WEDNESDAY, AUGUST 27, 2003, P.M.

SESSION 47: INTERNATIONAL SYMPOSIUM ON HYDROMETALLURGY IN HONOUR OF PROFESSOR IAN RITCHIE

SOLUTION PURIFICATION I: SOLVENT EXTRACTION IV

Sponsors: Hydrometallurgy Section of The Metallurgical Society of CIM (MetSoc), Extraction and Processing Division, The Minerals, Metals and Materials Society (TMS), and the Society for Mining, Metallurgy and Exploration (SME)

Room: Pavillion Ballroom A

Chairmen: J. LOMMEN, Fluor Daniel Inc, Arvada, CO, USA
D. HUGHES, Outokumpu Technology Group, Espoo, Finland

PAPER 47.1 — 14:00
MASS TRANSFER RATES FOR UP-PUMPING IMPELLER SYSTEMS.
D. ADAMS, B. GIGAS and M. GIRALICO, LIGHTNIN, Rochester, New York, U.S.A.

A number of gas-liquid processes require high-intensity agitation systems to provide uniform blending and dispersion of reactants in order to achieve desired end products. Processes such as hydrogenation, fermentation, and minerals processing have used conventional down-pumping or radial agitation systems with some success. In 1996, LIGHTNIN introduced the concept of up-pumping to the industrial marketplace as an improved mixing technology for these applications. For processes requiring gas-liquid mass transfer, such as those listed above, conventional mixing technology requires the use of gas introduction devices (sparges) below impellers. These devices can be a maintenance concern due to plugging and erosion in the presence of solids. Up-pumping impeller systems are able to draw in a significant amount of gas from the head space, much more so than conventional vortexing impellers designed for head space gas incorporation. This paper will demonstrate the effectiveness of up-pumping impeller systems that have the potential to eliminate the need for sparge devices entirely. It demonstrates the ability of up-pumpers to re-entrain gas for higher utilization compared with conventional impeller technology. This is significant in applications using costly gases such as enriched oxygen or hydrogen, reducing overall operating costs of production.

PAPER 47.2 — 14:25
DEVELOPMENT OF ON-LINE ANALYSIS IN NICKEL AND COPPER SOLVENT EXTRACTION.
D.V. HUGHES, M. KONGAS and E. RAUMA, Outokumpu Technology Group, Espoo, Finland

This paper covers the utilization of on-line analysis in process control of solvent extraction in nickel leach solvent extraction processes in Finland and Australia and in copper heap-leach and solvent extraction in Chile. The goals of and requirements for controlling the solvent extraction stages of the processes are reviewed. The applications at three plants are compared. The development of the technology used is reviewed and design considerations are discussed. Requirements for on-line control and analyzer performance are compared. A new generation of analyzers and their effect on the set-up process of a project is introduced.

PAPER 47.3 — 14:50
BIOLOGICAL DEGRADATION OF SOLVENT EXTRACTION CIRCUIT PLANT ORGANIC.
N.I. COLLAO, Compania Minera Quebrada Blanca S.A., Piso, Iquique Chile,
G.E. JENNEMAN, Conoco Phillips Petroleum Company, Bartlesville, Oklahoma, U.S.A.,
K.L. SUBLETTE, Environmental Engineering, The University of Tulsa, Tulsa, Oklahoma, U.S.A.,
M.D. BISHOP, Chevron Phillips Chemical Company LP, Bartlesville, Oklahoma, U.S.A.,
S.K. YOUNG, Versitech Inc., Tucson, Arizona, U.S.A., and
A.G. MORRISON, Teck Cominco Metals Ltd., Trail, British Columbia, Canada

Loss of the organic phase from solvent extraction circuits is a major cost factor for SXEW operations. Recognized sources of loss include evaporation, entrainment, and biological degradation. The mechanisms for both entrainment and evaporative losses are well recognized. Biological degradation of the organic has not been as extensively evaluated as the other mechanisms but is a major source of loss. This paper discusses the impact of biological degradation on an operating plant, potential mechanisms for degradation, conditions under which biodegradation of plant organic can occur and plant conditions that may assist in promoting biodegradation.

COFFEE BREAK — 15:15 – 15:30

PAPER 47.4 — 15:30
FRP (FIBERGLASS-REINFORCED PLASTIC) AS A MATERIAL OF CONSTRUCTION FOR SOLVENT EXTRACTION EQUIPMENT.
D. GOODMAN, Nemato Composites Inc., Menlo Park, California, U.S.A.,
R. AASLEPP, Nemato Composites Inc., Whitby, Ontario, Canada,
R. MOUBARAC, Experco Composites Inc., Pierrefonds, Quebec, Canada, and
M.T. BELFORD, The Dow Chemical Company, Freeport, Texas, U.S.A.

The typical operating conditions in solvent extraction plants will be presented, various materials of construction reviewed and the use of FRP (fiberglass-reinforced plastic) as a material of construction described with worldwide examples of this application.

