and P. Thompson
Canadian Nuclear Safety Commission, Canada

Objective scientific information should be the basis for understanding the health effects of uranium on workers and members of the public so stakeholders can make informed decisions about radiation protection. The Canadian Nuclear Safety Commission has participated in several recent epidemiological studies of the health effects of uranium workers and people living near uranium processing facilities. This presentation will discuss the findings, studies conducted elsewhere, international scientific consensus, gaps in knowledge, and plans for international collaborative studies. Finally, it will discuss the importance of epidemiological evidence for radiation protection and provide examples of how information has been communicated to stakeholders for evidenced-based decision making.

10:00  Coffee Break
10:30  Paper 4918
SOLUBILITY OF RADIONUCLIDES IN SIMULATED LUNG FLUID
G. Tairova¹, M. Boucher¹, K. Toews², M. Ioffe¹, J. Takala², M. Murchie¹, Engin Ozberk²
¹Innovation and Technology Development, Cameco Corporation, Canada
²SHEQ System, Cameco Corporation, Canada

The objective of this work was to assign FMS (fast, moderate and slow) absorption types to site-specific radionuclides found at various Cameco facilities. Kinetics studies of dissolution of various uranium-bearing samples in simulated lung fluid were carried out. Dissolution parameters were determined and the samples were assigned to the FMS absorption types. A software program was developed for the determination of dissolution parameters. The assignments were based on criteria established in the International Commission on Radiological Protection (ICRP) Publication 71. The assignments were used to determine the internal radiation dose for workers.

11:00  Paper 5344
EVALUATION OF CONTENTS OF THE URANIUM SERIES RADIONUCLIDES IN THE ENVIRONMENTAL MEDIA AND LOCAL FOODS AT THE RESIDENTIAL AREA CLOSE TO THE RUSSIAN URANIUM MINE FACILITY
N.K. Shandala¹, S.M. Kiselev¹, S.V. Akhromeev¹*, E.A. Khohlova², E.G. Metlyaev¹ and A.A. Filonova¹
¹Federal Medical Biophysical Centre, Russia
²Regional Management 107, FMBA of Russia, Russia

The goal of this study is to carry out comprehensive environmental and hygienic examination of the Health Protection Zone and the location area of the the Priargunskiy production mining and chemical association and to assess health conditions of miners. The media under examination were: common air, soil, vegetation, and water. Contents of natural radionuclides - 238U, 232Th, 226Ra, 210Po, and 210Pb have been determined. Concentrations of other chemicals have also been determined in common air. Radionuclide migration levels and accumulation coefficients of uranium series have been determined. Medical and dose information has been collected and verified to evaluate health conditions of miners.
Selenium is a contaminant encountered at uranium mines. When discharged into water, it can build up in the food chain and become toxic to egg-laying fish and shorebirds. This presentation reviews recent developments in its regulation, management and treatment. Selenium will soon be regulated on the basis of its concentration in fish or bird eggs, not its dissolved concentrations, which challenges managers trying to establish acceptable discharge limits. Information supporting this change will be discussed. Recent developments to manage and treat selenium will also be reviewed, emphasizing new chemical and biological treatment processes applicable at uranium mines and mill sites.

The mill effluent treatment, Bulk Neutralization circuit in the Cameco Key Lake Operation was modified in 2008 to enhance the removal efficiency of selenium (Se) and molybdenum (Mo) from the mill process water. This modification was completed in part due to increased knowledge of the effects these elements have on biota. In addition, legacy effects from the historical operation of the Key Lake mill in regards to Se and Mo were shown to have an effect on the regional biota in the downstream receptors. This was a challenging initiative as there was no off the shelf technology available and the removal process had to be incorporated into an existing (brownfield) process. These modifications have resulted in significant reduction in the concentration of these elements in the mill effluent. The removal efficiency for Se and Mo has increased to 85% and 96%, respectively. As a result, concentrations of Se and Mo are now consistently less than 0.02 mg/L and 0.6 mg/L. This paper will provide detail on the hydrometallurgical removal mechanisms and process modifications required in the Key Lake effluent treatment circuit to remove these elements to trace levels.

