MONDAY, AUGUST 27, 2007, AM

COM2007 and Cu2007 **Plenary Session 1 and 2**
Sponsors: Metsoc, IIMCh, GDMB, MMIJ, TMS, SME
Chair(s): J. Kapusta, Air Liquide;
M. King, Xstrata;
C. Twigge-Molecey, Hatch
Room Canadian—08:00

Paper #1097—08:15
Technology and sustainability - keys to unlocking the next generation of copper projects
C. Sartain, Xstrata Copper

In recent years market pressures have been building on companies to develop the next era of mining projects to follow the previous boom in copper projects of the mid 90's. However the response from the industry has been slow in coming, and somewhat muted. It is clear that there simply have not been the obvious quality projects waiting to be rapidly developed. Many of the known undeveloped copper projects have particular characteristics that have previously prevented their development, including mineralogical complexity in the ore bodies, environmental challenges or particularly difficult geographic locations. This paper describes how the Copper Division of an international mining company, Xstrata plc, is preparing to progressively develop an impressive pipeline of projects, armed with an array of proprietary technologies and with a strong approach towards sustainable development and community engagement. The approach being taken is enabling Xstrata to complement its acquisitive corporate philosophy with a management emphasis on project development and operational optimization and enhancement.

Paper #1098—08:55
Meeting the challenge – prospect of the European copper industry
W. Marnette, Norddeutsche Affinerie AG

Copper demand is booming. New epicentres with strong dynamic economic growth have arisen in China and other emerging markets. Furthermore, Europe contributes to higher copper demand due to positive economic growth. China and India are therefore expanding their smelter industries, with the backing of a coordinated policy of global raw material sourcing, which includes investments in raw material deposits and state-run measures to support their international trade and competition. Likewise, Europe faces scarcity of copper raw materials. The copper industry in Europe shows excellence in environmental protection and technical leadership. Recycling has always been an important sector. This is based on the recycling know-how which exists in the European sector. However, Europe still relies on importing a considerable amount of raw materials from foreign countries. As a result, the global competition for copper and copper raw

materials has increased. Tough competition as regards industrial location and costs, the emergence of corporate concentrations and the use of protectionist trading practices by countries like China and India, which distort the markets, now determine the picture. Hence, a copper smelter in Europe is forced to develop tailor-made concepts to safeguard and improve its international competitive position. It is imperative that this is also accompanied by improved conditions on the local level and a European raw material policy which takes account of the changed situation on the world market.

Coffee Break—09:35 – 09:50

COM 2007: International Symposium on **Light Metals** in Transport Applications
Session 1: Castings I
Sponsors: Light Metals Section of MetSoc, TMS
Chair(s): M. Sahoo, CANMET;
J. P. Martin, Aluminum Technology Center
Room Confederation 5—09:50

Paper #1114—09:50
Effect of superheat and section thickness on flow characteristics for thin section LFC of hypereutectic Al-Si alloy
A. Haldar, C. Ravindran, Ryerson University

This study focuses on the flow characteristics of hypereutectic Al-Si alloys in thin sections. The pattern assembly consisted of spiral horizontal patterns, 6.25 mm (0.25 inch) and 12.50 mm (0.50 inch) in thickness with a common sprue. Al-Si alloys with silicon levels of 14%, 18% and 22% were poured with superheats of 60ºC, 115ºC and 170ºC. It was observed that metal fluidity (in terms of flow length and metal velocity) increased with increase in silicon levels and superheat for both section thicknesses. It was also observed that, for a section thickness of 6.25 mm (0.25 inch), silicon level had more pronounced effect on the metal fluidity. For 12.50 mm (0.50 inch) thickness, both silicon level and superheat affected the metal fluidity. The surface hardness of the castings increased with an increase in silicon level of the alloys at the gate and the flow tip. Detailed study of the flow tip was also carried out with a view to understanding the effect of silicon level and superheat on undulated flow length, surface hardness and microstructure.complete the characterization.

Paper #1115—10:15
Study of flow stoppage in hypereutectic Al-Si alloy in the lost foam casting process
A. Haldar, C. Ravindran, Ryerson University

The major problem encountered in the casting of hypereutectic Al-Si alloys is the stoppage of flow below the rigidity level of solid fraction. In this study, the flow stoppage mechanism was studied using three Al-Si alloys with 14%, 18% and

22% silicon. The horizontal foam patterns used were 12.50 mm (0.50 inch) wide with two section thicknesses 12.50 mm (0.50 inch) and 6.25 mm (0.25 inch) with a common sprue. The primary silicon distribution along the length of the casting was studied to determine the mechanism of flow stoppage. It was found that the surface of the flow tip of Al-14%Si alloy was smooth with a few undulations. As the silicon level increased, undulations at the flow tip increased. The number and size of undulations were maximum for the Al-22%Si alloy. Microstructural analysis using optical image analyzer revealed that the flow tip consisted mainly of eutectic silicon in the aluminum matrix and a few primary silicon crystals (PSC). The PSC were in the interlocked condition few centimeters behind the flow tip. It was also found that the gap between the flow tip and the PSC concentrated area increased with an increase in silicon level. Phase characterization was done with SEM-EDX to identify the precipitating phases.

Paper #1125—10:40

Influence of artificial cooling and pressure application on the metallurgical quality in the LPPM casting of aluminium A356

F. Chiesa, Collège de Trois Rivières

Forty aluminium A356 castings were poured on a Low Pressure Permanent Mould industrial machine, 500x700mm in platen size. The 152mm wide casting comprised three steps, 25mm, 13mm, 6mm in thickness and a 2.5mm overflow which allowed to assess the thin wall capability of the process. The casting campaign, which produced 40 parts, allowed to test the influence of various production parameters including the time of application of the pressure in the crucible, artificial cooling of the mould and casting rate. The thermal history in the mould was recorded over the 40 cycles, which allowed to construct a reliable thermal model of the mould/casting assembly. The metallurgical quality of castings representative of the various conditions was assessed in the 25mm, 13mm and 6mm plates. This included measuring the level of microporosity, the dendrite fineness (DAS), along with the tensile properties in the T6 condition. The radiographic quality per ASTM E155 was also determined. Modelling filling and solidification allowed to verify the validity of the predictions based on available relationships relating microporosity, secondary dendrite arm spacing (DAS) and local tensile properties (Quality Index, Q) to the local thermal solidification parameters.

Paper #1144—11:05

Development and applications of microsegregation models for solidifying light metallic alloys

S. Uddin, M. Hasan, McGill University

Microsegregation manifests its effect on microstructural evolution of cast or welded alloys which in turn influences their important mechanical and electro-chemical properties. In the above context, mathematical models of microsegregation have proven to play an important role in estimating the nature

and predicting the effects of this phenomenon in wide varieties of solidification processes. Microsegregation models are useful in designing new commercial alloys, in estimating the homogenization time for the post-process heat treatments and in many other practical applications. In this study, two semi-analytical models of microsegregation were developed to predict the concentration field of solute in the liquid and solid regions for dendritic solidification of binary metallic alloys. Both models assume that the growing dendrites are cylindrical in shape. This assumption is more realistic compared to the common assumptions of plate like dendrites that most of the earlier researchers employed in their microsegregation modeling study. The solute redistribution profile, in the developing solid layer, necessary to determine the back diffusion parameter was derived from Fick's second law for the model without coarsening. The application of this parameter in a wide range of conditions and the use of its basic form in the model with coarsening has been verified. The concept of coordinate transformation and enhancement of back-diffusion Fourier number were used in deriving the model which took into account the coarsening of dendrites. The models are then extended to deal with rapid solidification and peritectic transformations and the results were compared with relevant experimental data for Aluminum and other alloys. A good agreement between model predictions and experimental results was found.

Paper #1147—11:30

Novel foam processing in aluminum lost foam castings

S. Jagoo, C. Ravindran, Ryerson University,
D. Nolan, Foseco

In the lost foam casting (LFC) of aluminum alloys, the expandable polystyrene (EPS) foam characteristics (foam composition, polymer processing and bead fusion) influence the formation of deleterious fold defects in the final casting. In this research, three types of EPS beads were investigated: (1) the regular EPS beads, (2) catalyst blended to EPS beads after the pre-expansion process of the beads and (3) fire-retardant blended to EPS beads after the pre-expansion process of the beads. The density of the regular and modified EPS beads was kept constant at 1.6 lb/ft^3. The morphology of the EPS beads and the degree of bead fusion were investigated. Thermo-gravimetric Analysis (TGA) was used to determine the onset temperature, rate constant and activation energy for the decomposition of the regular and modified EPS. Brookfield viscometer equipped with a mantle and a temperature controller was used to determine the viscosities of the regular and modified EPS at 260 ^{0}C. Aluminum alloy A356 was poured at 1023 K into a window pattern. The window patterns with regular EPS beads did not fill completely. The defects identified in the castings included carbon/oxide surface defects, blisters, porosity and lap folds due to the entrapment of liquid and gaseous pyrolysis products. However, the window patterns with the modified EPS beads were completely filled with fewer carbon/oxide surface defects and porosity.

