Electrometallurgy

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New stainless-steel solutions as permanent cathode plate materials for tank houses.

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Abstract

Austenitic stainless steel EN 1.4404 / ASTM 316L has been utilized for decades as permanent cathode plate in the last stages of pure copper production. Outokumpu Stainless has long experience in supplying cathode specific steel for this use. The development of new cathode plate materials has been initiated due to demand of longer service life and increased cost efficiency in the tank houses.
Austenitic acid proof stainless steel EN 1.4420 / UNS S31655 / 316plus is lean with volatile and expensive nickel and molybdenum making it more cost-efficient austenitic variant. The cathode specific 316plus has similar technical performance as typical 316L with increased strength and hardness ensuring flatness in the service together with enhanced wear resistance.

Austenitic-Ferritic Duplex stainless steel cathode plates provide considerably higher corrosion resistance and strength over austenitic grades. This steel family is by nature relatively lean with nickel which ensures cost stability. The corrosion resistance of cathode specific duplex stainless steel is considerably improved and thereby it is the material for tank houses suffering for corrosion with 316L.

About Of The "Plates Sticking" Problem In A Copper Electrowinning Process

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Abstract

In a Cu EW process that uses AISI 316L permanent cathodes, one of the most frequent and complex operational problems to solve is the so-called "plate sticking". The sticking of plates occurs when the "stripping machine" fails to detach the electrowon copper from the plate despite repeated mechanical attempts to do so. It is common to ascribe the responsibility to the chloride concentration in the electrolyte as the most important variable of the copper sticking, caused by pitting corrosion of the stainless-steel motherboards exposed in a strong sulfuric acid media and chloride anions concentration higher than 30 ppm in the aqueous solution. The aim of this paper is to analyze the solution of this problem based on an adequate control of the amount of organic additive that is added to the electrolyte to regulate the copper crystalline growth. This parameter must be a function not only of the imposed current, but also of other variables that are controlled daily in the Cu EW plants, mainly the chloride concentration, the spent electrolyte discard and the temperature of the aqueous solution.

Towards the intensified use of electronic waste for sustainable copper Electrometallurgy

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Abstract

Copper is a cornerstone metal in today's society and will play a key role in the technological transition towards a low-carbon future. Today, global copper production is mainly derived from primary ores. The switch from a linear to a circular economy necessitates recycling of secondary copper products. The copper industry can combine secondary copper materials into their smelter to increase the recycling rate, but processing challenges arise as their share increases. Electronic waste is the largest source of low-grade secondary copper considered for recycling, but its composition is complex and much more variable with respect to primary ores. Several impurity elements originating from electronic waste (such as arsenic, antimony and bismuth) follow copper in the flowsheet and dissolve in the electrolyte. In this paper, we discuss challenges that arise in the electrometallurgical production of copper from impurity containing electrolytes. Novel insights in copper contamination mechanisms are discussed together with possible solutions.

Copper Electrowinning: 2022 Global Survey of Tankhouse Operating Practice and Performance.

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Abstract

Global practice in copper electrowinning is reviewed, based on individual plant operating data for 2021. Similar surveys were carried out in 1997, 1999, 2003, 2007, 2013, and 2019. Historical and current data are compared. Evolving trends in operating conditions and performance, as well as equipment design and process technology choices, are analysed and differences in operating practices with location are assessed. Examples of recent technology and operating preferences to increase productivity, improve copper quality, and decrease electrical energy consumption are discussed. Spare electrowinning capacity and plant conversions are also considered.

Reducing the copper recycling in the smelter-refinery complex by an alternative scrap processing.

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Abstract

Electrorefining of copper produces most of the high-grade copper around the world; however, this process recycles to the smelter, as scrap, up to around 20 wt.% of the anodic mass fed to the refinery. This recycling of anodic scrap represents an important issue from the logistic and economic points of view, where several attempts to reduce it has been made. Since 2015 Codelco and Universidad Técnica Federico Santa María had been working together in the development of a new technology to avoid the recycling of copper to the smelter.

The production of a high purity acidic electrolyte with controlled content of copper and acid, amenable for electro-winning or electro-refining plants, was studied, at laboratory scale, by dissolving industrial scrap in batch and continuous reactive electrodialysis cells.

