WEDNESDAY, AUGUST 29, 2007, AM

Cu2007 **Plenary Session 5 and 6**
Sponsors: Metsoc, IIMCh, GDMB, MMIJ, TMS, SME
Chair(s): C. Twigge-Molecey, Hatch;
N. Piret, Piret & Stolberg Partners Consulting Engineers
Room Canadian—08:00

Paper #1107—08:00
Attracting and retaining professionals in mining and metallurgy – a high tech industry
D. Magoon, General Manager, Technology, Teck Cominco Ltd. and Towers Perrin Ltd.

The metals industry has enjoyed a resurgence in prices and demand for its commodities during the global surge in economic activity that began in 2005. This success has brought with it an unprecedented demand for professionals in all sectors of our economy. Nowhere is that more true than in the mining and metallurgy sectors. However, this welcome improvement follows on the heels of almost two decades of challenging markets for the mining and metallurgy. Our sector's protracted economic slump created a paucity of demand for professionals that had several consequences. Our industry came to be viewed as a low –tech, uninteresting place to work. Low demand for professionals encouraged students to seek other career options. Reduced demand for graduates, coupled with diminished program funding by our sector, resulted in dramatic shrinkage in university mining and metallurgy programs. This paper explores the lessons to be learned from our recent economic history and discusses some strategies for addressing our image issue. Attracting and retaining good employees is also strongly influenced by a company's reputation and record as a good employer. This reality is very well illustrated by the findings of an international survey undertaken by Towers Perrin in 2005 of 86,000 employees of mid-sized and large companies in 16 countries. The key findings related to attracting and retaining employees are presented. These findings are also discussed in the context of their specific applicability to the mining and metallurgy industry.

Paper #1102—08:45
Human capital available for the development of the mining industry of the future
L. Contreras, President, Institutos de Ingenieros de Minas de Chile (IIMCh)

This study has as an objective to analyze and to propose actions to improve the quantity and quality of the graduate education in the area of mining industry, specifically of mining engineers, metallurgists, geologists, to satisfy the expectations of professionals in the mining industry. Included are an analysis of the present scenario and the future demands in countries like Chile and

proposed plans for the Establishment of Educational Initiatives, country policies and market forecast, vis-a-vis the experience of Australia, South Africa, United Kingdom, Canada and the United States of America.

COM 2007: International Symposium on **Light Metals** in Transport Applications
Session 49: Primary Product and Light Metals I
Sponsors: Light Metals Section of MetSoc, TMS
Chair(s): D. Gallienne, Alouette;
G. Dufour, Alcoa
Room Confederation 5—09:50

Paper #2100—09:50
Airflows through openings of smelter buildings exposed to crosswinds
E. Dernedde, Kroll International

Cell rooms of aluminium smelters have large openings in the sidewalls and in the roof. These openings provide a high ventilation rate, which removes heat and contaminants emitted by the reduction cells and thereby ensures acceptable working conditions inside the cell room. However the large openings make the airflows through the smelter building sensitive to the wind. In this study equations for the airflow through the openings of a smelter building exposed to crosswinds were developed and verified against plant measurements. The equations were then used to estimate the airflows through a two-storeyed smelter building containing VS Søderberg cells. Wind protection by wind-covers over the sidewall openings and by upwind buildings made the airflows through the building less sensitive to the wind. Physical and mathematical modelling showed that working conditions inside the wind-protected cell room would be acceptable for crosswinds at speeds up to 16 km/h. These predictions were confirmed by measurements taken in a VS Søderberg smelter.

Paper #1142—10:15
Microwave heating behaviour of a gibbsite type bauxite ore
T. Lu, C.A. Pickles, S. Kelebek, Queen's University

Microwaves have considerable potential as an energy source in both mineral processing and metals extraction. In this research, the application of microwave radiation for the pretreatment of bauxite ores was investigated. The major focus of the present research was on the interaction of microwaves with the bauxite ores. Firstly, the real and the imaginary permitivities of the ore were determined as a function of temperature. Secondly, the effects of heating time, sample mass, particle size, microwave power and sample bulk density on the sample temperature in a microwave field were studied. Thirdly, it was observed that some fracturing of the bauxite particles occurred and this lowered the strength index. The results obtained with microwave irradiation are compared to those obtained with conventional heating.

Paper #1146—10:40

Kinetics of aluminium Gallam corrosion in Bayer liquor

A. Senyuta, Russian National Aluminium and Magnesium Institute

Electrochemical gallam process of gallium extraction from alkaline aluminate solutions was implemeted at several alumina refineries about 30 years ago. But till now there is no satisfactory analytical description of the processes of formation and decomposition aluminium gallam kinetics as at their research it is necessary to consider rather complex systems. Specificity of gallam process consists in the presence of three interacting phases in the only reactionary volume: alkaline gallate a solution, liquid gallium -aluminium alloy, and solid granulated aluminium intruded into gallam. Dissolution of aluminium in gallium and its further transition from gallam to liquor occur simultaneously. Accordingly processes of aluminium ionization and gallium reduction in parallel proceed.

Paper #1137—11:05

Chemical and physical characterization of bauxite residue (red mud) for concrete making

M.G. Davoodi, H. Nikraz, Curtin University of Technology,
E. Jamieson, Alcoa World Alumina Australia

This paper describes the works carried out in laboratory to investigate the possibility of using bauxite residue (red mud) and its derivatives as a fine aggregate in concrete mix designs. Australia is the major producer of alumina in the western world with production of more than 25 million tonnes of red mud per annum. Research needs to be undertaken to establish a sustainable use for this residue. The main purpose of this research was to establish a scientific solution for the utilization of Red Mud and its derivatives (Red Sand; unprocessed and high in silica) as a replacement of natural fine aggregate (yellow sand) in concrete mix designs. The comparative analysis between normal mix designs and the mix designs utilizing Red Mud & Red Sand was also achieved. The main aim of this project was to establish a scientific basis for potentially new approaches to substitute natural sand with Red Mud or its derivatives. This may lead the more sustainable use of the Alumina industry's waste material. In order to achieve this, the bauxite residue obtained in the Bayer process must be washed and separated by a magnetic separator to form different fractions such as fine red mud, unprocessed red sand and high in silica red sand. Firstly physical, chemical and mineralogical properties of this material have been tested and compared with that of natural sand. Several mixes of concrete were then designed in order to verify their effects on strength and other properties. From the results obtained, it can be deduced that this material can be used in a wide range of concrete applications in Civil Engineering and Construction.

Cu2007: The John E. Dutrizac International Symposium on Copper
Hydrometallurgy, Incorporating the 37th Annual Hydrometallurgy Meeting
Session 50: Technology Development I
Sponsors: Hydrometallurgy Section of MetSoc, IIMCh, MMIJ, GDMB, EPD of TMS
Chair(s): B. Harris, Metallurgical Consultant;
D. Dreisinger, University of British Columbia
Room Alberta—09:50

Paper#0998—9:50
On-line free acidity measurement of Cu and other base metal containing solutions
M. Huang, V.G. Papangelakis, University of Toronto

Electrodeless conductivity was employed to investigate the feasibility of continuous on-line monitoring of the free acidity of sulphate and/or chloride solutions of Cu and other base metals from various hydrometallurgical processes. These solutions were measured with both commercial and experimental electrodeless conductivity sensors from 15 to 250°C. It was confirmed that hydrogen ion has the greatest impact on conductivity by carrying the bulk of the current because it is the most mobile ion. In combination with a solution speciation analysis the conductivity sensor can be calibrated to account for the contribution of Cu electrolytes as well other dissolved salts allowing fast and accurate on-line measurement of free acid. The sensor was tested at both lab and pilot scale with very good performance. The average difference between the measured and the titrated acid concentration was less than 5%, which is excellent for industrial applications.