Bench-scale experiments were carried out to investigate a number of potential methods of selenium removal from purge water obtained from Cameco Resources Smith Ranch-Highland (SRH) operation. Test results indicated that the concentration of selenium in the effluent was consistently reduced to below the 0.1 mg/L target using a down flow column with fixed-bed active media. Based on the results of the bench-scale experiments, pilot studies were successfully carried out on site. A commercial-scale plant was built and commissioned in September 2009. To date, more than 75,000 m3 of water have been successfully treated.

Risks to aquatic receiving environments from uranium developments fall into three categories: physical (habitat change); chemical (e.g., uranium, selenium, total dissolved solids, metals including vanadium and magnesium); and radiological. Although all categories of risk need to be managed, chemical risks are the most significant and are typically chronic rather than acute. For instance, selenium toxicity is primarily manifested as reproductive impairment due to maternal transfer, resulting in embryotoxicity and teratogenicity in egg-laying vertebrates. Risk is best assessed using a site-specific weight of evidence approach focused on ecosystem services. Risk management should be based on both risk assessment and adaptive monitoring.
10:30  Paper 4749  
LEADING PRACTICE WATER MONITORING IN NORTHERN AUSTRALIA  
M.Bush and K.Turner  
*Supervising Scientist Division, Department of the Environment, Water, Heritage and the Arts, Australia*

Ranger Uranium Mine is undergoing an environmental impact statement assessment process to develop a Heap Leach facility to treat low grade ore on site. The facility is proposed to be located in the relatively unimpacted Gulungul catchment within the Ranger Project Area which itself is surrounded by, but excluded from, the World Heritage listed Kakadu National Park. The Supervising Scientist Division (SSD) acts to ensure the downstream environment is protected from mine-related impacts. To achieve this SSD will develop a leading practice monitoring program for Gulungul Creek to monitor potential impacts to this catchment from the Heap Leach facility.

11:00  Paper 5830  
IMPLICATIONS OF GROUNDWATER LEVEL FLUCTUATION ON URANIUM CONCENTRATION IN PART OF NALGONDA DISTRICT, ANDHRA PRADESH, INDIA  
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²Environmental Assessment Division, Bhabha Atomic Research Centre, India.

This study was carried out with the objective of understanding the spatial and temporal variation in groundwater level and uranium concentration in Peddagattu and Seripalli areas of Nalgonda district, Andhra Pradesh, India where uraninite deposit occur. Mining of uraninite from this deposit is proposed to commence in near future. From March 2008 to November 2009 groundwater samples were collected from forty five wells. Groundwater level in wells was recorded during sampling. The samples were analyzed for the uranium concentration using laser fluorimeter. The uranium concentration in the groundwater of this region ranges from 0.2 ppb to 118.4 ppb. About 20.61% of the groundwater samples had uranium concentration about the standards set by USEPA (30 ppb). The comparison between groundwater level and uranium concentration in groundwater shows that the uranium concentration increases with raise in groundwater table. This pattern of relationship indicates the effect of water table fluctuation between the weathered and fractured granites on concentration of uranium. In the event of opening up of mining activity in this region care has to be taken to look into this pattern of relationship for proper and effective management of groundwater quality.
In the solvent extraction of uranium the three most commonly encountered operational problems are (1) the transfer of impurities on the loaded organic, (2) poor phase separation and (3) crud formation. The chemistry and physics associated with these problems are discussed and suggestions are made as to how circuit design and operating procedures can alleviate these challenges.

Two types of equipment are used in the industry for solvent extraction (SX) of U: mixer-settlers (MS) and columns. Currently the only published type of columns applied in U SX is the Bateman Pulsed Columns (BPC). These columns have been applied for extraction of U for more than 13 years in Olympic Dam plant in Australia and in recent years were also introduced to additional plants in Australia and South Africa. Other plants are using MS of various types. The columns are currently used in the extraction battery only. For stripping and scrubbing only MS are currently used. Although pilot tests prove that the pH gradient required in the stripping may be successfully obtained in the BPC, they have not yet been applied in the industry. The paper compares the extraction and stripping in both types of equipment, regarding the capital cost, operating costs and operating conditions. The capital cost of the BPC is lower by 33-40%, depending on the size of the plant and the quality of the ore. The operating costs with the BPC are slightly lower, due to smaller losses of solvent. From operating point of view the BPC has the ability to recover from phase inversion and precipitation of yellow cake without the need to shut down the plant, if the problem is addressed within a few minutes.