Some metallurgical results were electrolytes having around 180 g/L of H_2SO_4, 40 g/L of Cu and less than 50 mg/L of As (Sb and Bi were not detected) with a faradic efficiency of dissolution over 100%. The anodic sludge was easily recovered from the bottom of the cell. Furthermore, the cathodic reaction is producing hydrogen gas, which is a valuable sub-product.

Cathodic Copper characterization influenced by Thiourea and investigation of effects of impurities on the surface nodules (in NICICO-Sarcheshmeh)

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Abstract

In this study, characterization surface structure and impurities elements of cathodic copper of NICICO-Sarcheshmeh refinery section, influenced by thiourea was carried out. To investigate the effect of Iranian-Thiourea (IR-Thio), modified Iranian-Thiourea (MIR-Thio) and Thiourea which is produced in another country (F-Thio) on the cathodic copper microstructure and impurities roles on nodule formation on its surface, SEM, EDS, optical microscope, and stereograph microscope was used. According to the results, by using the IR-Thio in the electrolyte, the rate of nucleation is higher than growth on the cathode surface and structure is inappropriate. However, the fine grain problem in cathodic structure is solved by using MIR-Thio, trapped particles are observed due to low solvability and overuse of this kind of Thiourea. Elements with anodes mud source have an important role in nodule nucleation. Although barium sulfate with the source of casting mold hasn't any effect on the kinetic and epitaxial copper grains, presence of them is observed in the traps.

Analysis of copper dissolution in acidic chloride electrolytes containing certain copper ions by cyclic voltammetry.

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Abstract

Voltammetry was used successfully to determine the dissolution processes of a copper rotating disk electrode immersed in an electrolyte containing copper and chloride ions. During the contact of copper and certain solutions, different cathodic and anodic reactions occur. Voltammetric techniques, especially cyclic voltammetry, represents an appropriate method to identify chemical incidents at the metal surface and to detect reversible and irreversible processes. The contact of copper and synthetically prepared solutions based on various concentrations of Cl^-, Cu^+, Cu^{2+} provided more details from the metal-electrolyte-system. Characteristic current peaks associated to certain potentials were extracted from the obtained voltammograms and assigned to specific anodic and cathodic reactions. Those included the formation of soluble and non-soluble copper chloride complexes and the reduction to metallic copper. With the generated knowledge about the behavior and the formation of different species, it is possible to influence the dissolution process of copper via defined parameter constellations of concentration, temperature and flow conditions.

De Nora DSA® Self protected Anode Solution

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Abstract

Lead alloy anodes have been the widespread reference in copper electrowinning; as an alternative, Mixed Metal Oxide anodes (Titanium substrate plus coating for Oxygen evolution) show excellent performance in terms of power consumption and guarantee removal of lead sludges and cobalt addition while giving the possibility to increase plant productivity due to their stability at Higher Current Densities. On the other hand, MMO anodes are less robust in case of short circuit and can be prone to localized corrosion in point of contact of a dendrite, with impact on maintenance and thus on time-on-line.

In this frame, De Nora has developed a solution (De Nora DSA® Self Protective Anode) able to withstand short circuit conditions with no damage to the anode by limiting the current flow on the short circuit, while maintaining all benefit of usage of MMO anode (capability of operation at higher CD, lower power consumption and at least same life as Lead alloy anodes). This paper will show technical concept, industrial setup and operational results of De Nora DSA® Self Protective Anode solution.

Failure analysis of copper wire failed during the wire production process (NICICO-Sarcheshmeh)

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Abstract

In present study failure analysis of copper wire failed during the wire production process which is produced by NICICO-Sarcheshmeh was investigated. To characterize the parameters which impact on the wire rupture, fractography analysis in Marco and Micro size was carried out. For microstructure observation and analysis SEM and EDS analysis were used. Results indicated that various factors have an important role in the failure of wires during production operations. The listed factors are classified into the two main groups of operations and materials. Non-symmetric and necking on the surface, distortion of dimples, poor ductile fracture characterization and presence of local destruction in absence of micro-inclusion are some important outcomes which are observed in fractography analysis of wires.

To eliminate the emissions of electrolyte heating in the electrowinning process with the lowest possible investment, solar heat cannot stand alone.