Paper #0970—10:15
Ferrous chloride oxidation using oxygen or ozone: stoichiometry, gas efficiency and application
J. Jara, S. Zuttah, M. Meimari, Air Liquide Canada,
D. Hewitt, McGill University

Oxygen, ozone and air were evaluated in the oxidation of ferrous iron in the presence of hydrochloric acid ranging from 0.1 to 4 M HCl. Stoichiometric coefficients were determined through mass balances of gases and ferrous titration. The molar ratio ferrous to ozone increases from two at 0.1 M HCl concentration to six at 4 M HCl. For oxygen the same ratio is constant and equal to 2 and it is in agreement with other works. The stoichiometric coefficient of hydrogen ion was not defined due to the effect of hydrolysis of ferrous and in particular ferric ion on measuring acid concentration by titration with sodium hydroxide. Agitation, gas flow and pressure contribute in the utilization of gas. A technique to compare the gas efficiency at several conditions is discussed and it is based on the relationship between oxygen and ferric during time. There is a strong compromise between gas efficiency and ferrous conversion. Oxygen

efficiency decreased with time due to ferrous depletion. The gas efficiency ranged from 3 % (low level of agitation) producing 25 g Fe(III)/h to 12 % at 1000 rpm with 60 g Fe(III)/h converted. At 405 kPa absolute the oxygen efficiency was in the range of 80 % producing 300 g Fe(III)/h. The replacement of chlorine with oxygen to enrich molybdenite concentrates by reducing copper to less than 0.2 % was evaluated. Oxygen can be employed in batch or continuous operation and it can treat molybdenite concentrates with high variation of copper content. The dissolution rate is mainly controlled by oxygen addition in which utilization of oxygen plays an important role. Improvement on safety and environmental conditions is feasible by using oxygen instead of chlorine gas. The economics indicate good opportunities to implement oxygen without significant modifications to the actual circuit and enough benefit when oxygen is well used.

Paper # 1002—10:40

Ore characterization, alteration coding and plant feed control in copper operations as directed by routine semi-automated mineralogical analysis

D. Allen, B. Baber, S. Eady, W. Baum, Phelps Dodge Process Technology Center

Faced with decreasing ore grades and harder ores, many mines today are forced to become more efficient with their approach to processing. Variability in ore hardness, mineral liberation, reagent consumption, sliming, and leach responses are all a function of the minerals present and their concentration. Modern semi-automated X-ray Diffraction (XRD) analyses using Rietveld refinement techniques, in conjunction with high speed quantitative Near Infrared (NIR) analyses, provide reliable quantitative mineralogical ore profiling. By the implementation of XRD with NIR, mining, milling and leaching operations no longer need to be dependant on visual estimates for GeoMetallurgical Modeling and are provided with a valuable forecasting and production control tool. This paper will illustrate the development, plant implementation and application of XRD and NIR at several copper operations.

Paper #0959—11:05

Copper sulphate pentahydrate production at Phelps Dodge Sierrata Inc.

G.T. Fisher, J.L. Beck, Phelps Dodge Sierrita Inc.

A continuous process is used at Phelps Dodge Sierrita Inc. to produce copper sulfate pentahydrate via a solution extraction – crystallization approach to supply the animal feed market. A review of the fundamental concepts of the process and unit operations is presented. Improvements in the process are aimed at achieving a controlled size distribution of product crystals (–40+80 mesh) with minimization of fines by primary nucleation and crystal breakage. An independent temperature control design was implemented for the heat transfer medium (water) in each crystallizer, albeit using common headers in and out of the chiller. This design was developed to maintain a controlled degree of supersaturation in each vessel while preventing localized spontaneous

nucleation of fines and reducing encrustation of the heat transfer surfaces in each crystallizer. A model was developed to calculate the heat load and heat transfer coefficient of each crystallizer along with the saturation copper tenor as a function of temperature and free acid.

Paper#1012—11:30

Solution management at Mantoverde Division of Anglo American Chile

U. Troncoso, C. Pérez, G. Zárate, Anglo American Chile

Mantoverde is a heap leach-SX-EW operation that was commissioned in December 1995 at a production rate of 42,130 ton of copper per year and 5.4 million ton of ore per year. Copper production has been steadily increased to reach 62,000 ton in 2005. The forecast copper production for 2006 is 60,300 ton for an ore treatment rate of 9.5 million ton. A first dump leach operation was started in 1999 at a production rate of 1,922 ton of copper. A second dump leach operation was started in early 2002 at a production rate of 2,805 ton of copper. Dump leach production will be increased over time to as much as 24,000 ton of copper. Several improvements in the heap leach process have been implemented to cope with the higher ore throughput and copper production. However, the solvent extraction plant has remained unchanged which has resulted in a lower availability of raffinate solution and, as a consequence, in longer leach cycles. Different studies have been undertaken in order to optimize the solution management system at Mantoverde, including column test work aimed to reduce the leach cycle and solvent extraction plant modifications aimed to increase the raffinate solution availability. The test work program and the economical evaluations carried out, as well as the conclusions and recommendations obtained, are discussed in this paper.

Paper #1024—11:55

The effect of copper monosulphide on the hydrometallurgical refining of nickel-copper concentrates at high-temperature

L.M. Chugaev, N.A. Berezkina, Y.M. Shneerson, Gipronickel Institute

In the course of the hydrothermal refining of copper-nickel products containing covellite, oxidation of Fe^{2+} ions by the $CuS–Cu^{2+}$ pair takes place, and iron is precipitated as hematite. Lower copper concentrations in the solution and higher solution acidity lead to the partial oxidation of sulphide sulphur, whereupon hematite is reduced by covellite causing iron to go back in solution. It is demonstrated that in the process of hydrothermal treatment of the covellite-containing solid product in pure water covellite oxidises millerite to polydymite (Ni_3S_4). Formation of polydymite during the process of refining seems to be due to millerite oxidation both by covellite and the $CuS–Cu^{2+}$ pair.

Cu2007: The John E. Dutrizac International Symposium on Copper
Hydrometallurgy, Incorporating the 37th Annual Hydrometallurgy Meeting
Session 51: Leaching IV
Sponsors: Hydrometallurgy Section of MetSoc, IIMCh, MMIJ, GDMB, EPD of TMS
Chair(s): D. Dixon, University of British Columbia;
V. Ramachandran, Consultant
Room Manitoba—09:50

Paper #0988—09:50
Matching theory and practice in heap leaching processes
J.M. Menacho, L.E. Gutiérrez, P.A. Chávez, De Re Metallica Consulting

Electrodeless conductivity was employed to investigate the feasibility of continuous on-line monitoring of the free acidity of sulphate and/or chloride solutions of Cu and other base metals from various hydrometallurgical processes. These solutions were measured with both commercial and experimental electrodeless conductivity sensors from 15 to 250°C. It was confirmed that hydrogen ion has the greatest impact on conductivity by carrying the bulk of the current because it is the most mobile ion. In combination with a solution speciation analysis the conductivity sensor can be calibrated to account for the contribution of Cu electrolytes as well other dissolved salts allowing fast and accurate on-line measurement of free acid. The sensor was tested at both lab and pilot scale with very good performance. The average difference between the measured and the titrated acid concentration was less than 5%, which is excellent for industrial applications.

Paper #0980—10:15
Impact of heap operational changes on Zaldivar Copper production
S.C. Bouffard, Barrick Technology Centre,
D. Flores Godoy, Compañia Minera Zaldívar

Barrick's Zaldívar operation in Chile produces copper by heap leaching, solvent extraction, and electrowinning. The heap consists of a dynamic pad, and its stacking and operating conditions have changed over its 11 years of operation. These changes have included pad re-mining midway through the cycle, tightening of the irrigation drip lines, an increase of the coarseness of the particles, and an increase of the heap height. This paper reviews the heap operating data to understand the effects of these changes on the kinetics and recovery of copper minerals. Field tests demonstrated that neither re-mining nor tightening the irrigation grid added value for both low and high grade oxide and sulfide ores. The P_{80} of the feed ore was increased by 0.8 mm, which did not reduce the copper recovery of oxide and sulfide ores. The increase of the heap height above 8 m lowered moderately the copper recovery from sulfide minerals, and very slightly the recovery from oxide minerals. Despite the lower recovery, the higher tonnage stacked in the taller heap increased the copper output.

Optimizing the chemistry of the agglomeration and feed solution holds more promise for increasing the copper recovery than the above physical changes.