A chemical property model was built for the process of stripping uranium from a loaded solution of a tertiary amine in kerosene with sulphuric acid. A combination of two software packages, OLI (OLI System, Inc) and IDEAS (Andritz Automation, Inc.) were used to develop a speciation-based thermodynamic model of the multi-stage counter-current process. Equilibrium constants for the reactions between uranium and sulphuric acid species were calculated by fitting to experimental data from different publications. The model was able to accurately predict most of the stripping process parameters (number of contacts, concentration of uranium in both phases, acid consumption, etc) in a wide range of process conditions. It was shown that the existing thermodynamic data alone is sufficient to design and optimize complicated uranium recovery processes.

Historically, recovery of uranium from high grade (→400 ppm U) leach solutions (PLS) was done by solvent extraction (SX), while low grade feed was treated by ion exchange (IX). Significant improvement in the SX technology, especially application of large pulsed columns instead of mixer-settlers (MS), have now made the SX more attractive for PLS with U below 100 ppm. Recently Bateman carried out three test work programs for direct SX of low grade (←100 ppm) U PLS, using BPC pulsed columns for extraction and MS for stripping and scrubbing. In all 3 cases the results prove that the direct SX is overall more economical that any combination of IX and SX. Based on these results, two industrial plants, in South Africa and Australia, were erected.
10:30  Paper 4747  
**INFLUENCE OF THE CHEMICAL DEGRADATION OF TRIOCTYLAMINE DISSOLVED IN N-DODECANE MODIFIED WITH TRIDECANOL ON URANIUM EXTRACTION PROCESS IN A PLANT LOCATED IN NIGER**  
A. Chagnes¹ and G. Cote¹, B. Courtaud², N.P. Syna² and J. Thiry²  
¹Chimie Paristech – Ecole Nationale Supérieure de Chimie de Paris (ENSCP), France  
²AREVA NC – Service d’Etudes de Procédés et d’Analyses (SEPA), France

Solvent losses in hydrometallurgical applications of liquid-liquid extraction are of great concern. In our earlier studies, we reported the chemical degradation of a solvent containing tri-n-octylamine extractant and 1-tridecanol modifier dissolved in kerosene. This solvent extractant is used for the recovery of uranium from sulfuric acid media in a plant located in Niger. Our studies have showed that tri-n-octylamine is degraded into dioctylamine via a radical mechanism due to the presence of Vanadium (V). Dioctylamine influences the kinetics of degradation of the extraction solvent and induces the formation of cruds in the presence of Molybdenum (VI). This paper will focus on the impact of dioctylamine on the solvent extraction operation of a uranium production plant.

11:00  Paper 5145  
**CRUD SEPARATION AND SX OPTIMIZATION AT KEY LAKE**  
T. Saruchera, J. Jarvi, and B. Moldovan  
*Cameco Corporation, Key Lake Operation, Canada*

The Key Lake mill processes a combination of high grade uranium ore and uranium-bearing mineralized waste from the McArthur River Mine. The mill uses solvent extraction for recovery and purification of uranium. Crud is an ongoing challenge to all SX circuits. Technical personnel at the Key Lake mill have gained an understanding of the mineralogical and hydrometallurgical origin of this crud. Further, mill processes have been modified to reduce crud formation. Finally, on-going R&D is in progress to further reduce the impact that crud has on mill efficiency. These aspects will be presented in greater detail.

11:30  Paper 5625  
**CRUD TREATMENT WITH 3 PHASE CENTRIFUGE IN HEAP LEACH URANIUM PROCESS**  
T. Hartmann  
*GEA Westfalia Separator Process GmbH, Germany*

