MONDAY, AUGUST 27, 2007, PM

COM 2007: International Symposium on **Light Metals** in Transport Applications
Session 13: Castings II
Sponsors: Light Metals Section of MetSoc, TMS
Chair(s): M. Sahoo, CANMET;
J-.P. Martin. Aluminium Technology Center
Room Confederation 5—15:00

Paper #1173—15:00
A study on fillability, DAS and microporosity in LFC of B206 aluminum – copper alloy
N. Dahata, C. Ravindran, F.H. Samuel, T.W. Gustafson, Ryerson University

B206 aluminum–copper alloy has a potential for wider use in the automotive industry due to its lighter weight and higher mechanical properties as compared to aluminum silicon alloys. The possibility of casting this alloy via lost foam casting (LFC) has not been investigated in detail. Therefore, patterns prepared with two types of foams: T170B (standard untreated EPS) and T175 (brominated EPS), different types of coatings (2), copper levels (2) and titanium levels (2) were used to study fillability, secondary dendritic arm spacing (DAS) and microporosity. The metal velocity in T175 pattern was higher than that in T170B pattern. For T175 pattern, the total solidification time was 3% higher and the loss of temperature for decomposition of EPS was lower relative to that for T170B pattern. The grain size, DAS, porosity levels and pore size were investigated using light optical microscopy (LOM). Image analysis suggests a larger grain size in the casting with T175 pattern. The DAS, the porosity level and the pore size decreased significantly with 0.25 wt% Ti in comparison to 0.05wt% Ti level.

Paper #1156—15:25
Determination of strain during hot tearing in aluminium alloys by digital image correlation
J.B. Mitchell, S.L. Cockcroft, The University of British Columbia

Using digital image correlation the evolution of strain and strain at the onset of localisation resulting in a hot tear has been determined for alloys AA6111 and Al-0.5wt% Cu during solidification. High resolution images of hot tear formation and growth were captured during a constrained bar test that incorporated a glass window above a central hot spot region. The images were analysed using digital image correlation software to measure the evolution of displacement and strain based on tracking the motion of discrete features on the as-cast surface of the sample. Temperature data was also acquired with a thermocouple cast into the sample in close proximity to the hot tear. The interval starting from the point immediately after solidification shrinkage ends (the metal pulls away from the glass) and finishing when the first sign of a crack or hot tear is visible to the eye

was used to determine strain data. The minimum strain at which strain localisation occurs was found to be 0.0069 in AA6111 and 0.0021 for Al-0.5%Cu.

Paper #1158—15:50

The effect of pressure depth on the globalization of AZ91 magnesium alloy

M.H. Heidary, M.B. Karimi, F. Khomamizadeh, Sharif University of Technology

In this investigation, effect of pressure depth on the globulizations of AZ91 magnesium alloy was studied. Cylindrical samples of AZ91 alloy with 1cm and 2cm in height and 2.5cm in diameter (H/D = 0.4 and 0.8) were prepared, then the samples were hot pressed at 10 and 30% strain at a constant temperature of 200°C; subsequently reheated at 555°C in different times. Results obtained from optical microscopy (OM) showed that the thickness of the samples and consequently, depth of strain affected regions have remarkable effect on the degree of globulization. In addition, it was found that at a constant strain and holding time, structure of thinner samples is more globular than thicker ones.

Paper #1170—16:15

Generation of single crystal magnesium wires by a heated mould continuous casting process

Y. Tajima, G. Motoyasu, Chiba Institute of Technology
H. Tae Kwon, Inje University
H. Soda, A. MacLean, University of Toronto

The heated mould continuous casting process known as the OCC (Ohno Continuous Casting) process has been used commercially for the casting of copper, silver and thermal fuse allow wires. In this study, the OCC process was applied to generate single-crystal, magnesium wires of 99.95% purity 6 mm in diameter. The crystal orientation in the casting direction was determined and mechanical tests have been performed. It was found that wires having an appropriate crystal orientation exhibited elongation by as much as 210%.

Paper #1139—16:40

Effect of iron content on the formation of B – Al_5FeSi and porosity in Al-Si eutectic alloys

M.A. Moustafa, Central Metallurgical Research and Development Institute

A preliminary investigation has been carried to evaluate the influence of Fe on Sr modified and unmodified eutectic Al-Si alloys in as-cast and heat treatment conditions. The castings were produced in zircon-coated steel permanent mold and were solutionised at 500 °C for 8 h and followed by artificial aging at 155 °C for 5 h, i.e., T6 temper. The microstructure changes in the β- Al_5FeSi particle morphology were analyzed. The results indicate that increasing the iron content leads to increase hardness either in the as-cast condition or after T6-temper. The Sr-modified alloys have higher hardness than unmodified at all Fe-added values. The precipitated long branched β- platelets result in the formation of large

shrinkage cavities due to the inability of liquid metal to feed the space between them during solidification.

COM 2007: International Symposium on **Light Metals** in Transport Applications
Session 14: Corrosion and Joining II
Sponsors: Light Metals Section of MetSoc, TMS
Chair(s): E. Ghali, Université Laval
Room Confederation 6—15:00

Paper #1175—15:00
Model of Al FSW nugget microstructure formation: piercing/extrusion with subgrain growth behind pin
H.J. McQueen, Concordia University,
M. Cabibbo, E. Evangelista, Università Politecnica delle Marche

Friction stir welding (FSW) generates complex microstructures in the nugget and thermomechamically affected zones (TMAZ) that have led to diverse explanations. However, consideration as an extension of microstructure development in piercing/extrusion can lead to a better understanding of flow patterns and microstructures during FSW. Furthermore, the intense strains in the nugget/TMAZ can be interpreted by comparison with ultra-high strains in torsion that exhibit dynamic recovery as extending into regions with high angle boundaries strongly serrated with spacing near the subgrain size defined by the high temperature. The subgrain diameter and extrusion pressure have been shown to be dependent on the Zener-Hollomon parameter Z (= $\dot{\varepsilon}$ exp(Q/RT), Q activation energy, R gas constant) combining temperature T and strain rate $\dot{\varepsilon}$ in the same manner as for torsion and compression. Moreover, such tests exhibited steady state stress σ_S above a certain strain ε_S (rising as Z increases) in which T, $\dot{\varepsilon}$, subgrain diameter and dislocation spacing remain constant. Due to the subgrain boundaries (SGB, low angle <5º, i.e.,LAB), continually rearranging by migration, decomposition and reformation, the subgrains remain equiaxed in elongating grains, whose boundaries (GB) become serrated as they migrate to absorb SGB. As confirmed by straining in torsion at constant T and $\dot{\varepsilon}$, more subgrains bordering the greater GB area have several high-angle facets (HAB) ; these small cellular regions with a mixture of HAB and LAB facets are designated HAB-subgrains. As serrations in neighboring grain boundaries impinge, the grains pinch off becoming shorter; this occurs at higher strains as subgrain size decreases with rising Z. The pinching-off makes the neighbors thicker so the grains never become thinner than about two subgrain diameters. In conjunction with such geometric dynamic recrystallization (gDRX), GB's undergo a net migration into grains with denser substructure, enlarging those with larger subgrains. Consequently a better name has been proposed: grain dimensioning dynamic recovery (gDRV).

Paper #1145—15:25

Physical and thermo physical properties of chromate conversion coatings on ALCLAD-7075-T6 al alloy for satellite application

S. Hosseinpour, K. Shirvani, Azad University of Saveh

Chromate conversion coatings (CCCs) are usually applied to these alloys to enhance their resistance to localized corrosion and to improve paint adhesion. The special properties of these coatings such as their low electrical contact resistance (ECR) make them suitable for satellites. This study is aimed to develop advanced CCCs with the proper appearance, morphologies and surface roughness and to evaluate their role on the ECR and thermo physical properties on hardened aluminium alloy of Alclad-7075-T6. Coating characterization was performed by means of scanning electron microscope (SEM) and atomic force microscope (AFM). ECR of coatings were measured by special laboratory designed instrument and α and ε were measured by Emissometer and Reflectometer respectively. In addition, corrosion performance of the CCC-coated alloys was determined by 168 hr exposing to salt-spray testing in accordance with ASTM-B117. The results of accomplished experiments on the developed CCCs in this study have been agreeable concerning available acceptability criteria for satellite surfaces

Paper #1151—15:50

Friction stir processing of sand cast aerospace Ze41A-T5 magnesium alloy

X. Cao, M. Jahazi, Institute for Aerospace Research

Friction stir processing (FSP) is used to produce wrought misconstrues at the surface of sand-cast aerospace grade ZE41A-T5 magnesium alloy. It is found that microstructures are significantly refined in the flow arm and stir zones. The stir zone is largely comprised of equiaxed magnesium grains of approximately 4.5 μm compared with about 50 μm in the base cast metal. In the stir zone, however, abnormal growth of some grains is also observed. Vickers microindentation hardness tests indicated that the stir zone experience some increases in hardness. Single surface passes with low distortion, lack of pores and cracks were successfully obtained indicating the great potential of the FSP technique for modifying, improving and repairing magnesium alloy castings. This will probably open new opportunities to apply magnesium alloys in aerospace industry.