Paper #0941—10:40

Agglomeration for copper heap leaching

K.A. Lewandowski, S.K. Kawatra, Michigan Technological University

Agglomeration of ore used in heap leaching allows for the immobilization of fine particles that would otherwise migrate and cause permeability problems in the heaps. For copper ore, binders are needed in order to make stable agglomerates. However, the majority of binders break down when introduced to an acidic environment, allowing fine particles to be released from the agglomerate surfaces. These particles migrate through the heap impeding solution flow, leading to a decrease in metal recovery rates. The authors have developed a series of testing procedures to determine the acid resistance of several binders. Only five binders were shown to be acid resistant in soak tests, decreasing fines migration by up to 93%, compared to tests which were agglomerated with leach solution, raffinate, as a binder. Flooded percolation column testing also showed that these binders were able to reduce the “slump” of the ore by up to 82% and increased the hydraulic conductivity by up to 90%, when compared to agglomerating with leach solution alone. The use of binders in the agglomeration of copper ore also showed no negative effects on the bacterial populations throughout a leach cycle.

Paper #0939—11:05

Acid curing and agglomeration

J. Lu, D. Dreisinger, University of British Columbia,
P. West-Sells, Barrick Technology Centre

The impact of acid treatment in agglomeration/acid curing on copper extraction and acid consumption was investigated with respect to acid dosage and moisture. Without the addition of water, no agglomeration occurred. At an acid dosage above 15 kg/t, the acid was not completely consumed during acid curing. With the addition of 6.2% water, the particles agglomerated together. Copper, iron, magnesium and manganese were dissolved as sulfates and enriched in the fine fraction of the ore. The copper extraction and net acid consumption increased with increasing acid dosage. The copper extraction for acid curing with the addition of 6.2% water was higher than that without the addition of water due to the improved permeability and the increase in the contact with acid-soluble copper. During acid curing, the reaction of sulfuric acid with muscovite, abite and nacrite mainly took place on the surface of the particles while the reaction of sulfuric acid with clinochlore occurred not only on the surface but also inside the particles.

Paper #1010—11:30

Searching for the optimal heap leach application rate

O. Bernal, G. Velarde, Sociedad Minera Cerro Verde S.A.A

The Sociedad Minera Cerro Verde S.A.A, a subsidiary of Phelps Dodge Mining Company, operates a copper mining facility located in southern Peru. This "mine-for-leach" operation currently produces 90,000 mtpy of copper cathode from secondary sulfide ore utilizing crushing, leaching, solvent extraction and electrowinning processes. The leach solution handling and application rates have undergone constant development over the years. This paper discusses the improvements in leach application designed to: 1) satisfy the needs of the "lixiviant request rate", which requires the use of application rates as low as 3.5 $L/h/m^2$ and as high as 15 $L/h/m^2$ with variable rest periods according to the leach kinetics, and 2) alleviate the poor solution distribution on the surface of the leach heaps inherent to drip emitters. Low application rates result in poor surface solution distribution and the formation of upside down cones of dry, non-leached material in the top meter of stacked ore, with heavy jarosite and iron salt precipitation; moreover, ferric iron is lost as insoluble precipitates. On the other hand, high unit flows associated with poor agglomerate quality can lead to uneven solution flow patterns within the heap leading to solution short-circuits, fines migration, and ponding with adverse effects on acid consumption and recovery.

Paper #0946—11:55

Bacterial leaching of a copper ore containing activated pyrite

Z. Manafi, S.A. Seyed Baghery, R. Atash Dehghan, Sarcheshmeh Copper Complex

Bioleaching of a copper sulfide ore containing "activated pyrite", using a mixed culture of mesophilic bacteria, was studied. This type of copper ore had been found unsuitable for flotation because it produces a concentrate containing relatively high iron concentrations and, therefore, a low copper grade. Microscopic observations showed that pyrite particles had been activated by the formation of a thin film of chalcocite. Hence, a bioleaching process was considered as an alternative to treat this ore. Following shake flask and acid consumption tests, column tests of the crushed ore (75% –12.5 mm) were initiated and the effects of culture medium, agglomeration, and irrigation type on copper recovery were studied. The results showed that all the columns containing bacteria had copper recoveries around 90% compared to the abiotic control column with a recovery of 50%. It was concluded that bioleaching could be successfully utilized to process copper ores containing activated pyrite.

Cu2007: International Symposium on **Electrowinning and Electrorefining**, Incorporating the 37th Annual Hydrometallurgy Meeting

Session 52: Electrowinning Plant Practices and Design

Sponsors: Hydrometallurgy Section of MetSoc, MMIJ, GDMB, IIMCh, EPD of TMS

Chair(s): M.J. Nicol, Murdoch University;
M.S. Moats, University of Utah

Room British Columbia—09:50

Paper #0787—09:50

Electrolytic copper electrowinning – 2007 world tankhouse operating data

T. Robinson, Freeport-McMoRan Copper & Gold,
W. Davenport, University of Arizona,
M. Moats, University of Utah,
G. Karcas, Outotec,
S. Demetrio, Smeltec

World copper electrowinning tankhouse plant practices have been surveyed. This survey is a supplement to previous surveys that have been carried out in 1995, 1999, 2001, 2002 and 2003. On a world basis, process technology trends include the further installation of automated electrode handling systems including permanent cathode systems, automated cathode handling machines, fully automatic cranes and polymer concrete cells. Designs also have included larger electrode sizes and higher electrolyte flows and current densities. Overall these trends have further resulted in optimized tank house productivities and improved electrowon cathode purity. Most greenfield copper electrowinning projects are occurring in South America and Central Africa.

Paper #0746—10:15

Trends in copper refining technology

J. Standen T., Aker Kvaerner Chile

The main purpose of this publication is to present relevant advances in processes and technologies of importance for consideration in the design of new refineries and the modernization of existing refinery facilities. Operation at current densities of between 300 A/m^2 and 350 A/m^2 is already part of the criteria customarily implemented on recent projects. This is due in part to the development of permanent cathode technology. In recent years, this technology has also been integrated with process control and automatic electrode handling and preparation machines. The combined implementation of these technologies has the advantage of enabling the process to be monitored, thus assuring traceability and allowing greater knowledge of the process to accrue.

Paper #0772—10:40

Status and improvement plans in CVRD Inco's electrowinning tankhouse

M. Sabau, K. Bech, CVRD Inco

The Electrowinning Plant at INCO's Copper Cliff Nickel Refinery is a precious metals upgrading plant. The feed to the plant contains copper, nickel, cobalt, iron, significant amounts of precious metals and some impurities. Copper is the most abundant element in the feed. This paper describes the major equipment and process changes over the last twenty years, geared to improve the tankhouse operation, workroom environment and recovery of copper from the acidic solution. Copper is plated onto titanium blanks using explosion-bonded crossrods, animal glue as levelling agent and an organic surfactant for mist control. The installation of the stripping machine in 2001 required a number of changes: cathode and anode contacts were redesigned, flat bus bars were replaced with dog-bone type, spacer boards for cathodes and anodes were installed, longer anodes started to be used, and the plating cycle was extended from 7 to 14 days. A number of initiatives for improvement are being carried out. Explosion-bonded crossrods are being replaced with titanium-clad crossrods. The plan for the near future is to increase copper production by increasing current efficiency and current density. The possibility of lowering the iron concentration in electrolyte and changing the acid mist control method is being investigated.

Paper #1178—11:05

The advantages of concurrently designing and engineering copper solvent extraction and electrowinning plants

G. Karcas, H. Laitala, L. Palmu, E. Tuupa, Outotec Oyj

Concurrently designing both the solvent extraction and the electrowinning processes of a copper SX EW project, in an integrated and consecutive approach, with one technology partner, will ensure continuity in the process flow and smooth execution of the engineering function with minimum duplication, time loss and errors, maximizing time efficiency resulting in excellent quality and quick and effective start-up of the plant. Projects will benefit significantly from the common technology partner approach as not only will the SX and EW processes be optimally efficient individually, but the overall process efficiency will be optimized eliminating the common problem of efficiency losses and integration difficulties when combining two consecutive processes which also require to circulate flows between them. Plant operation will also benefit from the fact that impurity control will be on a global basis, rather than concentrated on certain parts of the process, hence, better results and more efficient control. The operation of equipment will be more effective and efficient. Further, proprietary technological equipment that focuses on maximizing plant performance, such as Dispersion Depletor Gate (DDG) Fences and Outokumpu Cathodes, will be applied throughout the plant as the design philosophy will be to utilize technology to maximize production.

