SME Society for Mining, Metallurgy & Exploration®

MINEXCHANGE

2022 SME Annual Conference & EXPO

FEBRUARY 27-MARCH 2 » SALT LAKE CITY, UT

TECHNICAL PROGRAM

TECHNICAL SESSIONS

MONDAY, FEBRUARY 28
AFTERNOON

2:00 PM | ROOM 01

COAL & ENERGY: ACCESSING CAPITAL IN THE EVER-CHANGING ENERGY LANDSCAPE

Chairs: ***T. Alch****, Vice Chair NY Section of SME and Co Chair of SME's Mining Finance Conference, Edgewater, NJ*
P. Conrad*, Montana Tech, Butte, MT*

2:00 PM
Introductions

2:05 PM
Energy Industry Trends Impacting Transactions, Financings and Restructurings
R. Reeves; Northcott Capital, London, UK

This presentation will provide an update of the landscape and market for raising capital as the energy industry adapts to a new political landscape with respect to source of electricity generation. It will start with a brief overview of competing energy sources including coal, natural gas and renewables. It will also discuss recent developments in the coal as well as natural gas industry both nationally and internationally that are relevant for financing at the mine and corporate level. The discussion will focus on financing alternatives for a mature industry and explore possible alternatives or scenarios that could create upside for the industry and facilitate raising capital.

2:25 PM
Social Challenges for Coal in Raising Capital
J. Craynon; Mining Engineering, West Virginia University, Morgantown, WV

The continued focus globally on reducing carbon emissions and addressing climate change has created high social barriers for funding operations that focus on fossil energy, particularly coal operations. However, there are possible approaches to address the social challenges for coal in raising capital for new and expanding operations. Many of those approaches involve making a full life-cycle analysis for the entire operation and supply chain.

2:45 PM
Global Financing and a Thermal Coal Supply - A Perspective in 2022
M. Oommen; Mining Consultant, Ballwin, MO

Local energy markets, domestic electricity demand and national energy and natural resource policies continue to dominate the use of coal in power generation. However, external financing in the form of large development financing institutions in Japan, South Korea and Europe has been significantly curtailed in the shift toward financing of cleaner energy sources all parts of the world. China's economy continues to be powered by coal. About 240 gigawatts (GW) of coal fired plants are in the pipeline with almost 90 GW under construction and the remainder approved and permitted. India has almost 37 GW in the pipeline with Indonesia and Turkey accounting for about 41 GW that are under construction or already have been approved and permitted. Given the significant projects that are currently in the pipeline, it is hard to see demand for coal completely dying out in the next few decades with coal supplies expected to last at least through the financial tenor of the loans associated with projects currently in the pipeline.

3:05 PM
Supplying Raw Materials to the Infrastructure and Electrification Industry
K. Taylor; American Resources Corporation, Fishers, IN

This presentation will focus on supplying raw materials to the infrastructure and electrification industry.

3:25 PM
An Investment Bankers Perspective of the Uranium and Nuclear Energy Industry
R. McCormick; Energy & Natural Resources, Capstone Partners, Dallas, TX

There are a total of 441 nuclear power reactors currently operating in some 30 countries, and this is the 7th consecutive year nuclear generation has risen. Globally 50 new reactors were connected to the grid in the last 8 years. Add to that 54 nuclear power plants currently under construction around the world and over 165 planned through 2040 and you have a recipe for surging U308 prices generating increased M&A activity and significant capital requirements in the uranium mining sector. We can expect a 42% increase in nuclear generation capacity by 2030, which would necessitate a 60% growth in uranium production to 300 million pounds annually. The US Department of Energy ("DOE") is expected to begin purchasing uranium for domestic reserves after Congress' approval of an initial $75 million earmarked for purchase in 2021 from at least 2 US mines (10 year program). Higher uranium prices are ahead due to demand outstripping supply, inventory shrinkage, deposit depletion and continued high grading. Utility long term contracting, which will be occurring sooner rather than later, will be the main catalyst to drive uraium prices higher.

MONDAY, FEBRUARY 28
AFTERNOON

2:00 PM | Room 02

COAL & ENERGY: BEST OF GROUND CONTROL

Chairs: ***M. Murphy,*** *National Institute for Occupational Safety and Health, Pittsburgh, PA*
H. Lawson*, NIOSH, Spokane, WA*

2:00 PM
Introductions

2:05 PM
Exploration of Limestone Pillar Stability in Multiple-Level Mining Conditions Using Numerical Models
G. Rashed, B. Slaker and M. Murphy; CDC NIOSH, Pittsburgh, PA

Pillar stability continues to be a significant concern in multiple-level mining conditions particularly for deep mines when pillars are not stacked or the thickness of interburden between mining levels is thin. The National Institute for Occupational Safety and Health (NIOSH) is currently conducting research to investigate the stability of pillars in multiple-level stone mines. In this study, FLAC3D models were created to investigate the effect of interburden thickens, the degree of pillar offset between mining levels, and in-situ stress conditions on pillar stability at various depths of cover. The FLAC3D models were validated through in-situ monitoring that was conducted at two multiple-level stone mines. The critical interburden thickness required to minimize the interaction between the mining levels on top-level pillar stability was explored. The model results showed that there is an interaction between numerous factors that control the stability of pillars in multiple-level conditions. The results of this study improve understanding of multilevel interactions and advances the ultimate goal of reducing the risk of pillar instability in underground stone mines.

2:25 PM

Rail Road Bridge Movements Above a Deep Longwall Mine in the Eastern US

Z. Agioutantis[1] and S. Hicks[2]; [1]University of Kentucky, Lexington, KY and [2]Coronado Coal Co, Oakwood, VA

The prediction and control of ground deformations due to underground mining are important considerations in the permitting, planning, and monitoring of coal mining operations. Such movements mainly include subsidence, horizontal displacement and horizontal and/or ground strain. Predictions can be accomplished using regional subsidence parameters and site-specific data. Surface topography should be considered in ground deformation predictions, especially in cases where there are abrupt changes in the slope and elevation of the ground surface. This presentation discusses movements related to a railroad bridge which is undermined by a longwall panel. The bridge is transversely located above the panel which is part of a longwall mining operation in the eastern US. The presentation presents initial vertical and horizontal movement estimates for bridge abutments, the mitigation measures implemented to decrease ground strain on bridge alignment as well as monitoring results for the actual movements monitored when the bridge was undermined. Actual movements are critically compared to predicted movements especially with respect to ground strain along the bridge alignment.

2:45 PM

Assessment of Floor Heaves Associated with Bumps in a Longwall Mine Using the Discrete Element Method

B. Kim and M. Larson; CDC NIOSH, Spokane, WA

The floor-heave and no floor-heave phenomenon at a western US coal mine was not clearly demonstrated in the numerical model using conventional shear-dominant failure criteria. Kim and Larson (2019) demonstrated the floor-heave and no floor-heave phenomenon using a user-defined model of the s-shaped brittle failure criterion in conjunction with a spalling process in FLAC3D. However, the FLAC3D model adopted many assumptions and simplifications that were not very realistic. In order to overcome the simplifications of the FLAC3D model, 3DEC modeling in conjunction with the Discrete Fracture Networks (DFNs) technique was performed to better understand the true behavior of floor heave associated with underground mining in an anisotropic stress field. The effect of stress rotation in the mining-induced stress field was considered by using a different geometry of rock blocks system in the coal seam. The heterogeneity of the engineering properties were also considered by using Monte Carlo simulations. Consequently, the 3DEC models using the DFNs technique resulted in modeling calculations of floor heave agreed with observations of the relative amounts of heave from each gate road system.

3:05 PM

Stochastic Sampling on Synthetic Rock Mass to Study Effect of Natural Joints on Pillar Mechanics

M. Suner and I. Tulu; West Virginia University, Morgantown, WV

In general, underground stone mines have inherently strong rock and experience good ground stability. Also, modern pillar design guidelines developed by National Institute for Occupational Safety and Health (NIOSH) have improved the design of stable layouts for modern limestone mines. In these mines, previously mined sections stay open for the life of the mine which may be several years, and in some mines previously mined sections function as travel paths to reach working faces. In a recent massive pillar collapse in an old section of a mine in Pennsylvania, three miners were injured due to an air blast at the outside of the mine. Also, there are frequent reports indicating the pillar sloughing, spalling and roof falls. These incidents highlight the potential safety impact on the miners in underground limestone mines. In the pillar design guidelines published by NIOSH, pillars are mostly examined for the existence of large discontinuities crossing the pillar. However, the influence of the more than one joint set and natural fractures on the localized failures and on the general stability of pillar has not been studied.

3:25 PM

Observed Trends in Geotechnical and Hydrogeological Data for Appalachian Underground Coal Mines

K. Andrews and S. Keim; Marshall Miller & Associates, Blacksburg, VA

The geotechnical and hydrogeological characteristics of coal seams and rock strata above and below mineable coal beds are often studied to assess potential groundwater inflow to a mine, to evaluate the effect of groundwater inflow on mine stability, and to assess the potential for mining to adversely affect aquifers and streams. Geotechnical and hydrogeological characterization of coal and rock in the roof and floor of a mine also provides vital information for ground control design and mitigation measures such as grout and resin injection. Analysis of geotechnical and hydrogeological data collected over the last 30 years provides a means to better understand the typical range of values encountered in Appalachian coalfields and to identify empirical relationships amongst the main parameters. By analyzing the relationships amongst the main geological, geotechnical, and hydrogeological factors associated with mineable coal seams and mine roof and floor material, the current research provides a valuable reference for the coal mining industry in Appalachia.

3:45 PM

Roof Stability and Support Strategies Associated with Longwall-Induced Horizontal Stress Changes in Belt Entries

P. Zhang[1], G. Esterhuizen[1], M. Sears[1], J. Trackemas[1], T. Minoski[1] and N. Hlopick[2]; [1]CDC NIOSH, Pittsburgh, PA and 2Iron Senergy, Waynesburg, PA

Past experience of longwall mining in the US showed that occurrence of roof falls in belt entries was largely associated with high horizontal stress. It is important to understand how roof stability is affected by horizontal stress changes in belt entries during longwall retreat and to strategically install supplementary support during development. NIOSH measured horizontal stress changes in the immediate roof in the belt entries for two longwall panels in the Pittsburgh seam oriented unfavorably to high horizontal stress. Numerical models were set up to calculate the horizontal stress changes in the roof for the two belt entries that were monitored. With the calibrated model, investigations were made of how horizontal stress concentrated and relieved in the belt entry roof near the face under different panel orientations. Both measurements and modeling results showed that high horizontal stress and shear stress concentrated in the roof in the belt entry within about 20 ft outby the face when a longwall panel is unfavorably oriented to major horizontal stress. Roof support and operational strategies are discussed on how to maintain belt entry stability under such conditions.

MONDAY, FEBRUARY 28

AFTERNOON

2:00 PM | Room 03

COAL & ENERGY: RESEARCH AND INNOVATION IN COAL MINE DUST CONTROL

Chairs: ***R. Reed,*** *NIOSH, Pittsburgh, PA*
T. Beck*, CDC NIOSH, Pittsburgh, PA*

2:00 PM

Introductions

2:05 PM

A Summary of Respirable Coal Mine Dust and Respirable Crystalline Silica Dust Research Accomplished Through the MINER Act under the NIOSH Office of Mine Health and Safety Research

W. Reed and G. Luxbacher; Office of Mine Safety and Health Research, National Institute for Occupational Safety and Health, Pittsburgh, PA and Office of Mine Safety and Health Research, National Institute for Occupational Safety and Health, Atlanta, GA

As directed by the MINER act of 2006, the NIOSH Office of Mine Health & Safety Research (OMSHR) has annually awarded contracts to enhance mine safety and health. OMSHR has a history of research that focuses on

respirable dust and respirable crystalline silica (or quartz) dust, and contracts have been awarded since 2010 in support of our intramural research efforts. In 2018, a National Academies of Science consensus study report recommended expansion of respirable dust research. As a result, beginning in 2018 through 2021, seventeen contracts were awarded focusing on this area. These contracts can be grouped in three topic areas: characterization of coal/material, development of real time monitors, and improvement of respirable dust controls. This paper summarizes the outcomes of completed contracts and the progress of current contracts.

2:25 PM

Optimize Air Flow Distribution for Canopy Air Curtains to Improve Dust Protection

N. Amoah, A. Kumar and G. Xu; Mining Engineering, Missouri University of Science and Technology, Rolla, MO

Exposure to high concentrations of respirable coal mine dust causes coal workers' pneumoconiosis and silicosis. Underground coal mine roof bolter operators have a higher risk of excessive coal and silica dust exposure. The canopy air curtain (CAC) was developed to protect roof bolter operators from high coal dust concentrations. The CAC supplies filtered air over the breathing zone of the operator to dilute high coal dust concentrations. Many studies have been carried out to improve CAC efficiency. However, field test has shown variable dust control efficiencies indicating rooms to further improve due to the non-uniform airflow distribution across the plenum and ineffective perimeter flow. This study therefore redesigns the CAC with optimized flow distribution that effectively protects roof bolters from coal dust exposures. Computational fluid dynamics (CFD) simulations are used to optimize the uniformity of airflow distribution across the plenum to achieve the best possible uniformity. A lab experiment validates the CFD model and confirms the ability of this design to reduce floor dust pickup, prevent external wind infiltration, and offer an improved protection efficiency.

2:45 PM

Laboratory and In-Mine Testing of Novel Non-Clogging Impingement Screens for Continuous-Miner Dust Scrubber

N. Gupta, A. Kumar and S. Schafrik; Mining Engineering, University of Kentucky College of Engineering, Lexington, KY and Mining and Nuclear Engineering, Missouri University of Science and Technology, Rolla, MO

Research has conclusively established that continual exposure to coal dust causes permanent respiratory ailments in miners. Dust capture using a flooded-bed scrubber incorporating a multi-layered fibrous screen has been the traditional dust-mitigation technique since the early 1980s. These screens tend to get clogged leading to an increased pressure drop and reduced airflow through the scrubber, resulting in frequent maintenance and elevated dust levels within the working place. Two full-scale non-clogging impingement-type dust screens, developed as drop-in replacements for the fibrous screens, are described. Cleaning-efficiency results from experiments designed with coal and rock (limestone) dust in the laboratory are presented. Additional experiments were designed with limestone dust as the aerosol and conducted underground to compare the performance of each screen. Dust concentration results obtained from - OPS data in the laboratory and PDM 3700 data in a mine show the newly developed impingement screens to out-perform the cleaning efficacy of the fibrous screen at all airflows in the range of 4,000 – 8,000 cfm.

3:05 PM

A Laboratory Investigation of Underside Shield Sprays with a Shearer Clearer Water Spray System to Improve Dust Control on Longwall Faces

S. Klima, T. Beck, J. Driscoll and A. Mazzella; NIOSH, Pittsburgh, PA

Previous testing was performed by researchers at the National Institute for Occupational Safety and Health (NIOSH) to improve longwall dust control using underside shield sprays with a longwall directional spray system. This testing provided encouraging results toward respirable dust exposure reductions for longwall personnel, achieving as high as 99% dust reduction at some sampling locations along the longwall personnel walkway. Additional laboratory testing was conducted to test these underside shield sprays in conjunction with a shearer clearer spray system located on the longwall shearer body. The purpose of this was to determine if the underside shield sprays interacted positively or negatively with the shearer clearer sprays. Results from this testing indicate that while the shearer clearer system influences where the respirable dust particles are directed, underside shield sprays can still lower respirable dust exposure for longwall personnel.

3:25 PM

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3:45 PM

Eco-Friendly Bio-Inspired Surfactants as Dust-Controlling Materials for Coal Mining Industry

D. Hogan, T. Lee, R. Maier and M. Kim; [1]Environmental Science, University of Arizona, Tucson, AZ and Materials Science and Engineering, University of Arizona, Tucson, AZ

Coal workers' pneumoconiosis has long been recognized as one of significant occupational lung diseases in the coal mines and it is still closely related to the 38,353 deaths in the US (1999-2016). Water spraying is one of the common dust controlling methods and chemical surfactants are added to improve the wettability of coal in spite of their human health and environmental risks. To replace chemical surfactants, biosurfactant-inspired analogs have been developed as an alternative due to their advantages, such as low toxicity and high biodegradability. By controlling diverse parameters, promising glycolipid surfactants that efficiently mitigate coal dust will be reported.

4:05 PM

On the Occurrence of Coal-Mineral Microagglomerates in Respirable Coal Mine Dust

J. Gonzalez Jaramillo, C. Keles and E. Sarver; Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA

In a prior study of respirable dust samples from 23 coal mines, both scanning electron microscopy (SEM) analysis of individual particles and thermogravimetric analysis (TGA) of the dust mass were used to estimate fractions of coal and minerals likely sourced from rock strata in the mine. The SEM results consistently overpredicted abundance of such minerals, and underpredicted abundance of coal, relative to the TGA–especially for samples collected near active dust generation from geologic strata. One possible explanation is the occurrence of coal-mineral microagglomerates (MAGs). Coal particles covered in fine mineral dust could be mostly coal by mass, but classified as mineral by SEM due to their surface elemental content. An understanding of MAGs might be important in view of both dust control and exposure assessment. The current study: (1) explores a small set of mine samples to prove MAGs are indeed present; (2) uses lab-created dust samples to demonstrate MAG formation due to dust generation, rather than only as an artifact of dust sampling; and (3) attempts to disperse MAGs in phospholipid solution to shed light on the possible fate of such particles upon inhalation.

MONDAY, FEBRUARY 28

AFTERNOON

2:00 PM | Room 08

ENVIRONMENTAL: ENVIRONMENTAL SOLUTIONS TO PROTECT THE ENVIRONMENT

Chairs: ***N. Astillero****, Freeport-McMoRan, Inc., Tyrone, NM*
L. Blinn*, CEC, Pittsburgh, PA*

2:00 PM

Introductions

2:05 PM

Pit Lake Sediment Cover for Geochemical Control of Trace Metal Release: Geochemical Model, Bench-Scale Demonstration, Field Pilot, and Full-Scale Implementation

B. Schroth and J. Stefanoff; Federal & Environmental Solutions, Jacobs Engineering Group Inc, Davis, CA

A flooded open pit mine containing zinc-rich treatment sludge and sediment showed unacceptable concentrations of dissolved zinc in the lake water. When inflow of the high-pH water treatment sludge is terminated after closure, the slightly acidic native groundwater, runoff, and stream inflow can react with the sediment, resulting in desorption of zinc and subsequent increase in water column concentrations. This process was predicted using PHREEQC geochemical modeling coupled with diffusion calculations. Data from bench-scale testing verified the predictions. Subsequent field pilot studies allowed for design and implementation of an effective long-term two-layer gravel and limestone cover placed over the pit lake sediments. Two years of post-cover water monitoring indicates that pH is stable, metal concentrations are below regulatory criteria, and the lake water is expected to remain at high quality. Key measurements for the predictive model consisted of water column chemistry, sediment and porewater chemistry, sequential extraction analysis of sediments, bench-scale testing of potential future sediment exposure conditions, and biological indicators.

2:25 PM

Phytoremediation of Heavy Metals in Mining Liabilities by Stipa Ichu and Cortaderia Nítida: a Laboratory Assessment

M. Guzman, M. Romero Arribasplata, M. Flores Obispo and S. Bravo Thais; Mining Engineering, Pontificia Universidad Catolica del Peru, Lima, Lima, Peru

The impact generated by old abandoned mines in Peru have produced mining environmental liabilities, which can generate an impact on the environment. In the search for long-term sustainable solutions, Phytoremediation is presented as an interesting alternative, since it allows the use of Peruvian native plant species for the accumulation of heavy metals. In this paper, we present the results of native high Andean species: Stipa Ichu (Ichu) and Cortaderia Nítida (Cortadera). The final metal concentration in the aerial parts and in the roots of each plant show that Stipa Ichu is more efficient to recover Fe, reaching almost 364 times its initial value. In the same way, this plant is efficient to remove Cu, Cd and Pb, reaching maximum values of 40, 12 and 3.54 times its initial concentration respectively. Cortaderia Nítida turned out to be more efficient to recover Zn and Cr, with highest recovery of 116.84 and 137 times its initial value respectively. Finally, based on translocation factor, Stipa Ichu has better capacities of hyperaccumulation of Cu, Fe, Zn, Pb, Cr and Cd. Cortaderia Nítida only shows hyperaccumulation of Cr. Keywords: Stipa Ichu, Cortaderia Nítida, phytoremediation.

3:05 PM

Innovation in Environmental Monitoring with Remote Sensing Techniques

M. Rawitch; Ramboll Group A/S, Kobenhavn, Hovedstaden, Denmark

Large or remote areas are often challenging and expensive to monitor using ground-based methods. Recent developments in artificial intelligence allows for the rapid analysis of large volumes of remote sensing data for relevant environmental signals. This presentation will introduce how satellites, high–resolution imagery, and artificial intelligence are changing the way environmental monitoring takes place. We will also present a case study of remote sensing techniques utilized at a large alumina refinery where these technologies were used to monitor environmental impacts sitewide. The purpose of Ramboll's work with this project was to help the client rapidly assess the changing conditions of vegetation impacts at their facility, and to better understand the impact of specific conditions on the environment. The analysis produced from this project enables an additional line of evidence to support other site investigation and monitoring activities and creates the possibility to deploy an advanced monitoring system in an accurate, defensible, repeatable, and cost-effective manner. Having this information allows them to implement remedial plans more efficiently and effectively.

3:25 PM

Nature Based Solutions Transform a Riparian Corridor With Benefits to the Community, Environment in Butte, MT

L. Nelis[1], J. Bryson[2], K. Mustajärvi[3], Å. Swanberg[4], S. Franz[1], S. Robinson[5] and J. Crain[6]; [1]Ramboll USA Inc, Ramboll USA Inc, Arlington, VA, US, corporate/consult, Arlington, VA; [2]Atlantic Richfield Company, La Palma, CA; [3]Ramboll Finland Oy, Tampere, Uusimaa, Finland; 4Ramboll Danmark AS, Kobenhavn, Denmark; [5]Land Design, Inc., Billings, MT and [6]Butte-Silver Bow Department of Reclamation & Environmental Services, Butte, MT

Historic mining practices resulted in contamination of soils across the Butte hill and impacts to surface water and groundwater at and below the Silver Bow Creek riparian corridor. To benefit the community and the environment, the final remedy in the Butte Priority Soils Operable Unit will utilize the implementation of Nature Based Solutions. The Nature Based Solutions will complement historic mine waste removal and the capture and treatment of contaminated groundwater to ensure that surface water resources will be further protected, biodiversity will increase, and the community will gain a public natural area. The resulting Silver Bow Creek Conservation Area will be a 160-acre urban greenway in the heart of Butte which will include natural and landscaped areas, paths for exercise, and a planned outdoor amphitheater for community productions. In this presentation, we provide a case study in the use of Nature Based Solutions to convert a contaminated Superfund site into a sustainable riparian corridor that will have wide reaching net benefits for human health and the environment.

3:45 PM

Maximizing the Effectiveness of Electrical Leak Location Methods for the Mining Industry

A. Gilson; Liner Integrity Services, TRI Environmental, Auston, TX

Electrical Leak Location (ELL) methods are a critical final quality control step in order to ensure that installed geomembranes will perform as intended. Geomembranes provide critical containment for the mining industry, in particular pregnant leachate ponds and heap leach pads. Using case studies for mining specific applications, the capabilities and limitations of electrical leak location methods are discussed. Understanding method limitations allows for improved method specification, site preparation and project planning in order to maximize the effectiveness of ELL methods.

MONDAY, FEBRUARY 28

AFTERNOON

2:00PM | Room 07

ENVIRONMENTAL: GREEN MINING PART I - CHALLENGES AND OPPORTUNITIES

Chairs: ***E. Vahidi****, University of Nevada Reno, Reno, NV*

D. Reed*, Idaho National Laboratory Research Library*

2:00 PM

Introductions

2:05 PM

Circular Business Model Innovation in Mining: Towards a Sector-Specific Framework

S. Krause[1], O. Drusche[1] and J. Kretschmann[2]; [1]Geo-Resources and Process Engineering, Technische Hochschule Georg Agricola, Bochum, Nordrhein-Westfalen, Germany and [2]Technische Hochschule Georg Agricola, Bochum, Nordrhein-Westfalen, Germany

Mining companies are caught between the growing international relevance of ESG (Environmental, Social and Governance) investments and the need to secure their "social license to operate" by taking into account the needs of their stakeholders. In the search for sustainable business models, the concept of the circular economy (CE) is gaining momentum among practitioners and scholars, as it enables the creation of shared value and thus strengthens the trust of investors and stakeholder relationships. However, there is a lack of a sector-specific CE framework providing guidance to decision-makers in evaluating promising activities. A gap, which this contribution aims to address.

2:25 PM

Climate Change Adaptation and Mitigation in the Aggregates Industry

S. Escudero; School Mines, Universidad Nacional de Colombia Sede Medellin, Medellin, Colombia

In recent years, mining operations have experienced the impacts of climate variability, increasing costs, and changes in the socio-environmental dynamics of the territories. For this reason, the aggregates industry needs to design and define concrete and immediate actions to address climate change. An appropriate way to achieve this is as follows: – Calculate greenhouse gas emissions, sources, and relevance factor. – Make projections of future scenarios. – Design and implement action plans The proposed climate change mitigation and adaptation projects are logistical optimizations of mining equipment (mitigation). Second is the design of an early warning system to predict possible flooding (adaptation).

2:45 PM

Recovery of Gold Mining Tailings Sands for Clinker Manufacture

N. Jaramillo Zapata and O. Restrepo Baena; Materials and Minerals, Universidad Nacional de Colombia, Medellin, Antioquia, Colombia

In Colombia, more than 15 departments and close to 100 municipalities develop gold mining at different scales, and these operations generate mining waste composed of processing fluids and crushed rock with metals and high silica content. Cement production requires clinker, gypsum and other corrective additives. Clinker results from the partial fusion of some minerals including silica. This study proposes to evaluate the effect of the use of mining tailings sands from gold mining in the manufacture of clinker. The proposed methodology will allow the characterization of the sands to manufacture a cement specimen and measure its physical and fire properties.

3:05 PM

Environmental and Health Implications of Recycling Mine Tailings into Construction Materials for Community Purposes

J. Velasquez[1], M. Schwartz[1], O. Restrepo Baena[2] and K. Smits[1]; [1]Civil Engineering, The University of Texas at Arlington, Arlington, TX and [2]Materiales y Minerales, Universidad Nacional de Colombia Sede Medellin, Medellin, Colombia

To properly address mine tailing disposal and subsequently decrease environmental harm, many Artisanal and Small-Scale Mining (ASM) communities attempt to recycle mine tailings into construction materials. Although such practices show much promise in the encapsulation of contaminants, environmental and health (E&H) implications are often overlooked. Furthermore, recycling projects lack stakeholder engagement and identification of communities' needs. In this study, we examined the E&H implications of mine tailing recycling activity around the world, with a special focus on ASM, concentrating on the fate and transport of contaminants and health-related issues associated with exposure to heavy metals. Through a literature review, we determined the main environmental considerations of recycling mine tailings. We then developed a framework based on a conceptual model of risk exposure assessment. In this session, we discuss the main impacts that these recycling activities may pose to the environment and people's health, as well as ways forward to transfer the technical knowledge of safe mine tailing recycling practices for greener and more sustainable mining activities.