Paper #1131—16:15

Effect of heat treatment on the mechanical properties of Ti6Al4V alloy weldment

M. Heidarbeigy, F. Karimzadeh, A. Saatchi, A. Tahvilian, Isfahan University of Technology

In this study, effect of heat treatment on mechanical properties of Ti6Al4V alloy weldment was investigated. For this purpose a combination of stress relieving, solution treatment and aging were carried out on Ti6Al4V thin sheets alloy this alloy .The stress relieving and aging treatment were carried out at 600°C and 540°C ,respectively, for 1 h. Solution treatment was done at 950°C for half an hour followed by water quenching. The results showed that weld ductility of the as-welded sample be improved significantly by subjecting it to a solutionizing and aging treatment. Furthermore, the ultimate tensile strength of this sample was same as postweld aging sample but ductility was significantly higher. Stress relieving did not have any appreciable effect in improving the ductility of the as-welded sample.

Paper #1132—16:40

Evaluation of microstructure of Ti6Al4V weldment by artificial neural networks

F. Karimzadeh, A. Ebnonnasir, A. Foroughi, Isfahan University of Technology

In the present investigation, microstructure of Ti-6Al-4V alloy weldment has been examined by artificial neural networks (ANN). The MPAW procedure was performed at different current, welding speed and flow rates of shielding and plasma gas. Metallographic characterization was carried out by light microscopy and scanning electron microscopy (SEM). At the end, an artificial neural networks (ANN) was constructed and trained to predict grain size of fusion zone (FZ) based on different current and welding speed. Evaluation of grain size by prediction of ANN indicates that there is an especial area of current and welding speed for phase transformation of α→ β in the HAZ. In the case of lower energy input, grain growth of β phase in the HAZ could be restricted by α phase. The presence of small quantities of this phase at high peak temperatures in the weld cycle is sufficient to prevent beta grain growth of HAZ and fusion zone (FZ).

Cu2007: The John E. Dutrizac International Symposium on Copper
Hydrometallurgy, Incorporating the 37th Annual Hydrometallurgy Meeting
Session 15: Leaching I
Sponsors: Hydrometallurgy Section of MetSoc, IIMCh, MMIJ, GDMB, EPD of TMS
Chair(s): M. Free, University of Utah;
C. Anderson, Montana Tech
Room Alberta—15:00

Paper #0971—15:00

GALVANOX – a novel galvanically-assisted atmospheric leaching technology for primary copper concentrates

D.G. Dixon, D.D. Mayne, University of British Columbia,
K.G. Baxter, Bateman Engineering

A novel technology for leaching copper from primary copper concentrates has been developed at UBC. This patented technology takes advantage of the galvanic couple between pyrite and chalcopyrite to ensure rapid and complete oxidation of chalcopyrite under mild conditions in acidic iron sulfate solution, without the need for microbes, ultrafine grinding, or chemical additives such as chloride, nitrate, or surfactants. Copper recoveries of 98% or greater can be achieved at 80°C under atmospheric conditions in as little as 4 hours of residence time. The process is selective for chalcopyrite over pyrite, generates near-quantitative levels of elemental sulfur, and is fully compatible with conventional solvent extraction and electrowinning of LME Grade A copper cathodes. In this paper, the fundamentals of the Galvanox™ process are reviewed, and selected results of batch leaching tests on various concentrate samples are presented and discussed.

Paper #1006—15:25

Reaction product layer on chalcopyrite in cupric chloride leaching

M. Lundström, J. Aromaa, O. Forsén, Helsinki University of Technology,
M.H. Barker, Outotec Research Oy

The Outotec HydroCopper® process is a novel technology, developed and registered by Outotec Technology Oy, for leaching copper from chalcopyrite using cupric chloride solution. The leaching process is operated at atmospheric pressure in a stirred tank reactor, at temperatures near the boiling point of water and pH values between 1.5 and 2.5. During the leaching of chalcopyrite in cupric chloride solution, a reaction product layer forms on the mineral surface. In the present work, the formation and the composition of the reaction product layer was studied in an environment similar to that of the HydroCopper® process. The effect of the process parameters on the reaction product layer was investigated. Electrochemical measurements, including A.C. impedance spectroscopy and microscopic observations were carried out and an equivalent circuit was used to determine the surface parameters, such as the reaction product layer capacitance and the charge transfer resistance. The results suggest that, at low pH, a passivating sulfur-rich layer forms, whereas at high pH, a more porous iron-rich layer was detected. The values measured can give useful information for optimising the leaching parameters of the HydroCopper® process.

Paper #0994—15:50

New hydrometallurgical technology for processing of copper concentrates

T. Velea, V. Predica, L. Gherghe, National R&D Institute for Nonferrous and Rare Metals

The most widespread methods for producing metallic copper are smelting of copper sulphide concentrates (which generates various types of polluting substances) and the hydrometallurgical route which consists of leaching in sulphate and chloride media (usually employing high temperature, high-pressure and special equipments). This paper presents a process, called VEPE, which consists of oxidizing copper sulphide concentrates in weak alkaline media (Na_2CO_3 or/and NaOH solutions), under low pressure and with air sparging. The oxidized concentrate contains less than 0.4% S. Copper is recovered from the oxidized concentrate by the standard leaching–solvent extraction–electrowinning route, with a total efficiency of 98% extraction. The proposed technology could represent a good opportunity to recover copper from sulphide concentrates in a clean, simple and profitable way.

Paper #1001—16:15

Analysis of heap leach processes with modeling and simulation tools

J.E. Gebhardt, A. Hernandez, Process Engineering Resources Inc.,
M. Cross, C.R. Bennett, D. McBride, University of Wales Swansea

Advances in computational modeling provide unprecedented process simulation tools for the process engineer to examine and explore options for optimizing heap leach operations. A phenomenological model developed within a computational fluid dynamic software framework provides a general heap leach modeling tool that describes reactive dissolution and fluid flow through the stockpile. A one-dimensional form of the model is used to parameterize the kinetic leach reactions for a mixture of copper sulfide and oxide minerals against data from operational leach tests. A two dimensional version of the model provides a means to investigate the effects of irrigation rate, lift height, air injection, bacteria limitations, and other factors on recovery and pregnant leach solution concentrations. The model was calibrated for the Nifty Copper operation and ore type in order to simulate heap performance. Model simulations are reported for the chalcocite-type ore and compared to process data. The application showed that the multi-dimensional nature of heap leaching causes heterogeneous effects that are not always adequately described by one-dimensional models. Irrigation flow rate and aeration effects were simulated for a multi-lift heap section, and model results indicated that air injection at the base of the second lift would be required to achieve expected copper recovery under these lift height and flow conditions.

Paper #0967—16:40
Evaluating copper sulfide leach practices with a heap leach model
G.P. Cooper, T. Robinson, Phelps Dodge Mining Company,
C.R. Bennett, M. Cross, University of Wales Swansea,
J.E. Gebhardt, Process Engineering Resources Inc.

A comprehensive computational heap leach model was used to evaluate options for operating a chalcocite-ore heap leach process. The stockpile leach model is based on the computational fluid dynamic software framework PHYSICA+ and incorporates various physical and chemical phenomena to simulate fluid transport, mineral reaction kinetics, bacterial effects, and heat, energy and acid balances for the overall leach process. The leach model is calibrated against small-scale column leach tests, and simulation results are validated against closely controlled column pilot-scale tests. For a given set of ore conditions, the effects of raffinate irrigation rate are examined. Several options for pulse leaching were investigated, and the effects on copper recovery and pregnant leach solution (PLS) grade are described. Model simulations indicated that pulse leaching could be used to control copper grade of the PLS. Finally, an analysis of inventory issues is presented for various lift heights including multi-lift simulations to examine potential operating options. Using irrigation rate, raffinate copper grade, and lift height as variables in a factorial design of experiments, the simulations showed that raffinate copper grade is the main factor that affects the soluble copper inventory grade.