Cu2007: International Symposium on **Electrowinning and Electrorefining**, Incorporating the 37th Annual Hydrometallurgy Meeting

Session 53: Fundamentals and Modeling I

Sponsors: Hydrometallurgy Section of MetSoc, MMIJ, GDMB, IIMCh, EPD of TMS

Chair(s): H. Fukushima, Kyushu University;
A. Alfantazi, University of British Columbia

Room Toronto—09:50

Paper #0768—09:50

Modeling the temperature dependence of selected variables relevant to the operation of a copper electrowinning cell based on reactive electrodialysis

L. Cifuentes, J.M. Casas, Universidad de Chile,
J. Simpson, Universidad de Santiago

The temperature dependence of: a) electrolyte density, viscosity and electrical conductivity and b) the equilibrium constants of formation for all relevant species have been determined as part of an effort to model the operation of a copper electrowinning cell based on reactive electrodialysis. The studied ranges were: 1.01 to 1.25 g/cm^3 for density, 4.9x10^{-4} to 16.4x10^{-4} kg m^{-1} s^{-1} for viscosity and 0.02 to 86.0 Ω^{-1} m^{-1} for electrical conductivity. Density and the electrical conductivity of the catholyte increased linearly with temperature whereas the viscosity increase was exponential. The main effect of ionic speciation was to decrease the electrical conductivity with increasing metal concentration due to ion association (mainly the formation of bisulphate ion) which lowered the concentration of protons (the most mobile species) in solution. This effect was specially noticeable in the anolyte. Mathematical relationships with correlation coefficients between 0.959 and 1.000 have been found for all the studied variables.

Paper #0769—10:15

The effect of impurities on cell performance and on the quality of electrodeposits obtained at high current densities in a copper electrowinning cell based on reactive electrodialysis

L. Cifuentes, M. Grageda, J.M. Casas, T. Vargas, Universidad de Chile

Chemical and physical characterization of copper electrodeposits obtained on mesh and plate cathodes in conventional and reactive electrodialysis lab-scale cells have been carried out. The effect of Fe, Mn, Cl and guar on electrodeposit composition and morphology were determined by means of metallographies, scanning electron microscopy (SEM), atomic force microscopy (AFM), inductively coupled plasma mass spectrometry (ICP-MS) and Auger electron spectroscopy (AES). Each impurity influenced the deposit morphology in a different way (e. g. grain size, surface roughness). AFM proved to be a very effective tool for quantifiying and classifiying surface quality.

Paper #0774—10:40

Synergistic effect of polymer additives and chloride ion on copper electrorefining

H. Kuboyama, H. Nakano, S. Oue, H. Fukushima, Kyushu University,
S. Kobayashi, Kyushu Sangyo University

The synergistic effects of polymer additives such as gelatin and poly(ethylene glycol) (PEG) and Cl^- on Cu electrodeposition have been investigated by measuring the polarization curves for Cu deposition, by rotating ring-disk electrode technique and by AC impedance measurements. The cathode potential for Cu deposition was greatly polarized in solutions containing both Cl^- and gelatin or PEG, showing evident synergistic effect of polymer additives and Cl^- on Cu deposition. The cathode potential was shifted to the less noble direction with increasing the concentration of Cl^- in solutions containing polymer additives and showed the maximum polarization at Cl^- concentration range between 0.1 and 1mmol/L. The rotating ring-disk electrode technique revealed that Cu deposition in solutions containing small amounts of Cl^- proceeded with initial formation of adsorbed intermediate $CuCl_{ad}$. The Cole-Cole plots obtained by AC impedance techniques suggest that the reduction of $CuCl_{ad}$ is suppressed by polymer additives. The morphology of Cu deposited from solutions containing both PEG and Cl^- showed the compacted surface composed of smaller grains due to an increase in the overpotential for Cu deposition.

Paper #0775—11:05

Codeposition behavior of impurities in copper electrowinning from cuprous chloride solution

H. Nakano, S. Oue, H. Fukushima, S. Kobayashi, Y. Abe, Kyushu University

The codeposition behavior of impurities such as Ag, Bi, Fe, Ni, Pb and Sb with Cu was investigated galvanostatically at 5-3000 A/m^2 using a Pt cathode at 60 ˚C in acidic copper (I) chloride (cuprous chloride) solution at pH1-2 containing 1.0 mol/L of Cu^+ and 4.9 mol/L of Cl^-. The impurities were classified into two groups: Group I (Ag, Bi) which codeposits with Cu as a metal, and Group II (Fe, Ni, Pb, Sb) which is slightly involved in the deposited Cu in nonmetal form from the electrolyte. Silver and Bi in Group I behaved as more noble metals than Cu, and significantly codeposited with Cu, showing typical features of regular-type codeposition. When Cu was deposited dendritically, the Ag and Bi content in the deposit increased with increased duration of electrolysis as a result of decreased net current density caused by increased cathode area. The current efficiency for Cu deposition in impurity-free solution was 95-100% over 100-1000 A/m^2, but it abruptly decreased at above 1000 A/m^2 when the limiting current density of Cu was attained. Although Fe, Ni, Pb and Sb in Group II were involved to 0.01-0.02 mass% in the deposit, they had no influence on the current efficiency or morphology of Cu.

Paper #0781—11:30

Fluid motion characteristics with gas injection for copper electrorefining at high current density

H. Nakano, S. Oue, H. Fukushima, Kyushu University,
S. Kobayashi, Kyushu Sangyo University,
Y. Abe, Nippon Mining

Electrorefining at higher current density is desirable due to the increase in productivity attained without expanding the plant size. However, increasing the current density in common commercial practice causes problems such as anode passivation, dendritic deposition, cathode impurities and energy consumption. In general, agitation of the electrolyte is effective in suppressing these problems. To apply the agitation to commercial practice effectively, the method of agitation is important. One possible method is agitation by gas injection. In this study, fluid motion characteristics with gas injection between electrodes were investigated using a water model. Flow patterns were observed and fluid velocity was measured using a particle tracking method. It was found that the time-averaged velocity near the electrode walls was of the order of 0.1 m/s in the conditions. The flow was highly turbulent. The turbulent component of velocity was the same order as the time-averaged velocity. The mass transfer coefficient between the wall and fluid doubled when the effect of turbulent intensity was taken into account. The effects of gas injection on the electrolysis behaviour at high current density were discussed in terms of the mass transfer. It is suggested that gas injection could suppress the problems at high current density.

Cu2007: The Carlos Díaz Symposium on **Pyrometallurgy**

Session 54: Vessel Integrity I

Sponsors: Non-Ferrous Pyrometallurgy Section of MetSoc, MMIJ, GDMB, IIMCh, EPD of TMS

Chair(s): D. George-Kennedy, Kennecott Smelter;
S. Hills, WorleyParsons HGE

Room Territories—09:50

Paper #0813—09:50

Kennecott Utah smelter rebuild – 10 million tonnes of concentrate smelted

D. Janney, B. Foster, R. Burton, D.G. Kennedy, Kennecott Utah Copper Corporation

Kennecott's Utah Smelter commenced operations in June 1995 utilizing Outokumpu Flash Smelting (FSF) and Kennecott-Outokumpu Flash Converting (FCF) technology. After some initial teething and equipment problems the smelter achieved its design capacity in mid-1997 and now processes over 1.0 million tonnes of copper concentrate per year with exceptional environmental performance. The smelting furnace has operated for 11 years and the converting furnace for 5 years without major shutdowns. The first major smelter shutdown commenced in September 2006 after extensive planning. The FSF was

completely re-bricked and the latest above and below bath containment systems installed. The FCF was inspected and re-bricked with some improvements made to the above bath containment system. The FCF life is now anticipated to be the same as the FSF. Numerous improvements and modifications were made to the rest of smelter facility including extensive upgrades to the dry electrostatic precipitators. Production ramp-up was smooth with the smelter now frequently operating at acid plant capacity.