COM 2007: International Symposium on **Light Metals** in Transport Applications
Session 2: Corrosion and Joining I
Sponsors: Light Metals Section of MetSoc, TMS
Chair(s): E. Ghali, Université Laval
Room Confederation 6—09:50

Paper #1116—09:50
Corrosion study of the skin and bulk of die-cast and thixocast AZ91D alloy in Cl- solution using electrochemical noise technique
A-M. Lafront, D. Dubé, R. Tremblay, E. Ghali, Université Laval,
C. Blawert, W. Dietzel, GKSS Research Center

The corrosion resistance of die-cast and freely-solidified and electromagnetically-stirred thixocast AZ91D alloy has been studied using electrochemical noise technique in a 0.05M NaCl solution at pH 6.1 and 25°C. Specimens polished at different depths were immersed for a period of 75 min in order to assess the influence of the microstructure on corrosion kinetics and morphology. At depths between 10 and 50 µm (skin), all specimens showed general non-uniform corrosion with the lowest corrosion resistance. Between 100 and 200 µm (interior skin), the observed corrosion was accompanied by superficial undefined pits due to metastable pitting. The corrosion form for 100-200 µm gave the best corrosion resistance. Stable pitting corrosion was observed beyond 400 µm deep on the bulk specimens. The skin of all thixocast specimens prepared billets showed a more corroded surface than that of die-cast. The interior skin as well as the bulk specimens showed better performance than that of the die-cast specimens.

Paper #1118—10:15
Microstructure and tensile properties of friction stir welded joints of AZ31B magnesium alloy
N. Afrin, D.L. Chen, Ryerson University,
X. Cao, M. Jahazi, Institute for Aerospace Research

The microstructure and tensile properties of AZ31B-H24 magnesium (Mg) alloy after friction stir welding (FSW) were evaluated. The grain size was observed to increase from approximately 5 µm to about 9 µm after FSW. The obtained Hall-Petch type relationship showed a strong grain size dependence of the hardness values. While the FSW led to about half of the yield strength of the base magnesium alloy, the ultimate tensile strength after FSW could reach about two thirds of that of the base alloy. The hardening capacity of the FSWed samples was about twice of that of the base alloy. The strain hardening exponent of the base alloy was found to be about 0.1 whereas it became larger than 0.3 for the FSWed samples. After yielding the base alloy showed a high initial and almost constant work hardening rate, corresponding to linear hardening stage II, followed by stage III with a decreasing hardening rate. Stage II linear hardening was observed to be absent in the FSWed samples.

Paper #1119—10:40

Effect of friction stir processing on the microstructure and microhardness of AZ31B magnesium alloy

M. Fairman, N. Afrin, D.L. Chen, Ryerson University,
X. Cao, M. Jahazi, Institute for Aerospace Research

The effect of welding speed on the microstructure of friction stir processed (FSPed) AZ31B-H24 magnesium alloy was studied using light microscopy, image analysis, and microhardness tests. The grain size of the magnesium alloy was observed to increase after FSP from about 3.5 μm in the base alloy to about 8 μm in the stir zone. The aspect ratio decreased from 1.60 to 1.55 towards the center of the stir zone. The changes in the grain size and shape caused the microhardness of the samples to drop significantly across the FSPed region from 75 HV in the base alloy to below 55 HV in the stir zone. Decreasing the welding speed increased the grain size due to a greater input of heat energy. The faster heating rate due to the lower welding speed caused a deeper penetration of the annealing effects of FSP. It was also observed that the annealing effects caused by FSP were less pronounced with increasing distance from the interface between the sample and pin tool shoulder. The Hall-Petch type relationship of the micro-indentation hardness as a function of the grain size was observed to hold true after FSP.

Paper #1120—11:05

Microstructural features of dissimilar friction stir welding of AZ31 magnesium alloy to 2024 aluminum alloy

A. Liu, D.L. Chen, S. Bhole, Ryerson University,
X. Cao, M. Jahazi, Institute for Aerospace Research

The effect of welding speed on the microstructure of friction stir processed (FSPed) AZ31B-H24 magnesium alloy was studied using light microscopy, image analysis, and microhardness tests. The grain size of the magnesium alloy was observed to increase after FSP from about 3.5 μm in the base alloy to about 8 μm in the stir zone. The aspect ratio decreased from 1.60 to 1.55 towards the center of the stir zone. The changes in the grain size and shape caused the microhardness of the samples to drop significantly across the FSPed region from 75 HV in the base alloy to below 55 HV in the stir zone. Decreasing the welding speed increased the grain size due to a greater input of heat energy. The faster heating rate due to the lower welding speed caused a deeper penetration of the annealing effects of FSP. It was also observed that the annealing effects caused by FSP were less pronounced with increasing distance from the interface between the sample and pin tool shoulder. The Hall-Petch type relationship of the micro-indentation hardness as a function of the grain size was observed to hold true after FSP.

Paper #1130—11:30

Corrosion behavior of 6061 aluminum alloy weldment in chloride media

Z. Nikceresht, F. Karimzadeh, M.A. Golozar, Isfahan University of Technology

In this research, corrosion behavior of 6061 aluminum alloy weldment was investigated. Gas tungsten arc welding (GTAW) process was performed at different current and welding speed. Metallographic characterization was carried out by light microscopy and scanning electron microscopy (SEM). Corrosion behavior was studied in aqueous solution with 3.5 % NaCl. Accelerated immersion test was done according to ASTM G110. Results showed that pitting corrosion in all samples as well as local intergranular corrosion. Coarse Intermetalic particles such as Al-Si-Mg and Al-Fe-Si were found to be nucleation sites for pits. Electrochemical impedance spectroscopy measurements showed that at $E < E_{pit}$ a charge transfer semicircle was obtained. This semicircle was followed by a warburge diffusion tail at $E > E_{pit}$.

Cu2007: International Symposium on **Economics and Markets**

Session 3: Economics and Markets I

Sponsors: The Management and Economics Society of CIM, MMIJ, GDMB, IIMCh

Chair(s): C. Moscoso, Univsersidad de Chile;
P. Dietrich, CVRD Inco

Room Saskatchewan—09:50

Paper #1086—09:50

Real options for the valuation of mine assets: from an early stage of exploration through the sequence of engineering phases to production

E. Tulcanaza, Codelco

Mining companies normally establish exploration and research programs that include a series of actions in embryonic stage. At their early stages of development, these exploration and technological initiatives are subject to uncertainties that need to be resolved, deciphered or, at least, mitigated, first, for information reporting, later, for valuation reporting. Under these circumstances, mining companies establish a sequence of development activities that range from exploration and research activities to the profile, conceptual, and finally to basic engineering phases.For information reporting, the International Template for Reporting of Exploration Results, Mineral Resources and Mineral Reserves integrates the minimum standards being adopted by the relevant professional bodies in Australia, Canada, South Africa, Chile, USA, UK, Ireland, and other European countries which conform the Committee for Mineral Reserves International Reporting Standards (CRIRSCO). These standards are based on the progressive collection of relevant information to reduce present and future uncertainties over times under a context of transparency, materiality, and technical competence. For valuation reporting several procedures have been

disclosed and applied. However, in the last decades financial instruments such as real options, decision analysis, and games theory have developed into a niche of great potential for mine valuation applications. The objective of this paper is to provide a summary of the information reporting standards prepared by the Chilean National Commission for the Qualification of Competent Persons for Mineral Resources and Mineral Reserves and show a procedure and an application of real options to the valuation of the different development phases of a mine asset from the exploration stage through up to full development.