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Abstract

If you want to reduce the greenhouse gas emissions of the electrowinning process (EW) in copper mines, applying solar heat for the heating of the electrolyte is a good and economical approach, but it should not stand alone. A much better profitability can be achieved, if the solar heat integration is combined with an energy efficiency overhaul of the existing EW process with the profiles of the available renewable energy technologies in mind.
According to available findings, a very low number of only three solar thermal plants of more than 1,000 m^2 of solar collector area has been installed for EW processes of copper mines in the world. These sites include; Gaby (Codelco), Centinela (AMSA) in Chile, and Milpillas (Peñoles) in Mexico.

The author has during the past five years gained significant practical experience with the integration of solar heat in the EW process. In this study, he will undertake a multi-step approach. First, complete an energy mapping of a typical EW process. Second, suggest energy efficiency improvements combined with a method to integrate solar heat in the EW process. This approach is expected to eliminate greenhouse gas emissions and reduce the cost of heat by half compared to the present cost level of process heat generated by fossil fuel boilers.

Machine Learning in Copper Electrorefining: opportunities and limitations of its application in process control.

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Abstract

Copper electrorefining is a rather complex process involving multiple operational variables that affect its performance. Even though modern tankhouses have incorporated mechanization and automation in material handling systems, process control is still modest. The vast availability of sensing equipment enables using a data-driven approach for generating an automatic control strategy capable of improving the performance of the electrorefining process. In this context, machine learning techniques gain relevance.

This article analyses the opportunities and limitations of the use of machine learning in electrorefining for process control purposes. As a concrete example, a recent study developed in a major electrorefining tank house is described, where machine learning techniques were used on real industrial data for developing operational data-driven models capable of predicting production quality and process variables. The models were then used for generating a real-time Decision Support module, which is the first step towards developing a modern automatic control strategy for electrorefining.

Modelling of an Electrolyte Purification Route for Optimal Removal of Bismuth from Copper Electrorefining Electrolytes: SuperLig® Molecular Recognition Technology (MRT) Compared Against Conventional Methods

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Abstract

Impurity control is a primary concern during copper electrorefining. Maintaining acceptable levels of impurities in Cu electrolyte presents a challenge. One of the most critical impurities is Bi due to the possibility of plating in the Cu cathode and adversely affecting the quality of the resulting product. Management of the removal of Bi is vital during Cu electrorefining. Several methods for electrolyte purification regarding Bi removal exist, exhibiting different levels of success in the industry.

This paper simulates the behavior of a Bi removal plant based on SuperLig® Molecular Recognition Technology (MRT). SuperLig® MRT is compared against conventional methods, including ion exchange, liberator cells and their combination.

The simulation creates a model that can predict the most effective route to remove Bi depending on different operating conditions such as current density and impurity concentration.

Optimising MISTOP® acid mist suppressant at liberator cells in a copper electrorefining plant

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Abstract

An alternative acid mist suppressant was trialed at a copper electrorefining plant's primary liberator cell. These cells have no physical mist barriers or extraction system and are part of commercial tankhouse sections. The incumbent acid mist suppressant chemical used was FC-1100, a fluorochemical additive. Used at Copper Refineries Limited since 2011, FC-1100 had to be discontinued by the supplier to phase out PFAS bearing products.
The alternative chemical was Mistop®, a natural acid mist suppressant that is a non-flammable, non-toxic, non-ionic liquid surfactant, made from a refined plant extract. It has been used widely in electrowinning plants alongside physical mist barriers such as balls however there is no report about its use in liberators.

Mistop® was diluted with water and dosed into the primary liberator cells feed lines. There was concern about potential interaction between Mistop and the anode slimes however there was no effect on slimes behaviour.

At 2ppm Mistop concentration in electrolyte, acid mist level was kept at <3.1mg/m3, measured by gas detector tube at the cell outlet, compared to <4.0mg/m^3 in the cells using FC-1100. Stationary testing carried out adjacent to the liberator cells found that the sulphuric acid emitted was <1 mg/m^3 for an 8-hour TWA (time weight average). At higher concentrations, Mistop caused foaming at the liberator cells but not at the storage tanks. This was likely because Mistop degrades in the electrolyte over time.