Paper #0890—10:15

Refractory performance and campaign life extension of the reverberatory furnace at HBMS in Flin Flon

J. Cooper et al, Hudson Bay Mining and Smelting Co.

The HBMS reverb furnace in Flin Flon was originally designed in the late 1920s. Throughout the decades campaign life has been increased due to operational practices, technological changes and brick quality improvements. In recent decades the campaign life had been extended such that a complete rebuild was scheduled every 3 years. The latest furnace rebuild and start up has been after a campaign life of nearly 6 years. Brick construction methods and techniques along with furnace operational practices allow the present campaign to be double that of the historical campaign length.

Paper #0878—10:40

Advanced monitoring: Tapblock diagnostic system

P. Tracy, R. MacRosty, Q. Zhao, L. Gunnewiek, T. Gerritsen, Hatch

An advanced real-time monitoring system, called a “Tapblock Diagnostic System” is under development to help furnace operators manage the operation and maintenance of their tapblocks. The life of a water-cooled tapblock in a smelting furnace ranges from several months to several years, depending on the operating conditions. Tapblocks are typically replaced at regular maintenance intervals; a strategy based largely on historical records and not on the actual condition of a particular tapblock. The Tapblock Diagnostic System monitors the tapblock throughout its life and accumulates probable wear events to help the operator assess the residual integrity of the tapblock. Benefits of this system include the ability to provide early warnings of tapblock wear to provide improved safety and maintenance planning. Using cooling-water flow together with copper and water temperature measurements, the system performs calculations that compare the present tapblock performance with the expected operating envelope using a multivariate statistical method (Principle Component Analysis). The operating envelope is pre-calculated for a wide range of operating conditions using transient thermal modeling (Computational Fluid Dynamics). A state indicator in the form of a green, yellow and red light is used to inform operators of the tapblock performance and health status.

Paper #0841—11:05

Optimization of refractory lining design and installation practice to reduce vessel downtime and maximize performance of anode refining vessels

A.J. Rigby, M. Wiessler, C. Richeson, RHI Canada Inc.

Anode vessels are often relined with refractory every one to two years and a typical reline time can take between 16-20 days. Modern refractory designs using dense, corrosion resistant brick applied directly to the vessel shell in the high wear areas around and above the tuyeres and at the slagline can yield a lining life of up to 4-5 years before a complete reline is necessary. Installation methods using brick delivery on roller conveyors through an endwall access port and complete anchoring of the brick to allow for lining self-support can take days off the installation time. It is possible, therefore, to reduce the refractory relining period by 50% and increase lining life by 100% compared to typical anode repair schemes.

Cu2007: The Carlos Díaz Symposium on **Pyrometallurgy**

Session 55: Continuous Converting I

Sponsors: Non-Ferrous Pyrometallurgy Section of MetSoc, MMIJ, GDMB, IIMCh, EPD of TMS

Chair(s): P. Mackey, Xstrata Process Support;
J. Liu, CVRD Inco

Room Algonquin—09:50

Paper #0861—09:50

Latest developments with copper ISASMELT™

P. Arthur, Xstrata Technology

The copper ISASMELT™ process is a submerged lance bath smelting technology. In the 20 years since the process was first demonstrated on a semi-commercial scale at Mount Isa in north-west Queensland, Australia, copper ISASMELT™ plants have been constructed to treat concentrates or secondary raw materials around the world. The process is operating in smelters in Australia, the USA, Belgium, India, Germany, China and Zambia. ISASMELT™ plants have been installed to improve the environmental performance of operating smelters and reduce costs for smelting companies. A new copper furnace is being commissioned at Southern Peru Copper Corporation in early 2007, while more furnaces are under design for installation in Kazakhstan and Peru. Copper ISASMELT™ plants are supplied as complete technology packages including engineering design services for the furnace and key ancillaries, supply of core equipment, provision of intensive training programs in operating plant environments and commissioning assistance services. The proven technology transfer process ensures successful implementation of submerged lance bath smelting into large scale plants. This paper summarises developments at recently constructed copper ISASMELT™ plants.

Paper #0829—10:15

Converting using ISASMELT™ technology

J.S. Edwards, G.R.F. Alvear F., Xstrata Technology

The ISASMELT™ process is recognized worldwide as a modern, flexible, environmentally-friendly and low capital cost smelting technology. Due to the inherent simplicity, and the advanced process control that has been developed, personnel become competent within weeks of being introduced to the ISASMELT™ technology. This compares with the years required to become proficient with alternative technologies. Copper smelters in Australia, USA, India, China, Peru and Zambia have installed ISASMELT™ technology under licence from Xstrata Technology. In the secondary copper business, plants in Belgium and Germany are processing copper and/or lead materials in ISASMELT™ furnaces in a two stage process. In a single furnace smelting is followed by converting. Both plants have exceeded design capacities and are continuously improving their performance. The next evolutionary step for the technology is the implementation of the continuous copper converting process on a commercial scale. The present work describes the design status of the continuous converting process - ISACONVERT™.

Paper #0868—10:40

The Ausmelt continuous copper converting (C3) process

R. Matusewicz, S. Hughes, Ausmelt Limited

The key drivers for the copper smelting industry are a complex mix of economic and “human” factors which combine to drive technology in new directions and can provide a strong indication of future industry trends. Recent examples have been the drive to achieve increased scale of production and resultant cost efficiencies by using a single furnace high intensity smelting vessel, and the broad acceptance of Top Submerged Lancing (TSL) technology for this duty. The development and adoption of continuous converting processes to counter the increased pressures faced by the Peirce Smith converting process is another example of the need for innovation. This paper discusses the merits of the continuous converting process, describes how the Ausmelt TSL batch converting process has been adapted to the new Ausmelt Continuous Copper Converting (C3) process in response to these industry trends and examines the Ausmelt continuous converting flowsheet options available to the end user.

Paper #0834—11:05

Pilot-scale evaluation for the CODELCO continuous converting process

A. Moyano, C. Caballero, R. Mackay, P. Morales, J. Font, CODELCO-Chile

The development of the traditional converting process performed in a Peirce-Smith or Hoboken converter is limited by the investment magnitude associated to the fulfillment of the environmental regulations. Thus, the continuous converting process rather than a conceptual process alternative is becoming a necessity for

a smelter facing limited converting capacity and/or lacking of fulfillment of the environmental regulation with its maximum converting capacity. The objective of this paper is to present the progress of the CODELCO continuous converting process evaluated at pilot-scale level when converting solid mattes or white metal into blister copper. These tests allowed for gathering of relevant data to be considered for a new stage of evaluating the CODELCO continuous converting at industrial-scale test. The pilot-scale tests were done in a Teniente Converter pilot scale unit at the CODELCO Norte Smelter. The results of processing solid copper mattes (65-75% Cu) and producing low sulfur content blister copper with production of a constant SO_2 gas concentration, and the production of liquid slag with low copper solubility was achieved and is discussed in the present paper.

Cu2007: The Carlos Díaz Symposium on **Pyrometallurgy**
Session 56: Off Gas Handling I
Sponsors: Non-Ferrous Pyrometallurgy Section of MetSoc, MMIJ, GDMB, IIMCh, EPD of TMS
Chair(s): C. Harris, WorleyParsons HGE;
C. Caballero, CODELCO Norte
Room Quebec—09:50

Paper #0854—09:50
Regenerable SO2 scrubbing for copper smelters: an update
C. Harris, WorleyParsons HGE,
J. Sarlis, Cansolv Technologies Inc.

Cansolv® SO_2 Scrubbing Technology was described in a paper in Copper/Cobre 03. Four years on, the technology is operating at a full scale production facility. Hindustan Zinc Limited expanded their capacity by installing the AUSMELT process. The process proceeds through smelting, slag reduction, slag cleaning and holding stages sequentially in the same vessel, resulting in widely varying off gas characteristics. The off gas is suitable for treatment is a conventional acid plant for a modest proportion of the day, but at other times produces off gas too high in SO_2 to be discharged to atmosphere. Cansolv® SO_2 Scrubbing Technology was identified as a means of effectively removing the SO_2 down to low levels from the off gas during all stages of the pyrometallurgical process. Furthermore, the Cansolv® SO_2 Scrubbing System Technology produces high purity SO_2 that allowed for the captured SO_2 to be directed to an existing acid plant, avoiding the capital cost of new acid making capacity.