3:25 PM

Steps to Green Ironmaking

K. Reid; University of Minnesota, Eden Prairie, MN

Over 90% of global metal production is steel, the backbone of modern civilization, and all steel starts in an iron ore mine. To remove oxygen from iron ore, a reductant and heat are required. However, the tradition reductant has been carbon, supplied by charcoal, coal, coke, oil or natural gas, all of which discharge carbon dioxide, the dominant greenhouse gas. The reduction of greenhouse gases to avoid further global warming is a critical global issue. The evolution of ironmaking and historic improvements in carbon-based technology are discussed and steps toward carbon-free-hydrogen reduction outlined and discussed.

3:45 PM

Direct and Indirect In-Situ Bioleaching of Sulfide Ores Combined With On-Site Downstream Processing at the Research Mine "Reiche Zeche" in Freiberg, Germany

K. Götze, A. Braeuer and R. Haseneder; Institute of Thermal-, Environmental- and Resources' Process Engineering, Technische Universitat Bergakademie Freiberg, Freiberg, Germany

The steadily increasing demand on critical raw materials as well as the ever-rising difficulty regarding ore extraction, require new innovative and environmentally friendly extraction concepts. For this purpose, an in-situ microbiological leaching plant for the extraction of metal ions was installed at the research mine "Reiche Zeche" in Freiberg, Germany. For selective metal ion recovery, the bioleaching plant is directly combined with an underground hybrid membrane pilot plant. Previous studies regarding direct in-situ bioleaching from a pre-fractionated sulfidic ore vein showed a successful metal ion enrichment within the pregnant leach solution (PSL). Nevertheless, indirect in-situ bioleaching with continuous implementation of membrane technology can address the identified need for optimization. Through process redesign the oxidant regeneration by microorganisms takes place periodically outside the ore vein, resulting in an increased metal extraction rate through controlled adjustment of process parameters. The authors would like to thank the AUDI Environmental Foundation for financial support.

4:05 PM

Membrane Contactors to the Rescue: Compact Cyanide Recycling for Sustainable Gold Mining

V. Hammer[1], J. Vanneste[1], D. Vuono[1], F. Alejo Zapata[2], J. Zea Álvarez[2], H. Polanco[2], C. Zevallos2, L. Figueroa[1] and C. Bellona[1]; [1]Civil and Environmental, Colorado School of Mines, Golden, CO and 2Universidad Nacional de San Agustin de Arequipa, Arequipa, Peru

If a safe, easily scalable and cost-effective method of cyanide recycling can be implemented, then this would be a more sustainable alternative to chemical destruction using H2O2 or Caro's acid to meet the 50ppm CN limit in waste ponds to protect biota. Moreover, cyanide release into the environment can be minimized especially at artisanal and small-scale mining (ASM) operations where adequate destruction is not always guaranteed. Porous hydrophobic membrane contactors (MC) offer many advantages over the seldomly implemented state-of-the-art acidification, volatilization and re-neutralization (AVR) process: 1) MCs are extremely compact (>3000 m2/m3) and affordable (<$50/m2); 2) MCs can remove over 99% of cyanide at neutral pH on the feed side and pH 10.5 on the recovery side, dramatically reducing chemical costs; 3) Hydrogen cyanide is only present inside the pores of the membrane dramatically reducing the volume of volatile cyanide in the recycling system, hence improving safety; and 4) MCs can be easily scaled up or down for ASM operations unlike AVR columns. Results will be presented on wastewater from a major gold mine in the US which relies on cyanidation for gold extraction.

4:25 PM

Determination of Environmental Monitoring Points and Equipment in the Routes of Transportation of Minerals From South of Peru as a Measure of Prevention and Solution of Socio-Environmental Conflicts.

J. Arisaca; Facultad de Geología, Geofísica y Minas, Universidad Nacional de San Agustin de Arequipa, Arequipa, Arequipa, Peru

Social conflicts caused by complaints of contamination by mining projects in Peru are recurrent. One of the most recent cases of complaint for environmental pollution claims that the southern mining corridor, which uses state road infrastructure and trucks to transport mineral concentrates to the shipping ports, generates excessive noise pollution, vibrations and particle pollution, especially in the dry times of the year in the southern highlands of Peru. Critical places are identified to carry out environmental monitoring based on the areas of influence of the mining operations, population density, vehicle density, meteorological conditions and the history of social conflicts. Monitoring equipment is also identified to determine the levels of contamination by particles, vibrations and noise, its installation, the sampling work and a final performance evaluation are described. It is proven that through green mining and correct monitoring socio-environmental conflicts, costs due to operational stoppages, loss of human and material capital are avoided, and sustainable mining operations are achieved.

MONDAY, FEBRUARY 28

AFTERNOON

2:00 PM | Room 06

Health & Safety: New Technologies and AI Applications to Improve Hazard Identification

Chairs: ***M. Wegleitner****, Hecla Mining Company, Coeur d'Alene, ID*

S. Duzgun*, Colorado School of Mines*

2:00 PM

Introductions

2:05 PM

Advancing Natural Language Processing Based Random Forest Models in Analyzing Mine Safety and Health Administration (MSHA) Narratives

R. Ganguli and R. Pothina; Mining Engineering, University of Utah, Salt Lake City, UT

Natural language processing (NLP) is a powerful machine learning (ML) technique that breaks down human language (or narratives) into meaningful words that can be analyzed and interpreted. The recent advances in the area provides an opportunity for mines to analyze vast amounts of incident data at relatively short amounts of time utilizing minimal computer resources. After processing the incident narratives with NLP techniques, their "Classification" is an important step in understanding the accident types and circumstances. The ML based random forest (RF) classification algorithms are efficient tools in achieving the task. In the past, authors have developed RF based models to classify Mine Safety and Health Administration (MSHA) accident narratives into accident categories. The results were promising with considerable amount of success (75% across the board) and decent false positive rates. As a continuation to their pioneering research, novel NLP algorithms and strategies that can exploit grammar rules were developed in this paper to improve upon the previous success rates.

2:25 PM

Exploring Environmental and Work Factors That Drive Fatigue of Individual Haul Truck Drivers

E. Talebi Esfandarani and P. Rogers; Mining Engineer, University of Utah, Salt Lake City, UT

Many factors influence the fatigue state of human beings, and fatigue has a significant adverse effect on the health and safety of the haulage operators in the mine. Among various fatigue monitoring systems in mine operations, currently, PERCLOS is common. However, work and other environmental factors influence the fatigue state of haul truck drivers; PERCLOS systems don't consider these factors in their modeling of fatigue. Therefore, modeling work and environmental factors' impact on individual operations fatigue state could yield interesting insights into managing fatigue. This study provides an approach of using operational data sets to find the leading indicators of the operators' fatigue. In a previous study from the authors, top production factors among the operational data sets that impacted fatigue are investigated in a shift aggregated model. The individual level is chosen for the second iteration of the model. A selected algorithm, along with a big data set were able to create a decent model. The model was able to find the environmental and work factors driving fatigue with an improved score compared to previous models.

2:45 PM

Development of Machine Learning Models for Identifying Mining Injury Risk Factors Using Leading Indicators

P. M[2], S. Chatterjee[1], R. Kaunda[3], H. Miller[3] and A. Majdara[4]; [1]Geological and Mining Engineering and Sciences, Michigan Technological University, Houghton, MI; [2]Department of Mining Engineering, Final year, B.Tech, Surathkal, Karnataka, India; [3]Department of Mining Engineering, Colorado School of Mines, Golden, CO and [4]Electrical Engineering, Michigan Technological University, Houghton, MI

The mining industry has experienced a significant reduction in fatal accidents in the United States over the last two decades; however, injuries with restricted activities/days away from work remain high. The U.S. Mine Safety and Health Administration (MSHA) accident and injury data also show that the frequency of accidents in underground mines is significantly more than in surface mining operations. In this research, the last ten years (2011-2021) injury data from the underground metal mines were analyzed to identify the risk factors using leading injury indicators, i.e., days away from work, restricted activities, and no days away from work. Different risk factors were studied in this research include accident time, total experience, fiscal quarter, equipment type, underground mining method, body parts, and accident type. The machine learning models like k-nearest neighbor (KNN), classification and regression tree (CART), and random forest (RF) were applied for injury classification model development. Results show that the RF performs best using optimized risk factors with an accuracy of 0.97 and kappa value of 0.94, compared to other models when all risk factors were considered.

3:05 PM

Statistical Analysis of Diesel Particular Matter and Silica for Underground Stone Mines

M. Harris, E. Rubenstein, K. Raj and V. Gangrade; National Institute for Occupational Safety and Health (NIOSH), Pittsburgh, PA

Large-opening stone mine ventilation is characterized by high ventilation quantities with low resistances. These mines primarily face 3 challenges: moving adequate volumes of air, controlling and directing the airflow, and planning ventilation systems that work well with production requirements. Given these challenges, underground workers in these mines may be exposed to respirable crystalline silica (RCS) and diesel particulate matter (DPM) at levels above the regulatory limits set by the Code of Federal Regulations. These workers may be unknowingly subjected to conditions that contribute to respiratory diseases. This paper comprehensively examines the MSHA collected data to determine the extent to which RCS and DPM may be an issue in underground stone mines. Out of 522 sampled mines, there were 108 resulting RCS violations during 2000 – 2020. DPM was more prevalent than RCS in these mines with 382 citations when 929 mines were sampled during 2000 – 2020. With this knowledge, focused attention can be directed to these mines so that appropriate prevention and mitigation techniques can be utilized to prevent stone miners' exposure to RCS and DPM and subsequent respiratory diseases.

3:25 PM

Advanced Analytics Puts Our Haul Truck Drivers in the "Drivers Seat" of Safe Production and Operational Excellence

M. Golden and L. Walker; Operational Improvement, Freeport-McMoRan Inc, Phoenix, AZ

Haul Truck Operator Scorecard (HTOS) leverages advanced simulation techniques to give operators data-driven feedback on specific things they control that align with best operating practices. HTOS marries safety and efficiency into one advanced analytics tool for operators to gauge their own operating skills. We focus on safety in a new way that ensures our operators have the information needed to leverage safe performance under all conditions. An evolving organizational culture supported a change management approach that increased operator buy-in and resulted in a better solution. This presentation will describe how Freeport-McMoRan employees enabled the success of HTOS.

3:45 PM

Managing Ground Support for Long-Term Stability in Underground Mines – Introduction

D. Benton; NIOSH, Spokane, WA

In underground metal mines, the underlying issues and mechanisms that degrade ground support systems over time are not adequately understood. To prevent ground falls that result in injuries and fatalities, there is a need for more effective methods to identify, monitor, and mitigate the hazards associated with time-dependent degradation of ground support. To address these needs, the Spokane Mining Research Division (SMRD) of the U.S. National Institute for Occupational Safety and Health (NIOSH) has launched a 5-year research project titled "Managing Ground Support for Long-Term Stability in Underground Mines". The project will investigate the time-dependent performance factors of four specific subjects: (1) squeezing ground, (2) ground support corrosion, (3) backfill as ground support, and (4) hard rock seismicity. In introducing this research project to industry and academia, SMRD is seeking input from research partners to enhance the success of the project. This work is part of the SMRD mission of improving the health and safety of underground metal mine workers.

MONDAY, FEBRUARY 28

AFTERNOON

2:00PM | Room 09

INDUSTRIAL MINERALS & AGGREGATES: INFRASTRUCTURE MATERIALS

Chairs: ***S. Stokowski****, Stone Products Consultants, Lawrenceville, GA*
S. Gaillard*, United States Gypsum Co., Tawas City, MI*

2:00 PM

Introductions

2:05 PM

Panel Discussion: The Infrastructure Materials We Know

S. Stokowski; Stone Products Consultants, Lawrenceville, GA

What are Infrastructure Materials and Infrastructure? Are they the traditional construction materials (aggregate, cement, and asphalt) used to construct transportation such as highways, railroads, and airports? Are schools infrastructure, vis-a'-vis the Morrill Acts? How about changes to how the country generates power, i.e., solar and wind to replace coal, oil, nuclear, and hydro? And communications such as public broadband? Should we now include the materials to construct the virtual world, such as Si, Ge, As, Au, Cu, and Rare Earths? A team of panelists from industry, academia, and the government will discuss the concept of Infrastructure.

2:25 PM

Utah Industrial Mineral Production Contributing to Infrastructure

A. Rupke; Utah Geological Survey, Salt Lake City, UT

Thanks to Utah's diverse geology and mineral resources, the state has a steady history of industrial mineral production that contributes to infrastructure within the state and elsewhere. Utah produces several infrastructure-supporting commodities including construction aggregate, cement, lime, expanded shale, gilsonite, gypsum, high-alumina clay, and silica. Sand and gravel resources deposited by Lake Bonneville have helped fuel growth within the state, particularly along the Wasatch Front. Favorable Paleozoic and Mesozoic limestone deposits serve as feedstock for cement and lime production in multiple locations. Gilsonite, a solid hydrocarbon mineral commodity unique to Utah, is mined in veins and used in asphalt mixes to improve performance. Utah is also poised for production of pozzolan, used to extend and enhance cement, and fluorspar, used in both the cement and steel industries. Pozzolan deposits have been identified in volcanic units and Utah's primary fluorspar deposits are found in breccia pipes in the famous Spor Mountain mining district. Fluorspar production would make Utah the primary fluorspar producer in the United States.

2:45 PM

Diatomaceous Earth as a Possible Strength Enhancer in Concrete?

M. Lee; Westward, Boerne, TX

Fly ash and silica flume have long been the 'go to' materials for incorporating into concrete for added strength, workability, and other physical properties. However, with coal production and processing heading into its sunset years, a suitable replacement has yet to be proven. One potential substitute in certain applications may be diatomaceous earth (DE). DE is s basically single celled aquatic algae thus the high silica content and is plentiful in various locations in the US. Additionally, it has a very low density, is chemically inert and has high porosity and surface area properties. Although the silica content in DE is very high, there may be other potential issues such as void space, impurities and even moisture content. Given the recently passed trillion-dollar infrastructure bill, perhaps this is a time to revisit the use of DE in concrete.

3:05 PM

Pozzolans What is Old is New Again...

T. Newman; Holcim (US) Inc., Fort Collins, CO

The Romans discovered that pozzolans mixed with hydrated lime, water, and aggregate make durable concrete. The technology was lost during the "Dark Ages", then rediscovered in the 18th century, along with the invention of hydraulic and portland cements. Pozzolans fell into disuse in the middle of the twenty century when energy was plentiful. Pozzolans have been rediscovered, again, with a New Purpose! – ! Environmental Conservation ! by supplementing cements, conserving resources, and reducing energy consumption. Today, Let's discuss pozzolans for our 21st Century.

3:25 PM

Successful Permitting; Enlightened Beginnings Lead to Happy Endings

D. Bieber; West Division, Martin Marietta, Lakewood, CO

Permitting accessible aggregate reserves is critical for controlling infrastructure project costs. A lack of public understanding and a lack of affective communication by producers create permitting roadblocks. Permitting for the Parkdale Quarry in Fremont County, Colorado offers a case study for effective project communications. Front Range Aggregates permitted an expansion of the quarry with no opposition voiced at the local level, and minimal comments on the project Environmental Impact Statement. A key to the success of the permitting process was early, open, and on-going communication with potentially interested parties, including those likely to oppose the project.

3:45 PM

Aggregate Quality Testing for Concrete Infrastructure including USACE specifications

C. Braaten; American Engineering Testing Inc, St. Paul, MN

In this presentation we will cover some of the common concrete aggregate quality tests covered in ASTM/AASHTO. We will also cover some of the more unique tests and analysis that aggregate producers should be aware of such as ASTM C295. Finally, we'll look at some specifications that are encountered and why diligence is needed when preparing a submittal for infrastructure projects including USACE airfield pavements.

MONDAY, FEBRUARY 28

AFTERNOON

2:00 PM | ROOM 10

MINING & EXPLORATION: GEOSCIENCES: GEOLOGY: MAKING THE GRADE - OPERATIONAL PRACTICES FOR IMPROVING GRADE CONTROL

*Chair: **J. Baar**, Rio Tinto Bingham Canyon, West Jordan, UT*

2:00 PM

Introductions

2:05 PM

Reconciliation of Copper Grades Between Dispatch and Plant Using Advanced Statistics Techniques at Cerro Verde Mine

M. Calixto Rivera; Lima, Peru, Universidad Nacional de Ingenieria, Lima, Peru

Reconciliation in mining is a very studied technique but little analyzed at present at the statistical level, for which the performance of the mining company is valued, based on the comparison of the production recorded by Dispatch and Plant, although it has a simple approach, It has profound consequences and to control this, the Ore Control area is in charge, being a critical activity, is responsable of the mining extraction process that aims to classify the materials into ore and waste and destinations to process, also is based on geological, geometallurgical information and blast hole data. At the end of this study, it will help us to confirm the variability between Dispatch and Plant, justify best practices, explain problems and identify sub-processes with a high deviation from the plan through a discrepancy analysis.

2:25 PM

Improving Forecast and Mine to Mill Reconciliation at the Nevada Gold Mines Goldstrike Autoclave

T. Alvarez; Carlin Complex MRM, Nevada Gold Mines, Elko, NV

The Goldstrike Autoclave processing facility has been treating ore comprised of a single material type referred to as CT46 since September 2020. The plan maintains this single source until October 2022. The gold grade and constituents have displayed inconsistent reconciliation between mine and mill (F2). The grades are being used to forecast the life of mine (LOM) metal plan. In order to better understand the grade and constituents distribution of CT46, a reverse circulation drilling program was performed on three (3) twenty (20) foot benches of the stockpile. Subsequent inverse distance weighted (IDW) interpolation was performed on the results to obtain a block model with the gold grade and metallurgical constituents. The block model improved the forecast and reduced the variance of mine to mill reconciliation (F2). The sample rejects from the campaign were composited and used to perform bench top analysis to improve the forecasted recovery and optimize plant performance prior to treating the ore. This project has demonstrated that understanding geo-metallurgical characteristics of ores prior to being processed can help improve overall plant performance and maximize recoveries.

2:45 PM

Improvement of Productivity Through Mine to Mill Reconciliation

A. Samal; GeoGlobal LLC, Riverton, UT

The model to mine to mill (M3) reconciliation process is a way to learn about the reasons for the success that the mine operation celebrated or, any concern of low productivity. Generally, mining is an integrated operation that includes exploration, mining (extraction), processing, and metallurgy where metals are extracted. Success in annual production may be due to many reasons such as a good mine plan based on a nearly robust resource/ reserve model; execution of mine-plan in the operation supported by reliable laboratory services and disciplined work-culture led by a competent workforce. A detailed M3 reconciliation process leads to finding out the rooms for improvements at various levels. It's an excellent way to identify various nodes of the operation contributing to meeting or exceeding production targets. A healthy operation conducts the reconciliation at a regular time interval. This presentation is meant to start a healthy discussion on the reconciliation process as a tool for improving productivity in a mining operation.

3:05 PM

Economic Ore Control

J. Ruiseco, W. Hunt, D. La Rosa and L. Julian; Orica Ltd, Melbourne, VIC, Australia

Grade control (GC) complexity has increased such that classifying blocks can now require the evaluation of many attributes to determine their optimal destination. This has introduced two complications; creating effective cut off grades (COG) has become ever more difficult, and not all misclassification is symmetric, in some cases misclassifying many blocks to properly classify one is the most profitable option. Complex linear equations can easily determine the optimal classifications in a GC model but creating optimal polygons is a different problem. When creating polygons on post blast GC models, misclassification is unavoidable and managing this is the aim of dig line optimization. Best practices for ore control focus on minimizing ore misclassification. However, the most profitable solutions will often selectively misclassify to improve profitability. For the determination of the symmetry of the classification problem, economic values on a per-destination basis must be calculated. Creating these valuations are often easier than formulating COGs and can reduce classification errors significantly. This paper outlines the benefits derived from using economic ore control versus COGs.

3:25 PM

An Operational Tool to Adjust Ore Polygons for Blast Movement

S. Kanchibotla; Mining, Seshat Consultants Pty Ltd, Pullenvale, QLD, Australia

During blasting, the rock breaks and moves but standard grade control practices do not adjust the ore waste boundaries to cater for blast movement. The material movement resulting from blasting may result in mischaracterization of grade boundaries resulting in ore loss and dilution. Las Bambas operations of MMG Peru, realized the economic impact of blast induced ore loss and dilution. They use limited blast movement monitors (BMMs) to estimate blast movement and adjust post blast ore polygons. Polygon adjustments based on few blast movement measurements has limitations for everyday application. This paper discusses the advantages of disadvantages of current blast monitoring and modelling techniques and introduces an operational tool to estimate ore polygon movements for different blast designs and confinement conditions. Simulations from a proprietary discrete element model and site monitoring data from highspeed videos, blast movement monitors and muck pile surveys are used to calibrate the tool. Blast movement estimates from the site-specific tool have been compared against the estimates from BMM's for several production blasts and results were quite promising.

3:45 PM

A Novel Approach to Solve Truck Fleet Sizing Problem for IPCC-Based Open-Pit Mining

H. Askari-Nasab, A. Kamrani and A. Moradi Afrapoli; School of Mining & Petroleum Engineering Department of Civil & Environmental Engineering, University of Alberta, Edmonton, AB, Canada

The costs of the truck-shovel system in open-pit mining operation increases exponentially when the horizontal and vertical distances between mining faces and the dumping locations increase. In-pit crushing and conveying (IPCC) system is introduced to decrease these enormous operating costs that a truck haulage system can provoke in an open-pit mine. IPCC Implementation substantially reduces the haulage distance and subsequently the haulage operating costs which approximately account for half of the total operating costs in an open-pit mine. Finding the best locations for the IPCC in the different periods of mine life will impose a new set of requirements in solving the truck fleet sizing problem and can lead us to a new set of calculations for estimating the number of trucks. In this research, we introduced an optimization algorithm that simultaneously finds the optimal locations and relocation time for IPCC and solves the truck fleet sizing problem in an IPCC-based open-pit mine. The application of this developed algorithm in a case study provides proof for this inevitable fact that the optimal IPCC location and relocation time has a huge impact on the size of the truck fleet.

MONDAY, FEBRUARY 28

AFTERNOON

2:00 PM | Room 14

MINING & EXPLORATION: GEOSCIENCES: OPEN PIT GEOTECHNICAL: STRATEGIES FOR DESIGN & OPERATION

Chairs: ***J. Mattern****, Nevada Gold Mines, Elko, NV*
R. Sheets*, Barr Engineering Company, Bismarck, ND*
Sponsored by Barr Engineering

2:00 PM

Introductions

2:05 PM

Thermal Infrared Imaging for Rockfall Detection

B. Ross, E. Wellman, C. Williams, K. Schafer and G. Noonan; Geotechnical Center of Excellence, University of Arizona, Tucson, AZ

With a NIOSH research contract, the Geotechnical Center of Excellence (GCE) has evaluated using the Long Wave Thermal Infrared (LWIR) band to detect and record rockfall events and the thermal conditions that can lead to rockfall. The GCE acquired four commercially available thermal imaging cameras. The thermal cameras have been deployed to 5 open pit mines and have recorded rockfalls in air temperatures ranging from 4 F to 110 F. (-15 to 43 C). The LWIR cameras, in addition to established slope monitoring systems (e.g., radar), identify both isolated individual rockfalls and a series of smaller rockfall events preceding a larger slope failure. Thermal video recordings have also been useful to identify groundwater seepage. Similar to optical cameras, limitations for the thermal cameras in the LWIR include fog, precipitation, and limited visibility. The imagery collected to date indicates that these cameras work effectively at night or in low lighting and dusty conditions and expand the capability of a mine operator to identify potential hazards when environmental conditions are sub-optimal for optical cameras. Results will be presented from mines in Arizona, Colorado, and Utah.

2:25 PM

Utilization of Statistical Analysis to Identify Influential Slope Parameters Associated with Rockfall at Open Pit Mines

J. Bourgeois[1], S. Warren[1] and J. Armstrong[2]; [1]National Institute for Occupational Safety and Health, Washington, DC and [2]Kinross, Elko, NV

The application of statistical analysis software programs has proven useful for investigation of rockfall runout distance along a designed slope. Programs are continually upgrading with more sophisticated analysis tools, such as use of the rigid body vs. lump mass models. Engineers at mine sites utilizing the software may have varied experience related to these models, their associated input parameters, and how to interpret the generated results. To address this, researchers at the Spokane Mining Research Division (SMRD) of the U.S. National Institute for Occupational Safety and Health (NIOSH) investigated the influence of slope height, slope angle, slope material, and rock size for both rigid body and lump mass models in a 2-D statistical analysis program. Based on a literature search and industry input, specific ranges common to that of an open pit mining environment were chosen for each of the input parameters to determine 90% rock runout distance as well as their sensitivity to change. Data collected from this numerical analysis and simulation will be compared to empirical rockfall data gathered through the duration of the Highwall Safety project conducted by NIOSH.

2:45 PM

Automated Bench Conformance and Back-Break Measurements

K. Azocar, B. Peik, K. Lawrence, M. Valerio and T. Darakjian; Mine Stability, Golder Associates Ltd, Phoenix, AZ

Bench conformance studies require estimates of the distribution of bench face angle, catch bench width, and back-break from three-dimensional as-built pit scans to gain confidence in achieving bench design criteria. These measurements are often manually derived along a fixed number of cross-sections using well-known industry software. A Golder-developed automated approach to estimate bench conformance distributions will be discussed in this paper, including an overview of input requirements and a discussion on the key features/limitations. Results (parameter distributions, 2D/3D visualization) from three case studies will be used to demonstrate the approach, with validation provided through comparison to existing manual techniques.

3:05 PM

A Case Study at the Bingham Canyon Mine for the Observational Mining Approach

J. Danninger, M. Gaida and E. Woods; Minerals, Rio Tinto Plc, London, London, UK

In 2016 Rio Tinto Kennecott (RTK) was faced with a challenging business decision. The next two years of ore supply were under an area of lower slope stability. Unloading and depressurization measures could not deliver the modeled stability margins to meet RTK design acceptance criteria and a business risk decision was required. Using the observational mining approach, RTK was able to safely and successfully mine the planned ore, while providing the business with a clear view of the potential risks of this path.

3:25 PM

Comparison of the FOS and SRF Values from Slope Stability Analysis of a Large Open Pit

J. Killian and S. Cox; 3-D Modeling, Call & Nicholas, Inc., Tucson, AZ

The use of stability criteria within geotechnical engineering is the way the results of analyses are conveyed, and sensitivities and risk assessments are performed. Historically, the primary stability criteria for slope design has been the Factor of Safety (FOS) coming from a limit calculation. Increasingly, the value derived from Strength Reduction Factor (SRF) analysis is being used as the criteria for stability analysis. The purpose of this work was to study in detail the relationship between SRF values produced from a numerical modeling technique and the traditional FOS values produced from Limit Equilibrium (LEM) analyses. This study utilized a model of a ~914m slope with a 45-degree slope angle, assuming a perfectly-plastic mohr-coulomb constitutive model with high cohesions and friction angle values typical of a large hard rock mine slope. A number of variables effecting the values of the SRF in a numerical analysis were tested including zone size, insitu stress, tensile strength, and dilation angle. This paper demonstrates that in most cases SRF values are lower than the corresponding LEM FOS values.

3:45 PM

Evaluation of the Safety Factor Under Static and Pseudo-Static Conditions for Slope Stability and Redesign of Mining Phases in an Open Pit Mine in the Southern Highlands of Peru

Y. Mamani[2] and V. Tenorio[1]; [1]Mining and Geological Engineering, University of Arizona, Tucson, AZ and [2]Facultad de Geología, Geofísica y Minas, Universidad Nacional de San Agustin de Arequipa, Arequipa, Arequipa, Peru

This research is the result of a geotechnical study carried out on a natural slope in the proximities of an open pit mine at southern Peru, highlighting that earthquakes are an important cause associated with the case study presented. This leads to analyze the stability of a slope, according to the safety factor and thus consider a future construction strategy according to the requirements to be recommended. There are disasters known at national and international level that involve human lives as a consequence of the lack of analysis of slope stability conditions, which depend on the results that will allow control and correction measures to be taken. These mass movements occur within soils or rocks according to their classifications, taking into account the mechanism and type of rupture, as well as the presence of water, the speed and the magnitude of the shock wave. The movement problems are due to factors of inherent nature and constitute a reason to perform a calculation study in order to analyze and evaluate the safety factor of each of the evaluated cases.