Cu2007: The John E. Dutrizac International Symposium on Copper
Hydrometallurgy, Incorporating the 37th Annual Hydrometallurgy Meeting
Session 16: Solvent Extraction II
Sponsors: Hydrometallurgy Section of MetSoc, IIMCh, MMIJ, GDMB, EPD of TMS
Chair(s): K. Sole, Anglo Research;
G. Kordosky, Cognis Corporation
Room Manitoba—15:00

Paper #1019—15:00
Tailor-made crud treatment with 3-phase separating centrifuge
T. Hartmann, Westfalia Separator Industry GmbH,
J. Corbella, Westfalia Separator Chile S.A

The presence of crud represents a permanent challenge for solvent extraction in the hydro-metal industry. The crud is a stable emulsion which slowly spreads along the phase boundary between the aqueous and organic phase. The crud can significantly impair the efficiency of hydro-metal extraction because the phase boundary between the aqueous and organic phases assumes substantial proportions, and the settlers cannot react flexibly. In a chain reaction, all settlers connected in series become infected with crud. The transfer of organic phase to the electrowining (EW) cell can cause ‘cathode burn’. Continuous treatment of

the crud is extremely effective and reliable with a 3-phase separating solid bowl centrifuge. All three phases are separated distinctly from one another. All associated process steps exhibit a steady uniform efficiency. First and foremost, they ensure a reliable, continuous extraction process and, second, they recover valuable re-usable organics from the crud.

Paper #0983—15:25
Interface level control in settlers
M.F. Vancas, Bateman-Litwin

Control of the interface elevation between the aqueous and the organic phases in typical settlers is a fairly straight forward principle. However, when looking at the details involved in actually designing the aqueous and organic discharge launders and weirs, one comes to realize just how sensitive the system is to small variations in operating conditions and/or parameters. This discussion focuses on the details that must be considered during design, looks at the various types of control systems typically used (from the basic manual systems through to full automation), and equally importantly, looks at what happens in an operating plant when the conditions and/or operating parameters change.

Paper #1000—15:50
Optimization of Cu SX by control of the acidity
B. Grinbaum, Bateman-Litwin Solvent Extraction

The solvent extraction of Cu from acidic leach solutions is carried out using oxime extractants. The mechanism can be described as liquid ion exchange, where a labile H^+ in the oxime replaces Cu^{++} ion from the pregnant leach solution. The process is reversible and, at high acidity, the copper is stripped back to the aqueous phase. As the extraction proceeds, the acidity of the aqueous phase increases and the equilibrium may shift against the extraction reaction. This phenomenon may become significant in leach solutions with high copper concentration, where large amounts of acid are transferred from the solvent into the aqueous phase. An efficient way to increase the recovery of copper consists of splitting the extraction into two circuits, and either neutralizing with lime or extracting the excess acid of the intermediate raffinate. In the second case, the acid can extracted using a solvent, which can be stripped with a base, e.g., NaOH or ammonia. A third option is direct neutralization with soluble basic salt, e.g., Na_2CO_3, within a single extraction battery. The choice of the preferred process depends on the specific process demands and on the relative availability and price of the raw materials and by-products price.

Paper #1189—16:15
Non-dispersive solvent extraction of copper from ammoniacal solutions
M.L.F. Gameiro, M.R.C. Ismael, M.T.A. Reis, J.M.R. Carvalho, Instituto Superior Técnico

The aim of this study was to check the feasibility of non-dispersive solvent extraction to recover copper from ammoniacal solutions using hollow fibres as contactors. Data of mass transfer using the β-diketone LIX 54 as extractant was obtained. The influence of tube and shell hydrodynamics on the extraction rate of copper was studied. The overall mass transfer coefficient of copper was calculated from the experimental data by performing steady state material balance. Simultaneous extraction and stripping experiments were carried out using different volume ratios of feed phase to stripping phase. The results obtained showed that practically all the copper content was removed from the ammoniacal feed solutions. The recovery of copper reached nearly 100% in several extraction-stripping experiments.

Cu2007: International Symposium on **Electrowinning and Electrorefining,**
Incorporating the 37th Annual Hydrometallurgy Meeting
Session 17: Electrode Properties & Processes II
Sponsors: Hydrometallurgy Section of MetSoc, MMIJ, GDMB, IIMCh, EPD of TMS
Chair(s): A. Siegmund, RSR Corp.;
J.B. Hiskey, University of Arizona
Room British Columbia—15:00

Paper #0770—15:00
The effect of electrolyte composition on passivation of commercial copper electrorefining anodes
M.S. Moats, J.B. Hiskey, University of Utah

As smelter feeds become more complex, the impurities that ultimately report to electrorefineries are changing. Many of these impurities collect in the electrolyte and must be controlled. As commercial copper electrorefineries look to expand their capacities by increasing their operating current density, the interaction between electrolyte composition and anode passivation can cause operational difficulties. To improve the industry's understanding of the passivation phenomena, the role of electrolyte composition was evaluated using commercial electrorefining anode samples. The electrolyte composition variables examined were copper, acid, nickel, arsenic, chloride, thiourea and glue. Finally, the role of non-commercially utilized additives, such as bromide and polyethylene glycol were studied. From this investigation, electrolyte parameters that inhibit copper dissolution through copper sulfate precipitation, copper oxide stabilization and/or absorbed species lead to accelerated passivation. Species that prevent passivation have the ability to complex cuprous ions. Possible mechanisms for the role of each electrolyte parameter on passivation are presented.

Paper #0790—15:25

Problems in the electrolysis of copper anodes containing high nickel, lead, tin and antimony

Z. Mubarok, H. Antrekowitsch, G. Mori, University of Leoben,
A. Lossin, G. Leuprecht, Norddeutsche Affinerie

An overview of the problems encountered in the electrorefining of copper anodes containing high levels of nickel and antimony is presented. Our investigations have been focusing on the passivation behaviour of the anodes with high contents of Ni, Sb, Sn, and Pb, the formations of kupferglimmer and floating slimes. The results of linear voltammetry, chronopotentiometry and electrolysis test revealed a noticeable lower resistance of the anodes to passivation in comparison to those with lower contents of Ni, Sb, Sn, and Pb. Anode containing kupferglimmer exhibited oxygen gas evolution during the passivation state. Scanning electron microscopy (SEM) and energy dispersive X-ray (EDX) indicated that tin can replace and/or join antimony in the kupferglimmer structure. Under specified experimental conditions, floating slimes precipitations took place with high Ni, Sb, Sn, and Pb anodes prior to the end of one anode period.

Paper #1172—15:50

Using multivariable analysis for cathode quality improvement in Collahuasi electrowinning plant

F. Romero, G. Avila, R. Fester, Compañía Minera Doña Inés de Collahuasi,
L. Yacher, CONTAC

In the last four years, Compañía Minera Doña Inés de Collahuasi has been working in the application of advanced multivariate statistical techniques for the improvement of the metallurgical processes. In this paper the main conclusions for the application of multivariable analysis to the EW process are presented; including the identification of (target) process patterns according to throughput and quality criteria. Based on the process patterns, process variables hierarchies were identified by selecting the most influential ones, as well as to identify and isolate the root causes of pattern deviations and sub-standard operating conditions, cause-effect relationships were established, leading to the definition of process policies and controls to give early corrections to potential failures. The analysis was focused on cathode quality, specifically in its sulfur content, using an empirical model based on those variables that from a phenomenological and statistical stand point appeared to be the most influencing ones.

Paper #1103—16:40

Anode casting – chemical anode quality

C. Wenzl, H. Antrewkowitsch, University of Leoben,
I. Filzweiser, METTOP,
J. Pesl, Montanwerke Brixlegg

Anodes must have a certain physical and chemical quality in order to provide uniform anodic corrosion and meet the requirements of electrorefining, i.e. to achieve a high current efficiency, low energy consumption, low amount of anode scrap and low effort together with high cathode quality. Various properties of the anodes can be influenced directly by the casting process, which is the interface of pyro- and hydrometallurgy of copper. The aims of anode casting – high output and long mould lifetimes – are not consistent with good physical anode quality. The physical requirements of an anode are smooth surfaces, uniform weight and thickness, minimal edge effects, minimal distortion of the body and the lugs, as well as a homogeneous microstructure, in order to achieve uniform dissolution behaviour. The chemical quality of the anode copper is a task of electrorefining operations, but the elemental distribution within the anodes, which should be as homogeneous as possible in order to provide uniform anodic corrosion, can be influenced by the casting process. The cooling rate, which determines the grain size and microstructure, respectively, has a significant impact on elemental distribution. Hence it is vital to optimise the casting process, as the quality of the anode is decisive for electrorefining operation (output/efficiency, quality). Experiments investigated the elemental distribution over anode thickness and the resulting dissolution behaviour.

Paper #0782—17:05

Increasing anode thickness to optimise copper production at the Kidd metallurgical site

M.R. Coffin, A.R. Leggett, Xstrata Copper

In recent years, improved operation of the Kidd smelter has resulted in an increase in blister production capacity. Due to manpower and equipment limitations anode production and treatment rates could not be increased without incurring significant additional operating expenses. The option chosen to expand casting and refinery capacity to meet the available blister supply was to increase the anode thickness while maintaining the same anode exchange cycle in the refinery. This has resulted in a cathode production increase of almost 10% for minimal expenditure. Equipment and process modifications required to cast and refine the thicker anodes are discussed in this paper, along with the Six Sigma methodologies used to identify them. Key areas covered are Hazelett continuous caster operation, refining process parameters, plating performance and cathode quality.