Paper #1091—10:15

Mining ore valuation by real option under uncertainty and risk

M. D. Viera , Metaproject S.A.,
P. Lamothe, Universidad Autonoma de Madrid

The purpose of the study is to show through real cases of companies in Chile, the different problems about valuing or appraise economically a mining ore resource, with the traditional techniques. The study demonstrates that with the risk analysis and real options theory application one could determine the most probable value for a mining ore resource or mining business, and the risks cover under uncertainties scenarios. The study shows the different methods and criterions employed in the ore resource evaluation or mining assets. Moreover, it shows also a comparative analysis of the different methods in order to explain the different distortions, errors, risks and imprecision of each one of them. The companies are getting aware of the risks importance and the impact that they have in the commercial value and in the ore resource estimation models. The real options are now the technique that allows in some way to value and control the risk cover of the business. The company valuation could help to respond questions like: How much is my business worth? How much has been the investment profitability of my business? What could be done to improve this profitability and create value? The purchase and sale processes needs generally provide a quickly and reliable valuation that permits to the mining ore business owners to sell with security, or carry out studies, or additional investigations in order to know their true potential, and to the possible buyers to take solvents investment decisions, or in other case underrate the operation. Even the Public competent Administration should rely on valuations experts to the case of authorizing transmissions, opportunity costs judge and definitely know the public goods that one is yielding or privatizing, bringing as consequence losses for the country. Recent frauds with Mining Companies stock market values, like the case of the Canadian Brie-X Company has reveal the necessity that the valuations of this type of Companies or mineral ore resources, must be carried out under some type of control and that the technical stakeholders has the adequate professional credentials. The study introduces mineral ore resources and projects valuation in which after carrying out the purchase and sale process, they also carried out real options applications. The study demonstrates that there is value loss for one of the parts, by not providing an appropriate appraisal methodology.

Paper #1090—10:40

The economics of the custom smelter and its importance

K. Kitazawa, Pan Pacific Copper Co. Ltd.

1. The custom smelter depends on the fee paid by the copper mine (usually called as “treatment & refining charge”). 2. The custom smelter treats not only copper but also sulfur, iron and other various impurities in the copper concentrate. 3. The custom smelter is one of the wheels of the copper industry and its existence is very important together with the copper mine.

Paper #1084—11:05

Aplicación de un modelo de determinación de riesgos sobre variables presupuestarias

E. Alarcón, M. Marchese, Hatch

La variable riesgo ha sido considerada históricamente en los proyectos de inversión en forma esporádica y normalmente asociada con el impacto de eventos negativos sobre el resultado del mismo. Su estudio e incorporación en el desarrollo de proyectos ha sido desarrollado como una disciplina dentro de Hatch, con el fin de evaluar y cuantificar el impacto de los riesgos asociados y desarrollar planes de contingencia y mitigación que minimicen su efecto neto sobre el proyecto, en el caso de que sea un riesgo negativo, o permitan su máximo aprovechamiento en beneficio de él para el caso de presentar impactos positivos. A mediados del año 2005 para el área de evaluación de inversiones de una empresa minera productora de cobre, Hatch desarrolló un proyecto de aplicación de metodologías de evaluación y cuantificación del riesgo en proyectos de inversión para determinar el rango en los que las variables de presupuesto podían ser impactadas y al mismo tiempo de que modo estos impactos afectaban el Valor Presente del Proyecto. La técnica aplicada consistió en el uso de la Metodología VaR (Value at Risk) en términos de determinar el efecto potencial o impacto económico sobre el valor presente del proyecto, en función de las variables claves y su implicancia en el modelo de presupuestos. Este trabajo presenta los resultados del uso de esta metodología basada en la aplicación de un modelo de determinación de riesgos utilizando una distribución triangular de probabilidades. Como parte de este trabajo se incluyó la aplicación y entrega de la parametrización de la metodología, con el propósito de que ésta pudiera ser posteriormente utilizada en forma directamente por cualquier usuario y cómo el modelo puede ser enriquecido en la medida que sea posible alimentarlo con una mayor cantidad de datos históricos. Para lograr la aplicación de la metodología VaR fue necesario desarrollar un método de análisis de los niveles de información disponible y a la vez la identificación de los procesos unitarios, ítems de gastos, subítems de gastos y elementos de gastos asociados con el proyecto en evaluación. Una vez que dichos elementos fueron definidos, se determinaron sus rangos de valores máximos y mínimos que, en conjunto con el valor presupuestado, fueron utilizados para el cálculo del VaR y del gasto real seguro con un 95% de confianza, basados en la aplicación de la distribución

triangular de probabilidades de ocurrencia de los riesgos asociados, determinándose las correlaciones existentes entre los Elementos de Gasto Claves, con lo que se calculó el Valor en Riesgo (VaR) Total del Presupuesto de Gastos asociado al Proyecto.

Paper #1121—11:30
The Mongolian copper industry and its investment projects
A. Galsandorj, Mongolia Exporters Association

The presentation covers following four major areas of the Mongolia copper industry. At the beginning gives overview of the Mongolian mineral sector, its mineral production of past 5 years, mineral sector's contribution to the national economy of Mongolia and mineral sector's production and export incomes, value of exports by major mineral commodities. Also shows Mongolian mineral commodities' share in the world mineral industry, its future trends and foreign direct investment in the mining industry. Second part states the Mongolian copper industry, its geological exploration activities, identified resources and proven reserves, copper production and exports by existing mines and plants. Also says on the Erdenet copper mine and concentrator- Mongolian Russian joint venture, Erdmin Sx-Ew plant , their expansion plans and development policy issues for adding value added products, especially Sx-Ew project and copper rod processing project. Third part says on new world class copper projects to be exploited in the near future, like Oyu Tolgoi and Tsagaan suvrage copper projects. Briefs on main clauses and points of **Investment Contract** to be concluded between the Mongolian Government and Ivanhoe-Rio Tinto. Fourth part of the presentation concentrates on the Mongolian new mineral law and its rules and regulations, new mining, tax and investment environments.

Cu2007: The John E. Dutrizac International Symposium on Copper
Hydrometallurgy, Incorporating the 37th Annual Hydrometallurgy Meeting
Session 4: Process Development I
Sponsors: Hydrometallurgy Section of MetSoc, IIMCh, MMIJ, GDMB, EPD of TMS
Chair(s): V.I. Lakshmanan, Process Research Ortech Inc.;
J. Ferron, Recapture Metals
Room Alberta—09:50

Paper #0938—09:50
Abandoned but not forgotten - the recent history of copper hydrometallurgy
F. Habashi, Laval University

In the period 1970-1995, a number of hydrometallurgical processes to treat copper concentrates to overcome the pollution problem due to SO_2 emission in smelters were developed. Pilot and commercial scale plants were built and operated for some time, but eventually all were abandoned a few years later. It is

constructive to examine why these processes were abandoned after so much expenditure of funds and effort, so that errors should not be repeated in the future and lessons from the past are learned.

Paper #1008—10:15

Recovery of copper from a massive polymetallic sulphide by high concentration chloride leaching

G.B. Harris, G.P. Demopoulos, McGill University,
B. Ballantyne, Starfield Resources Inc.,
C.W. White, Consultant

A new process for the recovery of copper and associated base metals from a polymetallic massive sulphide ore is described. The massive sulphide contains copper and especially nickel sulphide in a mineralogical form which negates both good recovery and high grades in concentrates using conventional flotation methods. Flotation concentrate processing and smelting from this ore is therefore probably not an economically viable option. Utilising the properties of high concentration chloride brines, a flowsheet has been developed and tested whereby the recovery of all of the metals and some of the power requirements for the plant itself can be derived from the ore. The new process overcomes the less-amenable-to-flotation ore characteristics, and provides the opportunity of economic processing in remote locations where the dependency on fossil fuels is both a logistical and an economic concern. The Ferguson Lake deposit of Starfield Resources in Nunavut, Canada, is the subject of this paper, which focuses on the leaching and copper recovery unit operations of the proposed flowsheet.

Paper #0977—10:40

Hydrometallurgical processing of Polymet Mining's Northmet deposit for recovery of Cu-Ni-Co-Zn-Pd-Pt-Au

D. Dreisinger, PolyMet Mining Company,
K. Baxter, Bateman Engineering Pty Ltd.,
C. Fleming, J. Ferron, A. Mezei, J. Brown, R. Molnar, SGS Lakefield Research

The NorthMet deposit of PolyMet Mining is located in northern Minnesota, adjacent to the Iron Range. The deposit is polymetallic with values of Cu, Ni, Co, Zn, Pt, Pd and Au. The processing route selected for extraction of these values utilizes bulk sulfide flotation followed by hydrometallurgical treatment. The hydrometallurgical process has been thoroughly tested on the bench and pilot plant scale at SGS Lakefield Research. The major steps in the process are;

- Chloride-assisted total pressure oxidation for extraction of base and precious metals
- Thickening/filtration/washing of the barren residue from total oxidation
- Reduction and precipitation of Au, Pt, Pd from the oxidation solution
- Partial neutralization of autoclave acid using limestone
- Copper SX/EW for production of copper cathode

- Treatment of a portion of the raffinate from Cu SX to recover Ni/Co/Zn as either a mixed Ni-Co-Zn hydroxide or as separate Ni hydroxide, Co hydroxide and a Zn sulfate solution.
- Recycling of the remaining raffinate to the autoclave as coolant.