PAPER 47.5 — 15:55
SCALE-UP OF PUMPER-MIXERS FOR SOLVENT EXTRACTION.
T. POST, ConsultDrPost, Pittsford, New York, U.S.A.

The methodology of determining the optimum SX pumper-mixer system based on bench top, pilot, or small-scale solvent extraction systems is demonstrated. The design of small scale SX-plants is different than a full-scale plant. The difference is shown. The use of dimensionless parameters Nh, Nq, and Np that describe the head, flow and power of the pumper is shown and how to use them for the scale-up. Comparisons will be made with well known currently operating SX plants. The emphasis on the optimization of hydraulic efficiency will be shown on examples, including how the hydraulic efficiency is affected when the throughput of the system goes beyond the design. Designs of all sizes of equipment will be shown which optimize the hydraulic efficiency.

PAPER 47.6 — 16:20
ADVANCED MIXER SETTLER DESIGNS THAT WILL OPTIMIZE TOMORROW'S LARGE FLOW PRODUCTION REQUIREMENTS
M. GIRALICO, LIGHTNIN, Rochester, New York, U.S.A., and
T. POST, ConsultDrPost, Pittsford, New York, U.S.A.

The newest design in auxiliary mixers for solvent extraction allows for variable tip chord angles (TCA). These angles allow for the optimization of up-pumping impellers on the basis of flow and shear. Previously, only hydrofoils with a single TCA were used. In order to obtain the optimum flow, shear, flow pattern and impeller diameter, the TCA is an ideal parameter to change in the range of 10 to 35 . The optimum auxiliary impeller(s) is designed to maintain the dispersion from the pumper at the lowest possible power consumption. To achieve this, the auxiliary mix tank may have one to three impellers on a shaft to obtain flow and dispersion uniformity. The spiral impeller design has been claimed to achieve this. A comparison of up-pumping hydrofoils will be made with a spiral design to show that the spiral design does require more power and delivers more shear than the hydrofoils. The comparison will be made with laser-grams and CFD. Lastly, the optimum design of the mix tank will be discussed which compliments the use of these hydrofoils.

SESSION 48: INTERNATIONAL SYMPOSIUM ON HYDROMETALLURGY IN HONOUR OF PROFESSOR IAN RITCHIE

SOLUTION PURIFICATION II: ELECTROWINNING III
Sponsors: Hydrometallurgy Section of The Metallurgical Society of CIM (MetSoc), Extraction and Processing Division, The Minerals, Metals and Materials Society (TMS), and the Society for Mining, Metallurgy and Exploration (SME)
Room: Pavillion Ballroom B
Chairmen: P. MASON, Falconbridge (Australia) Pty. Ltd., Toowong, QLD, Australia
D. ROBINSON, Dremco, Inc., Milano, Italy

PAPER 48.1 — 14:00
SUCCESSFUL INDUSTRIAL USE OF QUILLAJA SAPONINS (QUILLAJA SAPONARIA MOL.) FOR ACID MIST SUPPRESSION IN COPPER ELECTROWINNING PROCESSES.
A.F. OTERO, Catholic University, Mackenna, Santiago, Chile,
R.M. SAN MARTIN, Catholic University, Mackenna, Santiago, Chile, and
A. CRUZ, CODELCO-Norte Division, Radomiro Tomic, Hydrometallurgical Plant, Calama Chile

Electrolytic processes produce significant quantities of highly toxic vapour due to the liberation of gases (oxygen and hydrogen) at cathodes and/or anodes. For example, in the electrowinning of metals (e.g., zinc, copper), bubbles of gas produced at the anodes rupture when they reach the surface producing an aerosol of sulphuric acid called acid mist. Acid mist affects the health of operators, the environment and plant infrastructure, for which reason strict environmental regulations exist concerning acid mist generation and control. Saponin-rich extracts derived from the Chilean endemic tree Quillaja Saponaria Molina, have been successfully used for the suppression of acid mist in copper electrowinning at an industrial scale, 950 tpd cathode copper production plant (Radomiro Tomic, CODELCO-Chile). Chemically, Quillaja Saponins are triterpenoids, with two sugar chains linked to carbons 2 and 23. Historically, they have been used as foaming agents in beverages, photographic film emulsions, etc. They are approved for human consumption by the FDA (U.S.), European Union, WHO Food Codex, and the Ministry of Health, Japan. In summary, this work establishes and determines technical parameters which enable the use of Quillaja extracts in electrolytic industrial application, such as, the copper electrowinning process, through the application of a natural base reagent, Mistop®, a product destined for both domestic consumption and overseas export.