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

Session 18: Anode Slimes and Electrolyte Purification

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

Chair(s): T.G. Robinson, Freeport-McMoRan Copper & Gold Inc.;
A. Alfantazi, University of British Columbia

Room Toronto—15:00

Paper #0759—15:00

Anode slime leaching and tellurium removal at Atlantic Copper refinery

R. Ramirez, G. Rios, A. Martin, Atlantic Copper S.A.

Atlantic Copper Refinery (Huelva, Spain) has operated the ISA permanent cathode technology since 1995. The current production rates are 260,000 t/y cathodes and 730 t/y anode slimes. These slimes undergo an atmospheric leaching in which their copper content is reduced from an average value of 24 % to 16 %. In June 2005 an optimization study of the leaching conditions was carried out aimed at lowering the copper content in the slimes to less than 8%. At the same time, a new mixer (Outukumpu Technology GLS-mixer) was installed in one of the three leaching reactors. As a result of the improvement of the leaching performance and to prevent the return of tellurium to the tankhouse, a cementation plant was commissioned in July 2005 to ensure a Te content below 50 ppm in the Cu-rich leachate. This paper describes the results of the improvement of the leaching conditions and the operation of the new tellurium removal plant.

Paper #0762—15:25

Upsets on antimony content in electrolytic copper produced at Caraiba Metais

I.M. Santos Moraes, Caraíba Metais S.A.

The control of minor impurities (mainly As, Sb and Bi) in copper refineries has been a great challenge. Caraiba Metais' copper refinery produces a very high quality copper, registered in LME as grade A, and recognized as amongst the top ten in the copper world. At Caraiba's Tankhouse Bi and Sb are controlled by means of electrolyte bleed-stream removal after partial decopperizing in a set of electro-winning cells (liberators). Another way of reducing the Sb and Bi content in the electrolyte is by means of the arsenate precipitation chemistry. It is well known that the use of high arsenic concentrations in copper refinery electrolyte has the advantage of causing most of the bismuth and antimony to report in the anode slimes. However, the use of such mechanism of control may contribute to other undesired problems such as antimony and bismuth precipitation in the bulk of the electrolyte, what may cause severe contamination problems. This paper describes a period when some cathode contamination with Sb occurred at Caraiba Metais' Copper Refinery. It also presents an analysis of several process parameters related to the problem, the possible causes for the contaminations as well as the actions taken to correct the problem.

Paper #0763—15:50

Studies on bismuth content variations in the Caraíba Metais' electrolytic copper

J.L. Rodrigues Bravo, Caraíba Metais S.A.

The aim of this paper is to show the results of the study that relate the variations of the bismuth content in the Caraíba Metais' electrolytic copper with the main electrolysis' process variables as electrolyte flow rate and temperature, anode's impurities content, electrolyte composition, current density, etc and their combinations and factors like cathode washing, blend of materials entering rod plant's furnace, analytical methods, shot-circuit inspection, etc. Also, the methodology considered arsenic, bismuth and antimony mass balance in the electrolysis and their electrolyte's molar ratio relations as well as bibliographic references of refineries that operate in similar conditions. The results showed the circumstances with the major probability of causing bismuth content increasing in the electrolytic copper and the main operating conditions that have to be fixed for having less bismuth variation and lower content in the electrolytic copper.

Paper #0764—16:15

Mineralogical characterization of a conventional copper refinery anode slimes treatment circuit

T.T. Chen, J.E. Dutrizac, CANMET-MMSL

A detailed mineralogical study was carried out to characterize the products generated in a conventional copper refinery anode slimes treatment circuit. The anode slimes, which are first leached in sulphuric acid media under an oxygen pressure to dissolve the copper and much of the tellurium, were found to contain various Ag-Cu selenides, $PbSO_4$, Ag, Au and $BaSO_4$. The resulting Ag_2Se, Ag_3AuSe_2, Se, Au, $PbSO_4$, $BaSO_4$, SnO_2 and silicate-rich leach residue is dried and pelletized. It is subsequently roasted to convert the selenium to Ag_2SeO_3, volatile SeO_2 and water soluble Na_2SeO_4. The roasted product, which was found to consist of Ag_2Se, PbSe, $PbSO_4$, $BaSO_4$, Ag_3AuSe_2, Au and SnO_2, is smelted and refined in a Dore furnace to produce a Dore metal that contains a (Ag,Au,Pd,Cu,Pt) alloy together with traces of CuO and a Cu-Pb oxide phase. Parting plant mud shown to contain AgCl, Ag, Au, (Au,Ag,Pd), $Ag_2Cu_2O_3$ and Ag_2O, and scrubber mud containing $PbSO_4$ and AgCl are also fed to the Dore furnace. The Dore furnace sequentially separates a silica slag which was found to consist of Ag, SnO_2, $BaSO_4$, Pb-Sb oxide, Fe-Sb-Ni-Cr oxide and a Pb-rich silicate phase, a soda-rich slag containing $Na_2CO_3.H_2O$ and $Na_2(Se,Te)O_3$, and a niter slag containing Na_2TeO_3, $Na_2(Se,Te)O_3$ and a Na-Te-Se-Pb-Ba-Cu oxide phase. The Dore metal is electrorefined in Moebius cells to yield high-purity silver and a gold mud which was shown to consist of a (Au,Ag,Pd,Cu,Pt) alloy and traces of CuO. Silver is leached from the gold mud and the resulting gold sand is cast into anodes and electrorefined in Wohlwill cells to produce pure gold.

Paper #1186—16:40

Processing of high nickel slimes at CCR refinery

J. Stafiej, M. Doucet, Xstrata Copper

The introduction of high-nickel anodes to CCR in 2006 resulted in an increase of nickel in anodic slimes. Removal of the nickel in these slimes to below 3.0% is necessary in order to prevent slag viscosity problems in the subsequent pyrometallurgical step. A lower specification of 0.5% was chosen in order to minimize Ni losses to the slag and to recover this nickel as $NiSO_4$. A 2-stage autoclave process, which was patented by CCR in 1992, was chosen to treat the high nickel slimes. Laboratory and plant–scale tests were performed in 2004 in order to validate the results of this process with the present slimes. These results along with corrosion tests were used to design two brick-lined autoclaves. These autoclaves were installed in October 2006 and successfully commissioned within 8 weeks. A “Design of Experiment” test program was performed in 2006 on an alternative autoclave process that reversed the cycles in the patented process. The effects of temperature and acid content were modeled using the results. The alternative process will be validated with the new autoclaves.

Paper #0752—17:05

A novel sustainable process for anode slime purification

E. Roman E., R. Alvarez P., J. Guzmán M., V. Carrasco T., M. Cifuentes M.,
CODELCO-Chile

A novel anode slime purification process was developed and tested at pilot scale in the Chuquicamata Refinery. The process consists of three main stages: First, an atmospheric alkaline leaching at 90ºC, under controlled pH and ORP operation parameters where metalloid impurities are preferentially removed from the anode slimes with high efficiency. In a second stage, alkaline washing of the mud leached with addition of reducing agent, with the intention of reducing the silver of the AgCl to metallic silver releasing the chloride, and finally, copper and other remaining impurities are leached out in mild conditions (60ºC, one hour in sulphuric acid). In a side process Se, Te, and Sb are recovery with high efficiency from the alkaline liquor as chemical grade products. The global balance shows a high mass loss yielding a final product with high precious metal and low impurities content showing advantages in both a technical and economic point of view with a clear environmental sustainability. This treatment allows either the direct sale of the purified anode slimes or its pyrometallurgical treatment to obtain metal doré without emissions of Se, Sb and As. Chemical mechanisms for this novel process are also described.

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

Session 19: Impurities

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

Chair(s): D. George, Rio Tinto;
A. Warczok, Univervity of Chile and Toronto

Room Territories—15:00

Paper #0807—15:00

Arsenic distribution in smelting via Teniente converter

C.M. Acuna, Division CODELCO Norte,
M. Sherrington, Training Management Institute, Inacap

In high temperature processes thermodynamic equilibrium is assumed and therefore chemical potential of elements, among the condensed phases, have to be the same. In such situation impurities distribute accordingly and their fractional distributions are affected by the masses of the coexisting phases. It has been claimed Teniente Converters perform quite well for smelting high impurity concentrates, especially in respect to volatilization and/or slagging. Production of high matte grade near white metal composition, requiring moderate oxygen enrichment in the process air, results in a huge mass of gas and therefore a high fraction of impurities report to it. Similarly, by recycling different sources of slag, flue dust or other materials, the mass of the final slag is increased and so do the masses of impurities reporting to the slag. Nevertheless, above a certain level the recycling of smelter byproducts is no longer feasible and the cycle has to be halted, unless higher impurity mattes are accepted. Although the process might be continued during converting and refining, lengthy and expensive measures have to be taken if suitable anode copper for electrolytic refining is to be achieved. In the present study samples of high arsenic matte grade and slag were obtained on a pilot scale. The matte samples, on the order 75%Cu, were equilibrated with slag at varying ratios in magnesia crucibles under CO/CO_2 atmospheres at 1523 K. After 24 hours equilibrium matte and slag were rapidly solidified and analyzed by copper, sulfur, iron and arsenic. Furthermore, industrial samples of matte and slag, in the order 75%Cu at 1523 K, were obtained via a special quenching sampling device to determine the association of copper and suspension of matte and copper in slag. Based on the results, the distribution coefficient of arsenic between slag and matte was evaluated along with copper species in slag and the fractional distribution of arsenic, in the coexisting phases, was determined as a function of the ratio mass of slag to mass of matte.