Expansion of Tankhouse at Boliden Harjavalta Copper Refinery in Pori.

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Abstract

Boliden Harjavalta has produced copper cathodes since 1941 at copper refinery in Pori. The essential idea has always been continuous development of process efficiency, environmental friendliness and effective investment execution. The most recent investment has been increasing the production capacity up to 173 000 tpy of cathode copper year 2020. This paper describes the refinery expansion project and summaries the recent process efficiency developments at refinery process.

Recent improvements in electrolyte impurities management at Atlantic Copper Refinery.

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Abstract

The Atlantic Copper Refinery (Huelva, Spain) has operated the ISA permanent cathode technology since 1995. Since then, through several expansions and technical modifications the cathode production has increased up to 290,000 tpy. The management of Group 15 elements (As, Sb and Bi) has been of great importance in order to achieve these production figures. In 2019 a new IX plant to remove Sb and Bi from copper electrolyte was commissioned enabling the treatment of anodes containing a higher amount of these elements. This paper describes the integration of this new IX plant in the daily operation of the tankhouse, as well as other operational improvements, that have allowed the copper refinery to maintain these impurities within an optimum operation region, in order to avoid cathode nodulation phenomena, while assuring cathode quality and the current efficiency of the plant

Research on intelligent monitoring method of electrolytic process based on machine vision and virtual reality

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Abstract

Aiming at the intelligent requirements of short-circuit detection and workshop management in the electrolytic workshop of copper smelting industry, this paper studies the short-circuit detection method based on machine vision, carries out regional on-line detection through the PTZ driven infrared double vision detection equipment, and quickly identifies the number and location of short-circuit plates combined with image segmentation and recognition, so as to realize the on-line and intelligent short-circuit detection. At the same time, it studies the process and mechanism of workshop production management, constructs a multi-source heterogeneous data platform for real-time database and relational database, and solves the interconnection of different data sources in the workshop; Based on VR technology, the 3D digital visualization and virtual simulation of workshop panorama are realized, and the digital twin system of electrolytic workshop is constructed with real-time data. Finally, the system is organically integrated into the intelligent information comprehensive management platform of electrolytic workshop, which plays a practical effect in the construction of intelligent electrolytic workshop.

Application Practice of Dual-Directional Parallel Flow Electrolysis Technology.

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Abstract

The dual-directional parallel flow electrolysis is an electrolysis technology of high current density independently developed by NERIN, which can significantly increase the capacity per unit area of tank house, reduce the number of electrolytic cells and plant investment. The cathode and anode cycle is short and backlogging of cathode and anode plates in the cells can be effectively reduced and the working capital consumption of the plant can be reduced as well as the financial cost. Because of its special electrolyte flow field, the deposition of anode slime is accelerated, and the silver content in cathode copper is reduced so that the recovery rate of silver can be increased. Since 2018 this technology has been used in two large copper smelter complexes in China, and is currently running stably at current density of 375 A/m^2 with excellent technical and economic indicators. In this paper, the working principle, engineering application and existing problems of this technology are introduced. At the same time, the differences of process parameters and technical indexes between the plants using this technology and the traditional PC process are compared in details.

Key Words: Dual-Directional Parallel Flow Electrolysis, High Current Density, Silver Content in Cathode Copper, Working Capital

Effect of mass transport limitations on the permissible current density in copper electrodeposition

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Abstract

The ability to plate smooth, compact copper electrodeposits depends strongly on mass transport limitations. The rotating cylinder Hull cell (RCHC) was used to plate deposits over a range of copper concentrations (30 – 50 g/L Cu(II)) and temperatures (30 – 50 °C), and current densities. Deposits without surface nodulation formed at current densities below 30% of the limiting current density in the absence of smoothing agents. Surface roughness increases rapidly above 40% of the limiting current density, which correlates with the appearance of nodules. Using this data, the maximum permissible operating current density was calculated as a function of copper concentration and temperatures. The permissible current density can be raised by a factor of three in a simulated air sparging cell. Current pulsing was found to decrease the size of nodulation in some cases, but not eliminate it, so the permissible current density was not affected by the wave form examined.

The detachment and flow behavior of anode slimes in copper electrorefining with high nickel electrolyte.