4:05 PM

Rumble in the Jungle: Lessons Learned from a Waste Rock Dump Failure

T. Braun; SRK Consulting (U.S.), Inc., Denver, CO

A greenfield gold project in Latin America was in the planning phase in the late 1990s. Approximately 15 million tonnes of waste rock would be moved to access approximately 11 million tonnes of leach ore. Construction started in late 2003 and the open pit gold mine began operations about 1 year later. Three years into production, the operations team observed cracks around the waste rock dump and the footprint of the uphill heap expansion. Nine months later, a geotechnical consultant acknowledged the potential for a deep-seated landslide below the waste rock and heap leach facilities. In response, the operator suspended operations and commenced rinsing of the leach pad to reduce cyanide levels. Less than 3 months later, the predicted deep-seated landslide occurred. Engineers estimated approximately 35 million cubic meters of mass movement below the waste rock and heap leach facilities. Approximately 2 years after the shutdown, the owner filed a Statement of Claim and named three engineering design firms and individuals involved in the project. This paper explores the factors behind the failure and offers post-failure insights of relevance to practitioners and stakeholders of today.

4:25 PM

OptimalSlope: A Novel Slope Optimization Software for the Design of Open Pit Mines of Improved NPV and Reduced Carbon Footprint

S. Utili and A. Agosti; School of Engineering, Newcastle University, Newcastle University, Newcastle upon Tyne, UK, Newcastle upon Tyne, UK

We showcase substantial increases of the financial returns for open pit mines obtained by the adoption of steeper non-linear in elevation geotechnically optimal pitwall profiles which are determined by a novel slope optimization software, OptimalSlope. The optimal profile is defined as the one maximizing the overall steepness of a pitwall given the geotechnical properties of the rock/soil formations encountered and a prescribed Factor of Safety (FoS). We considered two case studies: a copper and a gold open pit mines in development. We redesigned them adoopting optimal pitwall profiles featured by the same FoS as the planar pitwalls of the original design. To this end a depth varying angle, obtained as output from OptimalSlope, was prescribed as geometrical constraint for the pitshells produced by Whittle instead of a depth constant overall slope angle. From our analysis it turns out the design employing the optimal pitwalls exhibits increases of NPV of around 30% and 50% which are mainly to be ascribed to a similar reduction percentagewise of rockwaste volume. Such a reduction of rockwaste in turn results in a substantial reduction of the mine carbon footprint.

MONDAY, FEBRUARY 28

AFTERNOON

2:00 PM | Room 12

MINING & EXPLORATION: INNOVATION & TECHNOLOGY: DRONE APPLICATIONS, TODAY AND TOMORROW

*Chair: **K. Martindale**, Salt Lake Community College, Spring Creek, NV*

2:00 PM

Introductions

2:05 PM

Long Flight Drones (UAV) for Survey

M. Maier; Engineering, Empire Southwest, Mesa, AZ

2000 acres in one flight! That's right, we did 2000 acres on one battery with five ground targets and around 30 check shots. The results amazed us! We were not trying to do a super tight topo survey. What we were doing was more focused on training for a client and teaching them how to fly their new Quantum Trinity F90+. When conducting training it is always good to use real world projects. For this training we were performing a plant survey. Typical plant surveys don't require a lot of ground control or check shots. As it turned out most of our check shots ended up being very tight, and most shots were within a tenth vertically from our flown surface. We were amazed that such a large area could be flown with minimal ground control, and how well the data came out. The Trinity F90+ is designed for land surveying and generating high accuracy topography over vast areas. Looking at the Quantum spec sheet it shows at 120m AGL is capable of 1700 acres per flight. That's impressive. However, now using just a couple batteries, we can cover several square miles in a day! This means a contiguous model can be made for a whole mine site. This is a game changer.

2:25 PM

Mapping Clay Minerals with UAV-Based Hyperspectral Remote Sensing in Mining Environments

J. He and I. Barton; Mining Engineering, University of Arizona, Tucson, AZ

Mapping clay minerals is important in mining operations because clays can cause major geotechnical and metallurgical problems. However, clay minerals are fine-grained and difficult to map in the field and access is limited to some places, such as highwalls and leach pads. In order to acquire the distribution of clay minerals, a remote and efficient technique is required. We tested hyperspectral remote sensing for identifying clay minerals at two active mines in Arizona. The results show that UAV-based hyperspectral remote sensing can map some spectrally active phyllosilicate minerals such as kaolinite and muscovite, swelling clays such as montmorillonite. Clays, especially swelling clays, can weaken areas and cause geotechnical issues. They can also decrease permeability and cause metallurgical problems on leach pads. Furthermore, hyperspectral remote sensing can also map driplines, lixiviant ponds, and precipitates on leach pads. This presentation will talk about the advantages and limitations of using hyperspectral remote sensing in mining environments.

2:45 PM

Enterprise Unmanned Traffic Management (UTM) Solutions

A. Woolsey; Aviation Technology, Utah State University, Logan, UT

Unmanned Aerial System (UAS) technologies are improving data capabilities, operational cost efficiencies and safety with advanced UAS design, sensors and payloads. Novel approaches to sensor integration in combination with the dynamic UAS functionality are being realized with new, smart RF sensors capable of real-time and cooperative, non-GPS tracking. The sensors are long range, 300m-15km with accuracies of 7cm-1m. Adding to this sensor's capability set, multiple UAS operations can be tracked with enterprise unmanned traffic management (UTM). Allowing mine management risk mitigation and better decision-making capabilities in the current and future mosaic of mine operations.

3:05 PM

Comprehensive 3D Modelling of Large Underground Mine Pillars Using Drones

R. Bishop, A. Soni and N. Ripepi; Mining Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA

UAVs have become integral tools for mine planning, surveying, geotechnical analysis and inventory control in many surface mining operations. In underground mining operations however, their adoption requires modifications to address the challenges of lighting, collision avoidance and positioning in order to safely and effectively navigate and capture their surroundings in these GPS-denied confined environments to yield useful results. This presentation highlights recent drone-based surveys in an underground room and pillar mine, whereby UAVs were used to fully model a 30m (100') tall mine pillar using drone-based lidar and photogrammetry.

3:25 PM

Improving Reconciliation and Safety using Autonomous Cavity Monitoring System

I. Traore; Mining, Mining, Kibali, Congo (the Democratic Republic of the)

Over the past years Barrick's Kibali Gold mine made significant progress in production reconciliation by implementing autonomous cavity monitoring system. Located in northeast of the Democratic Republic of Congo, the Kibali underground mine stope scanning system consist of an automated smart mobile scanning unit mounted to a drone for scanning large open void. In this paper, the automated cavity monitoring system and its impact on the mining operation is presented. The implemented system reduced the exposure of surveyor to operate closer to open void while improving the overall safety of mining. It also improved the accuracy of the scan and allow effective mine to mill reconciliation.

3:45 PM

Analyzing Slope Design Conformance using Drone Survey Point Cloud in an Open Pit Mine

A. Soni[3], R. Zea[1], J. Combs[1], L. Tejada[1] and J. Johnson[2]; [1]Corporate Geomechanics, Freeport-McMoRan Inc, Phoenix, AZ; 2Freeport-McMoRan Safford Mine, Safford, AZ and 3Mining and Minerals Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA

Adherence to slope design in an operational mine environment is essential for geotechnically safe excavations and better production. As a pushback advances, tracking compliance to design, including bench face angles and catch-bench widths, allows for economic optimization of the highwall. This study utilizes scans from a drone survey and Maptek's Inter-Ramp Compliance tool to analyze slope design conformance. Virtual cross-sections across the bench profile are created and analyzed to check if bench parameters are within defined tolerances. Statistical data and heat maps are used to identify areas of concern and check the overall compliance in terms of reliability. Also, comparisons are made between compliance results for scans obtained by a drone versus a vehicle/tripod-mounted LiDAR. The results are used for improving future design parameters, excavation practices, and blast designs for safe and economical mining.

MONDAY, FEBRUARY 28

AFTERNOON

2:00 PM | ROOM 11

MINING & EXPLORATION: MANAGEMENT: INCLUSION & DIVERSIFICATION AT THE MINE SITE

Chair: ***J. Haraala****, Newmont, Herriman, UT*

Sponsored by Newmont

2:00 PM

Introductions

2:05 PM

Special Needs Parenting and the Working Mom; a Complicated Pregnancy and Child While Maintaining a Career in Mining

M. Sorensen; Rio Tinto, South Jordan, UT

Two areas of inclusion and diversity that are often overlooked are special needs parenting and accessibility in the workplace. According to the US Census Bureau, 1 in 26 families reported raising a child with a disability, and 20.9 million families reported having a member with a disability. As a parent of a medically complicated child, working in a career I love, there are challenges that an employer should be aware of, including weekly therapies, monthly hospital visits, and many doctor conversations. My daughter has Spina Bifida Myelomeningocele, and at 25 weeks gestation we underwent a fetal surgery to repair her back. As she grows older, flexible work arrangements and working from home willl be essential to sustain a demanding career. Transparency in need has also aided my ability to continue working full time while managing her healthcare and appointments. Companies should also actively work towards accessible workplaces, creating an environment from the beginning that can accomodate wheelchairs and mobility devices, as well as considering ADA compliance when building offices and workspaces. Asking more often "what is inclusive?" over status quo.

2:25 PM

Navigating the Mining Industry as an Achondroplasia Dwarf

R. Krok; Engineering, Morton Salt Inc, Grantsville, UT

I am an Achondroplasia Dwarf and ever since I was born, medical doctors have told my parents that I would not have a normal life due to my short stature. I have proved these doctors wrong. As a young adult, I became active within the Boy Scouts of America, earning the rank of Eagle Scout, and finding a passion for Mining by participating as a Mining in Society Merit Badge Counselor. Still today, I have to overcome obstacles, but never turn challenges down, especially with working in the industry. This summer, I have had the opportunity to make my industry debut as an Engineering Intern with Morton Salt on the Great Salt Lake. Some of my daily tasks require me to use resources around me to get work done, including things like using a step stool to operate a long-range 3D laser scanner for stockpile surveys. Being one of the only Achondroplasia Dwarfs within the industry, I want to demonstrate that you can achieve anything if you put your mind to it. Thinking on my feet is my route to success as I take on the Mining Industry, and anyone can do it. What I have learned is that as long as you have the drive and passion for something, being vertically challenged doesn't matter.

2:45 PM

Attracting Diverse Talent to the Mining Industry

S. Loomis; Caterpillar Inc, Denver, CO

The mining industry struggles with attracting diversity in the workplace. This results in high competition with limited talent availability. As the war for talent increases, that makes every requisition that much more critical to find the best talent, every time. The industry has been vocal about priorities of gender equality, and miners are setting aggressive and transparent targets for gender diversity. Studies have shown, a diverse workforce is a higher performing and highly engaged which translates to better financial performance. As more and more operations go autonomous, with centralized control rooms, there is more of a chance to find and retain diverse talent.

3:05 PM

Why Don't More Students Choose Mining? A New Study of Engineering Freshmen Busts Some Myths

J. Banta[1], I. Barton[2] and L. Hutson[2]; [1]UA Lowell Institute for Mineral Resources, Tucson, AZ and [2]Mining & Geological Engineering, University of Arizona, Tucson, AZ

Recruiting mining engineers is a pressing problem for the future minerals industry, but the reasons why few students major in mining engineering remain mostly speculative. To better understand them, we surveyed 350+ engineering freshmen's levels of knowledge and interest in mining engineering, influences on major choice, motivations, career goals, and demographics, at the beginning and end of their introductory semester. The results debunk several common myths: the obstacle to recruitment is not students' negative perceptions of mining as a low-tech, environmentally damaging industry, or other widely held beliefs. The primary obstacle is that students know less about mining than any other field of engineering, and their interest in fields correlates with knowledge. At the end of the semester, students' level of knowledge and interest had increased, as had the number and confidence level of those intending to major in mining. We present survey results quantifying these trends; identify what characteristics students find attractive/unattractive in a major and career, particularly mining engineering; suggest implications for improving recruitment; and outline continuing research.

MONDAY, FEBRUARY 28

AFTERNOON

2:00 PM | Room 13

MINING & EXPLORATION: OPERATIONS: UNDERGROUND PLANNING AND OPTIMIZATION

*Chair: **B. Drury**, Oceana Gold*

2:00 PM

Introductions

2:05 PM

2:05 PM

Scenario Analysis for Short-Term Underground Production Scheduling With Activity Start Time Penalties and Variable Target Deviations

R. Amoako and A. Brickey; Mining Engineering and Management Department, South Dakota School of Mines and Technology, Rapid City, SD

For many operations, short-term production schedules are developed based on the medium-term schedule and expected operational conditions. They define an extraction sequence by specifying activity start dates at a fine fidelity, e.g., shift, over a time horizon of one to three months. Using a metalliferous hardrock underground mine as a case study, we develop short-term production schedules that honor the medium-term forecast by introducing activity start time penalties and variable target deviations. The results provide a realistic schedule with minimal deviation from medium-term goals with computational times appropriate for short-term plans.

2:25 PM

Interlevel Ore Handling Systems at PT Freeport Indonesia's Grasberg Block Cave Underground Mine

A. Parhusip; Underground Construction, Freeport Indonesia PT, South Jakarta, DKI Jakarta, Indonesia

The Grasberg Block Cave (GBC) mine is the largest underground operation in the Grasberg minerals district in Papua, Indonesia, and is operated by PT Freeport Indonesia. Interlevel systems are an integral part of the materials handling system in the GBC mine, connecting the extraction-level production to the haulage level. This allows the distributed extraction-level production across a large footprint (1km x 1km) to be collected and transported using a rail haulage system to a series of crushers. This gathering system and the efficient transport of ore is critical to achieving the planned 130,000 tons per day mining rate in GBC. The interlevel ore handling system is divided into three separate sections: the ore pass, the service level and the chute pass. Each area has its own set of unique challenges during construction and maintenance. This paper describes the construction process of the interlevel systems, the challenges experienced in construction and maintaining these critical sections, and reviews the monitoring and rehabilitation processes being applied to keep the interlevel ore handling systems as reliable and efficient as possible to support the mine production rates.

2:45 PM

Resilience in Mine Planning: Implementing Skarn Sequence in Response to Local Seismic Event at PTFI's Deep Mill Level Zone (DMLZ) Block Cave Mine

R. Bastiawarman[1], N. Nugraha[1], A. Anugrahanto[1], S. Lolon[2], T. Semestario[2], M. Erhardt[2] and D. Zulfi[1]; [1]Freeport Indonesia PT, Mimika District, Papua, Indonesia and [2]Freeport-McMoRan Inc, Phoenix, AZ

Mine planning at any stage, strategic to short-range, is susceptible to changes and for this reason, a risk assessment is an important step to help ensure plan readiness for such changes and what-if scenarios. Not all risks can be predicted or controlled, and therefore, mine planning must also possess resilience to allow for the development of contingency plans. PT Freeport Indonesia, one of the world's leading mining companies, recently had a valuable opportunity to demonstrate mine planning resilience in response to a local 2.5 Mw seismic event that occurred in January 2021 within the DMLZ mine footprint. The resulting damage from the event spread across multiple mining levels and was considered one of the largest events to date based on the magnitude and damage extent. This resulted in the delay of two adjacent mining blocks, PB1S and PB3. Following this event, a skarn concept was proposed to accelerate PB2 West, allowing the operation to achieve a reasonably same production target with higher caveability, accessibility, and manageable seismicity. This paper discusses the successful collaboration and lessons learned from adapting the adverse mining conditions into the mining plan

3:05 PM

Configuration Layout of a Supervisory System for Underground Mining Operations Based on 5G Technology and Wireless Platform

K. Pacheco Hague; Mining and Gelogical Engineering, SME Tucson Chapter, Tucson, AZ

Mines are constantly trying to improve production processes by optimizing work cycles, reducing operational delays, minimizing costs, controlling equipment utilization, and preventing occupational hazards. Currently, advances in digital mining technologies within the concepts of 5G and Industrial Touch Internet are allowing better control and monitoring of underground mining equipment, with centralized control systems that unify data analysis for proper decision making. A wireless 5G-based platform for controlling and monitoring system for underground mine operations can be designed over a comprehensive layout in where bandwidth selection, sensor location, Wi-Fi repeaters and power distribution are put together to build a successful supervisory system. A case study is presented for a medium-sized underground mine with a multi-level network which includes tablets managed by production supervisors, along with other data collection devices installed in semi-autonomous mining equipment, and distributing data in near-real time, with interconnection to support areas on the surface. Keywords: optimization, near-real time, wireless, workstation, 5G technologies, Industrial Touch Internet.

3:25 PM

Jointly Optimizing the Mine Design and Long-Term Underground Mine Production Scheduling under Uncertainty for Sublevel Open Stoping Operations

M. Furtado e Faria[2], R. Dimitrakopoulos[2] and C. Lopes Pinto[1]; [1]Department of Mining Engineering, Universidade Federal de Minas Gerais, Belo Horizonte, MG, Brazil and [2]Mining and Materials Engineering, McGill University, Montreal, QC, Canada

Conventional underground mine planning follows a sequential approach: the stope layout is initially conceived, followed by the design of primary and secondary developments; finally, the long-term mine production scheduling is optimized aiming to maximize the net present value (NPV). Available mine planning methods rely on estimated orebody models, which are a smooth representation of the mineral deposit, and ignore its inherent spatial uncertainty and variability. Additionally, the interdependencies between the involved steps are not considered, having adverse effects on the mine design, schedule and NPV. A two-stage stochastic integer program for the integrated optimization of stope design and long-term mine production schedule for sublevel open stoping operations is proposed. The method uses a set of geostatistical simulations to quantify grade uncertainty and variability and seeks to maximize the NPV, minimize the development costs and manage the risk of not meeting production targets. The application of the method at an underground gold mine generates physically different schedules with 11% higher NPV and two-year shorter life-of-mine compared to the sequential framework.

3:45 PM

Strategic Underground Mine Planning Through Nested Stopes and Constraint-Based Scheduling

K. Jetmore[2] and C. Roos[1]; [1]Mining Engineering, Montana Tech, Butte, MT and [2]Nevada Gold Mines, Winnemucca, NV

Developing a strategic underground mine plan is challenging and investigating multiple scenarios may take weeks. This process can be sped up using the Theory of Constraints to isolate the bottleneck mining activity and simplify the mine schedule process. This paper presents a technique to apply the Theory of Constraints to test multiple cutoff grade scenarios in Mineable Shape Optimiser and quickly produce many high-level production-based schedules that can be easily interpreted using stope-by-stope graphs, the Hill of Value, and through incremental return analysis.

MONDAY, FEBRUARY 28

AFTERNOON

2:00 PM | Big Room

MPD: MPD PLENARY SESSION

*Chairs: **D. Kappes**, Kappes Cassiday and Associates, Reno*
***R. Washnock**, Weir Minerals North America, Vail*
***M. Blois**, Orion Resource Partners, Highlands Ranch, CO*

***Antoine M. Gaudin Award** Presented by Robert Washnock – Recipient and Lecturer: James E. Gebhardt*
***Robert H. Richards Award** Presented by Michael Blois – Recipient and Lecturer: Kathleen Altman*
***Milton E. Wadsworth Award** Presented by Daniel Kappes – Recipient and Lecturer: Matthew I. Jeffrey*

MONDAY, FEBRUARY 28

AFTERNOON

2:00 PM | Room 15

SME YOUNG LEADERS: A NEW ERA OF STUDENT ENGAGEMENT

*Chair: **K. Tew**, Cementation USA Inc., Herriman, UT*
Sponsored by Rio Tinto

2:00 PM
Introductions

2:05 PM

Encouraging Young People to Join the Mining Industry – New Approaches in Empowerment Learning

L. Michael[1], T. Rudolph[1], P. Goerke-Mallet[1] and J. Kretschmann[2]; [1]Research Center of Post-Mining, Technische Hochschule Georg Agricola, Bochum, Nordrhein-Westfalen, Germany and [2]Technische Hochschule Georg Agricola, Bochum, Nordrhein-Westfalen, Germany

The mining value chain plays an important role in our societal development. Even in a circular economy, mining and raw materials are in great demand, and so are skilled engineers. With the German STE(A)M project PepperMINT, we offer a digital and open educational platform, as a dynamic, massive open, online course (MOOC) for students and prospective engineers. Using adaptable MOOC classes and applied examples from the wide-ranging cycle of mining activities, we motivate students to engage in STEAM studies. Our adaptive and application-oriented content demonstrates the diversity of jobs and career paths in the mining industry. The empowerment approach helps us train the mining engineers of the future.

2:25 PM

A New Era for Mining and Mineral Resource Education at the University of Arizona

B. Ross; Geotechnical Center of Excellence, University of Arizona, Tucson, AZ

The UofA is excited about the creation of its new School of Mining and Mineral Resources. The mission of the School is to transform how students, professionals, and communities work across boundaries to meet the complex challenges of supplying economically, socially, and environmentally sustainable mineral resources to meet the demands of today's society. The new School will use a multidisciplinary approach to expand and improve the delivery of mining and mineral resource education and research across campus. A new minor will be offered to students from any discipline, from accounting to systems engineering, who will graduate with a strong understanding of mining and mineral resources. This paper will discuss the overall philosophies and structure of the new School, describe the curriculum being developed for the minor, and review the progress made to date. Since one of the overall goals of the School is to build strong strategic partnerships, the paper will also describe how anyone can be a part of this exciting new initiative.

2:45 PM

MacLean Academy - A Blended Learning Approach for Safety and Skills Development in 21st Century Mining

S. Lister, Maclean, Collingwood, Ontario

MacLean is a mining vehicle manufacturer with an almost 50-year history in designing, manufacturing, and commissioning specialized underground mining vehicles around the globe. Historically, the commissioning phase revolved solely around hands-on training from an expert MacLean trainer. Increasingly, mining customers are looking for blended learning options to support the safe and productive use of their mobile fleets. As a result, MacLean has heavily invested in people and tools to support a blended approach to safety and skills training, from e-Learning to livestream training to virtual reality. Each technology is being applied in an integrated manner, towards delivering the most accessible, learner-engaging, cost-effective, and trackable training offer possible. This talk will focus on the MacLean development of the 'MacLean Academy' vision that links its underground test facility in Sudbury, Ontario, an ideal setting for hands-on training in an underground environment, with online learning, livesream training, and VR training technology development.

MONDAY, FEBRUARY 28

AFTERNOON

TAILINGS: TAILINGS MANAGEMENT FRAMEWORKS – A LANDSCAPE REVIEW

2:00 PM | Room 05

Chairs: ***A. Adams****, Stantec, Denver, CO*
R. Jansen*, Paterson & Cooke, Golden, CO*
K. Morrison*, Newmont Goldcorp, Lakewood, CO*
Sponsored by Newmont

2:00 PM

Introductions

2:05 PM

Site-Specific Approach for Developing Profiles of Critical State Soil Mechanics Parameters in Mine Tailings Deposits

J. W. Harvey, Barr Engineering Co., Minneapolis, MN, USA

Critical state soil mechanics (CSSM) has become increasingly integrated in the characterization of mine tailings deposits; however, practical application of CSSM has been problematic in mine tailings. Estimation of the in-situ state parameter from cone penetration testing (CPT) based correlations involves considerable uncertainty, and universally applying laboratory-derived CSSM parameters (λ and Γ) from only a few samples may not sufficiently characterize highly variable mine tailings. In this paper, the authors present an analytical and statistical approach to characterize a mine tailings deposit using site-specific laboratory and in-situ testing data to develop estimated profiles of CSSM parameters that more reliably capture the material variability. CPT is used to capture near-continuous profiles of the in-situ response, and index properties from adjacent boreholes are used to associate CPT responses with CSSM parameters derived in the laboratory and interpolated as needed. In so doing, profiles of CSSM parameters can be combined with other site-specific data to estimate profiles of in-situ state parameter and undrained shear strength with less generality and uncertainty.

2:25 PM

Tailings Draindown Estimates: Implementation and Considerations

N. Rocco

Implementation of post-closure draindown estimates for tailings facilities are important predictive tools to for reclamation planning and often influence jurisdictional bonding. Simplified estimates of draindown have been proposed in the past, but it is clear that simplified methods are not able to capture many of the operational and material parameters that influence robust draindown estimates. This paper will discuss an iterative approach that relies on an unsaturated flow model to predict draindown rates and an associated pond inventory water balance that tracks inputs into the pond system, solution volumes, active evaporation, and recirculation. Specific design criteria such as climate, facility geometry, material properties, and initial conditions, as well as active closure operational considerations that can be used to influence the draindown estimates will be discussed. Concepts presented will be valuable for closure planning and to guide analytical analyses that support tailings draindown estimates.

2:45 PM

Dam Safety Inventory and Semi-Quantitative Risk Analysis for Saskatchewan Potash Mines

A. Kalmes, Barr Engineering Company & B. Dehler, Barr Engineering Company & D. Kopp, Nutrien, Saskatoon, SK &A. Olesen, Nutrien Potash, Saskatoon, SK

Nutrien operates six potash mines in Saskatchewan and has been pro-active at maintaining the integrity of their tailings facilities through ongoing assessment, design, operation, inspection, and monitoring. Nutrien commissioned a system inventory and semi-quantitative risk analysis (SQRA) of all dikes in an effort to further enhance environmental stewardship and understand degree of alignment with shifting industry standards and governance frameworks. The inventory assessed nearly 100 dikes. Each dike was rated according to a probability and consequence factor and assigned a risk score. The risk scores were used to develop a risk matrix for each site and risk response actions for each dike. The inventories and SQRAs will help each site assess priorities for investigation and risk mitigation, if necessary. The study results will also help Nutrien refine corporate-wide tailings governance standards and a timeframe for compliance with various governance provisions that may be established in the future as the industry continues to advance its practices. This presentation will discuss the inventories, the SQRA approach, and how the SQRA was applied at a representative potash mine.

3:05 PM

Thickening 101 – Putting Theory Into Practice

G. Seale, Paterson & Cooke, Golden, CO

Tailings thickening remains a relatively misunderstood process with many attributing it to 'anecdotal' science and 'bucket' chemistry. Tailings thickening is typically at the end of the process and consequently the last unit operation considered during both design and operations. When operating well, thickeners are ignored and left to run independently with minimal supervision. However, when operating poorly, there is a lack of basic understanding and remedial actions to solve issues are reactionary rather than proactively addressing shortcomings.

This paper aims to clarify many aspects surrounding the thickener process. Topics will range from test work methods, coagulant and flocculant basics, feed system importance, rake mechanism design and thickener operational control philosophy. Industry 'rules of thumb' for thickener types, applications, sizing practices, design aspects, and troubleshooting techniques will be discussed. This paper will improve understanding so that thickeners are no longer a 'black box', and operators will be more self-reliant and less dependent on supplier participation.

3:25 PM

Inherent Uncertainties in Determining Breach Parameters Utilized in Numerical Tailings Dam Breach Analysis

S. Melberg, NewFields Mining Design and Technical Services, Lone Tree, CO & M. G. Walden, NewFields Mining Design and Technical Services, Lone Tree, CO & R. Berton, NewFields Mining Design and Technical Services, Lone Tree, CO.