The presence of crud represents a permanent challenge for solvent extraction in the hydro-metal Uranium industry. The crud forms in the settlers of SX extraction. The crud is a stable emulsion which slowly spreads along the phase boundary between the aqueous and organic phase. Spreading of this intermediate phase is determined by the following influencing factors. Wind blows dust into the open settlers, some suspended solids coming with the pregnant leach solution (PLS) and wrong design of the mixers cause stable emulsions. Metallic solid residue is likewise responsible for the growth rate of the crud at the above-mentioned phase boundary. The crud can significantly impair the efficiency of hydro-metal extraction because the phase boundary between the aqueous and organic phases assumes substantial proportions, and the settlers cannot react flexibly. In a chain reaction, all settlers connected in series become infected with crud. The transfer of organic phase to the electrowinning (EW) cell can cause ‘cathode burn’. The entrainment of electrolyte into the extraction stage can result in loss of pH control in the extraction circuit which will cause a drop in extraction efficiency. On the other hand, entrainment of the organic in the raffinate will result in organic losses to the leach circuit. Continuous treatment of the crud is extremely effective and reliable with a 3-phase separating solid bowl centrifuge. All three phases are separated distinctly from one another. All associated process steps exhibit a steady uniform efficiency. The main benefit for the customer is that process fluctuations in the extraction process will no longer occur. The 3-phase separating solid bowl centrifuge consists of an axial solid-wall bowl. The solid-wall bowl has a cylindrical section for simultaneous separation and clarification of the aqueous and organic liquid phase and a conical section for efficient solids dewatering. The 3-phase feed suspension is fed into the solid bowl centrifuge through the feed tube and enters the separation chamber through the distributor. The scroll conveys the solids to the solids discharge.
Bench-scale experiments are carried out to evaluate electrokinetic (EK) dewatering of two tailings samples from uranium mines in Northern Saskatchewan. The study includes characterization of tailings, measurement of electrokinetic permeability ($k_e$), and electrokinetic enhanced gravity dewatering. It is found that tailings containing clay minerals respond well to EK dewatering. Significant EK flow is generated, which can be further enhanced by pH adjustment at anodes. The key parameters, such as density, electrical conductivity, pH, and mineral composition of tailings play dominant roles in the effectiveness of EK dewatering, which should be considered in the design for field applications.

14:30  Paper 4836
ELECTRICAL RESISTANCE HEATING FOR THAWING OF FROZEN URANIUM TAILINGS
C. Melis, P. Landine and T. Kotzer
Cameco Corporation, Canada

The Rabbit Lake In-Pit Tailings Management Facility contains frozen layers of tailings due to sub-aerial deposition during the successive winters. Thawing is required to ensure full consolidation of the tailings prior to closure and to regain disposal space presently occupied by ice. Electric resistance heating (ERH), which has been used to heat soil for bitumen extraction and remediation of volatile contaminants, was evaluated as a thawing mechanism. Two bench-scale experiments were performed wherein ERH was tested on about 0.3 cubic metres of frozen tailings frozen to a minimum of -20°C. Thawing occurred in both experiments with negligible geochemical effects, demonstrating the viability of ERH as a tailings thawing mechanism.

15:00  Paper 4840
TRANSPORT AND DEPOSITION OF THICKENED URANIUM TAILINGS
E. Paulsen
AREVA Resources Canada, Inc., Canada

The McClean Lake operation has experienced several problems relating to the thickened tailings disposal system. These include issues relating to segregation, inadequate pumping capacity, and unstable pipeline operation. Segregation in the tailings management facility is of particular importance since it negatively impacts the long-term containment of arsenic and the consolidation of the tail solids. These issues have direct implications on the regulatory requirements of the operation. As a result several initiatives relating to tailings thickening, transport, and deposition were proposed and implemented. This paper presents an audit of the existing tailings transport system based on the rheological requirements of homogeneous tailings as well as the proposed changes and preliminary results of this study.

15:30  Coffee Break

16:00  Paper 4868
CAMECO ENGINEERED TAILINGS PROGRAM: LINKING APPLIED RESEARCH WITH INDUSTRIAL PROCESSES FOR IMPROVED TAILINGS PERFORMANCE
T.G. Kotzer
Cameco Corporation, Canada