Paper #0863—10:15
Fluid-dynamic study of the gas handling system at Caletones smelter
P. Reyes F., B. Martinich, S. Rojas G., CODELCO División El Teniente,
R. Bustamante M., University of Santiago

The CODELCO Chile El Teniente Division Caletones Smelter has an objective to smelt 1,250,000 tonnes per year of copper concentrate. This is a great challenge

for the smelter facilities and particularly for the acid plants. The analysis ensuring that there are no obstacles to achieve the production capacity was of great importance. Therefore a series of activities were undertaken as well as studies dedicated to reach the target. This paper presents work focused on a fluid dynamic study, translated in an operation methodology of integrated handling of the smelting and converting gases with the objective to optimize the gas flow and SO_2 concentration. The optimization should be done employing the current installations, equipment and instrumentation and/or minor modifications. In the first part of the work the condition of the instrumentation involved in the gas handling was checked, improvements determined and the corresponding corrective actions were carried out. The proposed operation method consists of operation of the Cleaning Gas Plant 2 (TC's gases) and operation of Gas Cleaning Plant 1 (the remaining gas plus the gases from CPS). The implementation of the operation method involves the modification of the valve of the gas into the duct to plant 1 from On to Off to modulate flow. After modification a three days test was carried out. To evaluate the tests, a "Sulphur Capture" indicator was used. During the test the behaviour of the effluent treatment plants was closely examined. No problems or unusual operating conditions were observed. The reduced flow of gas to Gas Cleaning Plant No. 1 permitted the start up of the 2nd test day treating most of the gas received by Gas Cleaning Plant No. 2. The operation was carried out with the limitation not to increase the effluent pond level, which was maintained constant.

Paper #1108—10:40

The ALSTOM seawater FGD process

C.M. Sagedahl, ALSTOM Norway AS

The gas from the smelter is cooled and dust removed in an electrostatic precipitator before approximately 95% the SO_2 is converted to sulfuric acid. However, the tail gas may need to be polished to remove the rest SO_2 to meet demands. A flue gas desulphurization (FGD) system as usually applied to SO_2 removal on coal and oil fired Power Station is suitable for polishing tail gases from copper smelters. The ALSTOM Seawater FGD process makes use of the alkalinity in the seawater to absorb and neutralize SO_2. Before being returned to the sea, the seawater is treated to comply with environmental regulations. As the ALSTOM Seawater FGD process uses no reagent and produces no by-product, it is extremely cost-effective for coastal installations. The first SWFGD plant started operation in 1968. Over 60 of these units have been installed worldwide. The ALSTOM Seawater FGD process removes sulfur dioxide from flue gas flows corresponding to a total of 70 000 000 Nm^3/h. Suitable for thermal power stations, smelters and oil refineries, ALSTOM Seawater FGD plants efficiently treats flue gases in the range of 300 000 Nm^3/h to 2 700 000 Nm^3/h per FGD plant, containing 20 – 6500 ppm of SO_2.

Paper #0793—11:05

The metallurgical sulfuric acid plant design, operating and materials considerations 2007 update of new equipment and systems

L.J. Friedman, S.J. Friedman, Acid Engineering & Consulting Inc.

The recovery of sulfur dioxide from metallurgical gases for the production of sulfuric acid has been the primary means of reducing sulfur dioxide emissions from non-ferrous smelters. Sulfuric acid has been produced from gas originating from fluid bed roasters, electric furnaces, reverberatory furnaces, flash smelting furnaces, Pierce Smith and flash converters, sinter machines, etc. The gas from each of these sources has a unique set of variables that affect the design and operation of the sulfuric acid plant. In addition, the sulfuric acid plant itself has been evolving, with new equipment designs and materials. This paper will review each of the unit operations in the gas cleaning and contact sections of the metallurgical sulfuric acid plant, discussing various equipment designs, materials and the handling of gas stream variables and impurities. The paper updates to 2007 previous works on metallurgical sulfuric acid plants by the authors, and analyzes new equipment and systems, including: FRP or alloy quench systems, alloy converters, towers and pump tanks, heat recovery systems, high efficiency mist eliminators, tower packing, etc.

Paper #0864—11:30

Multivariate projection methods applied to the contact section of a sulphuric acid plant

P. Reyes, B. Martinich, F. Condore, CODELCO-Chile,
L.G. Bergh, Santa Maria University

On line monitoring and diagnosis systems of process operating performance are becoming an important part of industrial programs, leading to improve process operation and therefore product quality over time. In processes, such as the contact section of a sulphuric acid plant, a large number of input variables, highly correlated, are presented. These characteristics usually pose more difficulties in modelling the process for monitoring and diagnosis purposes. Multivariate statistical projection methods, such as Main Component Analysis, have been proposed to effectively deal with these situations. The application of these ideas to a section of a 2350 MTD sulphuric acid plant, located at the Caletones Smelter, including dry tower, gas blowers, catalytic reactor and SO_3 absorber processes, is discussed here. A PCA model with eight main components is used for monitoring and diagnosis of more than seventy operating variables. Hottelling`s T^2 and Q residuals test were used for detecting measurement problems in relevant variables, and for identifying which set of variables were responsible for driving the process outside its normal operating region. Furthermore, considerable information for the correction of the tested operating problems was given by the use of these techniques.

Cu2007: International Symposium on **Mineral Processing**
Session 57: Comminution Practice
Sponsors: Canadian Mineral Processing Society of CIM, Mineral Science and Engineering Section of Metsoc, MMIJ, GDMB, IIMCh
Chair(s): C.O. Gomez, McGill University
Room Tudor 8—09:50

Paper #0728—09:50
Energy calculations for SAG grinding of a sulfide copper ore
A.E.C. Peres, Federal University of Minas Gerais UFMG,
P.E.C. Pereira, ECM S.A.

The most expensive unit operation in the beneficiation of ores is grinding. The correct design of the grinding circuit is crucial to prevent unnecessary use of energy. Proper design and evaluation of SAG grinding circuits require the specific grinding energy, which is determined experimentally. The most common tests in SAG grinding are the Drop Weight Test, from the Julius Kruttschnitt Mineral Research Center (JKMRC) in Australia, and the SAG Power Index, from MinnovEX Technologies in Canada. The application of these tests to the same ore sample commonly produces different results. The work reported here aims at comparing the application of these two tests in the determination of the specific grinding energy for sulfide copper ores from Sequeirinho and Sossego deposits, Sossego Project, Companhia Vale do Rio Doce - CVRD, in Pará state, Brazil.

Paper #0729—10:15
Effect of blast modifications in semiautogenous grinding plant of CODELCO Chile Andina
G. Titichoca, L. Magne, University of Santiago of Chile,
G. Pereira, G. Andrades, P. Molinet, CODELCO Chile

Modification of the blasting process considers that any increase in the energy consumption generates greater benefits if done in the later stages (associated with a larger decrease in energy consumption). Therefore, although the blasting cost is doubled, generating a greater proportion of fines in addition to a weaker ore (because with greater loads and appropriate distribution of explosives a greater number of internal cracks is generated), the reduction of the unit cost that occurs in the grinding stages (SAG and ball mills) generates a positive balance in the overall size reduction process. CODELCO Chile, Division Andina, has developed an extensive experimental plan to evaluate the concept of blasting modification applying greater energy. This was implemented in two stages, each including a specific mine sector: La Union and Don Luis. This paper reviews the experience of implementing such blasting modifications at the La Union mine and its impact on the design concepts and the operation of the SAG mill plant.

Paper #0730—10:40
New strategy development for changing SAG mill liners
K.G. Markkola, J. Soto, G. Yañez, H. Jimenez, Minera Candelaria

The Minera Candelaria concentrator was commissioned in August 1994, and in October 1997 it doubled its grinding capacity. The concentrator was designed to treat 56,000 metric tonnes of copper ore with a primary crusher, two grinding circuits, pebble crushing, and flotation. The grinding circuit includes two 11.2 m (36 ft) diameter by 4.6 m (15 ft) long semi-autogenous (SAG) mills, each fitted with a 12 MW motor. Throughout the history of Candelaria, different strategies have been developed to maximize the plant's operational time, strategies that include increasing the life of the SAG mill liners and reducing the time involved in changing these elements. This work describes the improvements made in the design of the liners, the change planning, and a new strategy to change the liners with the purpose of increasing their use and throughput.