The 2019 Brumadinho dam failure incident in Brazil, has influenced many mining industry regulators to reassess their requirements for the numerical modelling of tailings dam failure. A dam breach analysis that meets the requirements of industry standard, typically begins with identification of credible failure modes and the estimation of the total volume of tailings and water contained within the facility at the time of the breach. The volume of released tailings can then be determined considering the appropriate angle of repose or available empirical equations. Subsequently, the breach hydrograph can be developed using the released volume of tailings and embankment materials. The following technical paper aims to provide guidance on how to address a wide array of uncertainties inherent in determination of breach parameters and breach flow hydrograph. The common methodologies utilized in breach parameters estimation are reviewed and the pros and cons of available methods are listed. The procedure suggested in this article will help practitioners make a risk-based decision on choosing the most appropriate matrix of breach parameters utilized in numerical dam breach modelling.

3:45 PM

Planning for Ore Variability in Filtered Tailings Applications

G Barr, Twin Metals Minnesota, Ely, Minnesota

The design of the dewatering step of a filtered tailings project must consider ore variability to ensure the circuit can produce on-spec filter cake from the entire ore body, and not just from where a bulk sample or small sample program was conducted within the ore body. For the Twin Metals Minnesota project, tailings dewatering variability was incorporated into the projects' 140 sample geometallurgical test program. This presentation will review the results of the test program and how such a program increases confidence in the dewatering plant design being proposed for the project.

MONDAY, FEBRUARY 28

AFTERNOON

UCA: TUNNELS

2:00 PM | Room 04

*Chair: **L. Waddell**, Lane Construction, Fort Wayne, IN*

2:00 PM

Introductions

2:05 PM

Investigation of Fire and Product of Combustion Spread in an Underground Mine: A Case Study

O. Salami and G. Xu; Mining and Nuclear Engineering, Missouri University of Science and Technology, Rolla, MO

Fire accident is one of the most classic safety concerns in underground mines. Fire releases heat, smoke, and other toxic gases such as carbon monoxide to the surrounding. This will make life unbearable for the miners. Due to the danger fire accidents poses to mineworkers and underground facilities, the effort to develop novel techniques to help underground miners self-escape has continued to gain attention. Notwithstanding, understanding the fire characteristics and behavior in the underground is important to help develop such self-escape techniques. Presently, much of the currently available literature uses data obtained from scaled model tunnels in the laboratory. A thorough investigation of fire characteristics and behavior in a real underground mine is therefore important to establish a reliable evacuation model. The objective of this study is to investigate how fire, smoke, and gases spread in a real underground mine by conducting a full-scale fire experiment. The results presented from these studies are crucial to developing evacuation models in underground mines as they are more practical and reliable compared to the data obtained from the model tunnel fire experiment.

2:25 PM

Faster Underground Mine Development Using a Novel, Non-Circular Tunneling Machine

D. Ofiara; Engineering, Robbins, Solon, OH

Tunnel Boring Machines (TBMs) have been used in mining in decades past, but their use has been limited and sporadic. This has changed in recent years, with TBMs being used at Stillwater Mine, Grosvenor Coal Mine Slopes, Sirius Minerals potash mine, and more. These machines are all full face, circular TBMs—a design that has thus far have been unable to tackle a larger issue for mines: typically a flat floor is needed for mining vehicles to traverse. A novel type of non-circular boring machine is now answering the need to quickly reach underground ore bodies while cutting a rectangular profile in hard rock. This cross section allows for use of typical mine trucks and other rubber-tired mine vehicles. The machine uses disc cutters to cut the rock, and has a support structure similar to an open type TBM; however, the cutting geometry is entirely different. The machine is currently cutting an access tunnel at a silver mine. This paper reviews the design and operation of the novel non-circular tunnel boring machine, and describes possible future adaptations to provide safe, sustainable mine development.

2:45 PM

Electrical Distribution Daisy Chains: Why You Should Avoid Them

J. Fisher; Stantec, Tempe, AZ

In Underground Mine electrical distribution systems, connecting a large number of mine power centers (MPC) to a single protective feeder is commonly referred to as Daisy Chaining. When more than three MLCs are strung out on a single feed there are operational and safety considerations that are often not accounted for or suppressed for adhoc production needs. Overload issues, poor motor starting, high fault currents and more catastrophic fault events can occur resulting in poor production. This paper reviews the safety and operation considerations of Daisy Chaining, how to remediate them and how to avoid them.

3:05 PM

3D Numerical Study of Stress Concentration Around a Tunnel Opening Near a Major Discontinuity in a Rockburst-Prone Rock Mass

K. Mizero Dusingize; mining engineering, Colorado School of Mines, Golden, CO

Tunnels are an important part of the infrastructure of today's modern world. As tunnel construction gets deeper, however, the risks of rock burst depending on the geology and lithology of the area become greater. Among the different rock burst types, fault slip is of major concern during tunneling due to its concomitant high energy release that can be disruptive resulting in immense excavation damage and in some cases, or fatalities. Fault slip-induced rock failure is the result of reactivation of an existing major discontinuity originating from mining-induced stress redistribution that either reduces the clamping force across the fault, leading to reduced shear resistance along the fault or increases the shear force along the fault. Stress redistribution around the tunnel opening can be effectively predicted using 3D numerical methods considering the influence of various factors, such as surrounding rockmass characteristics, discontinuity strength, discontinuity orientation, stress ratios and stress orientations. This study uses RS3 numerical simulations to investigate the effect of a major fault on stress redistribution around the tunnel opening during the excavation process.

3:25 PM

Decentralized Communication System for Underground Operations Such as Tunnels and Mines as well as Industrial Plants

T. Krichler, TU Freiberg, Freiberg, Germany

Currently, data communication in underground facilities is mostly based on fully networked systems by standard IEEE 802, using a large number of access points or fiber optics and copper cables. Both options are hardly feasible for SMEs. In goaf or abandoned areas inside the mines, these are not practical at all, even for large mines.

A newly developed decentralized communication system is discussed in this study covering the issue of data transport. Measuring stations are based on low-energy microcontrollers and can be distributed anywhere in a mine. When a data controller (counterpart station) approaches a measuring station, connection is established and all data is transmitted to the controller. To obtain high transmission range while ensuring high data rate, 433 MHz modules are used combined with a byte-based communication protocol. This communication enables the system to be expanded arbitrary on demand even during operations. The data collector will forward all previously gathered information as raw data to a central server by a freely chosen communication technology, for further evaluation. The delay depends only on the round-trip time of the data collector.

TUESDAY, MARCH 1

MORNING

9:00 AM | Room 20

BULK MATERIAL HANDLING: TOOLS FOR IMPROVING CONVEYOR SYSTEM RELIABILITY AND EFFICIENCY

Chair: ***R. Fulmer****, Kraft Power*

Sponsored by Siemens

9:00 AM

Introductions

9:05 AM

Conveyor Asset Management

A. Hustrulid; Shaw Almex, Bonita Springs, FL

Covid-19 has forever changed the way we work and travel. There are now fewer people onsite and increased costs and difficulty in having specialists travel to site to do conveyor audits. There is a critical need for smarter, reliable, conveyor systems that can be monitored and managed remotely. A vast array of "sensors" that measure information about a conveyor system are available and have been employed. None of these technologies have resulted in the required step change in the performance of conveyor systems. With the Internet of Things (IoT), big data, artificial intelligence (AI), and machine learning (ML) these sensors can be brought together to make conveyors smart. This paper begins with a summary of sensor technology used on conveyors including x-rays, magnetic belt scanning, rip detection, rfid chips, lidar, width/tracking measurements, instrumented cleaners, tonnage, power, FLIR, sound, temperate, fiber optic sensing, vibration, drones, and wear gauges. It then discusses how the data from these sensors can be utilized to better manage conveyors, through digital twins and how AI and ML are being applied to make conveyor systems smarter to better manage these critical assets.

9:35 AM

Operational Savings Case Studies Arising From Conveyor Asset Monitoring

R. Grevenstuk and B. DeVries; Flexco, Grand Rapids, MI

Remote monitoring is here. But does it live up to the hype? Presentation contains a short review of the monitoring technology deployed, the actionable events generated by the system, and the tangible increased production results seen by operations.

10:05 AM

Discrete Element Modelling (DEM) – When to Use it and When to Avoid It

T. Holmes and C. Hartford; Jenike & Johanson Inc, Tyngsboro, MA

Discrete Element Modelling (DEM) is a remarkable tool for the analysis of bulk solids handling systems that continues to develop at a rapid pace exceeding the rate of improved computational capabilities. But is DEM the tool to solve all problems in bulk solids handling? Should DEM be used for everything from transfer chute design to stockpile and bunker design? We will discuss the state of DEM, the proper application of DEM, and when and where DEM should be applied giving case study examples.

10:35 AM

Pulley Lagging Friction: Beyond the Capstan Equation

B. DeVries; Flexco, Grand Rapids, MI

Investigation into the actual behavior of lagging friction found that the coefficient of friction is far from static as published by both CEMA & DIN. Presentation explores the roles of other factors and provides predictive tools towards understanding puzzling lagging wear events.

11:05 AM

Stockpile Stability – Understanding the Instability Triggering Conditions and How to Avoid Them

C. Hartford; Jenike & Johanson Inc, Tyngsboro, MA

Stockpiles are unstable by nature relying on their own angle of repose for support and are not often compacted beyond the strength of their own weight. When stockpiles collapse it can cause major safety and environmental issues along with loss of production and profits during clean up. We will discuss causes of stockpiles collapses, how to predict if a stockpile will fail, and steps to take to minimize the likelihood of failure and/or how to mitigate the effects of a collapsed stockpile.

TUESDAY, MARCH 1

MORNING

9:00 AM | Room 01

COAL & ENERGY: INNOVATIONS AND IMPROVEMENTS IN COAL MINING I

Chairs: ***Q. Huang****, West Virginia University, Morgantown, WV*

M. Rezaee*, The Pennsylvania State University, University Park, PA*

9:00 AM

Introductions

9:05 AM

Applying Ultra-Fine Coal Dewatering Technology to Refuse Tailings Disposal

M. Barish, Somerset International, Brisbane, Australia

Somerset International has successfully installed over 20 Sub325® Fine Coal Recovery Systems in the United States, Australia, Canada and Russia. These installations recover between 5TPH and 40TPH for the host sites. In addition to the increased revenue from the direct recovery of a recirculating load, host sites have seen benefits ranging from improved operation of refuse equipment to a reduction in the solids content of the refuse streams.

As slurry ponds and boreholes are becoming difficult to impossible to permit and operate, there is a need for a reliable, low-maintenance, continuous operation that can produce a handleable refuse cake. With this in mind, Somerset has taken the initiative to expand upon the capabilities of the Sub325® Fine Coal Recovery System to include Refuse Tailings Dewatering to allow for co-mingled refuse disposal.

The ability to dewater -325 mesh material is a vital piece of processing capability for the continued production of mining operations across the globe. This paper highlights the success that Somerset has had in the coal industry worldwide as well as the initial successes with iron ore tailings and laboratory and pilot scale success in phosphate.

9:25 AM

Geotechnical Study for In-Pit Coal Refuse Tailings Cell

R. Sheets, Barr Engineering & F. Abbasy, Barr Engineering, M. Haggerty, Barr Engineering

To address coal refuse tailings storage needs for a mine operation in western Canada, a feasible solution was to convert excavated open pits into tailings cells. A slope stability investigation and design study was completed to determine the necessary width and slope geometry for in-situ native plugs. The native plugs separate the previous open pit from the current active mining area. This configuration allows for the deposition of refuse tailings in the previous pit while allowing mining to safely continue "downstream" of the temporary impoundment. As mining progresses, each subsequent pit will be filled with refuse tailings; thereby, buttressing the upstream slope of the previous native plug. Although these cells are excavated and the timeframe for downstream exposure is relatively limited, the native plugs are classified as dams and must be designed to meet regulatory safety of dam standards. They are features impounding water and tails above personnel exposed in the subsequent open pit. The presentation and paper will discuss the investigation and analysis conducted to develop the geotechnical and hydrogeological design recommendations.

9:45 AM

Asset Maintenance Readiness (AMR)

E. Gutierrez; Maintenance, Reliability and Planning, Universidad Simon Bolivar, Caracas, Distrito Capital, Venezuela, Bolivarian Republic of Venezuela

Metso Outotec Asset Maintenance Readiness (AMR) provides a maintenance strategy specific to your operation and business needs. AMR will provide a Reliability and Maintenance plan that will form a foundation for your plant and equipment before start-up and during operation. Having a dependable maintenance strategy before start-up is critical, particularly those crucial first weeks and months during which you are ramping up and stabilizing your production. AMR integrates the as-built CAPEX Design, Procurement, Construction, and Commissioning data into Reliability Centred Maintenance methodology through the use of reliability engineering software. We provide highly competent RCM facilitation combined with product expertise and industry standards to ensure a structured approach, including where nec¬essary dedicated workshops, to define the complete maintenance strategy that is right for you. Our Asset Maintenance Readiness will ensure you have a complete maintenance strategy that is tailored and optimized to give you the best results.

10:05 AM

Production of High-Value Carbon Products from Waste Coals Using the Hydrophobic-Hydrophilic Separation Process

C. Sechrist, S. Keles, A. Noble, R. Yoon, K. Huang, N. Youmans and J. Reyher; Mining and Minerals Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA and Minerals Refining Company, Richmond, VA

The recovery of ultra-fine particles, particularly those less than 44 microns, is a longstanding challenge for the coal industry. Conventional separation pro¬cesses, such as flotation, are unable to effectively upgrade this material, and as a result, many operators discard coal fines to slurry impoundments cre¬ating environmental liabilities. Some estimates show that the amount of coal currently stored in impoundments in the US exceeds 6 billion tons. To ad¬dress this challenge and provide a pathway for converting this liability into a valuable resource, Virginia Tech and Minerals Refining Company (MRC) have jointly developed the Hydrophobic-Hydrophilic Separation (HHS) process. Un¬like flotation, this novel process has no lower particle size limit and produces a dry product. This presentation describes the testing and optimization of a pilot-scale embodiment of the HHS process. Results to date on bitumi¬nous and anthracite coals show that the process can produce coal products with less than 1.5% ash and 2% moisture. In addition, opportunities for new product markets for this rich carbon product will also be discussed.

10:25 AM

Hybrid Microfluidic Chemical Speciation of Free Radicals-laden Silica Dust for Wearable Real-time Monitoring Applications

I. Paprotny and N. Jayakumar; Electrical and Computer Engineering, University of Illinois at Chicago, Chicago, IL and Mechanical Engineering, University of Illinois at Chicago, University of Illinois at Chicago, Chicago, IL, US, academic, Chicago, IL

Exposure to respirable silica dust in underground coal mines can cause detrimental airway diseases such as coal worker's pneumoconiosis (CWP), silicosis, and lung cancer. In this paper, we present a real-time hybrid mi¬crofluidic method for detecting of free-radicals in freshly ground aerosolized silica. This is motivated by the fact that free radical levels in respirable silica dust seem to be an important factor in the development of pneumoconiosis. Mechanical grinding of quartz was reported to generate free radicals with a half-life of 24 hours. We show a simple modified detection method modified for wearable application using microfluidics. It uses diacron reactive oxygen metabolites (d-ROMs) test and transition metals to catalyse in the presence of peroxides with formation of free radicals. Named the Fenton reaction – it delivers reactive oxygen species that are trapped by a colorometric subt¬strate – alchilamine, forming a colored radical detectable at 505 nm. ISO Respirable silica dust is deposited onto a liquid substrate, then mixed with reactants and incubated at 37 degrees Celsius to be read for optical density. Optical detection would be performed inside the device.

TUESDAY, MARCH 1
MORNING

9:00 AM | Room 02

COAL & ENERGY: INNOVATIONS IN MINE HEALTH & SAFETY

Chairs: ***P. Tukkaraja****, South Dakota School of Mines and Technology, Rapid City, SD*
K. Raj*, CDC NIOSH, Spokane, WA*

9:00 AM
Introductions

9:05 AM
A Novel Methodology to Locate an Abnormal Airflow in Underground Mine Ventilation Networks

D. Bahrami and L. Zhou; CDC NIOSH, Pittsburgh, PA

Mine ventilation is one of the most important aspects of mining operations in underground mines. It is critical to maintain and deliver required fresh air to the work zones, where miners are working, to reduce the risk of over-exposure to hazardous contaminants or explosive atmospheres. An unexpected event such as roof collapse, mine door closure/opening, a fire/explosion, or fan malfunction could adversely alter the airflow distribution within the mine ventilation network that could lead to a hazardous condition. Knowing the location of such incident is of critical importance. In this paper the authors developed a novel methodology to assist mine operators in quickly identifying the location of any abnormal airflow change within the network using the airflow changes at monitored airways. The concept is based on a direct derivative method developed by authors. The paper provides the detail of the developed method as well as numerical verification examples. The application of this method can benefit mine operators and safety personnel to make better decision during a mine emergency response operation to mitigate hazardous conditions arising from an unexpected airflow disturbance.

9:25 AM
Thermal Imaging Changing Mine Predictive Maintenance Practices.

P. Fostvedt; FLIR, Flir Systems Inc, Wilsonville, OR

CNA Insurance estimates its insureds whose electrical and mechanical equipment was tested with thermal imaging technology have realized substantial savings through lower repair costs, reduced unplanned shut downs, lower electrical costs and a safer work environment. Both fixed mounted and portable non-contact thermal imaging technology allow users to safely assess the condition of critical electrical and mechanical equipment within mining, utility and manufacturing operations and with technology advanced features can accurately determine temperature measurements, provide equipment trending information in a logical sequence for faster troubleshooting and repairs.

9:45 AM
Survey of Electromagnetic Emissions in Underground Coal Mines

R. Jacksha[1], C. Zhou[2], N. Damiano[2] and J. Srednick[2]; [1]Spokane Mining Research Division, Centers for Disease Control and Prevention, Spokane, WA and [2]Pittsburgh Mining Research Division, Centers for Disease Control and Prevention, Pittsburgh, PA

Modern electronic devices and systems used to enhance miner safety and health are becoming commonplace in underground coal mines. The ability for these devices and systems to function properly in the presence of electromagnetic emissions from other electronic and electrical devices and systems is not entirely understood. To investigate potential electromagnetic compatibility issues of critical mine electronic devices and systems, researchers from the National Institute for Occupational Safety and Health (NIOSH) are conducting surveys of electromagnetic emissions in underground coal mines. This paper presents the measurement system, methods, and results of electric field electromagnetic emission surveys conducted in three underground coal mine environments in the frequency range of 10 kHz to 1000 MHz. The survey data show that in some environments electric field electromagnetic emissions in underground coal mines approached or slightly exceeded limits as defined by other industrial sectors.

10:05 AM
Bio-Scrubber for Mine Ventilation Air Treatment

S. Jayaraman Sridharan[1], P. Obulisamy[2], P. Tukkaraja[1], V. Gadhamshetty[2] and J. Connot[3]; [1]Mining Engineering and Management, South Dakota School of Mines and Technology, Rapid City, SD; [2]Civil and Environmental Engineering, South Dakota School of Mines and Technology, Rapid City, SD and [3]Sanford Underground Research Facility, Lead, SD

Ventilation is the lifeblood of an underground mine and contributes significantly to total mine energy consumption. Other than dilution techniques, no technology is available to reduce or remove the toxic air pollutants from the mine ventilation air. Therefore, the development of new technologies for underground ventilation is essential to reduce energy and operational costs, enhance the health and safety of the miners, and increase productivity. In this study, a 3D-printed biofilm mat (3D-PBM) is developed and used to remove blast pollutants from the mine ventilation air at Sanford Underground Research Facility (SURF, Leads, SD). The blast pollutant concentrations are calculated using real-time gas monitoring data collected from a drift development operation at SURF and used as a base value for enrichment followed by treatments. A laboratory airflow setup with blast fumes injection is used to test the performance of the 3D-PBM in removing the blast pollutants. This study demonstrates the application of indigenous microbial community (biofilm) for removing toxic air pollutants from mining operations.

10:25 AM
Liquid Oxygen Storage Module Core Research for Next Generation Closed-Circuit Respirators

R. Fernando; NPPTL, National Institute for Occupational Safety and Health, Pittsburgh, PA

The Liquid Oxygen Storage Module (LOXSM) is an innovative concept to store oxygen in solid-state form, according to physisorption processes at any cryogenic temperature; and deliver it as a gas into the breathing loop of a closed-circuit respirator (CCR). The Core of the LOXSM employ nano-porous aerogel composites to store large quantities of fluid molecules in a physisorbed solid-state condition at moderate pressures and cryogenic temperatures. Through an inter-agency agreement with NASA – Cryogenics Test Laboratory, potential core material were researched to select the best candidates for oxygen storage and also potentially carbon dioxide sequestering from the breathing air. Prototype core modules were prepared for liquid oxygen loading and tests conducted using equipment built for this purpose. This presentation is on the results of core selection and preliminary design of the LOXSM for use in a CCR. When this core technology is integrated in future designs of LOXSMs, there is the possibility that closed-circuit respirators, especially closed-circuit escape respirators can be made to be smaller than the current devices.

10:45 AM

Evaluation and Testing of Pressure Relief Valves for Refuge Alternatives Subjected to Explosive Forces (Coal/methane Dust Explosion)

J. Calnan[1], L. Velasquez Acero[1], T. Petrov[2] and J. Silva[1]; [1]Mining Engineering, University of Kentucky, Lexington, KY and [2]Turbulence Analytics, LLC, Lexington, KY

Little research has been done in the evaluation, through testing, of refuge alternatives (RA) under explosive conditions. Moreover, no studies have been conducted to evaluate the performance of these structures when they are subjected to the NIOSH's recommended explosion pressure-time curve (triangular impulse overpressure of 103 kPa (15 psi) peak and 200 ms duration). A key component of the RA is the pressure relief valve (PRV). The PRVs are installed to exhaust the used air, keeping the internal pressure of the RA below a maximum recommended value (1.25 kPa). The University of Kentucky Explosive Research Team (UKERT), in a project funded by NIOSH, tested various PRV. This paper shows the development of a shock tube at UKERT to achieve the recommended testing pressure-time curve and the test results of the PRV explosion tests. The physical testing was supported by computational fluid dynamics analyses (CFD). Results indicate that the PRVs can stand a triangular time-pressure curve of 15 psi amplitude and a 200-ms duration. Besides, the valves kept working after being subjected to explosive forces and maintained the internal pressure of refuge alternatives below recommended values.

TUESDAY, MARCH 1

MORNING

9:00 AM | Room 03

COAL & ENERGY: RARE EARTH ELEMENTS IN COAL

Chairs: ***T. Ghosh****, University of Alaska Fairbanks, Fairbanks, AK*
X. Yang*, University of Kentucky, Lexington, KY*

9:00 AM

Introductions

9:05 AM

Ammonium Sulfate Leaching of Alkali-treated Monazite Under Mild Conditions

W. Liu and R. Yoon; Department of Mining and Minerals Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA

A novel method of extracting rare earth elements (REEs) from monazite has been developed. It consists of displacing the PO43- ions by OH- ions under conditions of relatively mild NaOH treatment, followed by ammonium sulfate ((NH4)2SO4) leaching at pH 4 and room temperature. In the first step, a monazite sample was treated in 30-50% NaOH solutions at 80°C to obtain recoveries in the range of 60-80% of the total rare earth elements (TREEs) depending on the particle size and reaction time, while the recoveries of certain elements were considerably higher. Lixiviants other than the ammonium sulfate were also tested with varying successes. A series of z-potential measurements coupled with thermodynamic studies suggest that the (NH4)-2SO4 leaching is one of ion-exchange extraction, in which the REE3+ ions in the vicinity of the NaOH treated monazite are displaced by the NH4+ ions.

9:25 AM

Correlations between the Mineralogy and Recovery Behavior of Rare Earth Elements in Coal Refuse

W. Zhang, B. Ji and Q. Li; Virginia Tech, Blacksburg, KY

Considerable efforts have been devoted on rare earth element (REE) recovery from coal-related materials, which has been progressed from a feasibility assessment to a pilot-scale production stage over the past several years. Regardless of the great progress on the recovery aspect, the mineralogy of REEs in coal-related materials is still obscure, and existing mineralogical studies reported in the literature are insufficient to explain the recovery behavior of REEs. Therefore, the authors performed a comprehensive study on the mineralogy of REEs existing in the coal refuse of two different seams. The study was also performed on leaching, calcination, and calcination-leaching products of the raw materials. Conclusions regarding REE mineralogy in the samples were obtained based on the elemental composition of hundreds of REE-bearing particles found using SEM-EDS. Meanwhile, changes in REE mineralogy resulting from leaching and calcination were also determined by comparing REE-bearing particles found from the different samples. Combining with REE recovery results, reliable correlations between the mineralogy and recovery behavior of REEs from the coal refuse were established.

9:45 AM

Enhanced Heavy Rare Earth Recovery from Bituminous Coal-Sources using Acid Baking

A. Nawab, X. Yang and R. Honaker; Mining Engineering, University of Kentucky, Lexington, KY

This study investigated a novel pre-leach treatment process aimed at enhancing the total rare earth recovery (TREE), especially heavy rare earth elements (HREEs), from bituminous coal sources while utilizing lower quantities of acid. The two-stage process involved roasting the solid coal waste material at 600°C followed by acid baking using sulfuric acid. Direct roasting at 600°C increased light rare earth (LREE) recovery to around 38.3% and HREE recovery to 21.3%. By acid-baking the roasted product, recovery values were increased to 77.0% for the LREEs and 79.6% for the HREEs. The results showed an association between REEs and aluminum (Al). Tests performed on pure kaolinite and illite samples, which are common clay types present in coal, indicated that the elevated REE recovery values achieved by acid baking were partially due to the release of REEs from clays. The results obtained from a systematic study on two coal sources will be presented.

10:05 AM

Recovery of REEs from Coal Coarse Refuse Via Heap Leaching – An Applied Approach

J. Werner and R. Honaker; Mining, University of Kentucky, Sadieville, KY

As part of an ongoing Department of Energy project the feasibility of recovering rare earth elements (REEs) from coal byproducts was investigated via heap leaching. In the first scenario, a 65' X 65' test pad was constructed and operated with acid generated from pyrite oxidation and circulated to the heap. A second scenario was tested where the acid was generated in situ via a 3 factor 2 level design of experiments in a set of leaching columns to evaluate REE recovery. The results are presented to evaluate the feasibility of the recovery of REEs from coarse refuse via heap leaching and the efficacy of biologically generated acid from pyrite oxidation.

TUESDAY, MARCH 1

MORNING

9:00 AM | Room 07

ENVIRONMENTAL: GREEN MINING PART II - TECHNOLOGY

Chairs: ***T. Graham****, Freeport McMoRan, Mesa, AZ*

G. Sutton*, Cemenation USA, Bunker, MO*

E. Vahidi*, University of Nevada Reno, Reno, NV*

9:00 AM

Introductions

9:05 AM

Newmont Energy and Decarbonization Program Overview

V. Gosteva; Asset Management, Newmont Corporation, Greenwood Village, CO

In November 2020, Newmont announced industry-leading climate targets of 30% reduction in greenhouse gas (GHG) emissions by 2030, with an ultimate goal of achieving net zero carbon emissions by 2050. In the following months, Newmont launched its Energy & Decarbnization Program, issued the inaugural Climate Strategy Report, and advanced on a number of activities on the pathway to climate targets. The Energy and Decarbonization Program is composed of several working groups with the focus on continuing to value robust governance and transparent reporting; advancing the use of renewable energy and other carbon reduction technologies; building further energy efficiency; evaluating technologies that would enable us to get to carbon neutrality; and establishing targets and expectations of our partners and joint ventures. In this presentation, we will provide an update on the progress of the E&D Program and will provide examples of the low carbon technology solutions that have been either implemenetd or are being evaluated in Newmont's decarbonization roadmap.