Mine tailings at Cameco’s operations are by-products of milling uranium ore having variable concentrations of uranium, metals, oxyanions and trace elements or elements of concern (EOC). Cameco has undertaken an Engineered Tailings (ET) program to optimize tailings performance and minimize environmental EOC impacts, regardless of the milled ore source. Applied geochemical and geotechnical tailings research is key within the ET program. In-situ drilling and experimental programs are used to understand long-term tailings behaviour and help validate source term predictions. Within this, the ET program proactively aids in the development of mill-based processes for production of tailings having improved long-term stability.
Tailings from a uranium mine have been tested to improve the dewatering properties and final weight percent (wt%) solids of the neutralized tailings. The objectives were to maximize water recovery due to the scarcity of water in the project area and to produce a suitable cemented paste fill to minimize ore dilution underground in order to maximize the head grade to the mill. The applicability of the controlled neutralization process, in which gypsum would precipitate as crystalline particles thereby improving the dewatering properties of the tailings through the use of a deep bed paste thickener, was tested. The acid leach slurry samples used were obtained from the end of the leaching circuit, before uranium recovery and lime neutralization. The tests conducted indicated that the controlled neutralization process greatly reduced the volume of neutralization precipitates which typically results in a higher final density and wt% solids. Additionally, it improved the dewatering (filtration) properties of the material. Controlled neutralization also reduced the amount of sulphate in the solution close to that of its saturation limit, which would reduce the amount of scaling that could occur during full scale applications and would increase the recyclability of the water back to the process. Deep bed paste thickening also improved the final wt% solids of the underflow. The tests demonstrated that it was possible, at the bench scale level, to improve final density and recover additional water. The increase in the filterability of the material provided a good indication that further increase in wt% solids and water recovery could be obtained in full scale applications. Unconfined Compressive Strength (UCS) tests improved for samples with reduced gypsum concentrations. While the strength achieved remained low, there was a substantial increase. Although further studies are required, neutralization of uranium tailings under controlled conditions to form gypsum as crystalline particles and/or reduce the gypsum content could possibly provide a viable option in the preparation of suitable paste material.

The consolidation of soil material is central to many types of engineering analysis. Problems such as the building of highway structures, landfills, or buildings over saturated soft clays require application of such theory. It has been found in industry that the application of consolidation theory has lagged significantly behind the theory which has been developed some time ago. The application of small-strain saturated consolidation theory was first proposed in a 1D form by Terzaghi. Although this theory has been available for some time, its implementation into software packages has been slow due to inherent complexities in the coupling equations. The flow and stress equations are also inherently somewhat unstable and this further complicates software implementation. Of particular interest in the mining industry is the consolidation of uranium tailings. One such disposal method that has been utilized is the subaqueous deposition of uranium tailings in large pit structures. When performing such deposition, the calculation of consolidation rates is central to determining final pit capacity and expected life. Consolidation software can be successfully used in such cases in order to determine pit filling rates. The primary complexity, however, is that tailings are typically deposited in slurry form and therefore the potential deformations are large. Large-strain consolidation theory is therefore required in order to properly solve the deformations over time. This paper presents the use of a large-strain consolidation analysis in order to predict long-term filling rates in a uranium tailings pit.
Beaverlodge mine and mill facilities operated from 1952 until 1982. Site decommissioning was completed in 1985 and a transition monitoring/maintenance phase followed. As described in this paper, although some properties have recently been transferred into Saskatchewan’s newly established institutional control program, most properties remain in transition phase, originally envisioned to last 10 years. Reclamation/decommissioning expectations were initially established, but over time societal and regulatory expectations and regulatory processes have changed. Cameco recently established a management framework to guide potential remedial activities which has been accepted by regulatory agencies. The framework seeks to balance current decommissioning expectations with the presence of legacy issues and past close-out agreements, ultimately relying on benefit-cost evaluation to determine final acceptance criteria for sites.

Since 1991 the Wismut environmental remediation project is one of the largest mine closure projects worldwide, entailing the rehabilitation of the former Soviet-East German uranium mining industry. The legacy of forty years of intensive uranium mining in East Germany enclosed a vast variety of radioactive contaminated sites and objects, including five underground mines and more than 3,700 ha of contaminated areas with ca. 500 million m3 of solid radioactively contaminated material. The multi-disciplinary remediation approach has developed robust solutions by ensuring rigorous site evaluations and impact assessments focused on key processes. Having realized more than 80 % of the remediation work to be performed, the paper highlights selected results and discusses key experiences gained, both from a technical and non-technical perspective.

In late 1950s and early 1960s 13 uranium mines operated in the South Alligator Valley of Australia’s Northern Territory. Once sales contracts had been filled the mines were abandoned and no remediation took place. In the 1980s the valley was designated as part of Stage 3 of the adjacent World Heritage-listed, Kakadu National Park. Proposals for remediation were only seriously put forward when the land was returned to the traditional Aboriginal owners, the Gunlom Land Trust, in 1996. Although they leased the land back so it would remain a part of Kakadu National Park the traditional Aboriginal owners required remediation to be complete by 2015. This paper tells the story of the development and implementation of the remediation process from the start of planning in 1998 to completion in 2009; and finally it describes the development of stakeholder relationships and the initial plans for long term stewardship.