Paper #0865—15:25

Minor element tolerance and control in copper smelting

R. Harris, A.E. Wraith, McGill University,
R. Parra, Universidad de Concepción,
J. Qiu, HudBay Minerals Inc.

Small pilot scale experiments have shown that it is possible to almost fully eliminate the minor elements (ME), namely As, Sb, Bi and Pb contained in smelter dusts by vacuum calcination of mixtures of the dust with sulphidizing agents such as dirty copper concentrate or elemental sulphur at 900 ºC and 80 +/- 30 Pa for 90 minutes. The products of this calcination are a residue comprising a purified mixture of copper containing compounds along with the gangue constituents and a high sulphur condensate comprising a mixture of the

minor element compounds. In particular, the Cu:ME ratios of the concentrate and dust were increased from 250 and 50, from 28 and 12 and from 36 and 8 to roughly 3000, 3000 and 100 for the calcine, for Bi, As and Sb, respectively. It has also been calculated that (i) the copper content of the vacuum calcine may be recovered by feeding it into a Peirce-Smith converter during its slag blow, and (ii) the resulting recycling could increase the minor element treatment capacity of a smelter by 100 % while also reducing the blister As content by a factor of three. The experimental results are briefly discussed and a treated dust recycling option is examined. Example operating conditions are presented and available commercial technology for the vacuum calcination of the mixtures is reviewed.

Paper #0832—15:50

High-arsenic bearing concentrates processed in the Teniente converter at CODELCO Norte smelter

A. Moyano, C. Caballero, R. Mackay, J. Font, CODELCO-Chile,
K. Itagaki, Tohoku University

CODELCO-Chile is considering different processing options for the new projected concentrate from the Alejandro Hales mine. This concentrate is featured by its high arsenic content of up to 6%. Thus, it is important for CODELCO Norte Smelter to define the technical feasibility for processing this high-arsenic bearing concentrate in its main smelting unit as it is the Teniente Converter, which beside of its dual feeding system can enhance the arsenic removal by volatilization. The present paper which is a part of an extensive research work will focus in the performed industrial scale test for processing about 7,000 tonnes of a high-arsenic bearing concentrates in the Teniente Converter at the processing rate of about 2,300 tpd. The impact on the chemical quality of the produced high grade matte will be discussed, and the effect of the As removal by increasing the Teniente Converter processing rate of concentrates up to 3,000 tpd when producing 70% Cu in the white metal will also be addressed.

Paper #0824—16:15

Phase relations and activities of arsenic and antimony in the Cu-O-As and Cu-O-Sb systems at 1523K

K. Yamaguchi, Iwate University,
D.G. Mendoza, L. Voisin, K. Itagaki, Tohoku University

The behavior of arsenic and antimony in the Cu-O system was thermodynamically investigated to understand their elimination during a blister-making stage in copper smelting. Firstly, the phase relations in a miscibility gap composed of the liquid slag and copper phases in the Cu-O-As and Cu-O-Sb systems at 1523 K were established by a quenching technique. It was found that arsenic and antimony distributed preferentially into the slag phase in the miscibility gap. Secondly, the activities of arsenic and antimony in the miscibility gap of these systems were determined at 1523 K by using a double Knudsen cell

- mass spectrometer method. It was clarified that the activity of arsenic in the copper and slag phases showed the negative deviation from ideality while that of antimony in the copper phase a slightly positive deviation. These data obtained in this study suggest a possibility to eliminate arsenic and antimony by means of over-blowing in a converter after discharging the slag.

Paper #0836—16:40

Thermodynamic assessment for arsenic in the slag cleaning electrical furnace

J. Font, A. Moyano, C. Caballero, CODELCO-Chile,
A. Warczok, Universidad de Chile,
K. Itagaki, Tohoku University

The CODELCO Norte Smelter process 2,500 tpd of arsenic-bearing concentrates with an arsenic content of up to 1.5% in one of its two main smelting units, the Teniente Converter. The product, 1,100 tpd high-grade matte or white metal, is traditionally fed to the PS converters, while the 1,700 tpd of slag is fed to the slag cleaning electric furnace for copper recovery. This is achieved in a very reductive environment which reduces the viscosity of the slag and enhances the sedimentation of the high-grade matte droplets. The behavior of arsenic in this non-oxidative environment was studied at lab-scale and fundamental thermodynamic data were obtained. Based on these data a thermodynamic-base model to assess the arsenic behavior in reductive environment was developed. It is based on a mass balance for the reduction and sedimentation stages performed in an electric furnace which allows the recovery of high-grade matte droplets after decreasing the viscosity of the slag. This model can be a very suitable tool for predicting fractional distribution of arsenic in the slag cleaning electric furnace, when the distribution ratio, vapor saturation degree, temperature, γ_{As} and pO_2 are given.

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

Session 20: Copper Smelting Technologies

Sponsors: Non-Ferrous Pyrometallurgy Section of MetSoc, MMIJ, GDMB, IIMCh, EPD of TMS
Chair(s): F. Kongoli, Flogen Technologies;
R. Dengel, SMS Demag
Room Algonquin—15:00

Paper #0894—15:00

Flexibility of the Outokumpu flash smelting for low and high grade concentrates - evaluation by CFD-modeling

T. Ahokainen, J. Järvi, Outokumpu Technology Oy

The Flash Smelting process is the most used production method for primary copper in the world. The basic idea of the Flash Smelting is to utilize the thermal value of sulfidic concentrates and melt the reaction product, in controlled

conditions, without a need for external energy. This basic principle is utilized both in matte smelting and in Direct-to-Blister Flash Smelting Processes. In this paper, the behavior of normal ($CuFeS_2$) concentrate of FSF-process is compared to the behavior of high grade feed material produced by Outokumpu Concentrate Upgrade Process with the aid of computational fluid dynamics (CFD) simulation using add-in subroutines developed by Outokumpu Technology. Results consist of the information concerning the behavior of the suspension, reaction efficiency and other parameters concerning the reactions of the feed material. It will be shown that, using the Upgrade Process, the throughput of copper from the Flash Furnace can be almost tripled.

Paper #0818—15:25

Transforming flash furnace feed and burner stability - powering performance and productivity

C.U. Jones, M.E. Reed, D.E. Fallas, P.A. Cockburn, WorleyParsons Services Pty Limited,
B. Snowdon, P.E Walker, R.C. Sims, Clyde Materials Handling Limited

An advanced Flash Furnace feed system is the key to improving furnace performance. Clyde-WorleyParsons has developed a revolutionary pulseless pneumatic injection feed system technology, capable of delivering a range of benefits to operators of Flash Furnaces. The solution was created by combining the pneumatic conveying and injection knowledge, expertise and technology of Clyde Materials Handling with WorleyParsons' flash furnace process and operating experience. Optimal furnace burner performance requires the feed material to be presented to the burner as a stable, pulseless and accurately controlled flow, distributed evenly around the burner tip circumference. These simple requirements appear obvious, but are extremely difficult to satisfy in industrial environments and are not achieved by conventional feed systems. Our analysis of existing operating furnaces has identified the link between pulses in concentrate feed rate caused by conventional drag chain conveyors and rapid fluctuations measured in the furnace pressure. These fluctuations occur at a timescale close to the reaction shaft residence time and lead to unwanted instability in the primary furnace reaction zone – the flame. Through the use of the solution created by Clyde-WorleyParsons, it is predicted that the much more accurate control of feed rates achieved can lead to substantial improvements in furnace output, increased oxygen efficiency and better control of the composition of furnace liquids, such as matte, blister or slag. All these improvements lead to significant increases in smelter output and efficiency, and deliver high economic value compared to the cost of the feed system. Clyde-WorleyParsons' solutions can be deployed on greenfield sites or retrofitted, and therefore, have the capability to improve feed control at both new and existing smelters. This paper will discuss the field test work undertaken to date, the impact of findings and the ongoing analysis of linkages between instabilities in the various components of conventional feed systems and furnace pressure stability.