PAPER 48.2 — 14:25
HYDROGEN INHIBITOR APPLICATIONS IN FUEL CELLS AND BASE METAL ELECTROWINNING.
B.W. DOWNING, MagPower Systems Inc., Vancouver, British Columbia, Canada,
E. GYENGE, J. LU, D.B. DREISINGER, The University of British Columbia, Vancouver, British Columbia, Canada, and
J. JUNG, BC Research Inc., Vancouver, British Columbia, Canada

MagPower has developed methods to control the detrimental formation of hydrogen that occurs in electrochemical reactions in numerous commercial applications such as the magnesium-air fuel cell, electrowinning, zinc alkaline batteries, hydrogen embrittlement, waste water/ metal recycling and coolants. The company's approach to an alternative energy source is the development of an environmentally friendly non-toxic alternative power source that generates electricity through a combination of magnesium, oxygen and a saltwater electrolyte with MagPower's patent pending hydrogen inhibitors. The magnesium-air technology has never reached the commercial stage due to its limiting power output caused by hydrogen generation. MagPower has solved this problem and has patents pending on its intellectual property, the hydrogen inhibitors and has developed several consumer power units for a variety of applications through licensing agreements. The company has also shown that the inhibitors have an impact on zinc electrowinning through laboratory test work where current efficiency was improved. This will significantly reduce power consumption and increase the efficiency of the electrowinning process, as well as reduce the potential acid mist hazards associated with electrowinning.

PAPER 48.3 — 14:50
DIRECT ELECTROWINNING OF SILVER FROM DILUTE LEACH LIQUORS.
S. JAYASEKERA, Lakefield Oretest Ltd., Kewdale, Perth, Western Australia

This paper describes the results of a study carried out to examine the feasibility of electrolytic recovery of silver from cyanide leach liquor generated from a Western Australian silver mine tailings using a novel high mass transfer electrowinning cell. The proposed circuit involves heap leaching and electrowinning in a closed loop. The filter-press-like closed electrode arrangement of the cell allowed much improved mass transfer of metal ions to the cathode surface, making direct electrowinning of metals from dilute solutions feasible. The tests were conducted both in the laboratory and at large scale using a prototype with 1.0 m^2 cathode area. The results showed that the recovery of silver from as low as 250 mg/L tenor was feasible. The silver deposit produced with the prototype cell was non-adherent and powdery and could be readily removed from the closed cell. A system was designed such that the silver powder was discharged continuously without having to open up the cell for regular cathode stripping.

COFFEE BREAK — 15:15 – 15:30

PAPER 48.4 — 15:30
HIGH CURRENT DENSITY COPPER ELECTROWINNING USING THE EMEW CELL.
V. ESCOBAR, CODELCO Radomiro Tomic, Calama, Chile
T. TREASURE, Electrometals Technologies Ltd., Ashmore, Queensland, Australia
R. DIXON, Blumos S.A., Santiago, Chile

In order to maintain high copper purity in a copper electrowinning (or electro-refining) tank house, a continuous bleed of solution must be taken from the tank house inventory to prevent closed-circuit build up of contaminants, and resulting degradation in cathode quality. In an SX-EW operation, this bleed stream is normally recycled back to the solvent extraction circuit, but is occasionally sent to the raffinate pond to re-enter the 'upstream' leach circuit.

Return of the bleed stream to the solvent extraction circuit creates a continually recycling load of copper in solution, which may limit overall plant capacity and expansion potential. Return of the bleed stream to the leach circuit has a similar effect. These practices represent an operational inefficiency, and methods to reduce its impact are always under consideration.

This paper presents the results of a two month pilot evaluation of EMEW technology at Radomiro Tomic, in Chile. The EMEW cell developed by Electrometals Technologies Ltd. tolerates substantially higher levels of contaminants than those found in conventional tankhouse, and operates at high current densities while maintaining copper quality at LME grade A to significantly lower copper concentration

Tests were run at ambient temperature on bleed electrolyte with current densities which varied between 250 and 1100 amps per square meter, with copper concentrations between 38 g/l and 1 g/l. A profile of maximum allowable current density with respect to concentration was developed, showing that high grade copper can be obtained at all levels of concentrations tested, by choosing an appropriate current density and electrolyte flow rate.

The results of this programme show that the recirculating bleed electrolyte can be converted into an expansion in copper production at a comparatively low investment cost. EMEW in this application offers a simple, single step method for expansion of an existing operation.

PAPER 48.5 — 15:55

PERFORMANCE OF INTERCELL BARS FOR ELECTROLYTIC APPLICATIONS: A CRITICAL EVALUATION.

G.A. VIDAL, E.P. WIECHMANN, University of Concepcion, Concepcion, Bio Bio, Chile

Recently designed facilities have substantially improved on plant layout, automated cathode processing and copper harvesting. Despite these advancements, only limited progress has been accomplished on the electric current distribution of the process. Lately, a number of proposals focused on preventing short circuits and balancing cathode currents have emerged. Among these are the AZSA intercell, the Outokumpu double contact, and the segmented Optibar. Although these intercell bars are clearly superior to the conventional bar, little or conflicting data is available about their merits. A critical evaluation of the performance of the aforementioned bars on the basis of the application is provided.