The process flowsheet, chemistry and bench/pilot plant test results will be reported in this paper.

Paper #1022—11:05

The re-development of the Kov, Kananga and Tilwezembe copper-cobalt deposits in the Democratic Republic of the Congo

L. Treadgold, Nikanor Plc Douglas,
J. Parker, Bateman Minerals and Metals

The KOV, Kananga and Tilwezembe copper-cobalt deposits in the Democratic Republic of the Congo have lain dormant for over ten years due to lack of funding by the State-owned mining company, Gécamines. Nikanor Plc through its operating company DCP has secured the mining titles from the DRC government and has commenced re-development of these large copper deposits. DCP plans to produce 250,000 tonnes per annum of LME Grade “A” copper cathode and up to 30,000 tonnes per annum of cobalt salts. This paper describes the geology, re-development of the KOV mine and the two smaller mines, Kananga and Tilwezembe, the design of a new copper-cobalt processing facility and the challenges in refurbishing the associated infrastructure.

Paper #1017—11:30

Sulfate-based process flowsheet options for hydrometallurgical treatment of copper sulfide concentrates

J.O. Marsden, J.C. Wilmot, Freeport-McMoRan Copper and Gold, Inc.

Over the past eight years, Phelps Dodge (a division of Freeport-McMoRan Copper and Gold, Inc.) has developed a suite of proprietary hydrometallurgical processes for the treatment of copper concentrates as an alternative to conventional smelting and refining technology. The technical viability of two processes has been commercially demonstrated in a large scale plant at Bagdad, Arizona, designed to process approximately 52,500 metric tons per year of concentrate containing 30.5% copper. The first process utilizes high temperature (225ºC) pressure leaching, followed by counter-current solid-liquid separation, and then blending of the copper-bearing solution with low grade stockpile leach solution for subsequent treatment by SX/EW for copper recovery. The second process uses super-fine grinding, medium temperature (160ºC) pressure leaching, followed by solid-liquid separation, and treatment of high grade copper-bearing solution by direct electrowinning to recover the bulk of the copper values. The latter process will be utilized at Morenci in a commercial facility designed to treat mixed chalcopyrite-chalcocite-covellite concentrates. This facility is scheduled to start up in 2007. Other flowsheet options have been developed by Phelps Dodge for application to a variety of concentrate materials

in specific situations. Examples of various flowsheet options are presented in this paper, and the advantages and disadvantages associated with each are discussed in detail.

Cu2007: The John E. Dutrizac International Symposium on Copper
Hydrometallurgy, Incorporating the 37th Annual Hydrometallurgy Meeting
Session 5: Solvent Extraction I
Sponsors: Hydrometallurgy Section of MetSoc, IIMCh, MMIJ, GDMB, EPD of TMS
Chair(s): I. Mihaylov, CVRD Inco;
R. Molnar, MetNet H2O Consultants
Room Manitoba—09:50

Paper #0961—9:50
Customising copper-iron selectivity using modified aldoxime extractants: pilot-plant evaluation
K.C. Sole, K. Viljoen, B.K. Ferreira, Anglo Operations Limited,
M.D. Soderstrom, O. Tinkler, L. Hoffmann, Cytec Industries Inc.

In most copper solvent-extraction operations, an important consideration in choice of extractant is the requirement for high selectivity of copper over iron. Ester-modified aldoxime extractants presently offer the best Cu:Fe selectivity. In some plants, however, the process feed liquors contain significant amounts of manganese but little iron. Although manganese is not chemically extracted by oximes, trace amounts are carried over to the electrowinning circuit by physical entrainment. This may result in anodic oxidation of manganese which, in turn, can cause oxidative degradation of the organic phase when returned to the solvent-extraction circuit in the spent electrolyte. Many of these operations prefer to operate with higher levels of iron reporting to the advance electrolyte, as appropriate control of the Fe(II)/Fe(III) couple will ensure that manganese remains in the benign Mn(II) form. A new reagent, LS 4202, designed by Cytec, now offers the possibility of tailoring the iron co-extraction, so that appropriate Cu:Fe selectivity can be achieved in the solvent-extraction operation to maintain an electrolyte Fe:Mn mass ratio of >10:1, while retaining the other benefits offered by ester-modified aldoximes. The results of an integrated solvent extraction-electrowinning pilot-plant trial are presented, in which the performances of the conventional extractants ACORGA® M.5774 and LIX® 984N are compared with LS 4202. The Cu:Fe selectivity is demonstrated, along with results on the transfer of other impurities to the advance electrolyte.

Paper #0955—10:15
Copper leaching aids – compatibility with the copper solvent extraction process
G. Kordosky, M. Virnig, Cognis Corporation

Leaching aids that result in an increase in leaching rates and overall copper recovery have the potential to be beneficial to copper leach/solvent

extraction/electrowinning operations. It is generally accepted that effective leaching aids facilitate the penetration of leach solution into ore by lowering the surface tension of the leach solution. Surfactants are designed to do this, and a leaching aid containing the widely used surfactant class, alkyl phenol ethoxylates, has been suggested. Alkyl phenol ethoxylates were tested to determine how they may affect phase separation, entrainment and degradation in a copper solvent extraction plant. The test results suggest the use of leaching aids at a regular rate, or even for a short time period, may have a long term impact on copper solvent extraction. Several scenarios are evaluated regarding existing operations and future solvent extraction projects and cautionary suggestions related to the use of surfactants as leaching aids are given.

Paper #0963—10:40

Degradation of copper solvent extraction reagents in the presence of nitrate – contributing factors

G. Kordosky, M. Virnig, Cognis Corporation

The experience of one plant regarding degradation of copper solvent extraction reagents in the presence of 20 to 30 g/l nitrate in the leach solution was described at Cobre 2003. However, little information is available about the degradation of copper solvent extraction reagents where the nitrate concentration of leach solution is much lower. Analysis of plant organic samples taken from an operating copper SX plant over a long period of time shows that small amounts of nitrate in the leach liquor can be a significant contributor to reagent degradation provided certain other conditions are present. These conditions are discussed and cautionary suggestions on copper SX plant operations in the presence of even low levels of nitrate in the pregnant leach are made based on industry experience with copper solvent extraction plants and copper solvent extraction reagents.

Paper #0989—11:05

Modeling of two-phase flow in a solvent extraction pulsed column

M.P. Schwarz, J.M. Bujalski, W. Yang, J. Nikolov, C.B. Solnordal, CSIRO Minerals

CFD (Computational Fluid Dynamic) models have been developed and validated for a pulsed column with disk-doughnut internals, as used for solvent extraction. First a single phase model was developed to simulate the turbulent oscillating flow around the internals of the column. This model was successfully validated using detailed PIV measurements of velocity taken at eight different phases through the pulse cycle. Second, the CFD model was extended to allow for a continuous aqueous phase and a dispersed organic phase (kerosene) flowing counter-currently. The model was a two-fluid model that accounts for droplet breakup and coalescence, and solves for droplet size distribution using a population balance model incorporated into the CFX4 package. PDIA (Particle Droplet Image Analysis) measurements were taken on a pilot scale solvent

extraction pulsed column to determine droplet size distribution for calibration and validation of the CFD model. The measurements were made under pulsing intensities ranging from 10 mm/s to 32.5 mm/s.

Paper #0965—11:30
Copper extractant strength: the effect of substituents in the 3-position on hydroxyoxime performance
R.S. Forgan, D.K. Henderson, P.A. Tasker, F.J. White, University of Edinburgh, J. Campbell, R.M. Swart, Cytec Industries UK Ltd.

The synthesis and study of a systematic series of phenolic oximes have shown that substitution in the 3-position can greatly affect extractive efficacy. Solid state, solution and gas phase analytical techniques, including X-ray crystallography, EPR and IR spectroscopy and collision induced dissociation mass spectrometry have been assessed for their applicability in interpreting the origins of differences in extractant strength. The dominant substituent effect on $pH_{0.5}$ is the change in ligand pK_a, with the more acidic ligands being stronger extractants. The influence of the 3-substituent on the stabilising intracomplex H-bonding of their copper(II) complexes also affects extractant strength. The 3-NO_2 substituted ligand shows the lowest $pH_{0.5}$ value, due to a combination of its low pK_a and a stabilising bifurcated H-bond assembly around the copper(II) centre. Appending an aminomethyl group to the 3-position gives a ligand capable of binding a metal and its attendant anion. These metal salt reagents show potential to open up new flowsheets for the processing of high tenor copper feeds.