9:25 AM

Employing Cleantech to Increase Productivity and Energy Efficiency at Open-Pit Mines

C. McKinnon[2], S. Tafazoli[3] and D. Cheng[1]; [1]Marketing, Motion Metrics, Vancouver, BC, Canada; [2]ESG Relations, Motion Metrics, Vancouver, BC, Canada and [3]Executive Team, Motion Metrics, Vancouver, BC, Canada

Climate change is the central challenge facing the mining industry, wherein producers must simultaneously ramp up production to provide the raw materials needed for clean technologies while transitioning to carbon neutrality. While transitioning to renewables will take time, mines can start improving energy efficiency while improving productivity today. This paper proposes a novel technology ecosystem that can help. By monitoring mine shovels, loaders, haul truck paths, and conveyor belts, the proposed technology enables particle size measurements throughout the operation, truck and belt volume monitoring, ground engaging tools monitoring, and boulder detection.

9:45 AM

Greenhouse Gas (GHG) Reduction Potential in the Mineral Industry Through Smart Fleet Management

D. Huo, Q. Zhang and Y. Sari; Robert M. Buchan Department of Mining, Queen's University, Kingston, ON, Canada

Greenhouse gas (GHG) emissions from primary mineral and metal production (excluding fossil fuels and mineral aggregates) account for ~10% of global GHG emissions. One of the main sources of GHG emissions in mining operations is the fuel consumption by haul trucks. Given their size and carrying capacity, the diesel consumption of haul trucks can approach 250 litres/hour. An average of 30% of the idle time of the trucks is spent while waiting in the queue for loading. Inefficient truck dispatch planning can waste resources, cause dilution, increase costs and elevate GHG emissions. A machine learning based truck dispatch approach has been developed to dynamically route haul trucks based on loaded material, road traffic, estimated wait time, and maintenance needs. We estimated the GHG reduction potential of this smart fleet management approach by calculating and comparing the related carbon emissions. Results suggest that this dynamic fleet allocation approach can reduce GHG emissions at mineral production sites by optimizing waiting times and the overall distance travelled while achieving the same production levels. The implication of heavy-duty electric trucks will also be discussed.

10:05 AM

Evaluating The Results of the Adoption of BEV service Vehicles

A. Griffiths; Mohawk College of Applied Arts and Technology, Hamilton, ON, Canada

Based on the past 12 months MacLean Engineering has gathered and analysed data from our BEV service Vehicle Fleet. The fleet size is 35 vehicles in operation and it will encompass units from Boom and Deck Truck to Cassette Carriers and also Shotcrete Sprayers, U/G Graders and other service and support equipment. This will show a wide cross section and summary of what service and support BEV units have on existing operations. Evaluated data will show daily, monthly performance numbers. Data collected will include; -run time. -time spent re-generating. - charging time. -idle time. -Unit operating time when plugged in. (for those units that have a cable reel, such as bolters and sprayers.) -Unit availability time. -work output numbers (i.e. number of bolts, qty. of shot crete sprayed, loads carried) Now that BEV units are being adopted on a wider scale, what effect is it having on mining projects and operations.

10:25 AM

Replacing Combustion Engines with Hydrogen Fuel Cells to Power Mining Haul Trucks: Challenges and Opportunities

A. Akinrinlola and K. Awuah-Offei; Thomas J. O'Keefe Institute for Sustainable Supply of Strategic Minerals, Missouri University of Science and Technology, Rolla, MO

With the proven advantage of higher energy density in hydrogen fuel cells over batteries, there is potential to apply fuel cells, in combination with batteries, to power mining haul trucks. This paper aims to highlight the major challenges and possibilities associated with integrating hydrogen fuel cells in mining haul trucks. The approach is to model a fuel cell electric haul truck, analyze fuel consumption for different duty cycles and compare differences in components with existing combustion engines. The work then uses the simulation results to identify the challenges and benefits of hydrogen fuel cell trucks. The preliminary results show that the main challenges are space and cooling requirements for the fuel cell trucks while the potential benefits include reduced carbon emissions. This work will help demonstrate the potential and challenges of using hydrogen fuel cells in the haulage system and facilitate better decision-making relative to fuel cell applications in mining.

10:45 AM

Characterizing Novel Bio-Inspired Glycolipid Surfactants for Mining Applications

K. Graves, R. Maier and D. Hogan; University of Arizona, Tucson, AZ

Surfactants are widely used in the mining industry for technologies such as flotation and dust suppression. Recently, advances in synthetic chemistry have enabled production of novel glycolipids with structures based on biodegradable and low-toxicity biosurfactants. Very little is known of the chemical characteristics of these new glycolipids. Therefore, a suite of glycolipids was investigated to determine their critical micelle concentration, minimum surface tension, emulsification index, and frothabiltiy index. These characteristics provide important insight into the potential uses for green glycolipids that can reduce the environmental footprint of surfactants used in the mining industry.

11:05 AM

Green Surfactants for Mining Applications: Biodegradability of Glycolipid Surfactants

A. Murrieta, R. Maier and D. Hogan; Department of Environmental Science, The University of Arizona, Tucson, AZ

There are numerous applications for surfactants in the mining industry, e.g. flotation and dust control. Due to widespread surfactant use, it is vital that these materials pose low risk to the environment in case of unintentional release or when disposal of solutions is desired. One environmental parameter to consider when selecting materials is biodegradability. Bio-inspired glycolipid surfactants have proven potential for mining applications, but their biodegradability has not been assessed. In this study, the biodegradability of a series of glycolipid surfactants is demonstrated and categorized according to Environmental Protection Agency standards.

TUESDAY, MARCH 1

MORNING

9:00 AM | Room 08

ENVIRONMENTAL: MINE WATER MANAGEMENT

Chairs: ***J. Tatum****, Brown and Caldwell*

L. Williams*, Brown and Caldwell, Phoenix, AZ*

Sponsored by Barr Engineering

9:00 AM

Introductions

9:05 AM

Developing a Strategy to Meet Water Sustainability Goals

T. Douglass; Brown and Caldwell, Boise, ID

Recent shifts in sustainability have enhanced the need for companies to develop new water sustainability goals. The process of establishing appropriate goals, developing a plan to execute them, and preparing a method for tracking and reporting progress can be challenging. Having worked through all phases of this process, we will discuss what it means to make a water sustainability commitment. We will explore methods for identifying, prioritizing, and selecting projects that best suit an organization's sustainability commitment and operational objectives. The way a company presents progress on its goals and return on investment is critical to the program's success.

9:25 AM

Making Informed Operational Decisions for Water Management at a Remote Legacy Mine Using a Probabilistic Water Balance Model

D. Kolstad and C. Anderson; Barr Engineering Co, Minneapolis, MN

Operators are often challenged with the management of water throughout the life cycle of a mine. High water levels can lead to physical or chemical instability of water-retaining structures. Operators need to predict changes in water levels to make timely operational decisions and plan for contingencies, particularly in remote legacy mines. A closed mine in northern Canada with no permanent on-site personnel had a simple water balance model that was effective for decades to inform annual water treatment operations. In recent years the region has experienced more precipitation and higher water levels, triggering emergency response activities and putting a strain on treatment campaigns. A calibrated probabilistic model was used to provide enhanced prediction capabilities and to identify key sensitivities in the water balance for monitoring. A several year case study shows the value that this modeling tool provided for mobilizing personnel and performing response actions, particularly the inclusion of probability paired with forecasted pond water levels. Annual drawdown targets were subsequently established which provided more certainty in scheduling of annual treatment operations.

9:45 AM

Geochemical Model to Predict Aquifer Restoration Following Low pH In-Situ Uranium Recovery

K. Johnson[1] and B. Schiffer[2]; [1]Barr Engineering Co, Minneapolis, MN and [2]WWC Engineering, Sheridan, WY

Demonstrating aquifer restoration is an essential component of regulatory approval needed to mine uranium, copper, and other minerals by in-situ recovery (ISR). A PHREEQC geochemical model provided a useful means of forecasting the time for restoration and predicting future groundwater quality following low pH mining at Strata Energy's Ross ISR Project in northeast Wyoming. The model simulated groundwater quality at three phases of the process: at the end of mining; during restoration; and post- restoration. The model utilized the one-dimensional reactive transport and dual porosity features of PHREEQC. Mineral surface ion-exchange, dissolution/precipitation reactions, and adsorption processes were simulated to estimate water quality as the pH was shifted from circumneutral to acidic and back to neutral during restoration. The model results showed that cost-effective management of mine water could meet regulatory requirements. Additionally, the model was used to interpret results from a field trial and inform operational decisions. The predictive approach and geochemical understanding developed have application in assessing aquifer restoration for other ISR projects.

10:25 AM

Wetbud: A Constructed Wetlands Design Tool

C. Gerwig[1], Z. Agioutantis[1], S. Stone[2], W. Daniels[3] and M. Rolband[4]; [1]Mining Engineering, University of Kentucky, Lexington, KY; [2]Wetland Studies and Solutions, Richmond, VA; [3]Virginia Polytechnic Institute and State University, Blacksburg, VA and [4]Resource Protection Group, Catlett, VA

Creating constructed wetlands is often a key part of mining infrastructure to remove heavy metals and contaminants from mining wastewaters. Constructed wetlands are relatively low cost in construction and maintenance in comparison to traditional wastewater treatment plants, provided there is sufficient land access for them to be used. This makes them an attractive option for mines needing to reduce acid mine drainage so that wastewaters can meet EPA regulations to be released into the environment. Wetbud is a design tool for wetland creation. In wetland water budgeting, there is a wide variation in water budgeting approaches across various agencies and consultants. Wetbud offers a variety of water budget calculation options including the Penman-Monteith method, Thornthwaite equation, and a user-defined series for calculation of evapotranspiration. The program includes 130 preloaded weather stations for user calibration to site conditions. Wetbud allows users to design an appropriate constructed wetland to meet the water filtration needs of their mining operation.

10:45 AM

Real Time Environmental Monitoring of Effluent Surface Water of a Tailings Facility: A New Approach to Surface Water Monitoring

M. Peters, G. Heath and M. Momayez; Department of Mining & Geological Engineering, University of Arizona, Tucson, AZ

Advanced automated monitoring techniques have recently gained traction within the mining industry due to their high reliability, and real-time remote monitoring capabilities. This can give operators the possibility to predict potential safety hazards or exceedances of environmental regulatory compliance limits A case study is presented for an tailings dam effluent water discharge monitoring system that collected laboratory grade water chemistry data between October 2016 and September 2021. Our study evaluated the feasibility of implementing such a system onto a mine site and determined if the system could be an advantage to operators.

11:05 AM

Impacts Assessment to Wetlands During Mine Development – Looking Beyond Drawdowns

V. Tandon, J. Wozniewicz and M. Nimmer; Mining, Foth Infrastructure & Environment, Saint Paul, MN

Mine operators and regulatory agencies are often required to predict and document impacts to wetlands associated with dewatering during open pit and underground mine operations. This is typically done by predicting drawdowns in groundwater caused by dewatering and establishing a not to exceed threshold and followed by implementing a monitoring program. Modeling at a mid-western US mining site indicates other criteria besides drawdown may serve as complimentary indicators of mine dewatering impacts. These include projected and measured changes in 1) groundwater flux to wetlands, and 2) the recharge/discharge relationship between wetlands and surrounding groundwater.

TUESDAY, MARCH 1
MORNING

9:00 AM | Room 06

HEALTH & SAFETY: APPLIED AND SURVEILLANCE RESEARCH IN RISK MANAGEMENT AND TOTAL WORKER HEALTH

Chairs: ***R. Walton****, Rio Tinto Kennecott*
A. Richins*, University of Utah*

9:00 AM
Introductions

9:05 AM
Freeport-McMoRan Tyrone Mine Wellness Pilot – We Owe Our Employees More Than Just a Paycheck

C. Mitchell, R. Vinroot, E. Bower and J. Taylor; Freeport-McMoRan Inc, Phoenix, AZ

The Freeport-McMoRan Wellness Program began five years ago with a pre-work warm-up to reduce risk of sprain and strain injuries. The results were outstanding, and soon expanded to all North American properties. Building off the success, we expanded to include areas in movement, nutrition, and lifestyle. Our goal is to make a difference in employees' lives by delivering a program that helps the workforce, yet is not seen negatively. The Tyrone Mine was our pilot site for this project to improve its focus on safety and people. We teamed with our corporate benefits group to serve as ambassadors for existing company benefits. Next, we evolved the pre-work warm-up program to focus on movement patterns, benefiting employees at work and home. Future initiatives will be guided by employee feedback. Our long-term goal is a wellness toolbox used by individual sites based on specific needs vs. a one-size-fits-all approach. We aim to build a healthy, resilient, productive workforce who are physically and mentally capable at work and home. Our employees are valuable assets that we believe we owe more than just a paycheck!

9:25 AM
Hand and Finger Injuries in the U.S. Mining Industry, 2011-2017

J. Heberger[1], M. Nasarwanji[1], J. Pollard[2] and L. Kocher[1]; [1]Pittsburgh Mining Research Division, National Institute for Occupational Safety and Health, Washington, DC and [2]National Personal Protective Technology Laboratory, National Institute for Occupational Safety and Health, Pittsburgh, PA

Injuries associated with hands and fingers are highly prevalent in mining. Identifying factors associated with these injuries are critical to develop prevention efforts. This study identifies non-fatal injury incidence rates, nature, work activities, glove usage, and sources of hand and finger injuries in the US mining industry, as reported to MSHA from 2011-2017. Hand and finger injuries occur at a rate of 6.53 per 1,000 full time employees, which is nearly double the rate of the next highest affected body part, the back. Most of the injuries were classified as cuts/lacerations/punctures (53%) followed by bone fractures/chips (26%). Materials handling and maintenance/repair were common activities at the time of the injury. Although information on glove use was limited, leather gloves were most often worn when an injury occurred. When worn, gloves were found to contribute to 20% of the injuries, indicating their potential to protect the hands; but also potentially put the hands at risk. Using gloves with appropriate protection against specific hazards are critical for preventing hand and finger injuries.

9:45 AM
Findings From a Systematic Review of Fatigue Interventions: What's (not) Being Tested in Mining and Other Industrial Environments

Z. Dugdale[1], B. Eiter[1], C. Chaumont Menendez[2], I. Wong[3] and T. Bauerle[1]; [1]Spokane Mining Research Division, National Institute for Occupational Safety and Health, Washington, DC; [2]Division of Safety Research, National Institute for Occupational Safety and Health, Morgantown, WV and [3]Division of Science Integration, National Institute for Occupational Safety and Health, Cincinnati, OH

Fatigue negatively impacts mine worker health and safety. We conducted a systematic review to identify fatigue interventions that have been tested on industrial shiftworkers and to explore their effects and the factors that may influence their application in an industrial setting, like a mine site. Bright light interventions improved sleep and alertness, while blue-light blocking glasses and sleep hygiene and alertness trainings were less effective. Factors such as timing, duration, and content influenced an intervention's effectiveness. Critically, no fatigue interventions were tested in mining. Future research is needed to identify best practices for implementing fatigue interventions in mines and to evaluate their effects on mine workers.

10:05 AM
Exploring Fatigue Management of Haul Truck Drivers Through Socio-Technical Perspective

S. Lee and P. Rogers; College of Mines and Earth Science, The University of Utah, Salt Lake City, UT

Fatigue management is becoming a more widely studied subject due to increased consideration for the "fitness for duty" of equipment operators at mines. This research aims to understand fatigue awareness, characteristics of fatigue among haulage truck drivers in mines, the action that has been taken against fatigue, and the social acceptance of the fatigue monitoring technology. Several research accounts for the 'tangible' factor of fatigue (ex. cost, operation, or profitability); yet, the 'intangible' factors (ex. culture, experience, or social acceptance) are under-researched (Gruenhagen et al. 2020). A survey is developed and aligned with the result of the focus groups and distributed to operators in four mine sites. The data is analyzed through three dimensions: mine sites, job experience, and the overall driving experience. A simple t-test is performed, and the initial analysis shows an interaction between the dimensions and the response. Through this research, we can understand fatigue monitoring (from operators' perspective) and awareness, leading to a better understanding of fatigue management.

10:25 AM
Groundfall Risk Assessment Methodology to Minimize the Number of Fatal Accidents in Artisanal and Small-Scale Mining (ASM): Miner's Perceptions in Human Behavioral Factors

C. Navia Vasquez[1], S. Cabrera Falcon[2], L. Moscol Sandoval[3] and R. Kaunda[1]; [1]Mining Engineering, Colorado School of Mines, Golden, CO; [2]Junin, Universidad Continental, Huancayo, Huancayo, Peru and [3]Universidad Nacional de Piura, Piura, Peru

Artisanal and Small-scale Mining in Peru involves a wide range of practices based on highly informal and low-mechanized mining operations and becomes even more challenging with limited equipment and training. Unfortunately, hazards in ASM are not properly identified, and the miners do not understand the associated risks. This study proposes a groundfall risk assessment tool that is systematic, simple, and economical to assess hazards estimating potential risks based on the identification of geomechanical, operational, design, and human behavioral factors. From the Peruvian Ministry of Energy and Mines, 44 fatality reports have been meticulously compiled, and also surveys were carried out to informal miners and Peruvian mining engineers in order to obtain their perceptions of their work on safety, mining operations, and geomechanics, that are influencing groundfall fatalities. As a result, it has been possible to show that the main factors that are influencing groundfall accidents in ASM are behavioral factors, non-compliance with safety protocols, lack of experience in young people between 20 and 35 years old, the presence of fractures, wedges, and fake walls in underground mining.

10:45 AM

Culture, Climate, and Safety in a Coal Mine – Observations Over Five Years

A. Richins and M. Nelson; Mining Engineering, University of Utah, Salt Lake City, UT

Culture and climate are terms use to describe the human conditions in a work place. Culture is understood to be the conditions as defined by the company and its management, to facilitate and encourage safe and productive performance by employees, while climate is the relationship that exists among the employees. Culture and climate are always related—each affects the other—but they are not identical, and can change independently of one another. The mine discussed in this paper has an admirable safety record, often going several years without a reportable incident. The authors visited the mine four times in five years, to assess the culture and climate there, and examine the effects of those systems on the mine's outstanding safety performance. In the first two visits, the contribution of culture and climate to workplace safety were plainly seen. In the third visit, the climate remained strong and supportive, but with the appointment of a new mine manager and changing conditions, the culture was clearly changing. In the fourth visits, the effects of the changes in the culture continued to be seen.

TUESDAY, MARCH 1

MORNING

9:00 AM | Room 09

INDUSTRIAL MINERALS & AGGREGATES: CRITICAL & BATTERY MINERALS

Chairs: ***G. Soni****, Outotec, Centennial, CO*
R. Dube*, Outotec, Centennial, CO*

9:00 AM

Introductions

9:05 AM

Assessing the Environmental Footprints of Critical Metals Recovery from Spent Li-ion Batteries Using Bio-Hydrometallurgical Processes

S. Kadivar, S. Mousavinezhad and E. Vahidi; Mining and Metallurgical Engineering, University of Nevada Reno, Reno, NV

A conservative assumption is that by the year 2030, we will be disposing of 30,000 metric tons of Li-ion batteries (LIBs) per year. It is imperative to develop means of both diverting spent batteries from the solid waste stream and also recovering critical materials from spent batteries to meet growing future demand. Contrary to the conventional hydrometallurgical and pyrometallurgical methods, recovery of metals by bio-hydrometallurgical processes such as bioleaching are considered as "clean technologies". Bioleaching methods rely on biodegradable organic acids or chelating agents produced by bacteria or fungi to leach metals out of waste streams. In this study, a life cycle assessment was conducted to evaluate the environmental performance of fungal and bacterial bioleaching processes for the recovery of critical materials from LIBs. Our results showed that comparing those two bioleaching processes, bacterial bioleaching has higher environmental impacts in almost all environmental categories. Moreover, electricity, as well as organic nutrients utilized as the microorganisms' growth media, had the largest environmental impacts among the input flows.

9:25 AM

Physical and Mineralogical Characterizations of Municipal Solid Waste Incineration (MSWI) Ash Product.

S. Escalante Pedraza, B. Ji and W. Zhang; Mining and Minerals Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA

Based on a U.S Environmental Protection Agency (EPA) report in 2018, 292.4 million tons of MSW were generated, and about 30 million tons were processed through incineration in waste-to-energy (WTE) facilities. Thermal energy recovery and volume decrease are simultaneously achieved during the incineration process. However, this process generates bottom and fly ashes, which contain heavy metals and other pollutants. According to the EPA, 8.8% of the MSW are metals, and 19.5% are durable goods (e.g., batteries and electronics). Therefore, MSWI ashes could be treated as a promising resource for critical and valuable metals, such as rare earth, Co, and Ni. In this project, a physical and mineralogical characterization study was performed on MSWI ashes collected from WTE facilities to determine the physical fractionation characteristics and occurrence modes of the critical and valuable metals. The physical characterization consists of sieving, float-sink, magnetic separation, and froth flotation tests. The mineralogical characterization includes but is not limited to X-ray diffraction analysis, scanning electron microscopy analysis, and sequential chemical extraction.

9:45 AM

Assaying Rare Earth Elements Inclusions Within the Apatite-rich Tailing from the Pea Ridge Iron Mine for Froth Flotation Processing

J. Corchado-Albelo and L. Alagha; Mining Engineering, Missouri University of Science and Technology, Rolla, MO

The US Department of the Interior has listed 35 minerals considered necessary for domestic production supply and defense security due to executive order 13817. From this list, rare earth elements are the stand-out critical minerals because of their applications in modern electronics, green energy, health care, transportation, and defense. Therefore, the mining and metallurgy sectors have considered REEs' domestic resources to address the production supply challenge. This study investigates the Pea Ridge Iron Mine, located in Washington, MO, with historical evidence of REEs deposits. The tailings are rich in apatite minerals, and the REEs are understood to occur as inclusions within apatite grains. Therefore, this study assays the rare earth element content and locking behavior of the apatite minerals discarded into the tailings dam, using characterization methods such as XRD, XRF, ICP-MS, and TIMA. Results pointed towards the use possible use of conventional apatite beneficiation circuits reliant on the froth flotation process to concentrate REEs. Thus, supporting the ongoing efforts to help impact the domestic production of REEs for the USA's critical minerals strategies.

10:05 AM

Critical Minerals in Heavy Mineral Sands in Georgia and Florida

J. Renner and A. Romeo; Titanium Technologies, The Chemours Company, Wilmington, DE

Mineral sands in Georgia and Florida contain at least 5 materials on the Department of Interior's Final List of Critical Minerals: titanium, zirconium, rare earth elements, uranium, and gallium. Critical minerals are "vital to the Nation's security and economic prosperity" and foreign dependence creates a "strategic vulnerability". Titanium minerals and zircon have been commercially developed since the early 1900s. Rare earth minerals are now marketed as a source of light and heavy REEs and uranium. Gallium-enriched staurolite is not yet exploited. Expanded development of critical minerals is influenced by extraction and separation challenges, domestic supply chain limitations, and mining opposition.

10:25 AM

Development of a Hydrometallurgical Path to Recovery of Critical Materials from Spent Lithium Ion Battery Black Mass

T. Lister; Chemical Processing, Idaho National Laboratory, Idaho Falls, ID

Lithium ion batteries (LIB) are poised to increase in use as the transportation sector is electrified. Within current LIBs are the critical materials cobalt, graphite and lithium as well as valuable nickel. Current recycling practice relies on smelting to recover primarily cobalt and nickel. This project, supported through the Critical Materials Institute and partner Retriev Technologies, is developing hydrometallurgical methods to recover battery grade materials. The starting point for this work is referred to as black mass which is a mixture of the active battery particles (both anode and cathode) along with residues such as copper and aluminum foils and steel. Progress has been made on the developing an efficient electrochemical leaching process, ion-exchange and solvent extraction separation methods, and an electrodialysis process to deliver pure Li salts. Combined, several viable options are emerging which permit flexibility based on battery chemistry (cobalt vs. nickel rich). This presentation will describe results for the various process steps being developed.

10:45 AM

Potential for Minerals Used to Make Batteries in New Mexico

V. McLemore; NMBGMR/NM Tech, Socorro, NM

A variety of minerals (Cu, Mg, REE, Co, Li, etc.) are required to manufacture batteries and some of these minerals are found in and even produced from New Mexico. There are four components to batteries: two electrodes (anode and cathode), a separator (to prevent shortening), and an electrolyte. Part of the electrode consists of the carrier or the mineral that moves the charge between the electrodes. Some minerals, such as V and Cd, are used in only one type of battery, whereas other elements such as Cu, Li, and Ni are used in many batteries. NM is 3rd in the US in production of Cu, which is essential in batteries, and is mined at the Chino and Tyrone mines in SW NM. Other minerals essential to manufacture of batteries are found in NM and some, such as Mg, Li, REE, and Ni, are current exploration targets. Additional minerals, such as Cd, Mn, Ti, Na, and V are found in NM but are not considered exploration targets at this time, but it is important to understand the potential resource of these minerals in case economics change. Although Fe, Pb and Zn deposits were produced in the past, it is unlikely that these small, uneconomic deposits will be economic in the future.

TUESDAY, MARCH 1

MORNING

9:00 AM | Room 11

MINING & EXPLORATION: GEOSCIENCES: EXPLORATION & FEASIBILITY: PREPARING FOR MINES OF THE FUTURE

Chair: ***S. Siebenaler****, Big Rock Industries, Cascade, CO*

9:00 AM

Introductions

9:05 AM

Iron Ore Prospects of the Western U.S.

E. Ronald; SRK Consulting, Denver, CO

North American iron ore production has steadily increased over the past decade influenced heavily by international exports to East Asia and Europe. The iron ore industry within the U.S. is heavily dominated by production from the Great Lakes region for domestic and international customers. The western states have a long and varied history of iron ore production though and is often a forgotten resource due to the focus on base and precious metals. Utah, Wyoming, Nevada, and California contain active mines, historic production, and potentially viable iron deposits. This talk will provide a high-level overview of the North American iron ore market and focus on the known prospects of western U.S. iron ore including deposit nature, general characteristics, and potential for future mining.

9:25 AM

Rapid Geotechnical Core Logging Using Electronic Bluetooth Tape Measures

D. Childs; Call & Nicholas, Inc., Tucson, AZ

Geotechnical core logging is a key part of rock mass characterization for both greenfield and operating mines. The most commonly collected parameter for rock mass characterization is the rock quality designation (RQD). RQD logging is typically a manual process where a geologist measures the intact pieces of a minimum length of rock and sums the total length over the drill interval. Recent advances in technology allow for a Bluetooth-enable tape measure to record and transmit the individual lengths of intact core instantly to a computer logging sheet. This allows for accurate and rapid data collection of the length of every piece of core. This paper presents the available hardware, a free software package for interfacing with the tape measure, example data sheets for processing the data, and recommended best practices for rapid and accurate data collection.

9:45 AM

Effective Framework for Improving the Transparency of Feasibility Reporting

I. Traore; Mining, Mining, Kibali, Congo (the Democratic Republic of the)

Over the years significant progress have been made toward the development of various standard and practices for reporting mineral resources and reserves. Even though various codes of reporting provide the basis for the definition and categorization of mineral reserves, there are still salient issues that competent person can use in their advantage to declare misleading feasibility report. In this paper, an effective framework for feasibility reporting is presented. The developed framework proposed an integrated approach and guidelines for the application of modifying factors. It also improved the transparency of the mineral reserve and feasibility reporting by disclosing the risk associated with the life of mine plan and geological uncertainties.