PAPER 48.6 — 16:20

COMMERCIAL DEVELOPMENT OF A DESCENDING PACKED BED ELECTROWINNING CELL.

D.J. ROBINSON and S.A. MacDONALD, Dremco Inc., Milane, Italy

This paper describes technical work done to develop a Spouted Bed electrode cell into a commercially viable electrowinning cell. The studies have included hydrodynamic tests to understand the criteria for the circulating flow of metallic beads in the cell, particularly in the region at the entrance to the draft tube, and electrochemical tests to find a suitable diaphragm for extended time electrolysis. Various patent pending features were developed including a double nozzle to allow for automatic stopping and restarting of the bed, an arrowhead-shaped draft tube to control the flow of beads into the entrance to the draft tube, a roof-top shaped device to control the flow of beads out of the top of the draft tube, an overflow weir to allow the continuous recovery of beads from the cell, and a family of diaphragm fabrics for extended operation. Prior to the identification of the diaphragm material, short circuits would develop within a few hours. A pilot-scale cell was operated for three days, with continuous operator attention, and then for ten days coverage only on day shift. The cell is currently advancing to the next stage of development which will involve continuous testing in a commercial copper electrowinning facility.

SESSION 49: INTERNATIONAL SYMPOSIUM ON HYDROMETALLURGY IN HONOUR OF PROFESSOR IAN RITCHIE

TECHNOLOGY APPLICATION: OPERATIONS

Sponsors: Hydrometallurgy Section of The Metallurgical Society of CIM (MetSoc), Extraction and Processing Division, The Minerals, Metals and Materials Society (TMS), and the Society for Mining, Metallurgy and Exploration (SME)

Room: Junior Ballroom C

Chairmen: N. HAZEN, Hazen Research, Golden, CO, USA
J. MARSDEN, Phelps Dodge Corporation, Phoenix, AZ, USA

PAPER 49.1 — 14:00

COPPER CONCENTRATE LEACHING DEVELOPMENTS BY PHELPS DODGE.

J. MARSDEN, Phelps Dodge Corporation, Phoenix, Arizona, U.S.A.

In early 1998, Phelps Dodge embarked upon program to investigate alternative technologies for the extraction and recovery of copper, and other metal values from copper concentrates. A review of all of the available process alternatives indicated that many were unsuitable for large-scale commercial application and others were clearly targeted at niche applications where contaminants (and consequently smelter penalties) were driving the decision-making. A result of this effort is the world's first commercial application of high-temperature pressure leaching of chalcopyrite concentrates which is under construction at Bagdad, Arizona, and start-up is scheduled for 2003. Other processes are in various stages of development. In addition to the obvious technical considerations, the economic aspects of this technology have been considered in detail at each step in the development of the program. The technology developments in this area are reviewed with emphasis on the economic viability and commercial application.

PAPER 49.2 — 14:25
HYDROMETALLURGICAL APPLICATIONS OF RHEOLOGY TESTING.
A. MEZEI, Lakefield Research Limited, Lakefield, Ontario, Canada

Experimental rheology data are needed to produce design criteria for mass and energy transfer processes. Large throughput plants operate under continuous flow mode. The capital cost is determined by the accuracy of the rheology data used for design. The operating cost is dictated by the energy required to sustain the flowing conditions of various process slurries. Typically, rheology investigations are carried out during the final stages of metallurgical test work, which is too late to set the design criteria for the pilot plant. This leads to increased testwork cost, and sometimes lowers confidence in the quality of the data produced. In addition, the engineering and feasibility studies are often delayed because of the lack of pertinent rheology data. The object of this paper is to emphasize the importance of timely planning and execution of the rheology study, which is shown to be a critical component of the overall testwork program. The application examples presented include slurry transport, separation processes and high-temperature rheology pertaining to precious and base metal metallurgy.

PAPER 49.3 — 14:50
THE DEVELOPMENT AND PILOTING OF AN INDUSTRIAL HYDROMETALLURGICAL GALLIUM PLANT.
C.G. ANDERSON, CAMP - Montana Tech, University of Montana, Butte, Montana, U.S.A.

Gallium is sometimes found in conjunction with zinc ores. In one existing North American hydrometallurgical facility, gallium will now be recovered as a value-added by-product. This paper will outline the process development, lab testing and pilot-scale confirmation undertaken to implement the technology. Pertinent economics will be discussed.