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Abstract

Nickel is the most abundant impurity in copper electrorefining. It has been previously suggested that nickel affects the porosity of the anode slime layer on the copper anode. This paper introduces a method for following anode slime particles in laboratory scale electrorefining using a Raspberry Pi camera and TrackPy Python package and discusses the initial findings on the effect of Ni on the slime detachment and flow behavior. Three different detachment mechanisms were identified, cluster detachment, cloud formation and individual particle detachment. The existence of floating slimes is well known, but the current study noted that normal slimes do not seem to directly follow the natural convection and settle straight to the bottom of the cell either. Detachment mechanism seems to be a major contributor in the flow behavior of anode slimes in the electrorefining cell.

Electrorefining of Anodes with high By-Metals.

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Abstract

In secondary copper production, but also to an increasing extent in primary copper, the processing of valuable metals other than copper is crucial. The target of the pyrometallurgical steps is the enrichment of these metals in the anode with the subsequent electrorefining aimed at not only purifying of the copper but also acting as a separation step for various other elements. This concept is not entirely new as in principle all refineries have limits for valuable by-metals (or impurities) in the anodes for maintaining quality of cathodes and efficiency of the process.

Trends in the in the supply of recycling materials indicate a need to recycle new materials with valuable materials which has lead to rising contents of elements in the anodes casted for the electrometallurgical refining of copper. To increase further the throughput of valuable metals at the Aurubis plant in Lünen, in 2015 the casting and refining of highly alloyed anodes was introduced. These anodes, representing 10 % of the entire anode production and containing between 5 and 7 % by-metals, are treated in a separate electrolyte circuit in the tankhouse.

Parameters of this electrolyte circuit is different to that of those of circuits with normal anodes. Quality and physical appearance of the produced cathodes are close to the requirements of cathode norms, however, silver contents of around 30 ppm still exceed these specifications. The paper aims to present changes and resulting outcomes.

Tertiary Current Distribution Analysis for Simulation of Nodule Growth in Copper Electrorefining

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Abstract

In the current copper electrorefining, the current efficiency is generally 93-98%. The loss is mainly caused by nodulation that occurs on the cathode to make short circuits. The growth mechanism of nodules after their outbreaks has not well been clarified, whereas it has been reported that the outbreaks may originate from some suspended particles which adhered to the cathode. In this study, to discuss the nodule growth mechanism, we performed numerical simulations of the tertiary current distributions, in which governing equations of mass transfer, electrode kinetics, and fluid dynamics were solved simultaneously. We focused on the contribution of the natural convection, caused by concentration differences in the electrolyte, to nodule growth. The results showed that the convective flow path and the diffusion layer thickness near the nodule were significantly influenced by the nodule length. It was suggested that the supply of Cu^{2+} ions to the nodule tip increases as the nodule grows to a length of 4 mm or more. That is, the nodule growth accelerates when the nodule tip is far above the natural convection layer.

Redesign of anode lugs at AURUBIS

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Abstract

Copper recycling is undeniably a global added value for saving costs, energy and greenhouse gases. Nevertheless, good process design can achieve further savings. In copper refining the anode scrap is returned to the smelter and molten again. A reduction of the anode scrap is therefore always beneficial for energy, CO2 and costs reduction.
The weight of the spent anodes beneath of the electrolyte surface depends on the efficiency of the process, the copper above the surface cannot be influenced during refining. The anode lugs and the bridge between the lugs have often be reshaped in the past, however the inner part of anode lugs has not been taken into consideration.

At Aurubis Lünen a new anode mould has been designed to cast anodes with notches in the lugs. In the first design the notches are still covered with copper, later moulds left the notches uncovered.

In the last two years brought investigations were carried out on casting behavior but also on the anode preparation in the tank house. The weight reduction of the casted anodes varies between 3 and 6 kg per anode depending on the notch design. For safety reasons it must be considered that only zero failure rate for lug tear down is acceptable.

Finally, the decision has been taken to equip in the first step one of the two casting wheels in Lünen completely with the new designed moulds.