10:05 AM

Adding Value With Exploration Dollars

J. Smith; Mining, SRK Worldwide, Reno, NV

Resource geology has focused closely on understanding interesting anomalies in the earth's crust and defining their genesis and proliferation. This work has not necessarily been focused on how these anomalies and associated mineralization will be profitably extracted. Certainly, various methods of prioritization are employed to rank drilling targets based on depth, expected grade, volume, and general continuity of a potential ore body. However, an actual quantification of the potential value of each planned drillhole in an exploration campaign is rarely performed. Exploration drilling is an incredibly expensive capital investment, and it is critical that drilling is designed in a fashion that maximizes the value produced, in the form of additional profitable resources or reserves. We will show that not only is the quantification of value possible to some extent, but also necessary to ensure the most value is gained from exploration and resource drilling. At the end of the day a mining project is a business, and it is the responsibility of those working for that business to ensure that expenditures are invested in a manner that maximizes the potential return for the business.

TUESDAY, MARCH 1

MORNING

9:00 AM | Room 13

MINING & EXPLORATION: INNOVATION & TECHNOLOGY: LEVERAGING DATA SCIENCE & MACHINE LEARNING TO MAKE MINING SAFER, SMARTER, AND MORE SUSTAINABLE.

Chairs: ***E. Tarshizi****, University of San Diego, San Diego, CA*
S. Tafazoli*, Motion Metrics International Corp, Vancouver, BC, Canada*

9:00 AM
Introductions

9:05 AM

Using Artificial Intelligence to Determine Cyclic Status of a Mining Shovel Operation using 3D Imaging of the Bucket

S. Tafazoli; Motion Metrics International Corp, Vancouver, BC, Canada

Mining shovels are employed round the clock at open pit mines in a cyclic manner as listed below: Digging the mine face, swinging towards the haul truck with full bucket, dumping the load on haul truck tray, and swinging away with empty bucket. As such, a typical operation for the mining shovel includes the above as well as the cases where the shovel is idle, under maintenance, or just cleaning up the face. In this project, a novel approach is presented that employs the combination of rugged 3D machine vision and supervised deep learning to automatically determine at each given time in what phase of the operation the mining shovel is. This is performed fast, efficiently, and with better than 90% accuracy using a powerful embedded computer onboard the shovel which is fed the output of the stereo camera pair. The results are then communicated via ethernet with a cloud computing and reporting platform. Such functionality will have multiple use cases such as scoring each shovel and improving blasting of each area of the mine face. Experimental results will be presented for 3 types of mining shovels: cable shovel, hydraulic shovel, and backhoe, all in operation in mines around the globe.

9:25 AM

Improving Error Reduction in Long-Term Mine Planning Models using Deep Learning

C. Olmos-de-Aguilera[2], P. Campos[2] and M. Risso[1]; [1]Electrical and Electronics Engineering, Universidad del Bio Bio, Concepcion, Bío Bío, Chile and [2]Sistemas de Informacion, Universidad del Bio Bio, Concepcion, Bío Bío, Chile

Long-Term Mine Planning Model (LTMP) and Short-Term Mine Planning Model (STMP) are essential nontangible resources that determine the mining operation and its feasibility. Due to their nature, these models are prone to discrepancies when compared which can lead to important economic and operational consequences. In order to improve the predictions associated, this work develops a Deep Learning (DL) model for copper grade estimation. Feedforward Neural Network (FNN), 1D Convolutional Neural Network (CNN) and Long Short-Term Memory (LSTM) models are implemented using a data set of 732,870 samples corresponding to a copper mine in Chile. DL models estimates are compared to STMP, leading to MSE improvements of 21% in FNN, 37% for CNN, and an improvement of 39% in LSTM over baseline. These promising results can later be integrated into mine planning software to further improve ore and production estimations.

9:45 AM

Rock Hardness Prediction using Geophysical and Geochemical Data and Machine Learning

N. Houshmand[1], S. Goodfellow[1], J. Ordóñez-Calderón[2] and K. Esmaeili[1]; [1]Civil and Mineral Eng., University of Toronto, Toronto, ON, Canada and [2]Kinross Gold, Toronto, ON, Canada

A good understanding of the hardness of ore being handled and processed in a mining operation can significantly improve operational efficiencies by providing valuable data to support decision making through the mining value chain (drilling, blasting, comminution). This study presents the results from the application of Machine Learning (ML) to predict rock hardness using various geophysical and geochemical features. Core samples from a mine site were logged using a multi-sensor core logging system. Measurements, including ultrasonic p-wave and s-wave velocity, elemental concentration via portable XRF, and Leeb Hardness, were measured every 2cm along the length of the core. The ML model was setup up to predict the Leeb Hardness using the elemental concentrations and ultrasonic velocities as input. The Leeb Hardness values were grouped into three bins and used as a classification target for the ML models. Various ML models, including linear regression, support vector machines, decision tree, Gradient Boosting, Random Forest, K-Nearest Neighbors, and Naïve Bayes were tested. Model performance demostrated that the Random Forest model producing the highest accuracy of 88%.

10:05 AM

Predicting Rock Types at a Large Mongolian Mine Using Machine Learning

N. Sarantsatsral, R. Ganguli and R. Pothina; Mining Engineering, University of Utah, Salt Lake City, UT

The copper hosting rocks in Erdenet copper mine in Mongolia are primarily classified into five groups. Rock type impacts various performance characteristics of an operating mine, from blasting costs to mineral recovery. Therefore, knowledge of rock type can help mine optimize processes. Machine learning methods were applied to the thousands of drillholes in the drillhole database at the mine to learn the rock type distribution. Models were evaluated using multiple scenarios. Results from predictive models are impressive and open up new avenues for automating and managing mining processes. The results demonstrate that though rock types are difficult to predict, machine learning of drillhole and sensor data can be leveraged to make smart operational decisions.

10:25 AM

Using Deep Learning for Improving Energy Efficient SAG Mill Control

M. Risso[1], P. López-Vidaurre[1], I. Reyes-Vejar[1] and M. Momayez[2]; [1]Ingenieria Electrica y Electronica, Universidad del Bio Bio, Tucson, AZ and [2]Mining and Geological Engineering, The University of Arizona, Tucson, AZ

Increasing operational costs along with lower ore grades are inspiring the development of innovations in energy efficiency strategies in the mining and minerals industry. Mineral processing requires a large amount of energy, from which SAG mills accounts for over 6% of the total energy consumption in Chile, the largest copper producer in the world. The challenge of implementing effective energy efficiency methods is benefited by the extensive development of advanced artificial intelligence (AI) algorithms. AI promises great results for mining operations, mainly due its ability to find proprietary process patterns, which were impossible to find a few years ago. This work presents a novel approach based on Deep Learning which allows for automatic mineral properties estimation in mineral processing, such as hardness and size. A Long Short-Term Memory (LSTM) model was generated using data from copper mines in Chile and lead to an low MSE in mineral properties estimation. This approach is later incorporated in the proposal of adaptive SAG mill control philosophies which can be implemented to reduce energy consumption.

10:45 AM

Using Advanced Analytics and Modeling Baseline Throughput and Metal Recovery to Measure the Impact of Major Concentrator Process Improvements

S. Ennis; Freeport-McMoRan Inc, Phoenix, AZ

There are many ways to measure the value of process improvements, but this becomes more difficult to do the more complex the process being evaluated is. The interactions of mineralogy, chemistry and mechanics in an ore concentrator are highly complex so it can be particularly hard to measure the impact of a specific plant change. This paper describes a method for modeling a baseline of throughput and metal recovery so that the value of a major process improvement can be measured. The models developed only consider variables that cannot be optimized, such as mineralogy or equipment availability. Linear regression, random forest, extreme gradient boosting (XGB), and simple two-layer neural network models of process value were tested as candidate baseline model types. XGB performed the best in terms of accuracy for both throughput and recovery models. Using an XGB model of non-optimizable process variables provides an accurate, dynamic baseline that can be compared with continuous production data to determine the value added by major concentrator improvements in real time.

11:05 AM

Contextualizing Multiple Data Sources to Generate Insights

A. Moharana, B. Marsh, R. Rojas Espinoza and K. McDonald; Prod Management, Eclipse Mining Technologies, Tucson, AZ

Mines generate enormous amounts of data daily. These data, when used properly, can become a primary asset for the mine, helping them realize greater productivity and value. However, using those data directly presents unique challenges of collecting the data, storing the data, cleaning, transformations, etc., while doing all of these in the context of what other data is being used. Data initiatives in the mines usually start looking at 1 or 2 data sources and fail to progress beyond them because of the lack of context between the data sets. This paper showcases the use of a data platform to generate a data pipeline that can allow the mine to progressively add more data sources in the mine while maintaining context. This can help the mine derive actionable insights to better operationalize the plan while increasing the value and decreasing the risk of variance between planned and actuals. The paper shows a methodology to add, contextualize and generate insights using planning data and operations data as well as publicly available datasets such as weather forecasts.

11:25 AM

Combining Rugged 3D Vision and Machine Learning to Analyze Haul Truck Loads at a Primary Crusher

S. Tafazoli; Motion Metrics International Corp, Vancouver, BC, Canada

Primary crushers play a very important role at open pit mining operations around the world. These giant structural buildings are often fed directly by large haul trucks full of rocks. In this project, a novel AI-based approach is presented to automatically analyze the load of each haul truck as it approaches the primary crusher at a very slow speed to dump the loaded material. A rugged stereo camera with onboard processing capability is installed together with several LED lights on a structure mounted on the roof the crusher and titled down towards the incoming haul trucks. Supervised deep learning is applied to the acquired 3D images to automatically determine the presence of haul tucks and to analyze their load in order to: (i) Sense the fragmentation of the loaded rocks, (ii) Accurately detect presence of the large rocks (boulders) (iii) Sense the 3D profile of the haul truck load, and (iv) Measure the volume of the material dumped by comparing the before and after profile of each haul truck, (v) Determine the percentage of carry back for each truck. Experimental results are presented using the system installed on a two sides of a primary crusher at a copper mine in Kazakhstan.

TUESDAY, MARCH 1

MORNING

9:00 AM | Room 10

MINING & EXPLORATION: MANAGEMENT: METRICS FOR PROJECT MANAGEMENT IN MINING

Chairs: ***D. Mason****, Atkinson Construction, Seattle, WA*

B. Spencer*, Sibanye Stillwater, Fishtail, MT*

9:00 AM

Introductions

9:05 AM

Lessons Learned in Metric Reporting and Data Governance in a Large Organization

K. Robertson and J. Snyder; C&D, Rio Tinto, Draper, UT

As new applications and reporting interfaces roll out in quick succession establishing a robust, well governed, maintained and value adding metric reporting system can prove a struggle. Layer that on top of disparate, aging data sources and you have a recipe for confusion and frustration leading to an inability to leverage the wealth of data that a large mining and processing operation has available. Join us for a discussion of lessons learned from the integrated planning and systems team as we navigate these challenges.

9:25 AM

Effective Mine Management Using Compliance to Plan Metrics

I. Traore; Mining, Mining, Kibali, Congo (the Democratic Republic of the)

Achieving the required compliance to plan is essential for delivering the medium and long term mine plans. In underground mining operation, compliance to mine plan is critical for delivering the overall project net present value. If the compliance to plan score being achieved is below the set target, it would highlight that there are potential issues which need to be address in order to deliver the business plan. In such circumstances we need to break down the key drivers influencing the metric to identify the required improvement plan. In this paper, important compliance to plan metrics are developed for measuring the compliance to the mine plan. In addition, a systemic value driver tree approach for improving the compliance to plan and optimizing the overall mining operation is proposed.

9:45 AM

Gain Practical Knowledge of How to Design, Implement, and Sustain a Management Operating System (Mining Ops/Maintenance)

D. Truchot; Hanzehogeschool Groningen, Groningen, Groningen, Netherlands

Management Operating Systems (MOS) are not well understood, and this course aims to share our expertise and some of the key tools to start identifying gaps that slow your organization' successes and launch correction action plans. We will review with you best practices that are in use at the bottom of pits or in maintenance workshops and share some of this insider knowledge so you can start optimizing your operations. Some of the key tools we will review are: Planning Controls, Short Interval Control, DWOR (Daily Weekly Operating Report), Skills Flex Matrices, Variance Reports, Robust Action Logs, and RCCA tools & processes. We will provide you with a critical approach and a proven suite of tools that are used in daily production meetings, at dispatch, or in maintenance workshops, day in/day out. We will also share with you some of the pitfalls and strategies to ensure your changes are sustainable. The course materials are based on years of analysis, design and sustainable implementation of robust Management Operating Systems at various production facilities or maintenance organizations in many industries across the world (Mining, Manufacturing, Oil & Gas, Aerospace).

10:05 AM

Setting Up and Executing a Trial in Mining

J. Heiner; Technical Services, Forte Dynamics, Bountiful, UT

Many trials fail or achieve bias objectives, and even successful trials can end with no approval to change. In my career, I have set up and managed dozens of trials. Some have been successful with no significant issues, while others have gone devastatingly wrong. Some keys to setting up a successful trial are proper planning, communication, clear key performance indicators, understanding of company culture and personality types.

10:25 AM

Improving the Production Planning Process Through Agile Project Management Principles

A. Murray; Stillwater Mining Co, Littleton, CO

The production planning process is repeated on a daily, weekly, monthly, quarterly, and yearly basis. Due to the short turnover, the monthly planning process is a prime candidate for an agile project managment approach. Through continuous improvement, the process can be improved each month utilizing the essential agile project management principles. Another essential tool is having motivated individuals surrounding the improvement process. Having a supportive Senior Production Engineer to encourage the overhaul and improvement of the system, a team of Production Engineers that want to see the monthly plan improve in accuracy and the ability to systematically repeat the results, and an operations team that wants to create an attainable plan that can be communicated to everyone. These are just a few of the essential principles used to overhaul the Stillwater Mine's monthly planning process. It resulted in the improvement of repeatability, accuracy, and overall plan understanding from the engineers to the operations team. It is an iterative process that will continue to evolve and improve each month, even as the engineers move in and out of the production engineer position.

10:45 AM

An Evaluation of Cemented Sand as a Backfill Method at the Stillwater Mine

M. Morgenthaler; Project Group, Sibanye-Stillwater, Red Lodge, MT

Sibanye-Stillwater is exploring the use of cemented sand fill as a backfill method for underhand cut-and-fill mining at the Stillwater East Mine located near Nye, Montana. Limitations in the existing paste backfill infrastructure has resulted in the pursuit of underhand quality fill alternatives in this region of the mine. A feasibility study found cemented hydraulic sand fill an economically favorable alternative through the utilization of the existing hydraulic fill infrastructure. Prior to advancing underhand cemented sand to full implementation, a pilot test was conducted in which the bench test design mixtures were generated and placed in a production stope for evaluation. The pilot testing was utilized as a proof of product test and validation of the product rheology and ability to pump through a positive displacement pump. The analysis and testing of the cement slurry placed at a test stope will determine the path forward for backfill infrastructure at the Stillwater East Mine continues to expand.

TUESDAY, MARCH 1

MORNING

9:00 AM | Room 14

MINING & EXPLORATION: OPERATIONS: DRILLING & BLASTING IN OPERATIONS

Chair: ***K. Slemko****, Major Drilling Group International Inc*

9:00 AM

Introductions

9:05 AM

Improvement of the Breakage Through the Drilling Deviations Control, Case "El Roble" Mine, Colombia

J. Rincon Duran; Faculty of Minas, Universidad Nacional de Colombia Sede Medellin, Medellin, Colombia

In the unitary operation of drilling and blasting it is very frequent that errors associated with deviations from exploitation works occur. Errors such as improper positioning of the jumbo arm, little parallelism between perforations, irregular lengths of the holes and poor symmetry of the mining front, allow blasting to be inefficient. Thus, from the data measured at the "El Roble" mine, located in Choco (Colombia), there is an associated improvement in the use of tools such as magnetic inclinometer, the use of PVC guide tubes, the 5 m flexometer and the rigorous layout of the Mesh of drilling in the front, to assure the slope of the exploitation work and to reduce the deviations. In this way the progress of the exploitation works is improved above 90%, recovering lost tons by 90.2% and reducing costs per meter of advance by 13% is improved.

9:25 AM

Explosives Charge Sequence and Vibrations

T. Worsey[1], J. Silva[2] and P. Worsey[3]; [1]DynoConsult, Dyno Nobel, Lexington, KY; [2]Mining, University of Kentucky, Lexington, KY and [3]Explosives, Missouri University of Science and Technology, Rolla, MO

Many variables influence the generation and behavior of blast vibrations. Among others, two are of particular interest; charge sequence and timing. "Explosives charge sequence" can be seen as the order in which explosive charges are fired in a blast. On the other hand, "Explosives charge timing" is the time delay between the detonation of two successive charges. Waveform superposition techniques have shown that the success of controlling blast vibrations is higher when the delay between the detonation of two successive charges is constant. This paper includes the vibration results observed in a series of tests where the relationship between timing, sequencing, and fragmentation was studied. The vibrations recorded during the tests show how the vibrations are affected by the sequence despite maintaining a constant timing between explosives charges. The three different sequences were firing by row, conventional en-echelon, and zigzag.

9:45 AM

High Wall Stability and Vibration Reduction with the Use of Frequency Control Timing and Optimization of Electronic Detonators

R. Cefalo; Drill and Blast, Forte Dynamics, Herriman, UT

Jake is an experienced operational mining engineer with over 10 years of experience at major mining operations and most recently working as the senior drill and blast engineer for the Bingham Canyon Mine. Experience includes cost reductions by expanding out blast pattern while optimizing product selection and maintaining production targets. Developed planning tools to create more efficient reporting, reconciliation, and compliance of monthly plans. Experience with managing explosives inhibitor levels for reactive ground, vibration and flyrock control blasting around buildings and critical infrastructure. Proficient with optimized timing with electronic and nonelectronic detonators for the reduction of wall response in geotechnically sensitive areas especially in the field of frequency control blasting techniques. Completed multiple training programs in drill and blast technical and operational courses.

10:05 AM

Effectiveness of Reinforced Blast Doors in Reducing the Air Blast Overpressure in Underground Operations

S. Jayaraman Sridharan[1], P. Tukkaraja[1], B. Meins[2], N. Rouse[3], A. Adhikari[1] and J. Connot[4]; [1]Mining Engineering and Management, South Dakota School of Mines and Technology, Rapid City, SD; [2]Detecht LLC, Socorro, NM; [3]Dyno Nobel Inc, Salt Lake City, UT and [4]SURF, Lead, SD

Most of the energy released during blasting (in the form of shock waves and high gas pressures) is used in rock fragmentation and displacement. A small portion of the remaining energy traveling through the ground generates ground vibrations and air overpressure if released to the atmosphere. When compared to an underground blast, the vibration and overpressure from a surface blast are widely investigated due to the use of bulk explosives and potential damages to the nearby sensitive surface structures. At the Sanford Underground Research Facility (SURF, formerly known as the Homestake Gold Mine) huge underground caverns are being constructed to house a gigantic state-of-the-art particle detector for the Deep Underground Neutrino Experiment (DUNE). The sensitive experiments that are being carried out in the facility pose unique challenges to the underground construction project. In this study, a custom blast door is designed to reduce the air overpressure from an underground blast and its effectiveness is evaluated using the blast monitoring data.

10:25 AM

Investigation of Underground Blast Fume Dilution Behavior Using CFD Techniques

A. Adhikari[1], S. Jayaraman Sridharan[1], P. Tukkaraja[1] and J. Connot[2]; [1]Mining Engineering and Management, South Dakota School of Mines and Technology, Rapid City, SD and [2]SURF, Lead, SD

Blast fumes need to be diluted and removed from the underground working areas within a reasonable time frame. The models used to calculate the mine re-entry times assume that all post-blast fumes are emitted upon detonation. However, previous studies indicate that as much as 60% to 70% of the fumes or gases produced during underground blasting can remain entrapped in the adjacent rock mass or the muck pile (Souza & Katsabanis, 1990; Taylor, 2015). This study will analyze the pollutant flow behavior, considering the entrapped fumes, under various ventilation parameters (Forcing, exhaust, overlap, airflow rate), using Computational Fluid Dynamics (CFD) techniques. The numerical model used in the CFD simulations is validated using real-time gas and dust monitoring data from underground development operations at the Sanford Underground Research Facility (SURF), Lead, SD. The preliminary results from CFD simulations suggest that entrapped fumes increase the total dilution time in the underground mining operations and the forcing auxiliary system favors the blast fume dilution over the exhaust system.

10:45 AM

Improving Fragmentation and Mining Recovery Through Accurate Production Drilling at the Kibali Underground Gold Mine

I. Traore; Mining, Mining, Kibali, Congo (the Democratic Republic of the)

Drilling of production hole with acceptable level of deviation is critical for achieving an efficient underground mine operation cycle. Higher drilling deviation results in poor fragmentation, higher dilution, higher ore losses, poor productivity and higher mining cost. Over the past years, the author undertakes extensive studies on the drilling deviation at the Kibali Gold Mines. As a result, the following potential causes of the deviation were identified: operator skills, drilling parameter (percussion, rotation, feed pressure…), length of the hole, ground condition, types of bit, setup & calibration of the drilling machine and the volume & pressure of underground air and water services. In this paper, various causes of deviation are analyzed and an holistic approach for optimizing the drilling operation is presented. Its results in substantially improving the fragmentation while reducing the deviation from 13.6% to 4.7%, and increasing the recovery from 86.7% to 94.8%.

11:05 AM

The Explanation, Application, and Importance of Velocity of Detonation and Monitors in the Blasting Process

B. Lewis, RESPEC

What is Velocity of Detonation (VOD)? This presentation will cover the basic definitions of VOD and review the benefits and importance of testing and verifying the VOD in the blasting process. Valuable information, such as bulk explosive product performance, product inefficiencies, and incomplete detonation of blast holes, can all be obtained from the collected data. Today, there are also multiple methods and products used for obtaining quality VOD information. This presentation will specifically cover the Shottrack VOD305 and its benefits over alternatives, including product performance and cost.

TUESDAY, MARCH 1

MORNING

9:00 AM | Room 12

MINING & EXPLORATION: OPERATIONS: MINING & RENEWABLES

Chair: ***Z. Khademian****, National Institute for Occupational Safety and Health Pittsburgh Research Laboratory, Pittsburgh, PA*

9:00 AM

Introductions

9:05 AM

Excavation Methods for Underground Energy and Water Storage

S. Nowosad, A. Hutwalker and O. Langefeld; Institut of Mining, Technische Universitat Clausthal, Clausthal-Zellerfeld, Lower Saxony, Germany

Pumped storage power plants are one of the options to store the fluctuating production of electric energy from wind and solar power plants in a sustainable manner. However, due to the extensive land use required when planning the connecting upper and lower water reservoirs, several projects have been declined after social conflicts raised. Nonetheless, after the flooding periods of 2017 and 2018 in northern Germany, and the catastrophic floods of July 2021 in south west Germany it is clear that the need for water reservoirs will only increase in the future, whether above ground or underground. The presentation shows a systematic approach for planning and designing large underground cavities for water reservoirs and connecting aqueducts between water dams and includes selected results of its application in the "Energy and Water Storage Harz" (EWAZ) research project. It also discusses the possibilities considering the available excavation methods and the technical challenges that are involved.

9:25 AM

Transforming Mine Power Supply: A Roadmap to Green Househouse Gas Reduction

D. McLane; Mining, Burns & McDonnell, Phoenix, AZ

The Mining Industry is all-in on greenhouse gas (GHG) reduction, with targets set at 20%, 25%, and even 30%. This is fantastic, but how do we get there? Often these goals are set with a cursory understanding of the feasibility, financial implications, and process to achieve such goals. This presentation discusses power supply options including utility green energy options, a variety of power purchase agreements (PPAs), and owner built renewable generation. A clear understanding of these options is critical to developing actionable and achievable goals and there are many variables to consider such as location, availability, utility tariffs, cost, schedule, risk, and balance sheet impact. A roadmap to achieving GHG reduction is presented, highlighting a bottom-up approach that results in goals you can stand behind.

9:45 AM

Mining Renewable Heat

M. Nakagawa; Mining Engineering, Colorado School of Mines, Golden, CO

Ideas of harnessing thermal energy from unconventional underground heat sources will be discussed. Hot fluid can be extracted from a geothermal reservoir. Depending on the temperature, geothermal fluid can be used either to generate electricity or directly for its heat. For the mining industry, hot water found underground is problematic, as it requires expensive pumping and ventilation systems to maintain a safe working environment for the minors. However, geothermal hot water can be used to cool deep underground mines and at the same time maintain the condition of surface operations comfortable in severe winter. The next heat source is more unconventional, and it is burning underground coal seams. They are problematic as they can burn at a very high temperature and emit toxic and greenhouse gases. However, we can use the heat by drilling a series of shallow heat-exchanger wells. The only problem is that this particular heat source moves around as the coal is consumed. At the presentation, I would like to share the solution to this challenging energy source with some cost analysis.

10:05 AM

Geothermal Energy for Mine Site Remediation

L. Dunnington; United States Environmental Protection Agency, Washington, DC

Many active and abandoned mines are located in remote regions, set apart from energy sources, population centers and infrastructure, rendering necessary remediation efforts in these areas slow-moving, expensive and in many cases space intensive. The primary demand from the industry and the government for these sites is a passive system that utilizes locally available and cheap material. Often the geothermal gradient available in mines, or the corresponding geothermal reservoir conditions proximal to the mine, is a viable heat energy source that can provide advantageous temperature conditions for established remediation techniques, namely bioremediation, which can run on diverse, inexpensive, and locally available material. Although geothermal direct use and bioremediation are proven technologies when practiced independently, the combination is not straight forward. The presentation will address the chemical, thermal, hydrological and biological intricacies of this process and its promise for providing relevant remediation to abandoned metal mines in remote regions.

10:25 AM

Lithium Ion Battery Thermal Runaway in a Methane-Air Environment

N. Rayyan, J. Soles, T. Dubaniewicz, L. Yuan, C. Brown and R. Thomas; PMRD, National Institute for Occupational Safety and Health, Washington, DC

As lithium ion batteries become more prevalent in the mining industry, new hazards of battery fire and explosion are emerging. Efforts must be taken to ensure that workers are safe from these new specific hazards such as batteries undergoing thermal runaway in underground areas that may have explosive methane-air mixtures. Researchers at the National Institute for Occupations Safety and Health (NIOSH) investigated overpressures generated within a sealed battery enclosure filled with an explosive methane-air mixture and a single cell lithium ion battery driven into thermal runaway using an accelerating rate calorimeter. For both iron phosphate (LFP) and nickel manganese cobalt (NMC) lithium ion batteries, the explosion overpressure remained unchanged with varying percentages of methane concentration in the atmosphere surrounding the cell. It's likely that the gasses released from the battery undergoing thermal runaway inert the atmosphere within the sealed cannister. The results from this study will help mining equipment manufacturers develop proper measures to keep miners safe while working with lithium ion batteries in underground gassy mines.

TUESDAY, MARCH 1

MORNING

Room 16 | 9:00 AM

MPD: CHEMICAL PROCESSING: BASE METAL RECOVERY AND DOWNSTREAM REFINING

Chairs: ***A. Chancellor****, Sibanye-Stillwater, Columbus, MT*
S. Gostu*, Air Liquide, Newark, DE*

9:00 AM

Introductions

9:05 AM

Where Have all the American Smelters Gone?