Paper #1176—11:05
Super fine grinding of copper concentrates for pressure leach processing by Phelps Dodge
S. Williams, J. Gillaspie, D. Mathern, J. Wilmot, Phelps Dodge Mining Company

Phelps Dodge has recently operated a commercial scale, super fine grinding circuit of copper concentrates for use in a medium-temperature pressure leaching process. Two 355 kW vertical stirred mills were installed in series, targeting a grind of 80% passing 7.5 µm and 98% passing 15 µm as outlined in Phelps Dodge's concentrate leaching patent portfolio. This paper details the operation and results of the test program at Bagdad, as well as some of the operating challenges encountered.

Cu2007: International Symposium on **Process Control, Optimization and Six-Sigma**
Session 58: Control, Automation, and Process Optimization
Sponsors: EDP of TMS, MetSoc, MMIJ, GDMB, IIMCh
Chair(s): C. Ciriello, Xstrata Copper;
R. Parra, Universidad de Concepcíon
Room Confederation 6—09:50

Paper #0700—09:50
Use of wireless technology and vision's systems to improve processes, maintenance and mineral movement in mining plants
H. Salamanca, A. Sanchez, P. Escobar, J. Tapia, HighService Ltda.

HighService has developed different equipment using wireless technology and machine vision systems that were specially designed to allow 1) the online determination of the SAG mills liner's service life, 2) the automatic detection of a missing dipper tooth in mineral extraction shovels, 3) the reduction of accident

risk potential in the mineral transportation within the mine, and 4) the reduction of collision risk potential between shovels and wheel dozers during mineral extraction. For the development of all these systems at HighService, extensive research has been done in radio frequency and image processing fields. The integration of both technologies with the expert knowledge of the company on the typical harsh environment conditions of the mining industry has led to the development of heavy duty equipment that tolerate the extreme mechanical requirements of SAG mills and electrical mining shovels.

Paper #0742—10:15

Robotic applications in mining process, a small investment and great profits in the short term

H. Salamanca, F. Ramirez, L. Baeza, C. Rodíguez, HighService Ltda.

Recently, the mining industry has become one of the leading target markets for the technology industry as they need to innovate in their productive processes in order to boost productivity, reduce operation costs, increase operation safety, and improve the quality of life of their workers. This work presents the technological developments that HighService has done in different stages of the mining productive processes to include robotic manipulators in their automation solutions as well as the development of new equipment and sensors. The robotic technology integration is presented in different applications such as handling and selection of cathodes in E-W machines, automation of base plate maintenance, automation of cathode stripping machine, and multi-tools handler for liner bolt replacement in SAG mill liner maintenance activities. The proposed solutions show technical and economical viability with low initial investment and short implementation period of six (6) to ten (10) months. The results have been validated in plant, obtaining higher production rates and availability.

Paper #1060—10:40

P-D central analytical service center; step change technology

E. Best, Phelps Dodge Central Analytical Service Center

In 2003, Phelps Dodge Mining Company decided to pursue the design and construction of a Central Analytical Laboratory to provide chemical analyses for their Arizona and New Mexico operations. This centralized approach was selected in place of refurbishing six (6) older laboratories that operated at the various Phelps Dodge sites, and which would not have permitted full automation and use of robotics. The new lab was designed by the Process Technology Center (PTC) Material Characterization Group in cooperation with IMP Group. The Central Analytical Service Center (CASC) encompasses fully automated sample preparation of blast holes and geological samples weighing up to 15 kg/sample. The CASC also includes the first “wet chemistry module” worldwide to be operated by robotics systems to perform Total Cu, Acid Soluble Cu, and Quick Leach Tests (QLT), and a fully automated lab for electrowon copper cathode. The new lab also offers flexibility for handling specialty samples and

analyses by either semi-automated or manual mode. Data handling and transfer is accomplished using the commercially available StarLIMS system. Commissioning was accomplished within five (5) months of startup during which the CASC also handled 86% of a full production load. The 24/7 lab operation has already exceeded its design capacity, has achieved considerable savings in operating cost, reduced sample preparation errors, and significantly increased analytical quality.

Paper #1018—11:05

Supervisory control project of a copper solvent extraction pilot plant

L. Bergh, E. Lucic, F. Zuleta, Santa Maria University

The experience developing a supervisory control and information systems in a SX pilot plant is presented. The plant is located at the Process Control Laboratory, Santa María University, in Chile. In this work, the problem of controlling this process is discussed and related literature is briefly reviewed. Then, an innovative control scheme organized in three levels, local, hydrodynamic, and metallurgical supervisory controls is presented in an architecture including field controllers, PLC, and PC networks. Operating decisions in the metallurgical supervisory control are taken with incomplete information from on-stream analyzers. The control proposed is based on metal and acid concentration predictions of intermediate and exiting streams through the use of dynamic and static models and flow rates and input concentration measurements. Preliminary results are presented. The main objectives are to develop and test intelligent techniques in a hybrid system, and to study measurement and supervisory control problems. It is expected to produce reliable results that will contribute to improve the efficiency of this emerging and important process.

Paper #1056—11:30

Geochemical Profiling of a Sulphide Leaching Operation: The Rest of the Story

A. Guzman, S.M. Flaherty, ARCADIS G&M,
R.E. Scheffel, Consultant
G. Ahlborn, S. Ramos, Compania Minera Quebrada Blanca

This article is the second in a sequel by the authors on the topic of geochemical profiling of a sulfide leaching operation which demonstrated that physico-chemical heterogeneity impacts negatively upon leaching performance. The information presented builds upon the characterization data documented in a previous article. The potential benefits to metal extraction rates and operational parameters are quantified as changes to the leaching process are implemented and the negative effects of heterogeneous physical and chemical conditions are reduced. The results of a pilot test comprising about 50,000 tons of ore subjected to improved ore handling practices and a specially designed irrigation strategy are compared to heaps with similar ore type and copper grade. This

comparison highlights the need to better understand the physical and metallurgical behavior of the ore and the opportunity to improve operational performance with new tools and characterization techniques to improve process control in leaching. A list of the key physical and hydraulic parameters necessary for a complete characterization of an ore is provided.

Paper #1057—11:55

Silica removing from cooling water and recovery of blowdown

M. Behrouz, E. Yosefnia, M.S.S. Zadeh, Sarchesmeh Copper Complex

Thermal power plants convert thermal energy due to nuclear reactions or the combustion of coal, gas, heavy oil, or some other hydrocarbon to electrical energy. They consist of a variety of equipment, such as boilers, turbines, generators, cooling towers, and auxiliary equipment. Any factor that affects the equipment efficiency affects the overall efficiency. Analysis of the cooling tower and raw water using the Langlier Saturation and Ryznar Stability Indices showed that the cooling water at Sarchesmeh was slightly scaling with respect to silica. Cold lime softening was found to be a cost-effective method to produce cooling water with adequate properties to reduce the cooling water make up from 85 to 70 m^3/h and blow down rate from 35 to 20 m^3/h.

Cu2007: International Symposium on **Sustainable Development, HS&E, and Recycling**, Incorporating the 6th Waste Processing and Recycling Symposium

Session 59: Tailings Management

Sponsors: The Environmental Society of CIM, the Environment Section of Metsoc, MMIJ, GDMB, IIMCh

Chair(s): R. Siwik, Consultant (formerly Falconbridge-Xstrata)

Room Confederation 3—09:50

Paper #0909—09:50

Passive biologically based anaerobic treatment systems for the removal of metals – an overview of current research with examples

A. Mattes, Nature Works Remediation Corporation,
J.P. Higgins, Jacques Whitford Limited,
W.D. Gould, CANMET MMSL

This paper presents an overview of passive, engineered, biologically-based anaerobic bioreactor (ABR) treatment systems of the sort that can be used to remove dissolved copper from mine wastewaters. The paper begins with a brief history of the origins of this treatment technology and continues with a discussion of principles of engineered wetlands (EWs, advanced kinds of constructed wetlands, CWs) and the use of vertical sub-surface flow (VSSF) varieties that contain pulp & paper biosolids as the reactive medium for EW cells. A brief outline of a procedural methodology used in evaluating the potential for biological treatment on a site-specific basis is also included. An introduction to the microbiology of passive biologically-based treatment systems is followed by

some recent research results in the general area of wetlands and ABR research. The paper concludes with a brief discussion of several sites known by the authors to have successfully (or not) demonstrated the potential of this treatment option.