Molten sulfide electrolysis for liquid copper production from chalcopyrite

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Abstract

Smelting is the only commercially viable route to process chalcopyrite, but alternate routes are investigated as ore bodies become more complex. Here, we propose processing chalcopyrite in an oxygen-free, sulfide regime. Using a molten sulfide electrolyte, liquid iron and liquid copper may be extracted in sequential steps while generating gaseous sulfur. Electrolysis experiments were scaled up to a 100A reactor capable of processing >1kg of material. Learnings from this scale-up process as well as a new process flow for a 100tpa plant will be presented. Overall, this route shows promise to supply the increasing demand for copper and byproduct metals with greater economic viability, fewer process steps and no noxious gases or oxidized by-products.

Development and Application of Intelligent Detection And Regulation Technology For Copper Starting Sheet Cathode Processing

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Abstract

The cathode electrolysis process of starting sheet is one of the two mainstream processes of copper electrorefining. Due to uneven thickness of the starting sheet, the verticality of the starting sheet is poor, resulting in high short circuit ratio of electrode plate and high production cost. This is also one of the main factors restricting the development of the process.

This paper introduces the intelligent detection and adjustment technology for the processing of copper starting sheet. Through the on-line real-time detection of the weight and thickness of each starting sheet, and through the analysis of intelligent mathematical model, the straightening machine system of starting sheet is adjusted in real time, so as to carry out differentiated adaptive processing for each starting sheet.

The technology has been applied in one 200kt/a copper tank house. The acceptability of verticality and thickness adaptation range of starting plate have been improved significantly, and the rate of defective straightening waste plate and short circuit rate of electrode plate have been reduced greatly. It has played a positive role in reducing the electrical efficiency index of electrolytic production and the number of operators around the cells.

Key Words: Copper Starting Sheet, Intelligent Detection and Adjustment, Straightening , Verticality

Electrical Potential Measurements as a Criteria for Cleaning Copper Ew Cells

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Abstract

Cell housekeeping involves a maintenance activity that must be carried out periodically in a tankhouse to ensure production, cathodic quality and energy efficiency of the copper electrowinning process. On the other hand, the housekeeping activities described in the operation manuals of the plants are mainly focused on the mechanism and frequency of the lead anode mud remove from the bottom of the cells, and the bleed of spent electrolyte for the control of total iron and of the chloride concentration in the water solution. However, to generate the electrons in the anodes of each cell that require the electrolysis process, it is also necessary to ensure the flow of those electrons towards the cathodes of each neighboring cell. Hence, it is essential to maintain an expedited way for the electrons flow in the electrical circuit of the tankhouse which implies carrying out permanent housekeeping activities focused on cleaning the DC current bus bars and of the support bars of the electrodes. An industrial study based on a comparison of the voltage data measured in the whole electrolytic cells is presented in this work, by using the monitoring of the cell potentials as a selection criterion from those cells that require intervention to clean the current conducting bars. It is shown that the permanent application of this specific housekeeping activity translates into an important benefit on the Kpi's of cathodic quality and energy efficiency in a copper electrowinning tankhouse.

Electrowinning kinetics and model for ammonia sulfate systems.

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Abstract

Copper in ammoniacal systems exists readily as both Cu(I) and Cu(II) complexes and provides a unique opportunity for coupling leaching with electrowinning via a self-regenerating oxidizer. Electrowinning may take advantage of this dual valance state by maintaining an abundance of Cu(I) in the electrolyte with the cathodic reduction facilitating the recovery of copper metal and the anode producing Cu(II) to be utilized as an oxidizer in leaching. This work outlines the theoretical basis for the system, investigates reaction kinetics, and proposes a coupled physiochemical electrowinning model of the ammonia sulfate system to allow electrochemical engineers insight into electrowinning cell design for such a system.

Ionic Exchange Plant Industrial Operation, CODELCO Chuquicamata Refinery

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Abstract

High content of impurities in concentrates in the northern district of CODELCO led to the construction of an ionic exchange plant, in order to increase flexibility in the specification of accepted anodes for the process of the Chuquicamata Refinery. The start of the operation was in January 2015, with 5 adsorption towers, using UR-3300 Unitika as resin and 6N Hydrochloric Acid as eluting reagent. By design, the extraction capacity of Sb was 8.7 g / L of resin and Bi was 1.68 g / L of resin. In practice, during 2016, the values obtained were around 9.0 g / L of resin and 1.2 g / L of resin respectively, highly dependent on the initial input concentrations. In the cases with high initial Sb/Bi concentrations, the design values were widely exceeded. The operation of the plant allowed to satisfactorily control the levels of Antimony and Bismuth in the electrolyte, in addition to a cathodic rejection below 4%. During 2016, the Ionic Exchange Plant processed around 507,000 m3 of electrolyte, equivalent to process a "full refinery" more than 35 times. In this paper, the working principle is introduced, and main results are detailed.