Cu2007: International Symposium on **Electrowinning and Electrorefining**, Incorporating the 37th Annual Hydrometallurgy Meeting
Session 6: Electrode Properties and Processes I
Sponsors: Hydrometallurgy Section of MetSoc, MMIJ, GDMB, IIMCh, EPD of TMS
Chair(s): J.D. Edwards, CVRD Inco;
G.E. Houlachi, LTE-Hydro-Quebec
Room British Columbia—09:50

Paper #0744—09:50
Electrorefining high level arsenic cast anode
A.C. Atenas, P.A. Muñoz, CODELCO

Control of arsenic in the Potrerillos' Refinery electrolyte has been obtained by withdrawing a bleed stream of circulating electrolyte and ensuring the ratio of [O]/[As] in the cast anodes is maintained between 0.9 and 1.0. In order to achieve this control the anode oxygen must be adjusted, depending on the arsenic level in the cast anodes. It has been necessary to modify the time of the reduction step in the anode furnace refining process. Control of this ratio has permitted electro refining of anodes with high levels of arsenic, up to 3000 ppm, while minimizing the volume of electrolyte that must be removed for impurity

control so as not to affect the copper concentration in the electrolyte. However this control strategy is not useful when the arsenic concentration in the cast anode is too high, because it is limited by the maximum oxygen concentration allowable for a good quality anodic. Costs have been reduced in anode furnace refining because it is no longer necessary to use alkaline flux injection to remove the arsenic in cast anodes.

Paper #0751—10:15

Tapered anodes for copper electrowinning

E. Guerra, J.L. Shepherd, Laurentian University

During industrial copper electrowinning, a fraction of the electrolyte becomes entrained with the oxygen gas bubbles that are evolved at the anodes. The fraction of entrained bubbles increases from the bottom of the anode to the top, resulting in a bubble distribution that appears as an inverted wedge between the cathode and anode. Since the bubbles act as insulating spheres, electrolyte resistance increases from the bottom of the electrodes to the top resulting in correspondingly higher local current densities and uneven copper growth along the cathode. To counter-act the inherent tendency toward excessive copper growth near the bottom of the cathodes, the use of tapered anodes was examined. The potential improvement in cathode current distribution was evaluated by comparing the primary current distributions for 2-D computer models of a copper electrowinning cell with plate shaped anodes against one with tapered anodes.

Paper #0758—10:40

Optimization of the technological parameters for the copper electrorefining using interference microscopy and digital image analysis

D. Zagidulin, G. Szymanski, J. Lipkowski, University of Guelph

Short term electrodeposition experiments (up to 80 min.) at two current densities 220 and 275 A/m^2 with varying concentrations of thiourea and glue were performed to determine the optimum levels of glue, thiourea and current density for industrial copper electrorefining. White Light Interference Microscopy was used to acquire digital images of the morphology of the electrodeposited copper. Scaling analysis was employed to parameterize the morphological information encoded in the images. The limiting roughness, $*$, the critical scaling length, L_c, and the aspect ratio, $4*/ L_c$, were determined as a function of the deposition time and the amount of organic additives. These parameters were used to calculate the dynamic exponent, β, the roughness exponent, 1/z, and the aspect ratio exponent, γ, plotted as a function of glue and thiourea concentrations. These 3D plots allowed us to find conditions corresponding to the minimum of β and γ, at which the deposited copper is characterized by a small roughness and a dense structure.

Paper #0766—11:05
Developments in permanent SS cathodes within the copper industry
K.L. Eastwood, G.W. Whebell, Xstrata Technology

The ISA PROCESS™ cathode plate is characterised by its copper coated suspension bar, coupled with a blade employing austenitic stainless steel alloy 316L. The blade material has become the mainstay of the technology and has been closely copied by competing cathode designs. Improvement to the cathode plate design remains a key area for research, and ongoing developments by Xstrata Technology's ISA PROCESS™ have recently been commercialised. Two such developments are the ISA Cathode BR™ and ISA 2000 AB Cathode. The ISA BR cathode is a lower resistance cathode that has proven to enhance operating efficiencies. The AB cathode was designed to improve stripping inefficiencies in the ISA 2000 technology. These developments have now had time to mature and their long term performance will be discussed. Rising material costs and the desire to extend the operating boundaries of the standard 316L cathode plate has triggered a number of significant advances. These involve the use of different stainless steels as alternatives in some operational situations. The technical aspects and results of commercial trials on this development will also be discussed in this paper.

Cu2007: The Carlos Díaz Symposium on **Pyrometallurgy**
Session 7: Keynote - General – Plant Upgrading
Sponsors: Non-Ferrous Pyrometallurgy Section of MetSoc, MMIJ, GDMB, IIMCh, EPD of TMS
Chair(s): D. George, Rio Tinto;
A. Warczok, University Chile and Toronto
Room Territories—09:50

Paper #0810—09:50 (Keynote)
The Copper-Cobre series of conferences: two decades of active discussion of copper smelting technology practice and innovation
C. Díaz, Consultant,
P. Mackey, Xstrata Process Support

Since its inception, in 1987, the Copper-Cobre series of conferences has established itself as the prime world forum for discussing advances in copper process metallurgy, in particular copper sulfide smelting, copper recovery by leaching and electrowinning and copper electrorefining. All copper producing countries have actively participated in the pyrometallurgy symposia held in the framework of these conferences. In 1999 and 2003, the close to 100 pyrometallurgy papers that were presented had to be accommodated in two volumes. In the present paper, the authors firstly provide a brief historical sketch of the Copper-Cobre conferences and then focus on providing a retrospective look at the dramatic changes that have taken place in copper smelting in the last few decades, primarily as discussed in the Copper-Cobre and precursor

conferences pyrometallurgy proceedings. Topics include: the development of autogenous, increasingly more intensive, environmentally sound and energy efficient smelting processes; significant improvements in Peirce-Smith converting practice and at the same time the commercialization of alternative continuous converting routes; the consequent expansion and modernization of smelters; the increasing compliance with strict government environmental regulations in most copper producing regions of the world; the realignment of the copper smelting industry throughout the world; and trends in copper smelting R&D. A look at the future closes these reflections on the contribution of the Copper-Cobre conferences to the advancement of copper smelting technology.

Paper #0876—10:30 (Keynote)
SO2 abatement from copper smelting operations: a 40-year perspective
S.W. Marcuson, CVRD Inco

In the late 1960's concerns about the natural environment reached high levels within North America and provided activists with suitable platforms for exerting influence over the general public and politicians. In response a host of regulatory mechanisms were developed, statutes, voluntary measures, land grants, codes of practices etc. Emerging environmental awareness from the era provided impetus for rapid technological change that encompassed all industries, especially the base metal business. The resulting clean up impacted all aspects of copper production, dealing with issues such as waste disposal, water and air quality with specific impact on emissions of sulfur dioxide and particulate. This paper provides a perspective of these changes reviewing the macro-economic impact of environmental movement in mining with its specific implications to the copper smelting industry. The fundamental challenges that were faced by the old, but capital-intensive North American plants and the approaches taken to deal with the changing times are reviewed with special emphasis on the conceptual approach to smelter SO_2 abatement and different paths taken in the USA and Canada. The role of economics, sustainable R&D and presence of technical infrastructure that facilitated the change process is elucidated, and speculations are made about the future state of pyrometallurgy and the natural environment.

Paper #1112—11:05 (Keynote)
Process costs: from conventional accounting to ABC
C.A. Landolt, Consultant, O. Schnake, M. Isakson, Datacom Ltd.

The paper presents the conceptual basis for the development of an Activity Based Costing system (ABC) for the analysis and estimation of process costs in mining and metallurgy. In particular, it discusses three major thrusts towards attaining increased efficiency in extraction and processing systems: (a) understanding the link between process and expenses, (b) identifying the chemical and physical factors that govern process costs and (c) using process and cost models of the production systems. The authors have developed

computer techniques to analyze data from conventional accounting and apply them to the development of process based ABC systems. The cost causing activities are linked to management units patterned after the organizational structure of the production system. All costs are associated with specific process functions such as charge preparation, smelting, refining, etc. The level of detail is determined by the quality of data available in conventional accounting systems. The system permits data analysis of historical cases and the projection of costs for new production schemes. Results can be presented in various levels of aggregation, following organizational and/or functional structures. The outputs of the system are tabular and graphical, typically following Pareto analysis concepts.