M. Moats; Missouri University of Science and Technology, Rolla, MO

Over the past fifty years, the United States has gone from a metal smelting and refining powerhouse to a country worried about the resiliency of its supply chains. Historic trends in copper, lead, zinc and aluminum production for the United States and China are discussed. Causes for the American decline are provided. Suggestions to improve and secure domestic metal production including critical mineral production are given.

9:25 AM

Successful Crud Processing Using 3-phase Decanter Technology

T. Ostrom and E. Gentis; Indiana University of Pennsylvania, Indiana, PA

Due to decreasing percentage of valuable metals in ores mined today, mining operations have opted to change over to the hydrometallurgy solvent extraction (SX) process to win the maximum value from their ore. One of the negative characteristics of the SX process is that an unwanted emulsion ("CRUD") is formed at the interface of the organic and aqueous phase in the solvent extraction loading- and stripping-process. The formation of CRUD degrades the SX process. The standard practice to optimize performance of the process (and to be able to recover and reuse the valuable organic) is the use of three phase centrifugal decanter. Since the organic and aqueous have different densities, the use of high centrifugal force is an efficient method of splitting the emulsion into separate organic and aqueous phases. As the recovered organic has a high value to the customer and lowers operation cost significantly, pay-back of the separation equipment is typically achieved in much less than 12 months. This paper shows how and why the system works, reviews a number of existing sites around the world, and presents an owner/operator's perspective on practical operation and maintenance issues and costs.

9:45 AM

Nodulation of Copper Electrowon Deposits

J. Bauer and M. Moats; Missouri University of Science and Technology, Rolla, MO

Nodulation of electrowon copper can lead to off-spec cathode and lower current efficiency. Nodules form when the operating parameters do not permit the formation of smooth, dense deposits. This presentation will discuss the fundamentals that cause nodules. Experimental validation is performed with the rotating cylinder Hull cell. The results will demonstrate that the critical current density which produces nodulation is related to operating parameters such as electrolyte composition, additives, air sparging and temperature. The concept of permissible current density will be explained and guidance given for operating practice.

10:05 AM

Use of Amino Acids for Copper Dissolution

C. Perea[1], O. Restrepo Baena[1], C. Ihle[2] and H. Estay[2]; [1]Materials and Minerals, Universidad Nacional de Colombia, Medellin, Antioquia, Colombia and [2]Advanced Mining Technology Center, Universidad de Chile, Santiago, Chile

In this study, a research on the use of monosodium glutamate for copper leaching, with emphasis on the thermodynamics and oxidant characteristics, is presented. Copper dissolution was conducted following a hydrometallurgical route, using monosodium glutamate in alkaline solutions. The effect of oxidizing agents such as hydrogen peroxide (H2O2) and potassium permanganate (KMnO4), and the efficiency of copper leaching with glutamate compared with glycine have been studied. Results, obtained at room temperature, showed 92% recovery of copper using 0.03 M hydrogen peroxide, 0.5 M monosodium glutamate at a pH of 9.44.

10:25 AM

Getting More From Conventional Leach Operations: Moving Raffinate Product Metal Forward (Representative Copper Case)

P. James; Blue Planet Strategies, Madison, WI

SX/EW leaves substantial residual product metal in the SX raffinate loop (circulating inventory). The associated revenue is delayed and a portion of the existing processing bandwidth is tied up which effectively lowers the net Ore-to-Product (OTP) processing throughput rate. Recent advances in low-tenor and mixed metal electrowinning now provide opportunity to profitability move that metal forward and capture the additional revenue NOW without additional mining using plug-in technology. Projected production output gains commonly fall in the range of 5% to 10% with direct incremental production cost often figuring in the $1.5/lb Cu to $2.0/lb Cu span. Possible process byproduct credits can further improve costs by another $0.20/lb Cu to $0.50/lb Cu in many cases. A representative case for a large mine utilizing SX/W processing is examined illustrating treatment implementation along with key production and financial impacts which such treatment might provide. Important drivers to site-specific treatment application are also examined to provide screening guidance on when such treatment may or may not be feasible.

10:45 AM

Laboratory Scale Copper Electrorefining – Copper Deposit Structure, Roughness and Adhesion to Stainless Steel

J. Young and M. Moats; Missouri University of Science and Technology, Rolla, MO

Short term laboratory cell electrorefining experiments were performed to examine the impact of electrolyte composition, current density and temperature on deposit structure, roughness and adhesion to 2B mill finished 316L stainless steel. Copper electrodeposits were produced using synthetic electrolytes and continuous addition of glue and thiourea. Deposit structures were evaluated using x-ray diffractometry and optical microscopy. Surface roughness was measured using profilometry and analyzed using scaling analysis. Finally, an internally developed method to method the force needed to remove a thick film from a rigid substrate was used to measure the adhesion of electrodeposited copper to stainless steel. A summary of these findings will be presented along with possible correlations.

11:05 AM

Mechanistic Study of Copper Leaching from Chalcopyrite Using Methanesulfonic Acid

E. Jones and J. Lee; University of Arizona, Tucson, AZ

Hydrometallurgical extraction of copper from its ores and concentrates are getting more attention to meet the global demand of copper. Many alternatives have been tried and methanesulfonic acid has been proven to be a great lixiviant with selective oxidant in the solution system. Copper extraction percentages of greater than 90% was achieve in higher than 70°C and the formation of K-Cr-jarosite formation was confirmed by mineralogical study. Usually, the chalcopyrite leaching was governed by the surface chemical reaction control with higher than 40 kJ/mol of activation energy. However, the reaction mechanism with different concentrations of lixiviant and oxidant was not fully understood. To investigate the reaction mechanism in a precise manner, a temperature-controlled reactor vessel was used to study the leaching characteristics of copper in methanesulfonic acid. Copper extraction efficiency was investigated in different conditions of solution chemistry and the clear mechanism was studied.

TUESDAY, MARCH 1

MORNING

9:00 AM | Room 19

MPD: COMMINUTION/PLANT DESIGN PANEL: OPERATION & CONTROL PRACTICES FOR SAG/BALL MILL AND WHERE WE'VE CONFUSED THE TWO

Chairs: ***M. Larson****, Molycop, Ewen, MI*
J. Wickens*, McClelland Labs, Sparks, NV*

9:00 AM

Introductions

9:05 AM

Operation & Control Practices for SAG/Ball Mill and Where We've Confused the Two

M. Larson; Molycop, Ewen, MI

Join a panel of industry experts for a spirited discussion around current SAG and ball milling issues ranging from design, operation and optimization

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TUESDAY, MARCH 1

MORNING

9:00 AM | Room 15

MPD: FLOTATION: FUNDAMENTALS AND APPLICATIONS I

Chairs: ***T. Myers****, Pionera, Henderson, NV*
A. Eskanlou*, West Virginia University, Morgantown, WV*

9:00 AM

Introductions

9:05 AM

Operational Improvements at the Rio Tinto Kennecott Slag Mill

S. Schwarz, C. Geraghty, T. Colwill and J. Reichart; RioTinto, South Jordan, UT

The slag mill at the Kennecott Smelter has seen significant improvements in terms of online time and throughput rate over the past 3 years. This has been due to a greater focus on the crushing and milling circuits, as well as improved collaboration between operations, maintenance and technical groups. This study includes discussion on the significant step-changes that have been made to the operating strategy, as well as technical improvements and adjustments.

9:25 AM

Are You Maximizing Your Net Metal Production Rate? Is Your Flotation Happy?

O. Bascur; OSB Digital, LLC, The Woodlands, TX

Ores are becoming extremely variable with mineralogy and hardness disturbing the integrated crushing, grinding, flotation, and thickening processes. The current mining, comminution, flotation and dewatering sensors provide large amounts of data for process optimization. To augment the operational knowledge for proactive actions for improving the performance of the integrated rock processing complexes, we need to add the right process knowledge context and operational modes. A novel approach of using machine-learning techniques coupled with dynamic process models in grinding, such as Dynamill™ and Dynaflote™, a new operational integrated process model is realized and implemented. The capabilities of the predictive model can be used for online sensing of the crushing-grinding-flotation and water separation performance and early identification of faults. The application of a digital plan twin to mining, mineral processing and extractive metallurgical process using advanced analytics tools is presented here.

9:45 AM

A Flotation Simulator that Can Predict Grade vs. Recovery Curves from Mineral Liberation Data

K. Huang, S. Keles, A. Noble and R. Yoon; Virginia Tech, Blacksburg, VA

Yoon et al. (2016) developed a flotation model from first principles by considering various subprocesses, e.g., bubble generation, bubble-particle collision, attachment, detachment, and bubble-coarsening in the froth phase. However, the bubble coarsening was predicted using a foam model as the first approximation. In the present work, we used the froth model developed more recently by Park et al. (2018) to predict bubble coarsening by considering the role of particle size, contact angle, and the critical rupture thicknesses of lamella films. The computer simulator based on the improved model has been validated using the pilot-scale flotation test results reported by dos Santos and Galery (2018). The simulation began with estimating the contact angles of the different classes of composite particles present in a feed stream from the size-by-class mineral liberation matrix. The simulation results are in good agreement with the experimental data. Thus, the flotation simulator developed in the present work can predict the grade vs. recovery curves that are commonly used for scale-up and daily operations.

10:05 AM

Characteristics of HOPG Surfaces for the Analysis of Carbonaceous Matter Separation from Sulfide Ores by Flotation

F. Sime, J. Jin, X. Wang, D. Bhattacharyya and J. Miller; Materials Science and Engineering, The University of Utah, Salt Lake City, UT

The efficient processing of base metal sulfide ores and sulfidic gold ores is sometimes compromised by the presence of carbonaceous matter (CM). One common way of dealing with the CM problem, as practiced at several mines, is to pre-float the CM before the flotation of sulfide minerals. In this regard, it is important to understand the structural and surface properties of the CM. Naturally occurring CMs most often have some characteristic graphitic structure, with variation in crystallite sizes, orientation, and degree of disorder/distortion as well as some variation in surface chemistry features. In this study, examination of the surface characteristics of face and edge surfaces of highly ordered pyrolytic graphite (HOPG) is reported to provide a foundation for understanding the behavior of CMs in sulfide flotation separations. In this regard, the face and edge surfaces of HOPG have been studied by XPS, AFM, and MDS and the results used to describe the mosaic surfaces of polycrystalline CMs consisting of graphite crystallites with variable exposure of graphite face and edge surfaces and with variable extents of oxidation/hydroxylation.

10:45 AM

De-sliming Followed by Froth Flotation for the Recovery of Phosphorus and Enrichment of Rare Earth Elements from Florida Waste Clay

A. Eskanlou[1], Q. Huang[2] and J. Zhang[3]; [1]Energy and Mineral Engineering, The Pennsylvania State University, University Park, PA; [2]West Virginia University, Morgantown, WV and [3]Florida Polytechnic University, Lakeland, FL

In the current study, the recovery of P and enrichment of REEs from Florida waste clay (WC) were investigated. A 1.5-in. diam. hydro-cyclone unit was initially employed for the removal of clays. Froth flotation was then examined for the separation of values from the cyclone underflow. Results showed that the direct flotation does not offer a solution for the selective recovery of P from WC. Despite their documented affinity for apatite and rare earths, hydroxamic acid collectors do not produce a selective separation. A single-stage reverse cationic process provides a more economically viable route, also owing to its relative capability to avoid the loss of REEs. Test results of the single-stage reverse cationic process indicated that the P2O5 grade was increased to 21 wt% from an initial grade of ~8 wt% with a corresponding recovery of approximately 80%. The REE content was elevated from an initial value of 307.1 ppm to 800 ppm with an 80% recovery resulting from the same process. The removal of clays, silicates, and carbonates up to a point to meet the medium-grade phosphate ore specifications also facilitates the subsequent recovery of REEs using chemical separation.

11:05 AM

Improving Cleaner Circuit Operations Using Improved Frother Selection and ControlStrategies

T. Bhambhani and E. Arinaitwe; Mineral Processing R&I, Solvay, Stamford, CT

Base metal (particularly Cu) operations are in the midst of increasing throughputs to deal with more complex, lower grade ore bodies, as well as maximize profits due to high metal prices. A major bottleneck for increasing throughput tend to be cleaner circuits, which suffer from deep froth beds arising from the use of "strong" frothers in the rougher circuit (which are not ideal for use in cleaning circuits). Solutions to this problems often include blends of "strong" and "weak" frothers, invariably leading to compromises in either the rougher or cleaner circuits. In collaboration with our customers, Solvay has developed new frother selection and control strategies to improve froth management in both parts of the circuit. The benefits of this include higher throughput processing, improved recovery of coarse particles, reducing circulating loads and higher overall recoveries.

TUESDAY, MARCH 1

MORNING

9:00 AM | Room 17

MPD: GEOMETALLURGY: PREVENTING ORE DEPOSIT MINERALOGY FROM WREAKING METALLURGICAL HAVOC

Chairs: ***I. Barton****, UA Lowell Institute for Mineral Resources, Tucson, AZ*
S. Schwarz*, RioTinto, South Jordan, UT*

9:00 AM

Introductions

9:05 AM

Geometallurgy – A Metallurgical Perspective

R. Kappes and M. Jeffrey; Newmont, Englewood, CO

Geometallurgy is generally defined as the practice of combining geology and geostatistics with metallurgy to create spatially based predictive recovery, throughput and cost models for mineral processing plants. However, definition of metallurgical domains (ore types) are often overshadowed by enthusiastic geology and mineralogy practitioners and these ore type definitions are frequently not focused on key metallurgical drivers. On the other hand, many metallurgists believe that a magnitude of 100-200 metallurgical tests can be spatially mapped using geostatistical techniques. This presentation aims to present a metallurgical perspective of geometallurgy, and highlights the benefits of a systematic approach that focuses on metallurgical drivers that will produce reliable metallurgical models that support the overall mine planning cycle.

9:25 AM

Practical Mineralogy: Solving Geometallurgical Concerns with Fast, Intuitive Mineralogy.

M. Sorensen; Rio Tinto, South Jordan, UT

Mineralogy looks at the vast, fine grained components of ore rock. It is the breakdown of the "copper minerals" often referred by metallurgists and mining engineers alike, and it can mean saving millions of dollars in headaches, and gaining more in successes if completed on time and correctly. At Rio Tinto's Bingham Canyon Mine, mineralogy is playing a key role in communication across the value stream, addressing a wide range of concerns through various methods. With the mine, mineralogy is looking at secondary copper species, magnetite concentrations, and gold, tellurium, bismuth deportment. At the concentrator, secondary copper species and clay speciations are communicated to ease processing. In the metals end, mineralogy looks for the deleterious elements, such as lead, antimony, and arsenic, to communicate these problems, and why and where they occur, downstream. This is all done through scanning electron microscopes and x-ray diffraction, with the help of microscopes, geological knowledge, and of course, Mineral Liberation Analysis (MLA). Addressing all of these issues creates a better understanding of the mine to metal properties of our ore.

9:45 AM

Geo-Metallurgical Characterization of Carlin Trend Gold Ore for Pre-Concentration

J. Jin1, E. Petersen[2] and J. Miller[1]; 1Materials Science and Engineering, The University of Utah, Salt Lake City, UT and 2Geology and Geophysics, The University of Utah, Salt Lake City, UT

Mineralogy of the Carlin Trend Deposit (CTD) has been well known for the gold-bearing sulfides disseminated in the silica and carbonate host rocks. From the QEMSCAN and gold analysis of a Twin Creeks drill core, the silica rich regions had a high grade of gold, in contrast the calcite rich regions were relatively poor in gold content. A coarse particle size sample from the Goldstrike mine was characterized by Micro X-ray Computed Tomography (XCT) to identify the rich and poor gold-bearing particles. Four classes of coarse particles were categorized based on the Micro-XCT determined silica/dolomite and calcite composition. The fire assay showed that particles with high calcite content contained significantly less gold, and vice versa, which was consistent with the QEMSCAN results. X-Ray Fluorescence (XRF) was used to determine the surface Ca composition of 1.5 kg ore particles of 2-4 cm in size. The particles were then classified and assayed. The Ca rich particles were found to contain less than 3 ppm gold, whereas the silica rich particles were found to contain more than 10 ppm. It appears that the CTD particles can be pre-concentrated based on the surface Ca composition.

10:05 AM

Geometallurgical Characterization and Gold Extraction Study for a Pressure Oxidation Residue of a Copper Sulfide Concentrate

J. Wu and J. Lee; Department of Mining and Geological Engineering, The University of Arizona, Tucson, AZ

A gold-bearing pressure oxidation (POX) residue of a copper sulfide concentrate was studied for geometallurgical properties and gold extraction using cyanide and glycine. Detailed mineralogical analyses showed that gold existed in a native gold and sub-microscopic gold by various techniques, including Scanning Electron Microscopy coupled with Energy Dispersive X-ray spectroscopy (SEM-EDX), Raman Spectroscopy and Dynamic Secondary Ion Mass Spectrometry (D-SIMS). The POX residue contained 3.1 g/t gold and 0.31% residual copper. Mineralogically, hematite and iron sulfate salts were the main mineral phases, with a small amount of un-oxidized sulfides. Native gold accounted for 32.3% and the remainder was sub-microscopic gold. Colloidal gold was dominant in secondary iron mineral phases, while solid-solution gold was found in sulfides. Gold extraction of 84% was achieved by 500 mg/L NaCN, and a comparable gold extraction was also observed using a mixture of NaCN and glycine as a synergistic lixiviant. Gold extraction results indicated that hematite did not hinder the gold extraction, but iron sulfates caused excessive lime consumption during the neutralization stage.

10:25 AM

A Microscopic Study of Leaching in Vanadium Silicate Ores

M. Drexler, M. Radwany and I. Barton; Mining and Geological Engineering, The University of Arizona, Tucson, AZ

The mineralogy of vanadium ores has important processing implications, as demonstrated by the experimental data and microscopic analyses presented in this talk. Laboratory sulfuric acid – sodium chlorate leaching experiments on uranium and vanadium ores from the Colorado Plateau in southeastern Utah show high recoveries of uranium, but some vanadium fails to leach. Comparative examination of head and tail samples suggests that vanadium-bearing illites, and other phyllosilicate minerals containing vanadium, remain incompletely leached despite the nominal solubility of vanadium under the pH and Eh conditions of the experiments and the ready dissolution of other V minerals. Transmission electron microscopy (TEM) analysis on progressively leached vanadium-bearing clays sheds new light on the crystallographic characteristics of vanadium in the ore minerals, the leaching mechanisms, and rates of release of phyllosilicate components, and the progressive decrepitation of the phyllosilicate lattice during leaching. Discussion includes the implications for the extraction of vanadium from these minerals.

10:45 AM

Penalty Element Metallurgical Amelioration by Automated Mineralogy: Progress Towards a Deportment of Fluorine in the Grasberg, DMLZ and Block Cave Mines, Papua, Indonesia

W. Mathews; Material Characterization, Freeport-McMoRan Inc Technology Center Tucson, Tucson, AZ

We report on the progress of an automated mineralogical deportment of fluorine (F) in two portions of the Grasberg District for the development of metallurgical amelioration protocols for Cu sulfide concentrates. Fluorine detection limits in automated SEM technologies range from 1% (TIMA) to about 9% (QEMSCAN), however substitution in hydrophobic minerals or those reporting to concentrate is typically much lower (<1-5%). F grades in typical concentrates have ranged near or above 1,000 ppm in the year 2020 from DMLZ; Initial F deportment studies by TIMA and SEM/WDS indicate talc and micas were the principal hosts for the currently mined DMLZ (Deep Mill Level Zone) ores as well as those of the recently milled stockpile and future GBC (Grasberg Block Cave) ores. SEM and TIMA data is then applied to QEMSCAN SIP files to calculate the deportment. Locking and liberation data indicates medium to high liberation for the most problematic species. Data shows fair to good deportment of F where gravitational segregation of particles does not exist. The data is used in projection and modeling of F behavior in Cu circuits to identify a suitable method of rejecting F in Cu cleaner circuits.

TUESDAY, MARCH 1

MORNING

9:00 AM | Room 18

MPD: PHYSICAL SEPARATION I

Chairs: ***J. McDonald****, Weir, Menasha, WI*

J. Rutledge*, Colorado School of Mines/Silvateam Indunor, Centennial, CO*

9:00 AM

Introductions

9:05 AM

Evaluation of Metallurgical Performance of Mineral Technologies FM1 and MG12 Spiral Separators for Fine Heavy Mineral Beneficiation.

J. Stacy and L. Russell; Mineral Technologies Inc, St. Augustine, FL

Poor recovery in fine heavy mineral beneficiation has been a barrier to ore commercialization for decades. Despite the introduction of specialized spiral models and innovative flowsheet designs, balancing grade, recovery, and capacity remains an elusive objective for fine heavy mineral producers globally. This study seeks to evaluate the metallurgical performance of a bespoke fine mineral spiral (FM1) versus a flagship multi-purpose heavy mineral spiral (MG12) for recovery of fine ilmenite, rutile, and zircon in a rougher capacity. This comparative testwork evaluates quantifiable performance metrics including grade, recovery, separation efficiency, and throughput of the FM1 and MG12 models.

9:25 AM

Realizing Tangible Impacts on Environmental, Societal and Governance Performance using Sensor-Based Ore Sorting for Pre-Concentration

M. Halle[1], H. Cline[2] and J. Rutledge[2]; 1Unearthed Consulting, Montreal, QC, Canada and [2]TOMRA Sorting, Golden, CO

This presentation outlines specific measures for proactively addressing environmental, societal, and governance (ESG) performance using sensor-based ore sorting (SBS) as a pre-concentration method. SBS involves separation of ore from waste material at coarse particle sizes typically following a primary crushing and screening stage. This pre-concentration of material upstream from comminution, separation and metallurgical processes reduces energy consumption and therefore carbon emissions. With less waste processed, water and reagent consumption are decreased, and the size of fine tailings ponds are reduced. By enabling mining of lower grade ores and historical stockpiles, SBS can extend the life of mine and reserves of projects. These are inherent aspects of ore sorting, reducing environmental impacts and increasing sustainability of both greenfields and brownfields operations. Introduced early in greenfield project stages, SBS can lead to optimized plant layout and capital costs. This presentation aims to demonstrate specific examples and evaluations of ESG benefits gained from implementing SBS into operations including social license and conservation of energy and resources.

9:45 AM

The In-Tank Clarifier, an Alternative for Counter-Current Processing

J. Werner and R. Honaker; Mining, University of Kentucky, Sadieville, KY

Typical counter current processes such as leaching often require the use of an agitated vessel combined with a clarifier to separate solids and liquids to achieve counter current operation. To decrease the capital expense and footprint associated with counter current processes, a design is presented for an in-tank clarifier which simultaneously allows for the agitation and the separation of liquids from solids. A preliminary finite element model was constructed utilizing Euler-Euler methods to simulate liquid particle interactions and simulate performance. A clarifier design and circuit configuration was constructed which allows for residence time control of both the solid and liquid phases independently. Data is presented on the validation and performance the apparatus and circuit.

10:05 AM

Dry Beneficiation of Minerals Using a Tribo-Electric Belt Separator

L. Rojas Mendoza, K. Flynn, A. Gupta and F. Hrach; ST Equipment & Technology, Needham, MA

ST Equipment & Technology, LLC (STET) has developed a processing system based on tribo-electrostatic belt separation that provides the mineral processing industry a means to beneficiate fine materials with an entirely dry technology. In contrast to other electrostatic separation processes that are typically limited to particles greater than 75 µm in size, the STET tribo-electric belt separator is ideally suited for separation of very fine (<1 µm) to moderately coarse (500 µm) particles, with very high throughput. The STET tribo-electric belt separator technology has been used to process a wide range of minerals and other dry granular powders. Separation results are presented for selected iron, bauxite, phosphate, barite, calcium carbonate and talc sources. New developments on the processing of phosphate tailings, metallurgical and non-met-grade bauxite ores, and on the effect of air classification on iron ore beneficiation are also discussed.

10:25 AM

Autonomous Filter Press Operation Using Artificial Intelligence

S. Nazari; Automation Solutions, Andritz AG, Graz, Steiermark, Austria

Filter press operation is a batch process that is performed semi manually. In an operation with one or two filter presses, manual decision making is a straight forward task. In this paper we show how to use the artificial intelligence to harmonize the operation of filter presses (four or more) to increase the availability and throughput of the operation. This AI algorithm is borrowed from gaming industry to provide a persona for each filter press. With this persona, each filterpress assesses the upstream and downstream situation, as well as, the efficiency of its filtering. Based on status of other filterpresses, each filterpress decides what is the most optimum action to be taken. AI algorithm, allows individual decision making to be synchronized with all other filterpresses so that the final throughput is maximized and the filtration cost is minimized. Each filterpress decides if it is time to filter, wash, change cloth or stay idle to preserve energy. In this talk we show implementation results as well as live interactive demo to showcase the intelligence behind the technology. Using this technology we are able to step toward autonomous operation in tailing.

10:45 AM

Implementation of Sensor-based Sorting Technology and Its Economic Impact at Untuca Gold Mine

A. Gallegos Gutierrez; Universidad Nacional de San Agustin de Arequipa, Arequipa, Peru

Untuca gold mine is owned by Cori Puno SAC and it is located in Puno, Peru. Their operations include an underground mine and a processing plant, and also include a marginal open pit mine and low-grade stockpiles. In 2019, to maximize the production by benefit marginal material, Cori Puno started to implement the sensor-based technology in their operations by building a sorting facility. Commissioning started in early 2021. Sensor-based sorting is a generic term for all applications where particles are detected by sensors and rejected by a mechanical or pneumatic process. Sorting technology is based on characteristics including specific gravity, color and other physical characteristics which allows the removal of waste material earlier to comminution and concentration stages. The technology's benefits are already known such as the reduction of water, chemical reagents, and energy consumption, however, the understanding of the economic impact of ore sorting is limited. This paper provides an overview of the implementation of sorting technology, its main challenges, and the key points to be aware during commissioning. Moreover, economic impacts are also discussed within this paper.

TUESDAY, MARCH 1

MORNING

9:00 AM | Room 4

VALUATION I- CASE STUDIES

Chair: ***B. Suppes****, IIMA, Johnstown, PA*

9:00 AM

Introductions

9:05 AM

Asset Appraisal versus Company Valuations – Part 2

A. Jacobsen and R. Cameron; Behre Dolbear Group Inc., Edgefield, SC

When determining the quantum of damages in legal arbitration cases, there are a number of schools of thought regarding the best approaches and methodologies in reaching a "Fair Market Value" to be used in achieving settlement. In such cases, the line sometimes becomes blurred between valuing the asset for damages and valuing the damage to a company's share value. This paper further dives into the differences between asset value and share value and how those valuation methodologies were applied in a few recent case studies. This paper also briefly looks at how the concept of ex-ante and ex-post analysis might change the quantum of damage.

9:35 AM

Creating Value and Managing Risk with Staged Project Development

M. Samis[1] and D. Laughton[2]; [1]SCM Decisions, Toronto, ON, Canada and [2]David Laughton Consulting, Edmonton, AB, Canada

Staged project development is pushed by the mining industry as a means of reducing capital costs and financing requirements. Companies justifying a staged development approach often rely on qualitative arguments and financial analysis that is unable to demonstrate the true value and risk management benefits of this approach. In this paper, we consider the Blackwater Gold Project to highlight the full value and risk management benefits of staging a project. We show that a staged project design reduces capital risk exposure by more than half while increasing value in contrast to a conventional design with a large initial capital investment.