Paper #0749—10:15

Electronlytic treatment of highly contaminated effluents from copper smelters

S.R. Stopic, K.B. Friedrich, A.W. Widigdo, IME Process Metallurgy and Metal Recycling

The EU-financed INTREAT Project (Integrated treatment of industrial wastes towards prevention of regional water resources contamination) addresses the environmental pollution associated with solid and liquid wastes/effluents produced by complex sulphide ore mining and metallurgical activities. The results concerning the electrolytic recovery of copper from effluents formed after mixing of streams from Copper Refining, Precious Metals Plant and Electrolyte Regeneration in the Balkan Area will be shown. The waste water is characterized by low pH values and high contents of heavy metals, such as Cu, Ni, Bi, As, Sb. The majority of these waste water flow untreated into the natural water streams and through the network of existing rivers, which end up in the river Danube. The influence of current density and flow rate on the deposition rate, the quality of copper and the process efficiency will be presented. The full continuous process is based on cells with rotating disc cathodes and represents a pre-treatment step before common neutralisation in a cascade line.

Paper #0714—10:40

Real behaviour of thickened tailings

C. Cano, G. Rivera, M. Carcamo, Hatch Ingenieros y Consultores Ltda.

One of the main concerns within the mining industry is to minimize the impact of tailing facilities to the environment and nearby communities. Since the implementation of the first thickened tailings disposal (TTD) methodology at Kidd Creek in 1964, the thickened tailing disposal has been growing alternative disposal technology to mitigate the environmental impacts. Technical investigations on the TTD technology have been studied in detail to counteract the increasing shortage of water resources. One of the benefits observed with TTD is its resistance to potential earthquakes, particularly in zones with high seismic activity (Los Andes). TTD technology optimizes the maximum possible density for the material and generates a negative internal pore pressure in the material due to the surface and sub-surface water evaporation. This internal pore pressure should be enough to resist the pores pressure to which tailings are subject due to an earthquake action.

Paper #1016—11:05

Management of contaminated soil and groundwater: a perspective for the Chilean copper industry

A. Bezama, M. Sanchez, University of Concepción

For over a decade European countries have addressed contaminated sites by developing technologies for managing both polluted soil and groundwater. This development has not only been driven by health and environmental aspects, but also because of economic pressures, as the remediation and redevelopment of derelict areas can be a meaningful alternative to undeveloped areas for the establishment of new industrial, recreational, housing and service locations. In most developing countries, however, the subject of contaminated sites is a new environmental issue that authorities have recently started to deal with. Among these countries, Chile has just started to prepare the country's legal context as well as to foster the formation of research and investigation groups that will deal with the exploration, investigation and management of contaminated sites. That requires a comprehensive technical, scientific and legal support in this stage. Goal of this article is to present the state-of-the-art technologies for site remediation currently applied in industrialized countries, in order to identify the most interesting approaches that can be implemented within the Chilean situation, especially considering the influence of the copper mining industry on the soil and groundwater quality of the environment surrounding their production facilities.

Paper #0904—11:30

Numerical information system supporting safe management of copper post-flotation tailings reservoir - "Zelzny Most" Poland

W. Swidzinski, IBW PAN,
W. Swierczysski, K. Janicki, KGHM Polska Miedź S.A. Hydrotechnical Division,
A. Naguszewski, BMT Cordah sp. z o.o.

“Zelazny Most” post-flotation copper mine tailings pond is the only place to store wastes for KGHM POLSKA MIEDZ S.A. The flotation tailings is the main waste stream in copper mining in Poland. Sufficient storage capacity for tailings is crucial for uninterrupted production of copper. The pond covers a 14 km^2 area, almost 50 m high dams making this dam construction one of the largest in the world. The risk assessment of potential damage due to unstable dams or environmental contamination, as well as safely constructing dams within the design criteria, require quick access to a large amount of monitoring data that needs to be analyzed and reported every day. This paper describes the numerical information system “SyZeM” #1098 - Missing Location, Abstract used for the “Zelazny Most” pond, based on the Oracle database and Geographical Information System to manage the graphical and descriptive data in coherent way. The main structure of the system, as well as the methodology of storing, processing and reporting the geological, geotechnical, hydrogeological,

geophysical, chemical and survey data are shown. Optimizing risk mitigation and safe management of copper wastes with the help of “SyZeM” are discussed.

Cu2007: International Symposium on **Downstream Fabrication and Applications**
Session 60: Furnace, Casting and Maintenance Innovations
Sponsors: SME, Metsoc, MMIJ, GDMB
Chair(s): J. Hugens, North American Manufacturing Company, Ltd.
Room Tudor 7—10:15

Paper #1031—10:15
Production and performance of casting moulds for copper anodes
F. Shulz, Norddeutsche Affinerie AG

NA’s primary smelter has continually increased its production output in the past decade, making it necessary to improve the lifetime of the casting moulds for copper anodes. The current throughput of more than 1,100,000 tonnes per year of copper concentrates amounts to an output of about 450,000 tonnes per year of anode copper at NA’s Hamburg plant. The anodes are cast on a single casting wheel with 24 anode moulds. Besides the stable chemical analyses, the reproducible geometry of the anodes is an important precondition for the success of the subsequent electro-refining process. The anode moulds are subjected to thermally-induced alternating stress and side reactions with the melt. Typical signs of wear will be shown and discussed. Different processes to produce anode moulds will be introduced and the results in terms of their lifetime and the quality of the anodes themselves will be discussed. Finally an outlook is given on possible efficiency improvements.

Paper #1053—10:40
Investigation of alternative materials for the burner system on the shaft furnace
T. Stergiou, HALCOR S.A. – Foundry

An extensive research is being carried out on the shaft furnace operation in order to minimize down-times and reduce operational cost. The need to increase the scrap percentage on the charging mix, together with the need of cheaper spare parts has led to the investigation of alternative materials for the burner system on the shaft furnace. This system consists of a burner block and a flame holder. Traditionally these items are constructed either from SiC – oxide bonded or SiC-nitride bonded. A lot of problems have been confronted over the past 8 years of operation. Usually, large cracks are formed on both flame holders and burner blocks. This resulted in leakage of combustion gases to the back of the lining and a quick erosion of it. Additionally, the burner blocks suffer from chemical erosion, due to the increased amount of scrap used in the charging mix and the presence of slag inside the furnace. Alternative materials such as stainless steel for the

flame holder and alumina-chromia refractory for the burner block have been tested in terms of life-time and resistance on chemical erosion. Furthermore, additional changes have been made on the burner block design in order to alter the flame shape and improve the scrap melting operation.

Paper #1039—11:05

Designing and implementing a maintenance program with SAP in the Paranapanema Group

J.R. Pacheco, Paranapanema Group

Paranapanema group has decided to implement the business system SAP R/3 in all companies of the group in order to replace all current applications. This project has taken nine months to be completed. This paper describes the phases of this implementation, with focus on the Plant Maintenance component. In addition, it gives an idea of the effort required to implement SAP R/3 on an organization the size of Paranapanema group.

Paper #1028 – 11:30

New concepts in refractory linings for copper shaft furnaces

B. Huffman, Atlantic Refractory Technologies Incorporated

This paper examines several new trends in the design and application of linings for copper melting shaft furnaces including the use of large shapes, monolithic back-up linings and improved refractory engineering to significantly reduce refractory installation time, diamond saw blade costs, fuel and down-time. The net results are shown to be dramatically increased refractory service life, reusable safety linings, elimination of hot spots and lower refractory disposal costs.