Paper #1159—11:30
Continuos reactor, Altonorte smelter
R. Zapata N., Xstrata Copper

In the following report, Altonorte Smelter owned by Xstrata will explain its experience with its denominated furnace called "Continuous Altonorte Reactor" since started up in March 2002. The Reactor is the main and only smelting furnace since the operation of Reverb Furnace was stopped (15 days after the start up of the Reactor) and it can be operate with dry concentrate for injection by tuyere and wet concentrated via Garr Gun when the injection system fails. From the started up of the Reactor, three operational campaigns have been carried out where in each one they have been increased their smelting throughput and availability. The flexibility reached by the technology bath smelting has allowed a high level of smelting of concentrate and revert materials. The high availability of the Reactor and overcoming problems that were considered of high complexity like the extraction of white metal and slag, refractory campaign, etc. has allowed the Altonorte smelter to project to smelting 1,200,000 tonnes per year with its only Reactor in next year.

Cu2007: The Carlos Díaz Symposium on **Pyrometallurgy**
Session 8: Fundamental Metallurgy
Sponsors: Non-Ferrous Pyrometallurgy Section of MetSoc, MMIJ, GDMB, IIMCh, EPD of TMS
Chair(s): F. Kongoli, Flogen Technologies;
R. Degel, SMS Demag
Room Algonquin—09:50

Paper #0870—09:50
Liquidus temperatures in calcium ferrite slags equilibrated with molten copper at fixed oxygen partial pressures
S. Nikolic, P.C. Hayes, E. Jak, PYROSEARCH - Pyrometallurgical Research Centre

Calcium ferrite slags are currently used in a number of copper-converting

processes. Despite the industrial importance of this system the phase equilibria have not been fully investigated. Characterization of this slag system is necessary to improve the control of process parameters, including fluxing and operating temperatures. Recently, a modified experimental method has been developed; this involves rapid quenching of slag samples equilibrated at high temperatures with the resulting phase assemblages analysed using electron probe microanalysis (EPMA). In the present study, experiments were completed under controlled temperatures and oxygen partial pressures using CO/CO_2 or H_2/CO_2 gas mixtures. The investigated slags were supported during equilibration by a substrate of the primary phase. This technique removes the limitations arising from the use of crucibles and facilitates rapid quenching of the melt. Experiments were carried out at 1200°C and 1250°C (1473 K and 1523 K) and in the composition range 0-40 wt. % Cu_2O, 0-25 wt. % CaO and 45-80 wt. % Fe_2O_3. Liquidus and solidus data are reported for the primary phase field of spinel between the oxygen partial pressures of $10^{-4.5}$ to $10^{-6.5}$atm. The analyzed compositions of liquids and solids are used to construct the phase diagram of "Cu_2O"-CaO-"Fe_2O_3" system in equilibrium with metallic copper at fixed oxygen partial pressures.

Paper #1101—10:15

Experimental investigations of phase equilibria for copper smelting and converting silicate slags in the "Cu_2O"-FeO-Fe_2O_3-CaO-SiO_2 System at controlled oxygen partial pressures

E. Jak, S. Nikolic, B. Zhao, H.M. Henao, P.C. Hayes, PYROSEARCH - Pyrometallurgical Research Centre

There is renewed interest in the improvement of existing copper smelting processes and the development of new technologies. It has become clear that further accurate information on slag properties, in particular, on phase equilibria are required in order to optimize these processes. It is in this context that improved experimental research methodologies have been developed specifically to provide information on phase equilibria at the oxygen partial pressures encountered in copper smelting practice. The methodology involves synthetic slag equilibration at controlled gas atmospheres, quenching and measurement of compositions of phases with an electron probe X-ray microanalyser (EPMA) with wavelength dispersive detectors (WDD). Application of modern analytical tools and careful design of experiments greatly improve accuracy of determination of phase equilibria in complex, multi-phase slag systems. New experimental data on phase equilibria for the copper smelting and converting silicate slags at controlled oxygen partial pressures in the temperature range between 1200^{O}C and 1350^{O}C in the "FeO"-CaO-SiO_2 system and in the "Cu_2O"-"FeO"-CaO-SiO_2 system in equilibrium with metallic copper are reported, and differences between various data sources are analyzed.

Paper #0852—10:40

Phase relations and precious metals distribution in the Cu-Fe-S-As and Cu-Fe-S-Sb systems saturated with carbon at 1473 K

L. Voisin, K. Itagaki, Tohoku University

In the reductive smelting of the copper concentrate like a blast furnace operation using coke as fuel and reductant or in processing the copper concentrate which contains coal in the bulk, a sulfur-deficient matte phase often coexists with an iron base alloy in the bottom of the smelting furnace. This alloy is generally called furnace residue or speiss when considerable amount of arsenic or antimony is contained in the alloy and in the extreme case of reducing condition the alloy is saturated with carbon. As a fundamental study to know the behavior of some precious metals such as silver, gold and platinum between the sulfur-deficient matte and the furnace residue or the speiss which are in equilibrium under reducing condition, the phase relations and distribution of precious elements in the Cu-Fe-S-As and Cu-Fe-S-Sb systems saturated with carbon were determined at 1473 K by a quenching method.

Paper#1110—11:05

Study of the equilibrium between blister copper and oxide-silicate melts containing Cu_2, NiO, FeO(Fe_2O_3), SiO_2

L.B. Tsymbulov, N.A. Fedorova, Gipronickel Institute JS, NORILSK NICKEL RJS

The equilibrium of exchange reaction (Cu_2O)+[Ni]=(NiO)+2[Cu] taking place in the course of interaction of metallic nickel–containing copper melt with different oxide melts (Cu_2O–NiO, Cu_2O–NiO–SiO_2, Cu_2O–NiO–FeO(Fe_2O_3)) in the area of their homogeneity has been studied. By the results of the fulfilled studies, on the basis of the known value of equilibrium constant, copper and nickel activity indices in metallic melt and equilibrium concentrations of Cu, Ni, Cu_2O and NiO, the g_{NiO}/g_{Cu2O} ratios in the oxide melts of the above systems were defined. For the equilibrium between nickel–containing copper and binary oxide melt Cu_2O–NiO, values of g_{NiO} and g_{Cu2O} were determined by calculations and experimentally. Based of the obtained data considerations regarding oxide melts construction are presented.

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

Session 9: Plant Upgrading I

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

Chair(s): B. Imrie, Bechtel;
A. Luraschi, Cadeidepe

Room Quebec—09:50

Paper #0859—09:50

Opportunities, problems and survival strategies reflected in recent developments in the copper concentrate treatment and smelting practices

at Vedanta's Konkola Copper Mines in its smelting operations in the Zambian copperbelt
M. Syamujulu, Konkola Copper Mines Plc

Subsequent to the unbundling of the Zambia Consolidated Copper Mines (ZCCM) and the privatization of its constituent parts, the Konkola Copper Mines (KCM) represents a third of the original conglomerate. Now run by private hands as a sub group of Vedanta Resources Plc of India, KCM is strategizing on how best to deal with the operational issues of the organisation to resolve some of the difficult, logistical, environmental, mineralogical and metallurgical problems being encountered to turn them into opportunities as the company turns around. This paper reviews the options being put in place to provide appropriate solutions and strategies including the treatment of the highly siliceous low energy copper belt concentrates in its mining operations in Zambia.

Paper #0848—10:15
Improving flexibility: recent developments at the Horne smelter
P. Lind, Xstrata Copper Canada

The Horne smelter is a custom copper smelter located in Rouyn-Noranda, Quebec. In 2005, the smelter produced 145,000 t of copper containing 807,000 oz of gold, 20,388,000 oz of silver in addition to 515,000 t of sulphuric acid. Recently, a flexible flow sheet has been developed incorporating the intermittent use of the Noranda Continuous Converter allowing for the increasing or decreasing of production based on market conditions, while attaining 90% or greater sulphur fixation regardless of operating mode. For 2006, the smelter is operating in full production mode and production is expected to be approximately 185,000 tm of copper. Mechanical modifications, process changes, metallurgical concepts, minor element treatments, and operational techniques that have allowed the smelter to develop this flexibility are presented. Current efforts to increase the productivity of the converter aisle and anode furnaces as well as improvements being made to address fugitive emissions are also discussed.