COFFEE BREAK — 15:15 – 15:30

PAPER 49.4 — 15:30
THE SEPON COPPER PROJECT : DEVELOPMENT OF A FLOWSHEET.
G. PRATT, Oxiana Resources NL, Melbourne, Victoria, Australia,
K. BAXTER, Bateman Metals Pty Ltd., Victoria Park, Perth, Western Australia, and
D.B. DREISINGER, Metals and Materials Engineering, The University of British Columbia, Vancouver, British Columbia, Canada

The Sepon Copper Project is located in Laos and has a mineable reserve of approximately 16 Mt of ore grading 5% copper with minor gold and silver values. The deposit is a clay-hosted secondary copper mineral suite predominantly chalcocitic in nature with minor pyrite. The current project design is based on the production of 60 000 t/a of LME Grade A cathode by an acid leaching process followed by solvent extraction and electrowinning. Significant metallurgical testwork was conducted as part of the Definitive Study (DFS) with process challenges identified and overcome at each phase of testing. Flowsheet configuration is geared to autogenously generating sufficient acid and ferric iron to leach the copper and is strongly influenced by the proportion of pyrite in the ore presented to the process facility. This paper will outline flowsheet development from preliminary variability testing to pilot plant and DFS design. The Sepon process solution provides a balance between operability and capital/operating costs and provides insights to the basic mechanisms influencing flowsheet selection for these ore types.

PAPER 49.5 — 15:55
THE TECK COMINCO HYDROZINC© PROCESS.
H.M. LIZAMA, J.R. HARLAMOVS, S. BELANGER and S.H.R. BRIENNE, Teck Cominco Metals Ltd., Trail, British Columbia, Canada

A new integrated process, known as HydroZinc©, is described for the recovery of zinc from sulphide ores that includes heap leaching, neutralization, solvent extraction, and electrowinning. Unit operations were scaled up from bench scale to a 1 t/d zinc cathode demonstration plant. Studies defined the process chemistry and a process flowsheet. Column tests were used to design full-scale heaps for zinc bioleaching and a mini-pilot rig was used to design a solvent extraction circuit. The characteristics of the process required development of a novel bleed circuit for water and impurities. The complete integrated process was tested on a demonstration plant scale for two years, with about 10 000 t of zinc sulphide ore being bioleached in two 6 m tall test heaps. In addition to 1 t/d of zinc cathode, iron hydroxide and gypsum residues were also made as well as a small effluent bleed. Over the course of the two-year demonstration test, a number of technical hurdles were overcome and a number of improvements were made. Some of the more significant ones are presented along with process descriptions and experimental and pilot plant data. Some engineering aspects and economic evaluations of the new process are also discussed.

PAPER 49.6 — 16:20
REMOVAL OF PHOSPHORUS FROM LISAKOVSKY IRON ORE BY A ROAST-LEACH PROCESS.
H.R. KOKAL, Ispat Inland Research Laboratories, Ispat Inland Inc., East Chicago, Illinois, U.S.A.,
M.P. SINGH, Iron Ore Division, Orken LLP, Karaganda, Kazakhstan, and
V.A. NAYDYONOV, Orken LLP, Lisakovsk, Kostani, Kazakhstan

Lisakovsky is a 3 billion ton oolitic iron ore deposit in north central Kazakhstan operated by Orken LLP, a subsidiary of Ispat Karmet and the LNM Group. The iron oxide minerals are goethite and limonite. The gangue occurs as discrete quartz grains and an unidentified form of colloidal silica-alumina. The concentrate produced contains about 49.5% iron (Fe) and 0.7% to 0.8% phosphorus (P) or 10 to 20 times the acceptable phosphorus level. The phosphorus is intimately associated with the iron oxide and colloidal gangue, no discrete phosphorus minerals are found, and beneficiation is not possible. Therefore, to reduce the phosphorus, a hydrometallurgical process that includes roasting followed by leaching in dilute sulphuric acid has been developed. Phosphorus extraction is 70% to 90%, with only a minor loss of iron. The process has been tested in the laboratory and in a pilot plant at 50 to 300 kg/h. Planning for a 900 000 t/y demonstration plant is under way.

SESSION 50: INTERNATIONAL SYMPOSIUM ON HYDROMETALLURGY IN HONOUR OF PROFESSOR IAN RITCHIE

LEACHING I: HEAP LEACHING II AND GENERAL

Sponsors: Hydrometallurgy Section of The Metallurgical Society of CIM (MetSoc), Extraction and Processing Division, The Minerals, Metals and Materials Society (TMS), and the Society for Mining, Metallurgy and Exploration (SME)

Room: Pavillion Ballroom C

Chairmen: G. WARDELL-JOHNSON, A. J. Parker Centre for Hydrometallurgy, Murdoch University, Murdoch, WA, Australia

M. VANCAS, Bateman Engineering, Tucson, AZ, USA

PAPER 50.1 — 14:00
THE DYNAMICS OF CHALCOCITE HEAP BIO-LEACHING.
J. PETERSEN, Metals and Materials Engineering, The University of British Columbia, Vancouver, British Columbia, Canada, and D.G. DIXON, University of Cape Town, Rondebosch, South Africa