Paper #0887—15:50

Numerical simulation of combustion phenomena in a flash smelting furnace considering collisions of concentrate particles

Y. Sasaki, Y. Mori, Sumitomo Metal Mining Co.,
T. Miura, H. Aoki, Tohoku University

In a flash smelting furnace, easily combustible concentrate particles excessively oxidized and melt. The excessively oxidized molten particles then collide with less oxidized solid ones to create uniform oxidized molten particles. This collision phenomenon plays a very important role in achieving high smelting performance. The authors developed a mathematical model describing above combustion phenomena. This model incorporated fluid flow, heat and mass transfer, chemical reactions and collisions of concentrate particles. Both gas flow and particle motion were calculated using the Eulerian method. Copper concentrate was assumed to consist of chalcopyrite($CuFeS_2$). Considered in the concentrate reactions were the decomposition of $CuFeS_2$, and the oxidation of the resulting sulfur(S) and pyrrhotite(FeS) to produce magnetite(Fe_3O_4) and sulfur dioxide(SO_2). Moreover a reaction due to concentrate particle collisions, in which Fe_3O_4 in the excessively oxidized molten particle reacts with FeS in the less oxidized particle, was also considered. The particle collisions were assumed to occur according to a collision probability rule obtained by computational experiments. Particle growth in diameter was described as a change in the volume fractions of particle phases. When applied to a commercial flash smelting furnace, this model reproduced the particle growth and component transfer as observed in the actual furnace.

Paper #1109—16:15

Processing of copper sulphide ores and concentrates resulting in the production of high-grade matte and rejected slag in one unit – two-zone Vaniukov's furnace

M.V. Knyazev, A.G. Ryabko, L.B. Tsymbulov, L. Sh. Tsemekhman, NORILSK NICKEL RJS

Gipronickel Institute, JS has developed a new process and equipment for melting copper raw material in a two–zone Vaniukov furnace resulting in the production of white matte and low–grade slag in terms of copper content. Tests on processing copper nickel–containing ore from Norilsk (Cu – 17 %), Ni – 3 %) were conducted in Vaniukov pilot furnace (total area 11.4m^2) of Severonickel Combine. The amount of the processed material was about 11 thousand tons. Principal results of pilot testing are presented.

Paper #1111—16:40

Pilot testing of a process developed for treatment of copper concentrate with nickel content obtained in the course of high-grade matte separation resulting in blister copper production in a two-zone Vaniukov's furnace

L.B. Tsymbulov, M.V. Knyazev, A.G. Ryabko, L. Sh. Tsemekhman, NORILSK NICKEL RJS

Gipronickel Institute, JS is developing a process of continuous converting of Ni-containing copper matte and concentrates resulting in the production of blister copper and fluid NiO-containing slag in a two-zone Vaniukov furnace. The process under development is an alternative for the existing technology of blister copper production in converters, the latter being characterized with insufficient sulphur utilization, low direct copper recovery and the production of inconvenient for further processing solid slag on the basis of NiO and $NiFe_2O_4$. The results of pilot testing on processing of copper concentrate obtained from high-grade matte (HGM) separation in the two-zone Vaniukov furnace with the hearth area of 11.4 m^2 are presented.

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

Session 21: Plant Upgrading II

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

Chair(s): B. Imrie, Bechtel;
I. Wilkomirsky, Universidad de Concepcíon

Room Quebec—15:00

Paper #0886—15:00

Teniente converter - A decade of achievements at the Southern Peru Ilo smelter

E. Herrera, L. Mariscal, Southern Peru Ilo Smelter

The Teniente Converter (wet charge type) was commissioned in august 1995 and was designed to smelt 744 tpd (metric tons per day) of dry copper concentrates. Its products are white metal (73% Cu) that is sent to the Peirce Smith converters, slag that is cleaned in Reverberatory Furnaces and the process gases that are sent to the Sulfuric Acid Plant. Since its start up, the Teniente Converter smelting capacity was increased 1.6 times, from 800 tpd to 1,280 tpd using 33% oxygen-enriched air, and reaching an operative availability of 97%. By the other hand its campaigns have reached a record duration of 530 days without hot patching tuyeres and a partial refractory lining repair in the last four campaigns. This paper describes the most relevant improvements, as well as the strategies that had been used to reach these achievements.

Paper #0889—15:25

Operation optimization and capacity expansion in Jinlong Copper flash smelter

L. Keming, Z. Jun, Jinlong Copper Co.

Jinlong copper smelter, originally designed for 100,000tpa primary copper and started up in 1997, has been expanding its production by operational optimization and by modifying its facilities. Currently it is producing 220,000tpa primary copper, and the new phase of expansion project with a target capacity of 350,000tpa primary copper is on the way. This paper expounds progresses made in operation and their effects on capacity expansion in the smelter. Optimized modifying solutions to the existing facilities for the ongoing expansion project are present.

Paper #0891—15:50

Secondary copper smelting

S. Tandon, K. Guha, B. Kamath, Jhagadia Copper Limited

At Jhagadia Copper Ltd (India), Copper is produced through secondary route using Top Blown Rotary Converter (Kaldo Furnace). The basic raw material being treated includes Matte-slag Reverts, Copper Cakes, dross & Cement, Oxide Ore, Low S bearing Concentrates & various metallics along with high grade copper scraps. The plant has capability to refine & produce Blister grade copper from Kaldo furnace as well as PS Converter . Blister is fire refined in Anode furnace & electro refined in Refinery to produce cathode copper. Our product , Copper Cathode , has already been established in the market as its quality is better than 'LME Gr'. The paper deals with the experiences encountered during commissioning & stabilization of the plant.

Paper #0844—16:15

Paipote Smelter: in a continuous optimization process

J. Sanhueza, O. C. Rojas, J. Vargas, Empresa Nacional de Minería

Empresa Nacional de Minería (ENAMI) is dedicated to the promotion of small and mid scale Chilean mining industry. Paipote, ENAMI Copper Smelter, processes a variety of mineral products as the result of this promotion. The mineral products characterize a wide variation of copper, iron, sulfur and precious metals content as well as the significant dispersion in the content of impurities, such as arsenic, antimony and bismuth. The Smelter Modernization Program, initiated in1997, introduced a series of technological and operational changes. The development of operational planning and control strategies was necessary to optimize the blending of a wide variety of concentrates and the control of metallurgical processes in order to ensure the stable operation, fulfillment of environmental regulations and the quality of produced copper anodes. A permanent optimization process carried out in the last decade led to the permanent increase of the smelting capacity and the production of anodes

and sulfuric acid. Additionally, introduced improvements affected the smelter efficiency and metallurgical recovery, demonstrating the possibilities of the optimization of a small smelting facility reflected in good metallurgical and economic results. This paper presents the smelter evolution, introduced technological and process control changes as well as incorporated new reactors and equipment as a continuous process of optimization.

Paper #0825—16:40

New challenges facing Cumerio Med Pirdop plant

P. Barrios, T. Beamish, E. Marinov, I. Vasilev, D. Kirilov, Cumerio Med JSCo

In April 2005, Umicore Copper de-merged from Umicore Group and created a new independent Copper company called Cumerio. As a separate company, Cumerio is a major European copper smelter and refinery and a leading producer of copper products such as wire rod, billets, cakes and specialty rod with a total production capacity of copper products in excess of 500,000 tpy with production plants in Belgium, Italy and Bulgaria. The Pirdop Smelter is the only state-of the-art smelter in South East Europe and it makes Pirdop the natural hub for the copper industry in the region. In order to be competitive in the international market the main challenges facing Cumerio are to maintain its low cost structure and to achieve higher production volumes while reducing its impact to the environment and striving for continuous improvement of the production process. Cumerio's state-of-the-art smelting facility in Pirdop has recently increased the anode production capacity to 250,000 tpy by the installation of the third evaporative cooler on the converters section that allows operating with three-hot converters. In April 2007 a general shut-down for repair and modification on the Flash Smelting Furnace and Waste Heat Boiler is envisaged. At this time a revamp of one of the existing Sulphuric Acid Plants is planned, resulting in a further copper capacity increase to 275,000 tpy with modest Capex. In 2005 Cumerio received from the Bulgarian Ministry of Environment and Water the Complex Permit under the EU IPPC criteria. Accordingly an Environmental Compliance Program was defined targeting a large reduction in the secondary emissions. The system will be commissioned in May 2007. In order to better integrate the smelter and refinery in Pirdop and to respond to the growing demand for cathodes in the region, a new state-of-the-art Electrolytic Refinery with an installed capacity of 180,000 tpy will replace the existing refinery. The new refinery is expected to be fully operational as from early 2008. This paper describes the challenges and the projects.