Paper #0867—10:40
Operational strategy at Chagres smelter, maximize installed
R. Subiabre, R. Bonifaz, Chagres Smelter Division

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 review 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 studied various options for investment that will yield a suitably profitable business to benefit both Anglo American and Chile. The most relevant technical indicators are: energy consumption=6,3 GJ/ton fine copper (1st in the world), intensity of smelting rate in Flash Smelting unit of 6,900 ton of copper concentrate/m^2 of furnace area (1st in the world) and to be one of the top five smelters in achieving the lowest direct cash cost .

Paper #0885—11:05

Modernization and start-up of the SPCC Ilo smelter

W. Torres, L. Mariscal, Southern Peru Ilo Smelter

The Ilo Smelter has been continuously operating since 1960 with reverberatory furnaces and Pierce Smith converters producing blister copper. The original installed capacity of 1.134 tons per day of concentrated was expanded in 1976. A process of modernization started in 1995 and 1998 with the installation of an El Teniente Converter, a sulfuric acid plant and an oxygen plant to reduce the gaseous emissions to the atmosphere. With the official approval of the Environmental Compliance and Management Program (Programa de Adecuación y Manejo Ambiental – PAMA) in January 1997, Southern Peru Copper Corporation made a commitment to capture 91.7% of the SO_2 generated at the smelter by January 2007. After an evaluation of six different technologies, the ISASMELT process was selected because it can be easily adapted to the present operation, has a lower capital cost and it is a simple process. The fast learning curve to reach the total capacity will allow to fulfill the PAMA commitment in time. The project construction is in process and SPCC is prepared for a successful start-up and transition of the current operations at the end of year 2006. This paper outlines the factors considered by SPCC in its choice of ISASMELT technology and describes the construction and the start-up activities of the new facilities.

Paper #1069—11:30

Recent improvements at Tamano smelter

M. Furuta, S. Tanaka, M. Hamamoto, T. Sunamoto, S. Udo, Hibi Kyodo Smelting Co.

Tamano smelter & refinery has expanded its production from 228kt/y to 260kt/y since 2006. It was not a big jump, but efficient and economical improvements were executed. These were not only de-bottlenecking and modernization of the smelting plant, including the acid plant, but also additional processes were commissioned, e.g. slag cleaning furnace and steam dryer. On the other hand, a conversion to ISA process in the #2 tank house was the biggest impact on production efficiency for the refinery plant. In order to overcome the drastic change of copper business, although each scale is not so big, yet continuous improvements are very important to survive. This paper mainly describes the recent improvements of the smelting plant.

Cu2007: International Symposium on **Mineral Processing**
Session 10: Flotation Fundamentals
Sponsors: Canadian Mineral Processing Society of CIM, Mineral Science and Engineering Section of Metsoc, MMIJ, GDMB, IIMCh
Chair(s): R. del Villar, Université Laval
Room Tudor 8—09:50

Paper #0710—09:50
Carrier-microencapsulation for suppressing floatability and oxidation of pyrite in copper mineral processing
J. Satur, N. Hiroyoshi, M. Ito, M. Tsunekawa, Hokkaido University

In copper mineral processing, pyrite coexisting with copper sulfide minerals like chalcopyrite is separated by flotation as tailings and its oxidation in tailing dams causes the formation of acid mine drainage. This paper proposes carrier-microencapsulation (CME) as a new method for suppressing pyrite flotability, as well as its oxidation. In this method, an organic carrier combined with Ti is used to form a thin TiO_2 layer on pyrite, which gives a hydrophilic property and acts as a protective coating against oxidation. To form the coating, a ground pyrite sample was treated with Ti-catechol complex solution under various conditions. Bubble pick-up experiments and flotation experiments showed that the treatment of pyrite with Ti-catechol complex changed the hydrophobic nature of pyrite into hydrophilic even in the presence of xanthate as a flotation collector. Oxidation testing of the CME-treated pyrite by 0.02 kmol m^{-3} HNO_3 showed that Fe release was suppressed by the CME treatment with respect to the control. This is assumed to be due to the formation of TiO_2 coating on the pyrite surface. The effect of CME treatment on chalcopyrite wettability is also discussed.

Paper #0712—10:15
Removal of arsenic content from copper concentrates by electrochemical flotation
H. Guo, Wardrop Engineering,
W.T. Yen, Queen's University

Arsenic bearing minerals such as enargite (Cu_3AsS_4) and tennantite ($Cu_{12}As_4S_{13}$), which may associate with major copper minerals such as chalcopyrite ($CuFeS_2$), chalcocite (Cu_2S) and bornite (Cu_2FeS_4), usually report to the copper concentrate in conventional flotation due to their similar flotation properties. Arsenic in a copper concentrate causes environmental problems and also problems in the subsequent pyrometallurgical process. Voltammetric studies were carried out to investigate the oxidation characteristics of enargite, tennantite, chalcopyrite, chalcocite and bornite. Contact angle measurements and micro-flotation tests were conducted to examine the flotation characteristics of enargite and chalcopyrite under controlled pulp potentials. Selective flotation of enargite from chalcopyrite under varied pulp potentials was conducted to

investigate the feasibility of arsenic removal from a copper concentrate. The test results indicate that the non-arsenic bearing copper minerals (chalcopyrite, chalcocite and bornite) were easier to oxidise than arsenic bearing minerals (enargite and tennantite) in an alkaline solution. Enargite floated well at a potential as high as +0.45 V vs. SCE while chalcopyrite was completely depressed at a potential higher than +0.43 V vs. SCE. Selective flotation revealed that enargite can be successfully removed from chalcopyrite through controlling the pulp potential at +0.30 ~ +0.50 V vs. SCE.

Paper #0713—10:40

Reduction of fine gangue entrainment in flotation of a copper ore

M. Ourriban, G. Bartolacci, Y. Peng, COREM,
P. Pelletier, Iamgold,
J. Girard, Inmet-Troilus,
H. Jang, Q. Liu, University of Alberta

In the flotation of a copper ore, entrainment of fine silicate and iron sulfide gangue minerals resulted in poor copper concentrate grade. In the cleaning stage, rejection of these gangue minerals was particularly difficult due to severe mechanical entrainment when the rougher concentrate was ground to 10 µm. To reduce gangue entrainment, polymeric depressants were tested. The rationale being that with the use of such polymeric depressants that also possess flocculation power, not only minerals-to-be-depressed can be made hydrophilic, but their particle size can also be enlarged. In this manner both the “genuine” flotation and the mechanical entrainment can be reduced. An effective polymer to reduce entrainment of silicate gangue mineral in sulfide flotation was identified from bench flotation tests conducted on single minerals. It was then applied to the flotation of a copper-gold ore confirming the beneficial role of the polymeric depressant in the reduction of fine gangue entrainment.

Paper #1190—11:05

Impact of stockpiling conditions on flotation kinetics and size by size recovery of chalcopyrite

B. Nanthakumar, S. Kelebek, Queen’s University

The impact of stockpile oxidation on chalcopyrite was studied through collectorless and collector-induced flotation conditions. In both cases, the Cu grade–recovery performance of stockpiled ore showed relatively poor concentrate grades with respect to that of a fresh sample. However, the oxidation had a minor effect on chalcopyrite recovery itself. The poor concentrate grades resulted from dilution effect primarily by excessive flotation of pyrrhotite. Size-by-size analyses indicated that for the collectorless flotation, the recoveries in the coarse and fine particle-size regions, were higher for fresh ore than for stockpile sample. A greater impact was seen in the coarse size regions for both types of sample, compared to the collector-induced case. The Cu recoveries showed a remarkable increase in the coarse size range for both samples when a collector

was used. However, the case for stockpile sample was a marginally higher compared to the fresh sample. This difference has been offset by an opposite trend that was observed between these two samples in the fine size region. It is concluded that in contrast to the case with nickel-bearing sulphides, stockpiling conditions do not show a significant adverse effect on behaviour of chalcopyrite due to its strong floatability, regardless of oxidation.

Cu2007: International Symposium on **Sustainable Development, HS&E, and Recycling,** Incorporating the 6th Waste Processing and Recycling Symposium
Session 11: General Overview
Sponsors: The Environmental Society of CIM, the Environment Section of Metsoc, MMIJ, GDMB, IIMCh
Chair(s): D.D. Rodier, Hatch
Room Confederation 3—09:50

Paper #0897—09:50
Towards sustainable mining – improving industry performance by aligning our actions with the priorities and values of Canadians.
G. Peeling, P. Gratton, The Mining Association of Canada

The Mining Association of Canada launched the Towards Sustainable Mining initiative in 2004. TSM's goal is to improve the mining industry's performance by aligning its actions with the priorities and values of Canadians. The initiative currently includes performance indicators for four areas: tailings management, energy use and greenhouse gas management, external outreach and corporate crisis management planning. Over the past year, the association has been designing a performance assessment and verification system for these performance areas, as its members prepare to move external verification of their performance in 2007. The initiative and its evolution, as well as the challenges faced in developing a verification system applicable to an entire sector will be examined.