As part of its mine closure program Wismut GmbH is remediating the Uranium tailings ponds Culmitzsch and Trünzig covering 3.6 km² pond area including approximately 104 Mill m³ tailings. From 1960 till 1990 tailings were discharged into tailings ponds erected in a densely populated area. Contaminant leakage from the tailings enters the surrounding aquifers and the receiving streams. Dry remediation in situ started with first securing measures in 1991 and will last till 2020. The paper presents the conception for the entire remediation of the tailings ponds, the actual remediation status achieved to date and an outlook to the future.
Golder Associates Ltd. (Golder) provided overall radiological direction and assistance to the client in planning for the remediation of a Calciner Room which had once operated as the final stage of a uranium processing circuit. Afterwards, Golder provided operational radiation protection services during the remediation work. The project was somewhat unusual in that the contaminated steel from within the Calciner Room was recycled. In addition, the presence of concentrated uranium within the process equipment required stringent radiation protection measures beyond those normally employed for such remediation. This part of the project was completed successfully with worker radiation exposures well below the regulatory dose limits and with the effective protection of the environment.
Cameco Corporation ( Cameco ) aligns its social and environmental responsibilities with its vision, mission and values. Environmental Leadership is established as a corporate objective that emphasizes the triple-bottom-line and a systematic approach to understanding environmental, social and economic issues, risks and opportunities. These are ingrained in the project culture, systems and processes and used to influence solutions derived by the project teams to achieve Cameco’s objectives. This paper traces the organizational objectives from the early stages of a project through to implementation and turn over to Operations. A case study is used to demonstrate how an asset is influenced by Cameco’s strategy.

14:30 Paper 5583
AFFECTIVE INTEGRATION OF ENVIRONMENTAL LEADERSHIP AND ENVIRONMENTAL MANAGEMENT SYSTEMS WITHIN Cameco’s MINING DIVISION
K. Nagy and S. Borchardt
Cameco Corporation, Canada

To support the implementation of its integrated Safety, Health, Environment & Quality ( SHEQ ) Policy, Cameco has undertaken an environmental leadership initiative with the goal of moving beyond regulatory compliance and significantly reducing environmental impacts in five key areas: air emissions, treated water quality and quantity, energy use and greenhouse gas emissions, and waste generation. To ensure environmental leadership becomes routine business practice, it was necessary to integrate the initiative into Cameco’s programs and management systems at the corporate and operational levels. Operations-based environmental leadership strategies and action plans have since been developed, as well as a corporate reporting system to monitor Cameco’s environmental performance.

15:00 Paper 5097
ADVANCES IN CANADIAN URANIUM MINE ENVIRONMENTAL MONITORING PROGRAMS
Cameco Corporation, Canada

By world mining standards, the uranium sector is relatively small, with limited sector-specific standards upon which environmental performance can be evaluated. To fill this gap, environmental monitoring programs have expanded, largely driven by new environmental effects monitoring and environmental assessment program requirements. Much more emphasis is now being placed on evaluating environmental interactions with the near-field receiving environment – both through more sophisticated field monitoring and effects-based modelling. End-of-pipe effluent objectives can now be reverse engineered from these effects-based monitoring and modelling results. This presents new challenges for mine operators and new tools that promote more engaging stakeholder discussions.

15:30 Coffee Break

16:00 Paper 5345
COMPREHENSIVE STUDY OF THE ENVIRONMENTAL CONDITIONS AND HEALTH OF WORKERS AT THE RUSSIAN URANIUM MINING AND MILLING FACILITY
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The goal of this study is to carry out comprehensive environmental and hygienic examination of the Health Protection Zone and the location area of the the Priargunsky production mining and chemical association and to assess health conditions of miners. The media under examination were: common air, soil, vegetation, and water. Contents of natural radionuclides - 238U, 232Th, 226Ra, 210Po, and 210Pb have been determined. Concentrations of other chemicals have also been determined in common air. Radionuclide migration levels and accumulation coefficients of uranium series have been determined. Medical and dose information has been collected and verified to evaluate health conditions of miners.