Chalcocite, the most common secondary copper sulphide, leaches by a two-stage mechanism. The first stage is rapid, whereas ,the second stage proceeds slowly at ambient temperatures. Nonetheless, this rate is still considerably faster than what is commonly realized in a full-scale chalcocite heap leach operations. Column leach tests of a chalcocite ore have shown that the mineral leaches in a zone-wise fashion corresponding to the two stages. The rate of migration of the zones is directly related to the rate of acid supply in the column feed, and acid supply rather than mineral kinetics controls the overall rate of leaching. In full-scale heaps, there is evidence to suggest that solution distribution favours channelling between relatively large clusters of material exposed to stagnant solution. The rate of mineral oxidation is therefore governed by the rate of acid diffusion through long stagnant pores. Column experimental results have been reproduced with a comprehensive heap modelling tool. The model predicts that by simply changing the length of the average diffusion channel from column conditions (a few centimetres) to heap conditions (tens of centimetres), extraction times can change from weeks to years under otherwise identical conditions.

PAPER 50.2 — 14:25
THE LIFE CYCLE OF A CHALCOCITE HEAP BIOLEACH SYSTEM.
D.J. READETT and L. SYLWESTRZAK, Straits Resources Limited, West Perth, Western Australia

Bioleaching of chalcocite ores in heaps has been practiced for many years. Recently, Straits Resources Limited successfully implemented heap bioleaching of chalcocite at its Nifty Copper Operation, transferring its operational experience from its previous successful Girilambone Copper Operation. In order to obtain a greater fundamental understanding of the heapbioleach system, Straits has been working closely with CSIRO. An 85 000 t chalcocite test heap was established at Nifty to allow for detailed study. On an ongoing basis the physical, chemical and biological components of the system were monitored. Due to implementation of a heap management strategy and the specific mineralogy of the heap, it was possible to maintain operating conditions within the heap of 40 C to 70 C. There was a significant change in the chemistry and bacterial biota over the life of the heap. Initially only mesophilic bacteria were detected. However, within two months of the commencement of leaching, the presence of moderate thermophiles was detected. As leaching progressed the moderatethermophile speciesstabilized as did the mesophiles. This has been the first time that moderatethermophiles have been detected at a Straits operation. It was achieved without the external inoculation of moderate thermophiles. The elevated temperature and controlled physical and chemical heap environment resulted in a significant increase in copper extraction kinetics, with +45% recovery in 50 days and +70% recovery in 180 days. Ultimate target extraction of 85% was achieved in 300 days. Previous data from GCC gave optimum recoveries of 85% in 480 to 600 days. The paper covers in detail findings from the 85 000 t test heap.

PAPER 50.3 — 14:50
FEASIBILITY STUDIES - JUST HOW GOOD ARE THEY?
M.F. VANCAS, BATEMAN Engineering, Tucson, Arizona, U.S.A.

Virtually every new process plant project goes through the "feasibility study" phase before actually being built. The feasibility study is used by the owners and the bankers to evaluate the economics of the project and determine whether or not the proposed investment meets their respective investment guidelines. With a positive result, the project is approved and goes to construction and operation. Then, the actual costs are incurred and these actual costs may or may not agree with what the feasibility study predicted. Just how good have feasibility studies been? This paper looks at various projects and compares predicted to actual results and also gives information on how to spot a poor feasibility study.

COFFEE BREAK — 15:15 – 15:30

PAPER 50.4 — 15:30
INNOVATION: THE WAY FORWARD FOR HYDROMETALLURGICAL PROCESSING.
V.I. LAKSHMANAN, R. SRIDHAR, G.B. HARRIS, Process Research ORTECH Inc., Mississauga, Ontario, Canada, and
V. RAMACHANDRAN, RAM Consultants, Scottsdale, Arizona, U.S.A.

While the prices of metals in nominal terms have largely remained static over the past thirty years, in real terms, the primary metals industry receives very much less today for its products than in the past. Yet, it has largely managed to remain competitive, despite the fact that ore reserves are not only diminishing, but are of lower grade and higher complexity, and that there are much greater pressures on companies to be good environmental stewards. This paper examines how hydrometallurgical processing has shown itself to be highly innovative in order to remain viable both economically and environmentally. Aspects of process chemistry are discussed, and the lessons to be learned from having a good understanding of this chemistry are highlighted with reference to a number of case histories such as HPAL for nickel laterites, the Avmin/Chambishi Cosac Project, use of chloride chemistry for titanium extraction, and plant effluent treatment and recycle.

PAPER 50.5 — 15:55
ON-LINE ANALYZERS IN HYDROMETALLURGICAL APPLICATIONS.
R. KRENTZ, Sherritt International Corporation, Fort Saskatchewan, Alberta, Canada

Two separate on-line analyzers have been commissioned at the Corefco metals refinery. The first application is an on-line refractometer which measures the ammonium sulphate concentration in the primary feed slurry tank. The second application is a multi-stream X-ray fluorescence analyzer which measures the metals and sulphur concentrations in eight key refinery streams. Specific applications of the on-line analyzers with advanced control systems for improved process control will be discussed.