Paper #0927—10:15
Engineering SD into industry; unlocking institutional barriers
J. Medveçka, University of Queensland,
P.J. Bangerter, Hatch

Sustainable development has become a driving imperative for the resource industry as it is for the rest of the global business world. Being unsustainable is a risk no business can afford. Yet implementation of sustainable development practices beyond satisfaction of compulsory reporting is still sporadic. The current standard approaches to problem analysis and decision making are too narrow to capture the complexity of the issues at stake. Hence it is necessary to develop innovation in thinking and in doing. Those who search for ways to implement sustainable development use concepts such as Whole Systems Thinking and Eco-efficiency as well as tools like Life Cycle Analysis. Others

develop their own instruments. In their effort to innovate they face both resistance and support within their organisation as well as within the industry or the wider context. This paper explores the factors that support, hinder and shape the sustainable development drive of the industry and proposes a comprehensive decision-making framework that links the goal of sustainability with the tools of sustainable development. This exploration is illustrated by a case study used in a doctoral research conducted on an engineering firm providing services to our industry.

Paper #0898—10:40

A view in sustainable development of non-ferrous metals production

T. Kagawa, N. Masuda, Japan Oil, Gas and Metals National Corporation,
A. Fuwa, Waseda University

Ever-increasing demands for non-ferrous metals owing to population growth and improvements in the standard of living in the world, under the constraint of limited availability of natural resources, would easily make us imagine that more efficient and sustainable developments in mining and smelting activities are required in the near future with due consideration for environmental concerns. In order to realize the efficient and sustainable development of mining and smelting activities and operations, the following issues are indispensable: (1) to investigate the up-to-date pollution control technologies of mine and smelter, (2) to promote those technologies, (3) to develop technologies which are environmentally friendly. This paper discusses the recent technologies for environmental conservation/prevention and their diffusion in the world, and also the key technologies required for the most desirable sustainable development.

Paper #0934—11:05

Sustainable development and self-organization

F. Flores, Instituto de Ingenieros de Minas de Chile

With the World Summit for Sustainable Development planned for 2002 in mind, nine of the world's largest mining companies decided to initiate a project to examine the role of the minerals sector in contributing to sustainable development, and how that contribution could be increased – the Mining, Minerals and Sustainable Development Project (MMSD). This project assumed from the start that sustainable development could provide a useful framework to guide the minerals sector which main goal was integrating economic activity with environmental integrity, social concerns, and effective governance systems. The broad steps of MMSD project strategy can be grouped into four major categories: increase understanding of sustainable development; create organizational-level policies and management systems for implementing the principles of sustainable development; collaborate with others with common interests to take joint steps towards sustainable development, and; increase our ability to work towards sustainable development at the local, national, and global levels. In opinion of the article's author, to go ahead with the MMSD strategy and achieving the

sustainable development objectives, it is necessary to consider the concept of self-organization, fundamental of the emergent new scientific paradigm, and the consequent epistemology and values that conform a supporting culture for sustainable development.

Paper #0902—11:30

Regulatory tendencies and abatement technologies used in the Chilean copper industry

M. Sánchez, Universidad de Concepción,
A. Valenzuela, AL Prospecta Consulting

In the last decades, the Chilean copper mining and metallurgical industry have had to modify their technological processes to meet the environmental regulations implemented by the Chilean government, and also to support the pressure of the public opinion. Thus, air quality standards for sulfur dioxide and particulate matter (primary and secondary), plans for reducing emission of arsenic by the Chilean copper smelters, effluents discharge limits, among others regulations were applied by the environmental agency. Additionally, agreements on cleaner production were carried out by mining sector and government. Now, a draft law on mine closure, and another on environmental mining wastes (abandoned mines) are being discussed by the authorities and the mining sector. In the context, production and environmental impacts in different ways to produce copper in the Chilean mining industry are reviewed and regulatory tendencies as well as abatement technologies today used are exposed and discussed in this presentation. Pyro, hydro and electrometallurgical processes employed and their current effluent and contaminants are presented showing various alternatives of treatment in the copper industry. An update of regulations established in Chile vis a vis copper production, with an especial attention to mine closure are also presented.

Cu2007: International Symposium on **Downstream Fabrication and Applications**

Session 12: History and Overviews

Sponsors: SME, Metsoc, MMIJ, GDMB
Chair(s): J. Hugens, North American Manufacturing Company, Ltd.
Room Tudor 7—10:15

Paper #1050—10:15

An overview of the international copper association's pre-competitive R&D portfolio of copper-related technologies

H. Stillman, International Copper Association

The International Copper Association, Ltd. (ICA) is responsible for guiding strategy and policy, and funding international initiatives that help deliver the benefits of copper around the world. ICA's technology initiative supports this mission by funding pre-competitive technology development and accelerating the

commercialization of new copper-related technologies. The R&D portfolio includes some projects that defend existing applications such as plumbing tube and data cabling, but the majority of projects are designed to enable new applications for copper. The current technology portfolio is focused on leveraging copper's unique electrical, thermal, mechanical and antimicrobial properties to define and expand the role of copper in areas poised for future technological growth: reducing disease transmission, sustainable energy generation, reducing the environmental impact of production processes, and in increasing energy efficiency. Projects related to these areas are conducted at qualified external organizations including universities, early-stage firms, and large OEMs worldwide. This talk will provide an overview of ICA's technology initiative's principles, projects and partnerships to stimulate the audience to think about copper-related innovations.

Paper #1036—10:40

The antimicrobial properties of copper alloys and their potential applications

H.T. Michels, Copper Development Association Inc.

Recent laboratory studies show that several bacteria, known to be human pathogens, die when they come in contact with copper and copper alloy surfaces. The amount of live bacteria drops by several orders of magnitude, to zero, on copper alloys in a few hours. In contrast, no reduction is seen in the concentration of live organisms on stainless steel during the six-hour test period. Aluminum painted and coated surfaces and plastics would show behavior similar to stainless steel and show no effect. Coatings and other surfaces claiming to be antimicrobial showed little to no effect. These results suggest the selection of copper alloys for surfaces exposed to human touch can materially assist in reducing the transmission of infectious organisms. In order to make antimicrobial claims in the United States, the approval of the US Environmental Protection Agency (EPA) is required. The EPA-required efficacy testing is described and the test results are summarized. It is anticipated, that once regulatory approval is obtained, that this will facilitate the introduction of antimicrobial copper alloys in hospitals, nursing homes and other healthcare facilities, as well as schools, and public buildings. Some of the application and barriers, to entry into the healthcare markets are mentioned.

Paper #1032—11:05

A history of copper and wire drawing: the past 11,000 years and beyond

H. Pops, Horace Pops Consulting

This paper summarizes important developments that have occurred in the mining and subsequent production of copper into rod and wire from 9000 B.C. until the present time. Principles and practices associated with continuous rod production are discussed from a metallurgical perspective, and include the effects of oxygen content and impurities. A brief historical review is also given of important wire

drawing events dating back thousands of years. Finally, predictions concerning the future of the wire and cable industry are presented with particular emphasis upon copper wire, technology in this market, and competitive materials.

Paper #1043—11:30

Innovations in the field of non-ferrous metal processing

M. Schwarze, SMS Meer GmbH

SMS Meer GmbH with its COPPER PLANTS DIVISION produces a full line of systems and machines for the processing of copper. The product range includes: shaft melting furnaces, anode casting lines, horizontal and vertical casting lines, casting and rolling lines for copper wire rod and strip, cold pilger mills, planetary rolling mills as well as tube drawing equipment. The new designed shaft furnaces are the most economic way of copper melting. The CONTILANOD® system with hydraulic shear represents a breakthrough into higher production capacities and improved geometrical accuracy of anodes. The new generation of CONTIROD® lines with individual drives of rolling stands guarantee cost effective production of highest rod quality. A new horizontal continuous casting technology for the production of tube shells as feed stock for the copper tube manufacturing process – directube® was developed and introduced into production. A first line for continuous vertical strip casting - called VERTICAST® - for higher production rates and improval quality of cold-rollable strips is in the final stage of commissioning. These innovative technologies increase product quality, reduce process costs and help for a wide use of copper in all sectors of life.