Cu2007: International Symposium on **Mineral Processing**
Session 22: Flotation: Plant Practice and Innovations
Sponsors: Canadian Mineral Processing Society of CIM, Mineral Science and Engineering Section of Metsoc, MMIJ, GDMB, IIMCh
Chair(s): S. Schwarz, JKTech Pty Ltd.
Room Tudor 8—15:00

Paper #0705—15:00
Non-oxidative acidic treatment of copper sulfide concentrates in the flotation circuit
A. Luszczkiewicz, T. Chmielewski, Wroclaw University of Technology,
A. Konieczny, M. Kowalska, KGHM

This paper presents the beneficial effects of non-oxidative leaching of final and intermediate copper sulfide concentrates with sulfuric acid prior to the final cleaning stage of flotation. This unique process, combining leaching and flotation, appears to be advantageous for difficult-to-treat carbonate-bearing Polish copper ores, such as those processed in copper concentrators at KGHM Polish Copper. It was shown that after the chemical decomposition of about 70 % of the total carbonates naturally present in the flotation feed, a considerable enhancement of subsequent flotation results (both grade and recovery). The resulting products of non-oxidative leaching are solid hydrated calcium sulfate (gypsum), soluble magnesium sulfate and gaseous carbon dioxide. The beneficial effect established by the laboratory leaching tests was subsequently confirmed during a pilot plant operation treating final copper concentrate and a problematic intermediate concentrate at the Lubin concentrator.

Paper #0706—15:25
Leaching of bulk flotation concentrate as an alternative to treat a complex sulfide ore
C.A. Sosa-Blanco, C. Lara-Valenzuela, Servicios Industriales Peñoles S.A. de C.V.

Minera Sabinas in central Mexico treats a complex sulfide ore containing galena, chalcopyrite, sphalerite and argentite as valuable minerals, and in some cases important amounts of non-magnetic pyrrhotite. For high pyrrhotite ores, results obtained by selective flotation showed good grades and recoveries in the lead-copper circuit, but a commercial zinc concentrate could not be produced due to the high floatability of pyrrhotite. When this is the case, an alternative method was proposed to produce a bulk concentrate by flotation which is then leached to recover copper and zinc from liquor in a SX-EW circuit. Leaching was conducted in an autoclave in order to study the effect of temperature and pressure, but bioleaching tests were also conducted. Leaching lead-silver residues were treated by cyanidation in order to recover silver values. The results obtained by selective flotation and by bulk flotation with leaching of the bulk concentrate

showed that the latter alternative increased zinc recovery by 30 % with similar recoveries of the other metals.

Paper #0708—15:50

The impact of flotation in improving the economics of Barrick's Buzwagi project

B.K. Gorain, P. Beaudoin, P. Kondos, J. McMullen, J. Shuttleworth, Barrick Gold Corporation

Barrick's Buzwagi copper-gold deposit in Tanzania comprises oxide, saprock and sulphide mineralized zones averaging approximately 0.058oz/t gold, 0.13% total copper and 0.03% cyanide-soluble copper. A comparative evaluation of the project based on two potential flowsheet alternatives is presented. The first flowsheet included a gravity- concentration and carbon-in-leach (CIL) plant. The second flowsheet was based on a Gravity-Flotation-CIL plant, which proved to be more economically robust. Selective flotation of copper minerals to produce a saleable copper concentrate proved to be challenging. Detailed characterization of the Buzwagi deposit was carried out through understanding of ore mineralogy, mineral liberation, floatability and selectivity, reagent chemistry and regrinding issues. With this insight, a flotation concentrate of greater than 25% Cu was achieved, recovering a significant amount of copper minerals and tellurides. The overall economics of the project improved significantly with the addition of flotation. Leach tests on gravity and flotation tailings showed an overall increase in gold recovery of approximately 6% for a Gravity-Flotation-CIL plant compared to that for a Gravity-CIL plant.

Paper #0707—16:15

Flotation copper recovery from the converter slag of the Sarcheshmeh Khatoonabad smelter

A. Eslami, Sarcheshmeh Copper Complex,
S. Banisi, Shahid Bahonar University

When producing high grade mattes in smelter plants, copper losses in the slag are inevitable. Hence, the recovery of copper from slag has been the focus of many research projects, copper flotation being a widely used process. In the Khatoonabad converter, 200 t/d of slag are presently produced with a grade of 2.3% Cu. Assuming a 85% recovery by flotation, about 3.9 t/d copper could be produced, which is of prime importance economically. In the present work, a sample of this slag was crushed and ground in the laboratory to liberate the copper-bearing minerals. Following mineralogical studies, optimum laboratory flotation parameters were obtained, resulting in 90.27 % recovery and 9.42% of copper grade for the rougher stage. At pilot scale, a pulp of 28% solids was floated at ph 10.5 using 40 g/t of Z6, 25 g/t of R407 and 20 g/t of MIBC and A65. A recovery of 83.52% was obtained for a concentrate grade of 28.36% Cu. In the rougher cells, the feed consisted of particles 94% finer than 74 microns whereas in the cleaning stage, particles were 95% finer than 44 microns. Based on the

obtained results, the Sarcheshmeh Khatoonabad converter slag is presently being fed to the Chargonbad flotation plant, where a concentrate of 32% copper at 86% recovery is being produced.

Paper #0718—16:40
Metallurgical assessment of the scavenger stage in a copper concentrator
C. Cortés, V. Conejeros, Universidad Católica del Norte

Flotation is a highly interactive process where a change or disturbance in any part of the circuit results in different final grades and recoveries. This high variability of the circuit metallurgical performance complicates the diagnosis of the scavenger stage at the end of the line, as copper losses in the final tailings are erratic and not totally a consequence of problems in the scavenger section. The assessment of the scavenger performance requires a more elaborated procedure than that used for others stages of the circuit. This communication describes the application of an approach that combines results of laboratory flotation tests with those of surveys performed at the plant. Circuit feed samples from one of the local concentrators were collected and divided in three groups (low, medium, high) based on their copper content. These samples were analyzed for mineral composition and degree of liberation of the minerals of interest. Laboratory flotation tests demonstrated that the residence time of the scavenger cells was adequate. Plant samples of the scavenger feed and tailings streams were also collected and fully characterized (size, chemical, mineralogical and liberation analyses). To determine scavenger copper recovery surveys were conducted to collect samples, from all the plant streams, for total and size-by-size analysis. The results showed that copper losses come mainly from oxidized minerals present in the fine sizes (less than 9 micron). Copper and iron recoveries increased when pH was increased.

Cu2007: International Symposium on **Sustainable Development, HS&E, and Recycling,** Incorporating the 6th Waste Processing and Recycling Symposium
Session 23: Communities, Operations and Materials Stewardship
Sponsors: The Environmental Society of CIM, the Environment Section of Metsoc, MMIJ, GDMB, IIMCh
Chair(s): T. Nakamura, Tohoku University
Room Confederation 3—15:00

Paper #0928—15:00
Involving communities and measuring the impacts
D.M. Aloi, The Hatch Group

In today's evolving and globalized world, mining companies are being pressured to move beyond compliance towards long-term sustainability and sustainable development. Companies are expected to "engage" with communities and measure the success of these engagements without a clear understanding of "how" to do this. This move, away from "Corporate" Social Responsibility (CSR)

and compliance, develops more of a focus on “Community” Social Responsibility and sustainability. This shift in focus leads to the development of world-class projects that provide sustainable development for people, reduces the incidence of costly delays, and promotes good global citizenship for corporations. The process of “engaging” communities in mining project design and development leads to a stronger license to operate and sustainable development. To create this mutually beneficial relationship between communities and companies, communities must be “engaged” in the mining process as early as possible, preferably during the exploration or the concept phases. How to create this “engagement” remains elusive. How to measure the progress of this engagement is also problematic. The quantitative and qualitative metrics needed to measure both positive and negative impacts of the mining and community relationship will be discussed.

Paper #0929—15:25

Community development at Anglo American Chile’s Chagres smelter

C.A. Clark, Anglo American Chile

The Chagres Smelter is located 80 kilometres north of Santiago - Chile, in the middle of an agricultural valley which is also one of the poorest districts in the country. This condition sets the main focus for the smelter’s Corporate Social Responsibility (CSR) programmes, which ultimately aim at building self sustainable social and economic capital in accordance with the local capacities. With the help of Anglo American’s SEAT (Socio Economic Assessment Toolbox), a corporately developed instrument designed to help the operations understand the needs of the communities and the impacts of those operations, the Chagres Smelter implemented several programmes, such as the CETTA (Experimental and Applied Technology Transfer Centre) programme. This project started in 2003, and consists of creating a centre for the transfer of sustainable techniques and skills for the small agricultural and livestock producers that live in the rural areas near the Chagres Smelter. Its main impacts are: Improved production quality (goat cheese and bee honey) and access to relevant markets, improved training and self-sustainability levels of producers, enhanced socio-economic level of the District’s inhabitants by improving their income earning opportunities and technical knowledge, creation and promotion of a local brand as a symbol of quality products from the valley and a positive environmental impact of good breeding and native flora protection practices in the area. Other relevant social programmes are the ‘Environmental Strivers’, which created a recycling centre in the community; and the ‘Beautiful Valley” project, which provides management knowledge and skills to local youngsters and leaders who can contribute to finding solutions for local environmental needs.