PAPER 50.6 — 16:20
RECOVERY OF CHROMIUM(VI) FROM ELECTROPLATING RINSE WATER: THE DEVELOPMENT OF A HOLLOW FIBRE SOLVENT EXTRACTION PROCESS.
P.J. HARRINGTON and G.W. STEVENS, Department of Chemical and Biomolecular Engineering, The University of Melbourne, Melbourne, Victoria, Australia

Recovering and recycling of low concentration metal and other ions has traditionally been carried out using adsorption or ion exchange processes, these, however, become uneconomical at higher concentrations such as those that occur with many intermediate or waste streams. This paper describes the development of a process based on hollow fibre or non-dispersive solvent extraction for the recovery of chromium(VI) from electroplating rinse water. During the chromium plating of steel the concentration of chromium(VI) in the rinse bath rises to approximately 100 ppm when it becomes unusable and is then disposed of. The aim of this project is to investigate processes for recovery and recycling of the chromium in the rinse bath. The recovered chromium is required to be concentrated and purified before reuse. Tertiary amines have been shown capable of concentrating and purifying the chromium(VI) in solution. However, solvent extraction processes that have been applied to the recovery and reuse of metals from waste streams have had only limited success in the past, primarily because of the relatively high solvent losses when existing contracting equipment is used on low feed concentrations. Attempts to eliminate losses by immobilizing these complexing agents on substrates have not been successful. In order to control the losses and maintain specificity, a hollow fibre contained liquid membrane has recently been trailed in a pilot plant to recover chromium from chromium plating waste streams. Details of the trial are presented and show that the level of losses is significantly reduced. However, issues relating to fouling still need to be addressed. This type of equipment has many applications in the recovery and recycling of a range of materials in the manufacturing processes.

SESSION 51: INTERNATIONAL SYMPOSIUM ON HYDROMETALLURGY IN HONOUR OF PROFESSOR IAN RITCHIE

LEACHING II: PRESSURE AND AUTOCLAVE

Sponsors: Hydrometallurgy Section of The Metallurgical Society of CIM (MetSoc), Extraction and Processing Division, The Minerals, Metals and Materials Society (TMS), and the Society for Mining, Metallurgy and Exploration (SME)

Room: Pavillion Ballroom D
Chairmen: K. LAMB, AMEC E&C Services, Vancouver, BC, Canada
V. RAMACHANDRAN, RAM Consultants, Scottsdale, AZ, USA

PAPER 51.1 — 14:00
USE OF PRESSURE HYDROMETALLURGY IN DIRECT PROCESSING OF BASE METAL/PGM CONCENTRATES.
J.C. MILBOURNE and L.S. GORMELY, AMEC E&C Services, Mining and Metals, Vancouver, British Columbia, Canada

Available processing technology for use in treating copper-nickel-cobalt-platinum group metal concentrates will be surveyed. Block flowsheets will be provided and the technical characteristics will be compared. The probable economic impact of the technical features will be assessed qualitatively. The current state of development for each process will be summarized. Perceived risks and rewards associated with each technical concept will be provided in the conclusions.

PAPER 51.2 — 14:25
DEVELOPMENT AND IMPLEMENTATION OF A NOVEL PRESSURE LEACH PROCESS FOR THE RECOVERY OF COBALT AND COPPER AT CHAMBISHI, ZAMBIA.
E. MUNNIK, H. SINGH, Chambishi Metals P.L.C., Chambishi, Zambia,
T. UYS, Anglovaal Mining Ltd., Marshalltown, South Africa,
B. HARRIS, Process Research Ortech, Mississauga, Ontario, Canada,
K. FRASER, Hatch Associates Ltd., Mississauga, Ontario, Canada,
M. BELLINO and J. DU PLESSIS, Hatch Africa (Pty) Ltd., Gallo Manor, South Africa

The Chambishi Metals Cobalt Plant in Zambia has recently installed a novel oxidation/precipitation pressure leach process as part of the COSAC (cobalt from slag and copper as by-product) Project. An iron-cobalt-copper alloy, produced by the carbothermic reduction of slag, is atomized and pumped to the COSAC leach plant, where cobalt and copper are recovered as dissolved sulphate salts, and iron is rejected primarily as hematite. Cobalt and copper are subsequently recovered as cathode metal in the existing Chambishi operation by conventional electrowinning. This paper examines the challenges faced during the design and subsequent successful commissioning of the COSAC leach plant. The challenges discussed include alloy handling, autoclave design, autoclave cooler design, residue liquor recovery and the water balance design.