Key Words: Ionic Exchange, Bismuth and Antimony Extraction, Cathodic Rejection.

Lead sludge removal and air sparging system integrated in a grating located at the bottom of a EW cell.

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Abstract

The electrowinning of copper uses lead anodes in almost all its plants, which during the process degrade, generating lead sludge that accumulates at the bottom of the cells. This lead ends up being part of the impurities that contaminate the cathodes, reducing the quality of the product, generating rejection and discard, with the consequent loss of value. The removal of these sludge from the cells implies a procedure that involves the use of human resources and the crane, in addition to the partial detention of the cells to be cleaned. On the other hand, there is a need to produce intensively to advance the recovery of production values, which is achieved by increasing the flows and current density in the process, which increases the appearance of nodulations and other surface imperfections in the cathodes by effect of a less controlled deposit. For this, the air sparging systems promote greater agitation and renewal of the copper-rich solution in the areas surrounding the plates, improving the deposited grain, and thus counteracting the unwanted effect mentioned before. A removable grating made of plastic materials allows cleaning without isolating the cell from the circuit, and at the same time supply air sparging, applying both concepts in the same device, which has internal channels for the passage of a nozzle for sludge suction and this nozzle connected to a unit that sucks them by vacuum directly from the bottom of the cells. Additionally, the body of the grating combine both the rich electrolyte circuit and the air distribution for agitation using removable cartridges to inject both fluids separately just below each cathode plate.

Metallurgical Test Work and Flowsheet Development for Gold Recovery from Anode Slimes

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Abstract

Copper Electro-Refining (ER) processes produce anode slimes that contain gold, silver, and other precious metals along with some impurities. Freeport is designing a Precious Metals Refinery (PMR) for treating anode slimes generated from smelting copper concentrates produced at PT Freeport Indonesia (PTFI). The PTFI concentrate contains high levels of gold and silver. The anode slimes produced from copper ER are unique due to the high gold, silver and lead that deports from the PTFI concentrate to the anode slimes.

Freeport has conducted extensive laboratory test work, industry benchmarking, and engineering to develop a flowsheet for recovering gold, silver and other precious metals from copper ER anode slimes. Commercially, two types of processes are used to treat anode slimes, namely the pyrometallurgical process and the hydrometallurgical process. There also are commercial examples of a combination of hydrometallurgical and pyrometallurgical unit operations in the same flowsheet. All available flowsheets were studied, and engineering trade-off studies were conducted and subsequently a hydrometallurgical- based flowsheet was selected for treating anode slimes produced from PTFI concentrate.

This paper presents a summary of the engineering trade-off's and some of the reasons for selecting a hydrometallurgical flowsheet. Additional studies, test work and process optimization were completed to eliminate some of the known weaknesses in the hydrometallurgical flowsheet. Test work results also were used to enhance the process design basis and equipment design criteria. Key results are presented from the test work conducted for gold leaching and purification from various phases of the program and on multiple anode slimes samples. Major process design criteria and salient features of metallurgical development and flowsheet design also are presented and discussed.

Global Survey of Copper Electrorefining: 2022 World Tankhouse Operating Data

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Abstract

Operating data have been collected from many copper electrorefineries around the globe. This survey builds upon previous surveys presented at every Copper meeting since 1987. Analyses of recent data and historical trends are presented on anode composition, electrolyte chemistry, electrolysis parameters, tankhouse design and cathode quality.