Paper #0933—15:50

Sustainable development perspectives of RTB Bor copper mines after the consolidation

S.L. Zekovic, Institute for Architecture and Urban & Regional Planning of Serbia

This paper analysis the medium and long-term perspectives, framework and considered possibilities of sustainable development of RTB “Bor” (Copper mines in East Serbia) after consolidation in the period of transition. The copper mine was opened in 1903. and today is the best quality copper producer on Balcan. This paper are elaborates the problems of privatization, debt, investment, growth of copper production from own mines (and imported raw), opening of new mines, economical efficiency of production, markets, environmental problems and impacts of the recent industry consolidation. The RTB “Bor” is a serious hot spot in Serbia. Unsustainable trends and processes are identified, as follows: openpit waste dumps, flotation tailings, mining and processing waste waters, air pollution; no efficiency (excessive) using nonrenewal resource in the copper production; inefficiency in the use of energy, water and other inputs in copper complex; transboundary character of emissions of dust; environmental degradation and quality of wide area and ecologically highly risk, etc. Analysing some trends and planning-developmental perspectives and development strategies of company, it might be assumed that in the forth coming period, in parts of the Serbia, the borders areas of Bulgaria and Romania, there is an anticipated increase of ecological risk.

Paper #0932—16:15

Operational strategy at Chagres smelter, maximizing installed capacity

R. Bonifaz, R. Subiabre, Anglo American

The Chagres Smelter, part of the Anglo American plc group situated 80 Km north of Santiago in Chile, completed a series of operational improvement in 2005 resulting in an optimum capacity in its operational units. At present the Chagres Smelter has developed an operational strategy which seeks to reduce bottle-necks in the production process. In this way we have managed to lower operational cost, decrease energy consumption and maximize the capacity of the Acid, Oxygen, and Smelting, Converting, Refining and Casting units. A constant application of international benchmarks together with continuous staff improvement and the latest smelter technology have combined to place Chagres among the finest smelting works in the world. In response to environmental challenges, we have studying various options for investment suitable for a profitable business of benefits to both Anglo American and Chile as a whole. The most relevant technical indicators are the figures : Energy consumption less than 6,3 GJ/ton fine copper, Intensity of smelting rate in Flash Smelting unit of 6900 ton of copper concentrate/m2 settler of furnace area and be one of the top five smelter in direct cash cost .

Paper #0917—16:40
Maximizing value – promoting material stewardship in the minerals and metals sector
J.K. Atherton, B.E. Davies, International Council on Mining and Metals

If the metals sector is to contribute successfully to sustainable consumption we must adopt principles and practices which address the entire life cycle of the materials we produce. Progress must be founded on a sense of shared responsibility for the resources we utilize and the materials we create - it is this integrated approach which lies at the heart of materials stewardship. Materials stewardship means mining and metals companies producing materials in a responsible manner and then working with others, beyond their site, to ensure that the downstream material flows and applications are managed properly to create maximum societal value. In September 2006 ICMM published 'Maximizing Value: Guidance on implementing materials stewardship in the minerals and metals value chain'. This document takes a practical view presenting structured guidance as well as good practice case studies. In the publication, materials stewardship is described in terms of the range of activities that can be undertaken to ensure that all parties work collectively toward the responsible use of metal and mineral resources. This paper introduces the materials stewardship concept as set out in 'Maximizing Value' and describes the business case for implementation as well as the ICMM framework for promoting materials stewardship.

Cu2007: International Symposium on **Downstream Fabrication and Applications**
Session 24: Continuous Casting For Wire Rod
Sponsors: SME, Metsoc, MMIJ, GDMB
Chair(s): J. Jacobsen, Norddeutshche Affinerie AG
Room Tudor 7—15:00

Paper #1047—15:00
The SCR process produces high quality copper rod around the world
P. Ware, Southwire Company

The majority of all refined copper is consumed to produce electrical conductors. Most copper conductors are drawn into wire from 8 mm ETP copper rod produced from high purity copper cathodes. Southwire Company has more than 40 years experience using, designing, fabricating and marketing a process for continuously producing ETP copper wire rod. This process is called the SCR® (Southwire Continuous Rod) process. Today, approximately half the copper wire rod produced in the world, or more than one third of all refined copper consumed, is produced using the SCR process. Southwire has sold 75 SCR copper rod mills to metal producers and wire manufacturers around the world. Southwire is North America's largest electrical wire and cable producer. Southwire operates a 48 metric ton per hour SCR® copper rod system in Carrollton, Georgia. This allows

Southwire to provide technical support for existing SCR® system customers based on first-hand knowledge. Rod fabricators and their wire customers are always striving for copper rod that improves productivity. They are looking for improved surface quality, finer wire sizes and fewer wire breaks per ton of rod drawn. This paper will present a brief history of the SCR® process, a description and recent process developments.

Paper #1054—15:25
Innovations in twin belt compliant mold casting technology
R. von Gal, Hazelett Strip-Casting Corporation

Hazelett Strip-Casting Corporation has been producing the Hazelett® twin-belt casting machines for copper casting since the mid-1960s. The first commercial casters were developed for copper alloy strip and anode plate. In 1968, development work was started to adapt the twin-belt caster for copper bar casting to be rolled in-line into wire rod. Since then, 36 casters have been sold as part of the CONTIROD® system for the production of a substantial portion of the world's copper rod supply. A unique feature of the twin-belt caster is the mold's ability to comply with the size and shape of the cast bar as it shrinks during solidification. Maintaining contact between the mold and the bar provides a high rate of heat transfer as well as other benefits, including the prevention of surface imperfections caused by remelting in the mold. This paper will give an overview of the continuous evolution of the twin-belt caster technology with an emphasis on recent developments in compliant mold technology for copper casting.

Paper #1038—15:50
Recrystallization of copper wire rod
J. Schmidt, Norddeutsche Affinerie AG

Cold drawing of copper wire rod is usually combined with an in-line annealing process to adjust the ductile microstructure of the wire again. One important key factor for successful annealing is the quality of the copper itself. Rod producers can check the recrystallization behaviour of the rod by different methods: chemical analysis, Spiral Elongation Test (SEN) as well as the Rapid Elongation Test (AR) are some examples of common testing methods. The comparison of the results of these methods does not always show sufficient correlations. The paper introduces firstly the SEN and AR-Tests and their different approaches to the mentioned task. The second step is to compare some results of the SEN-Test with the results of the AR-Test and identify causes of deviations. Thirdly, the effect of pre-annealing is discussed, which is especially common for wire rod with diameters of more than 8 mm.

Paper #1029—16:15

Overview on contirod® wire-rod plant operations in Sarkuysan (Modernization Activities and Results)

T. Ediz, S. Elvi, A.S. Sarkuysan

Sarkuysan Electrolytic Copper holds three competitive technologies namely Outokumpu, Southwire (SCR®) and CONTIROD® under the same roof. After more then thirty years experience of Outokumpu Upcast ® in producing oxygen free wire- rod, and twenty years of SCR® experience, in 1999 it was decided to introduce the CONTIROD® process to the customers with a chance and advantage to test capabilities of each process in order to fulfil their requirements, expectations, and turn this know-how to their benefit. After reviewing the milestones of Sarkuysan's evolution in Turkey as global wire-rod producer, this paper will briefly present the modernization and expansion activities in the CONTIROD® plant consisting of the different phases following the first start-up, and the results of these activities. It will highlight the gains and improvements of some operational parameters within this period.

Paper #1030—16:40

Operating experience of copper and acid recovery from rod pickling solution using EMEW® technology at Phelps Dodge, El Paso Works

D. Fenton, Phelps Dodge Refining Corporation

The Phelps Dodge El Paso Rod Mill produces approximately 2.4 million pounds per day of copper rod from a casting and rolling operation. The newly formed rod is treated to remove mill scale and oxides using a sulfuric acid and hydrogen peroxide solution which is bled periodically when the copper concentration reaches 30-35 g/L. The bleed solution is heated to 75° C to destroy the residual peroxide. Copper is then recovered in a 270 cell EMEW electrowinning plant. Clean acid is also regenerated in the EMEW plant and is returned to the rod cleaning circuit. The EMEW plant commissioned in January 2006, has two operators and replaces a copper sulfate plant with fourteen operators. The EMEW plant has a capacity of 1700 kg/day of cathode copper at 2.1 kWh/kg copper deposited. The electrowinning plant operates in closed circuit with the rod mill returning up to 2600 kg/day of sulfuric acid resulting in zero discharge. Use of dimensionally stable anodes ($DSA_{®}$) ensures that the acid quality is maintained in the closed loop operation. The operating conditions, performance and plant experience of the EMEW copper and acid recovery plant are discussed.