PAPER 51.3 — 14:50
PH MEASUREMENTS IN HIGH-TEMPERATURE HYDROMETALLURGICAL SYSTEMS.
V.G. PAPANGELAKIS, D.S. SENEVIRATNE, Department of Chemical Engineering, University of Toronto, Toronto, Ontario, Canada,
X.Y. ZHOU and S.N. LVOV, The Energy Institute and Department of Energy and Geo-Environment Engineering, The Pennsylvania State University, University Park, Pennsylvania, U.S.A.

The implementation of a flow-through yttria-stabilized zirconia (YSZ) sensor for pH measurements in high temperature and concentrated electrolyte systems relevant to hydrometallurgical processing of nickeliferous laterites is discussed. Instrumentation involved the use of a custom made flow-through titanium electrochemical cell. Accuracy and validity of the pH measurements at temperatures up to 250 C were assessed using concentrated sulphate process solutions ranging from synthetic binary sulphuric acid-water solutions to progressively multicomponent metal-sulphate solutions simulating laterite pressure acid leach conditions. The measurements were also compared with theoretical models using recently obtained thermodynamic data. An average difference of ±0.15 pH units was observed between measured and calculated pH over a vide range of temperatures. This is an acceptable difference given that these are the first direct high-temperature pH measurements ever on the concentrated acidic sulphate solutions. This result is encouraging more research for the development of industrial electrochemical systems for direct pH measurements in autoclaves.

COFFEE BREAK — 15:15 – 15:30

PAPER 51.4 — 15:30
DESIGN OF HORIZONAL AUTOCLAVES — PILOT PLANT EVALUATION OF SOLIDS SUSPENSION, BLENDING AND RESIDENCE TIME DISTRIBUTION.
P. FORSCHNER, D. HOULTON, EKATO Rühr und Mischtechnik GmbH,
R. KLEPPER, EKATO Corporation, and
V. KASSERA, CF Consultants

Mixing theory is based on applying many fundamental correlations to symmetrical vertical cylindrical vessels with dished or flat bottoms. Horizontal autoclaves have been used for more than two decades to rapidly complete chemical reactions at elevated temperatures. All compartments, and especially the first and last compartments, are asymmetrical. To date no comparison of the effects of the asymmetric geometry on mixing system design and scale-up has been published. The results of investigating solids suspension, mixing time, momentum of impeller to feed slurry and feed location in the first autoclave compartment are presented as influences on residence time distribution and presented using CFD modelling that was verified with test apparatus.

PAPER 51.5 — 15:55
CFD IN AUTOCLAVE VESSEL DESIGN.
L. OSHINOWO, L. GUNNEWIEK and K. FRASER, Hatch Associates Ltd., Mississauga, Ontario, Canada

The trend in process engineering is to design compact, more efficient processes that utilize expensive materials of construction. There is the paramount requirement to get the job done right the first time going from the drawing board to full-scale commercial operation. There is the need for tools beyond the traditional engineering tool kit to evaluate designs through virtual prototyping thereby reducing the risks associated with making design decisions. One of the most important tools thathas recently come to the forefront of process design and development is computational fluid dynamics (CFD). CFD has been used to address the key process parameters that drive the design of the hydrometallurgical unit operation. This paper will detail the role of CFD in achieving a superior level of confidence in the process design of autoclave technology. Specifically, the optimum application of multiphase modelling including hydrodynamic, heat and mass transfer and chemical reaction to hydrometallurgy operations, the impact of non-Newtonian slurry rheology on autoclave performance, and the challenges of optimizing the mixing of key reactants into slurries in autoclave reactors, is discussed. In addition, model verification and validation is presented.

PAPER 51.6 — 16:20
AUTOCLAVE TECHNOLOGY FOR MINERAL PROCESSING.
A.V. TARASOV and E.M. TIMOSHENKO, State Research Institute of Non-Ferrous Metals, "GINTSVETMET", Moscow, Russia

The high efficiency of autoclave processes is attributed to the fact that they are suitable for processing of refractory raw materials, have low capital costs and high productivity, ensure integrated utilization of the feed materials, produce innovative saleable products, completely eliminate any air emissions, provide low-waste or waste-less technology, as well as mechanization and automation of production processes. In the immediate future, it might be expected that autoclave processes will find use on commercial scale for production of heavy non-ferrous metals in combination with other processes (hydrometallurgical, upgrading, sorption and solvent extraction, electrolytic, etc.) to ensure: integrated processing of refractory ores and concentrates (pyrrhotite, zinc, copper-zinc, lead-zinc, nickel-cobalt, copper, pyrite); and production of metallic powders of base metals as commercial products (copper, cobalt, nickel, etc.), composites on their bases, final products and saleable salts. Processing technologies incorporating autoclave processes, especially at the stage of liberation (chemical upgrading) of minerals, are characterized generally by high overall recoveries of valuable constituents significantly exceeding recoveries common for conventional pyrometallurgical processes (for some elements by several tens of percent).