The Electrochemical Behavior Of Pb-Ca-Sn Anodes With Superimposed Dc+Ac Current Signals

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Abstract

Copper electrowinning plants use Pb-Ca-Sn anodes for the water oxidation reaction. These anodes must operate at an electrochemical potential greater than 1.65 V/ENH to keep the PbO_2 porous coat that covers the surface of the anodes and that serves as a catalyst for the main anodic reaction. In a conventional copper electrowinning process operating at 300 A/m^2, the anodes are polarized at an electrochemical potential V(+) ≥ 2.2 V/ENH, which means a cell potential Uε[1,8 - 2.0] V. The lead dioxide (PbO_2 (s)) is a strong oxidizing agent and its effective electrochemical stability in cells depends on the imposed anodic polarization to prevent it from galvanic discharge that generates $PbSO_4$ (s) which passivate the surface of the anode forming also lead mud in the cells. This phenomenon also leads to reducing the useful life of these electrodes due to loss of thickness over time. Electrolysis experiments carried out on a pilot scale by using superimposed current signals (DC+AC) has shown that a non-passivating porous coat of $PbSO_4$(s) is formed on the anodes surface when the electrode remains de-energized. As well as in acid batteries, in such cases the anodes of copper electrowinning behave reversibly when the cell is re-energized. The positive effect of the superimposed current DC+AC signals on the electrochemical behavior of Pb anodes in a pilot Cu EW cell is described in this work. It should be noted that the cathodic process benefits of the DC+AC technology is described in patents 0817-2007 and 3315-2013 assigned by INAPI in Chile.

A process scheme for direct electrorefining of copper blister

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Abstract

In the current electrorefining technology copper cathodes of electrolytic grade are obtained in an electrolytic cell by the direct dissolution of copper anodes, approach which implies some intrinsic drawbacks. For an efficient performance in the electrorefining cell copper anodes need to have a composition which prevents formation of surface blisters and enables them to be dimensionally and structurally stable. For this purpose, in the fire refining stage the content of sulfur and oxygen contained in copper blister need to be conveniently reduced. In addition, molded anodes need to be mechanically straightened and surface treated before being electrolyzed. However, even when operating with good quality anodes the increase of operating current densities in an electrorefining plant can be limited by the risk of anode surface passivation.

The present work proposes a novel process scheme for the electrorefining of copper without the need of fabricating anodes, directly from copper blister or copper fire refined. The process involves two main stages, oxidative leaching of small beads of the impure copper in a reactor followed by copper electrowinning in an electrochemical cell with regeneration of the leaching oxidant in the anode. Results presented at this stage, which are based on experimental results using ferric ion as leaching agent, indicates that impure copper can be electrorefined with a high current efficiency, minimizing copper inventory in the plant. The impact of costs savings related to elimination of fire refining and copper molding stages on the economics of copper electrorefining will be analized.

Machine learning techniques for predicting copper cathode quality

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Abstract

The production of high-quality copper cathodes through an electrowinning process requires careful adjustment of factors affecting production. Depending on the values of the variables that measure such effects during the period from anode placement to take out cathode, the product results in one of four different qualities. Although the ideal situation is to obtain the highest quality cathodes the dynamics of the process and the diversity of the factors cause that the final quality obtained is not always as desired. By analyzing data recorded over a period in an electrochemical plant and using machine learning techniques, this work presents mathematical models that allow predicting the quality of the cathodes before they are produced. To this end, stored data from the production of a set of taken out cathodes of the electrolysis tank is used. To predict cathode quality the computational performance of neural network, random forest, support vector machine and LightGBM classifiers were compared. The models were calibrated by grid-search and over and under sampling techniques were used to obtain a proper data balancing. Also, the use of regularization and cross validation allowed to strengthen the classifiers. The results show that the score classification is an accuracy of 95% when two classes are considered and 83% by considering four classes.

The adhesion of copper electrodeposits to stainless steel

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Abstract

In modern copper electrolysis, proper adhesion of copper to stainless steel substrates is necessary to decrease premature delamination (self-stripping) or sticking. The effects of electrolyte composition, current density and temperature on adhesion of electrodeposited copper to 316L stainless steel were studied. Copper electrodeposits were produced in a laboratory electrorefining cell using synthetic electrolytes and continuous addition of glue and thiourea. The force needed to remove the electrodeposits from new 2B mill finish 316L surfaces was measured using an applied perpendicular load. The tensile force required to remove the copper deposits from the stainless-steel substrate ranged up to 1.2 MPa. Over the ranges of electrolyte composition, current density and temperature studied, the operating parameters had no discernible effect on the average adhesion of electrodeposited copper to new industrial stainless-steel samples.