10:05 AM

Assessing Diminution in Value in Eminent Domain Proceedings

J. Beck; J. M. Beck & Associates, Lakewood, CO

Mineral properties are often subject to eminent domain actions providing for or establishing rights-of-way for highways, utilities, temporary construction easements, etc. Such rights-of-way or easements are typically narrow, linear strips of land (of limited areal extent), and are known as "partial takings". Partial takings, however, often (but not always) result in otherwise unforeseen damage to the "larger parcel" disproportionate to the tons or surface actually taken. The "remainder" can be damaged (or not) or rendered uneconomic, effectively resulting in a diminution in value. Condemnation documents and condemnor appraisals often fail to recognize the incremental damages that are unique to mining, as well as the manner in which such damages can be realistically quantified. It is incumbent upon the appraiser to identify such damages and opine diminution of value, if any, because the opposing appraiser may fail to do so. The appraiser must possess both minerals expertise, as well as a sufficient command of eminent domain appraisal procedures in order to correctly define the "larger parcel", "part(s) taken", and "economic/uneconomic remainders", and, do so in a compelling manner.

10:35 AM

Gold Property Transaction Values – A Deeper Dive into Human Factors

G. Malensek[1], W. Roscoe[2] and P. Chamois[2]; [1]US Mining Advisory, SLR International Corp., Lakewood, CO and [2]SLR Canada Mining Advisory, Toronto, ON, Canada

SLR Mining Advisory has updated its global market transactions database to include 2020 transactions on gold properties containing mineral resources and mineral reserves. In this presentation, besides presenting current results in normalized $/oz or gold equivalent where gold is the dominant component, a subset of property transactions will be assessed against 14 physiographic factors with an emphasis of looking at "Human Factors" such as Regional Investment (as expressed in Fraser Institute rankings), environment/permitting, and social aspects of the properties in the analysis.

11:05 AM

Determination of the Fair Market and Orderly Liquidation Values of a Producing Mine

D. Noll; Amphenol Industrial Products Group, Sidney, NY

The determination of a mine's fair market and orderly liquidation values involves a large degree of judgement by an appraiser. Ultimately, reasonable exposure time is key, but consideration of the status of the existing assets plays a large part in assigning reasonable exposure time, the highest and best use, and the appraisal approach. In this case history the assets include the following: the producing mine, the adjacent properties, and the existing finished product stockpiles. The producing mine is contained within properties that meet the definition of a proven reserve. The adjacent properties are controlled, have been drilled and tested, but are not yet permitted. These were classified by the author to be either probable reserves or inferred resources, depending upon their highest and best use. The finished product stockpiles were classified as personal property. The nature of the assets dictated the appraisal approach used to determine a cumulative value. The income approach was utilized for the producing mine, the market approach was utilized for the personal property, and the market and cost approaches were utilized for the adjacent properties and their buildings.

11:35 AM

The Search for Mineral Property Comparable Sales

F. Pirkle[1] and E. Mallard[2]; [1]Gannett Fleming Inc, Saint Augustine, FL and [2]EAM2Services, Hawthorne, FL

The search for comparable sales in a nondisclosure state can be daunting. Nondisclosure states record transactions, makes them available to the public but do not list financial terms. How are comparable sales found and how are qualifying comparable sales selected? The subject property is a sand mine in a nondisclosure state. The search for comparable sales candidates is facilitated if there are prior sales. The prior sale must be at the same stage of use as the subject property. In this study the comparable sales search was undertaken by identifying sand mines within about a 15-mile radius, reviewing sales history, and determining the comparable sales candidates' Highest and Best Use at time of sale. Candidates also included properties identified by market knowledge. The candidate transactions must meet the definition of Fair Market Value to be reliable and relevant. Sales data, tax records, loan instruments and other property lists were used in the search as well as deed searches from real estate transactions. Through diligent searches, the sales comparison candidates could be adjusted to provide the Fair Market Valus of the subject property.

TUESDAY, MARCH 1

MORNING

WHAT HAPPENS WHEN MINING IS DONE?

9:00 AM | Room 05

Chairs: ***J. Brune****, Colorado School of Mines, Golden, CO*

P. Goerke-Mallet*, Technische Hochschule Georg Agricola Iniversity, Bochum, Germany*

9:00 AM

Introductions

9:05 AM

Research Center of Post-Mining at THGA Bochum/Germany

P. Goerke-Mallet, C. Melchers and J. Kretschmann; Research Institute of Post-Mining, Technische Hochschule Georg Agricola Iniversity, Bochum, Germany

Mining always leaves a mark behind. Dealing with this legacy is not only a tremendous challenge in Germany, but internationally too. The Technical University Georg Agricola (THGA) in Bochum, Germany, has established a Research Center for Post-Mining. Researchers combine expertise from a variety of technical and non-technical fields in their quest to shape the post-mining era that completes the mine life cycle. In this respect, the Research Center focuses on four research areas: Perpetual tasks and mine water management, Geomonitoring, Material sciences and site transition. With more than 200 years of successful partnership with the mining industry in Germany and abroad, THGA offers a perfect setting for fresh and sound ideas in order support mining's social license to operate. The aim of the paper is to describe the Post-Mining Research Center along with exemplary research projects that are of interest to the mining industry globally and to foster technical communication and research networking.

9:25 AM

Transformation of Lignite Mining Regions: The German Strategy

J. Kretschmann[1], V. Kai[2] and J. Brune[2]; [1]Colorado School of Mines, Golden, CO and 2THGA, Bochum, Germany

In 2018, the German Federal government decided to phase-out the energy production using coal-fired power plants and to terminate lignite mining completely by 2038 at the latest. This decision will impact approximately 60,000 jobs. It will have an enormous impact on the socioeconomic development especially in all German lignite mining regions. To avoid economic and political friction, it is of utmost importance to achieve a sustainable transition towards a post-mining era and to offer residents in the mining districts perspectives for a good future that include adequate job opportunities. In this context, the German government is providing massive structural aids early on. As previous closure experiences from the German hard coal mining industry have shown, it takes at least a generation to overcome the effects of a strategic closing decision of this magnitude. Therefore, the planned closure process appears to be a long time at first glance. In fact, however, it is not.

9:45 AM

Park City and Kennecott—Post-mining Land Use at Two Historic Sites in Utah

M. Nelson[1], A. Richins[1] and d. Symonds[2]; [1]Mining Engineering, University of Utah, Salt Lake City, UT and [2]Donovan Symonds LLC, Midway, UT

Mining at two locations in Utah have resulted in vastly different post-mining land use. Copper ore was discovered in Bingham Canyon in 1848. Mining of placer deposits began in 1863, and high-grade porphyry ore in 1887. Low-grade porphyry copper was not mined until D.C. Jackling started open-pit mining with steam shovels and rail haulage in 1906. The Bingham Canyon mine is still operating, at about 200,000 st of ore daily. High-grade silver ore was discovered near Park City in 1872. The district produced complex ores containing lead, zinc, copper, gold, and silver. Production slowed in the early 1950s, and the last mine closed in 1982. Post-mining land use in these two sites varies markedly. Bingham Canyon is an active mine, with large waste dumps, a mill, a tailings pond, and a smelter. Still, several areas are undergoing active redevelopment. Park City is now a high-end ski resort town, with million-dollar vacation residences, and its own Lululemon store. It also has a legacy of post-mining land use challenges, including deteriorating head frames and shafts, malls and houses built on unreclaimed tailings, and more. This paper describes some of the activities of in both areas.

10:05 AM

Post-Coal Mining Transition and the UN Sustainability Goals

J. Brune[1], P. Goerke-Mallet[2] and J. Kretschmann[2]; [1]Colorado School of Mines, Golden, CO and [2]Technische Hochschule Georg Agricola, Bochum, Nordrhein-Westfalen, Germany

Coal production and coal use for electric power generation is diminishing worldwide. Germany will phase-out lignite mining as well as lignite and hard coal-powered electricity generation by 2038. In the United States, coal production has dropped by more than 50% since 2006, including in key production states like west Virginia and Wyoming. Closing mines and power plants across entire mining regions has significant socio-economic impacts. Existing industries must be focused on the post-mining economy, new industries attracted, job retraining programs offered to displaced workers and former regions areas transitioned towards future agricultural, industrial and recreational use. This paper examines the "exit from coal" under the 17 UN Sustainability Goals and illustrates the complex procedures, interrelationships, risks and rewards of the transition towards renewable energy sources, including wind, solar hydrogen and bio-resources.

10:25 AM

Mine Closure and Post-Mining in Small-Scale Mines in Colombia

D. Lezcano and J. Kretschmann; Technische Hochschule Georg Agricola, Bochum, Nordrhein-Westfalen, Germany

In the Boyacá region of Colombia, mining authorities use forced shut downs to pressure miner operators into improving their mining practices. This strategy has quite the opposite effect. Mines are low-tech, planned and operated day by day, without a long-term business vision. Reclamation and post-mining activities are not in the minds of the miners. When the authorities threaten to shut a mine down, operators rather abandon the mine as they consider that the demands by the authorities expensive and unreasonable. This situation generates environmental, social and economic problems that are not remedied. It is easier for miners to start a new mine than to deal with the authorities. This government strategy only encourages informal mining and abandonment. This research aims to propose strategies to help both miners and authorities tackle the challenges that the post-mining process brings. Colombia must revise sanctioning policies to improve the current and future situation for its mines and miners.

10:45 AM

Modern Methods of Geomonitoring in Post-Mining Processes

M. Pawlik[1], X. Yin1, T. Rudolph[1], P. Goerke-Mallet[1] and J. Benndorf[2]; [1]Research Center of Post-Mining, Technische Hochschule Georg Agricola, Bochum, NRW, Germany and [2]Technische Universitat Bergakademie Freiberg, Freiberg, Sachsen, Germany

Geomonitoring of former mining areas is an eternal task in the post-mining period. Challenges include detection of environmental changes and management of ground and surface water. Modern geomonitoring methods use optical, multispectral, hyperspectral and microwave sensors and cover a wide range of spatial dimensions and spatio-temporal resolutions from satellites to unmanned aerial vehicles (UAVs) and to in-situ sensors. Big data integration combined with local site knowledge provides the basis for comprehensive modeling of post-mining changes in the environment. This furthers the understanding of the environmental impacts and their causes and becomes an integral element of public acceptance. In this paper, we provide an overview of various geomonitoring projects in the Ruhr-area, Germany, where coal mining ceased in 2018.

11:05 AM

Tailing Dam Monitoring – Safety Enhancement Through Data Fusion

A. Mueterthies[2], T. Rudolph[1], P. Goerke-Mallet[1] and J. Kretschmann1; [1]Technische Hochschule Bochum University, Research Center of Post-Mining, Bochum, North Rhine Westphalia, Germany and [2]Research and Development, EFTAS, Muenster, North Rhine Westphalia, Germany

Catastrophic failures of dams and tailing storage facilities (TSF) have triggered the development of integrated ground monitoring concepts for hazard assessment, risk management and public safety. These concepts are based on knowledge and expertise of persons technically responsible for TSF. The aim is to combine this implicit and explicit knowledge with the data of in-situ- and remote sensors. Risk management for TSF must include a comprehensive monitoring program that draws data from both ground based, air-borne and satellite-based sensors. Researchers at Technical University Georg Agricola (THGA) in Bochum, Germany, are fusing a variety of sensor data to enhance the capability and performance of TSF monitoring to ensure public safety downstream of TSFs. This paper describes the variety of sensors implemented in numerous research projects. It gives and outlook in terms of planned satellite missions with innovative equipment like hyperspectral sensors. The implementation of the data of these sensors in the analysis will increase the understanding of spatio-temporal impacts of mining activities.

TUESDAY, MARCH 1

AFTERNOON

Room 20 | 2:00 PM

BULK MATERIAL HANDLING: PRACTICAL APPLICATIONS OF NEW TECHNOLOGIES AND FIELD PRACTICES FOR CONVEYOR SYSTEMS

Chair: ***C. Hartford****, Jenike & Johanson, San Luis Obispo, CA*

Sponsored by Siemens

2:00 PM

Introductions

2:05 PM

Ore and Waste Handling at Nevada Copper's Pumpkin Hollow Mine

D. Ekmark[2], T. Dake[3], J. Cline[1] and J. Vespa[4]; [1]Mining & Met, McGill University, Montreal, QC, Canada; [2]University of Minnesota Twin Cities, Minneapolis, MN; [3]University of Nevada Reno, Reno, NV and [4]Engineering, University of Minnesota Duluth, Duluth, MN

Nevada Copper, Inc. (NCI) is a mining company engaged in the development of a fully permitted underground copper deposit in the United States. Their Pumpkin Hollow Mine, located on 10,000+ acres of private land east of the town of Yerington in Lyon County, Nevada is currently under construction and in the initial ramp-up of concentrate production. When completed, the mine will have one of the most advanced underground materials handling infrastructure in western Nevada. To fast-track early production from the underground, an interim materials handling system (Phase-1) was designed to integrate into the 5000 tpd final materials handling infrastructure that is planned for the underground operations. This integration will allow future operational efficiencies and higher overall throughput. This article will focus on the design, construction and operation of the underground materials handling facility including the safety and failsafe system integration, the decision to develop and incorporate the Phase-1 system into the life of mine materials handling infrastructure, from design development to construction, commissioning and operations.

2:35 PM

Novel Installation Method of Conveyor Belt in Bangladesh

A. Hustrulid and M. Derige; Shaw Almex, Bonita Springs, FL

This paper outlines the replacement of 34 km of conveyor belt transporting limestone from a quarry in northern India to a cement processing plant in Bangladesh. The terrain and inclement weather posed unique challenges to belt installation personnel as monsoons and flat terrain make most of the conveyor inaccessible to heavy equipment. Furthermore, we only had access to the Bangladeshi portion of the conveyor. A novel solution was developed that utilized the available space near the tail pulley while minimizing conveyor downtime. A splicing station was constructed and a total of 11km of belt was spliced, x-rayed and flaked onto a cleared area adjacent to the tail pulley. This belt was spliced to the existing belt and pulled onto the conveyor system by two powerful 150 kW winders. This method was set to be repeated a total of three times. However, with knowledge gained during the first shutdown, the procedure was improved so that the remaining 23 km would be installed at once. This procedure allowed the belt to be installed within a single four-day shutdown period instead of two shutdowns lasting one week each.

3:05 PM

Seismic Elastic Behavior of Mine Head Frames

M. Hardy, Golder WSP, Lakewood, CO & J. Driscoll Golder WSP, Lakewood, CO

The structural design of mine headframes is challenging due to the significant differences in the geometry, rigidity, and behavior of these structures compared to conventional buildings. The differences are related to the main purpose of these structures, which is not human occupancy, but rather the support of hoisting equipment. The main objective of this paper is to present the seismic elastic behavior of headframe structures in comparison with conventional buildings, which is the base case for the definition of seismic loads. This paper highlights the impact of backlegs on the dynamic behavior of mine headframes, more specifically the resulting torsional sensitivity.

3:25 PM

Gearless Conveyor Drives – A Step Towards Greater Sustainability and Carbon Footprint Reduction

C. Dirscherl and C. Voelkel; Minerals, Siemens Industry Inc., Littleton, CO

Sustainability is one of the most importantly discussed topics in regard to mining amongst the public as well as the industry itself. Supplementarily, and due to the more and more obvious effects of climate change, the carbon footprint of any activity is in the spotlight. Siemens Gearless Drives for conveyors can be an important part of the mining industry's journey towards a sustainable future. By increasing efficiency and availability, as well as a reduction of parts and thus maintenance activities, a smaller carbon footprint is achieved, safety is increased, and environmental risks are reduced.

3:55 PM

Bearing Solutions for Harsh Environments in Mining Conveyor Applications

N. Bhatti; Industrial Bearing Technology, NSK Corporation, Ann Arbor, MI

Spherical roller bearings are used in conveyor pulley applications for their high load capacity and misalignment capability. Bearing durability and reliability are paramount where failure can impact an entire operation. Bearings used in these applications often deal with heavy load, mechanical shock, dirt, contamination, and marginal lubrication conditions which severely deteriorate bearing life. This paper will review spherical roller bearing product solutions have been developed to withstand the environmental stresses seen in mining machinery and equipment. These solutions include: -increasing capacities for high loads and high speeds -advanced materials for durability, wear resistance and longer life -seal technology for clean running and proper installation These long-life bearings provide operators of mining machinery the benefits of increased uptime and assure predictable reliability.

4:25 PM

Practical Experience with BeltGenius

M. Ziegler; Belt Conveyor Systems, J.M. Voith SE & Co. KG, Nörvenich, North Rhine-Westphalia, Germany

Voith will present field results of its digital twin in the assessment and optimization of two conveyor systems in both copper and coal applications. These examples show what comprehensive insight Voith's digital twin provides into the utilization and operating behavior of a conveyor system, thus improving the overall economy, reliability, and energy efficiency. In addition, BeltGenius is a powerful tool to examine the system behavior. The benefit for the customer arises increasingly by implementing automatic detections of critical deviations from the target state in connection with the operational requirements aligned with the customer to system deviations detected by BeltGenius.

TUESDAY, MARCH 1

AFTERNOON

Room 03 | 2:00 PM

COAL & ENERGY: COAL-GAS INTERACTIONS AND METHANE MANAGEMENT

Chairs: ***R. Pandey****, Peabody Energy*

M. Mohanty*, Reno, NV*

2:00 PM

Introductions

2:05 PM

NIOSH Gas Well Stability Research Program – Status and Significant Findings

W. Su, P. Zhang, H. Dougherty and M. Van Dyke; MSSB, National Institute for Occupational Safety and Health, Jefferson Hill, PA

To provide critical scientific data and engineering guidelines to federal and state regulatory agencies as well as the coal and gas industries, the National Institute for Occupational Safety and Health (NIOSH) initiated a Gas Well Stability Research Program in 2016. This paper summarizes the critical scientific data acquisition, interpretation, and modeling by NIOSH regarding the stability of unconventional shale gas wells influenced by longwall mining. Results from the NIOSH field instrumentation programs, which include surface, subsurface and underground instrumentation, and the parallel 3-dimensional numerical modeling programs indicate that under shallow and medium covers, the measured horizontal displacements within the abutment pillar are one order of magnitude higher than those measured under deep cover. Casing couplers and cementing alternatives are found to play an important role in longwall-induced casing deformations and stresses. Engineering guidelines on longwall-induced deformations, casing and cementing alternatives, gas well setback distances, as well as risk assessment strategy are proposed.

2:25 PM

Investigating Relationships Between Methane Emissions, Atmospheric Data, and Production Parameters in Underground Coal Mines

J. Diaz Martinez[1], Z. Agioutantis[1], S. Schafrik[1] and D. Hristopulos[2]; [1]Mining and Mineral Department, University of Kentucky, Lexington, KY and [2]Technical University of Crete, Crete, Chania, Greece

Big data is generated from both surface and underground mining operations. Such data contain a wealth of information concerning safety and health in the workplace and production parameters. This paper will discuss the progress towards developing an accurate forecasting model for methane gas concentration based on the analysis of data collected from Atmospheric Monitoring Systems in underground coal mines employing time series models. Several procedures need to be applied to raw data, such as data cleaning and filtering for outlier removal, data homogenization, and exploratory statistical analysis. The data analyzed were retrieved from two coal operations in the Eastern US. A negative correlation between barometric pressure and methane gas concentration was established, at least for certain data segments. Such correlations raise the possibility that barometric pressure data can predict variations of gas concentration in the mine. The datasets will be further investigated to establish the robustness of barometric pressure and gas concentration correlations and to explore the dependence of gas concentration on other factors related to mine design and operations.

2:45 PM

Rockmass Permeability Induced by Longwall Mining Under Deep Cover: Potential Gas Inflow from a Sheared Gas Well

Z. Khademian, K. Ajayi, W. Su, S. Schatzel and G. Esterhuizen; Mining Systems Safety Branch, National Institute for Occupational Safety and Health Pittsburgh Research Laboratory, Pittsburgh, PA

Stability of unconventional shale gas wells drilled through current and future coal reserves can be compromised by ground deformations due to nearby longwall mining. Depending on the longwall-induced rock permeability, the high-pressure gas from the damaged well may reach mine workings and overwhelm the mine ventilation systems. This study uses geomechanical models to estimate the rockmass permeability induced by mining. A two-panel longwall model of a deep, 341 m cover, mining site in the southwestern Pennsylvania is constructed in 3DEC to explicitly model the rockmass by a Discrete Fracture Network (DFN) technique. Stress-induced fracture apertures and permeabilities are calculated across the model and are validated against limited permeability measurements. A Fracture Flow Code is developed to use these results to predict potential inflow to the mine should a gas well breach occurs. Results show the average gas volume flow rate to the mine is 0.015 m3/s and 0.094 m3/s for a gas pressure of 2.4 MPa and 20.7 MPa, respectively. These results can help assess the potential hazards of a shale gas well for the mine safety and evaluate the ventilation requirements to mitigate the risk.

3:05 PM

A Network Model of an Unconventioinal Well Breach in an Underground Coal Mine

H. Dougherty, E. Watkins and R. Kimutis; National Institute for Occupational Safety and Health, Pittsburgh, PA

Gas wells often intersect mining resources, but unconventional shale well drilling has more recently challenged mines to balance the risk of interaction due to higher pressures and larger quantities of gas. Full extraction mining such as the longwall method induces ground movement that may influence the casings if wells are drilled in the mining area. The possibility of a casing shear would lead to the risk of unplanned gas migration into the mine which has the potential to overcome the ventilation system, if ignited has catastrophic consequences. The utilization of software to model mine ventilation is a common practice in the mining industry and can assist with a well breach scenario. We model a well breach in between two longwall panels after second panel mining with gas entering through the gobs of both longwall panels. Using the software Ventsim a gob zone and ventilation network were created to better understand the distribution of gas and the limitations and effectiveness of a ventilation system. Using a standard Pittsburgh coal seam longwall ventilation scheme, we find that the system can handle a significant inflow of 1200 cfm Ch4 before the gas travels back on the face.

3:25 PM

Simulating the Impact of a Shale Gas Well Breach on Longwall Mine Ventilation Utilizing a Scaled Physical Model

V. Gangrade, R. Kimutis, E. Watkins, S. Schatzel, J. Addis and C. Hollerich; National Institute for Occupational Safety and Health (NIOSH), Pittsburgh, PA

The recent shale gas revolution in the USA has led to the drilling of hundreds of unconventional shale gas wells in active and future coal reserves in traditional coal-mining regions of Pennsylvania, West Virginia, and Ohio. This paper summarizes the impact of a shale gas well breach on the mine ventilation system of an operating longwall panel. The study utilizes a 1:30 scaled Longwall Instrumented Aerodynamic Model (LIAM) to simulate a single panel longwall operation. The LIAM will be utilized to identify flow pathways and distribution patterns of gas from breached gas well scenarios in an operating longwall in the Pittsburgh Coal Seam. Sulfur hexafluoride (SF6) tracer gas is utilized to simulate a breached gas well. Preliminary findings suggest that the breached gas is diluted to regulatory levels and does not accumulate in the mine entries or in the longwall gob when the longwall panel is adequately ventilated. Overall, this study characterizes the potential interaction between shale gas wells and the mine environment in the event of a gas well breach, which provides critical information to the industry and regulatory agencies for improving miners safety, health, and welfare.

3:45 PM

Gas Source Discrimination Methods to Identify the Occurrence of a Hypothetical, Unconventional Gas Well Breach into a Nearby Longwall Mine

S. Schatzel, K. Ajayi, E. Watkins and V. Gangrade; PMRD/MSSB/VEP, National Institute for Occupational Safety and Health, Washington, DC

The National Institute for Occupational Safety and Health (NIOSH) is conducting research on unconventional gas wells in abutment pillars associated with longwall mining. A portion of this work is aimed at characterizing a hypothetical casing breach and its effect on the safety and health of miner, gas well workers and the public. An important task is the distinguishment of coalbed gas from shale gas in the mine as an indicator of a casing breach. Another non-coal gas source exists, local underground gas storage fields where gas could migrate towards mine workings. If a breach occurred, additional natural gas in the mine will exceed the anticipated ventilation loading, creating a mine explosion hazard. A methodology has been developed to distinguish the sources. Samples from the three sources were analyzed by gas chromatography and interpretive methods were applied. Samples of non-coal gas contained under two percent CO2 and all coal samples included greater than this amount. A multivariate t-test indicated the sources separate and distinct gas populations. Stakeholders from the mining and gas production industries could utilize this method to identify potential casing breaches.

TUESDAY, MARCH 1

AFTERNOON

Room 01 | 2:00 PM

COAL & ENERGY: INNOVATIONS AND IMPROVEMENTS IN COAL MINING II

Chairs: ***S. Schafrik****, University of Kentucky, Lexington, KY*

C. Seaman*, CDC/NIOSH/PMRD, Pittsburgh, PA*

2:00 PM

Introductions

2:05 PM

Identifying Longwall-induced Fractures Through Core Drilling

M. Van Dyke and P. Zhang; Ground Control, NIOSH, Pittsburgh, PA

The National Institute for Occupational Safety and Health (NIOSH) has been evaluating longwall mining induced strata deformations and their impacts on casing stability of Marcellus shale gas wells. NIOSH researchers drilled a corehole into the fracture zone above the Pittsburgh coal seam after the longwall panel had been retreated. Knowing the extent of the fracture zone will help researchers and mine operators have a better understanding of the possible interaction between Marcellus gas wells and the mining operations. The longwall panel dimensions were 1,500 ft wide and 12,000 ft long in which the total fracture zone height was found to begin at 345 ft above the top of the Pittsburgh seam where 40 to 60 degree fractures were observed. In addition to core drilling through the gob, FLAC3D modeling was also used to simulate the formation of fracture zone and the orientations of longwall-induced fractures. This study provides much needed evidence on the fracture zone of modern sized Pittsburgh seam longwall panels to help place Marcellus gas wells within a safe distance from active mining areas to prevent high pressure natural gas from entering the operating mine.

2:25 PM

Lithium-Ion Battery Technologies for Underground Coal Mines

J. Haughey; Joy Global, Warrendale, PA

As coal mines continue to work to protect workers and the environment, while continuing to be profitable, advances in battery technologies can provide a way forward. One such technology is lithium ion (Li-Ion), a technology that can offer a significant leap forward in energy storage and availability. This paper will look at the current Li-Ion technologies available and their suitability for underground coal mines. Second, the paper will discuss the requirements for the safe use of such technologies. Finally, initial field experience of Li-Ion batteries operating on battery haulers will be provided.

2:45 PM

Geology Oriented Abutment Load Estimation Approach for Underground Coal Mines

D. Tuncay, I. Tulu and H. Zhao; Mining Engineering Department, West Virginia University, Morgantown, WV

In commonly used pillar design tools for underground coal mines, overburden loading is estimated by simple geometric rules and these methods usually overlook the effect of mine-specific overburden geology. This study aims to develop a geology-based mechanistic loading estimation approach to improve the shortcomings of current design methods for underground coal mines. A database of 13 field measurement studies from 12 different U.S. longwall mines with detailed core log information is put together. These mines are numerically modeled using FLAC3D and the models are verified against the field measurements such as surface subsidence, and stress measurements. The numerical models are then used to estimate the side abutment loads and gob loads which are used as the response of the statistical model. As the geological parameter, the critical span values of the overburden layers are investigated for this study. These span values together with other operational parameters such as panel width and overburden depth are used for the regression analysis to construct an abutment loading model, and successful results have been achieved.

3:05 PM

Implementing a Laminated Overburden Model to ALPS

M. Ates, D. Tuncay and I. Tulu; Mining Engineering, West Virginia University, Morgantown, WV

In previous research, the laminated overburden model from the LaModel program was integrated with Analysis of Retreat Mining Pillar Stability (ARMPS), and ARMPS-LAM program was developed. This program takes the basic ARMPS geometric input, and then automatically develops, grids, runs, and analyzes a full-scale laminated model (LaModel) of the mining geometry to output the ARMPS stability factors (SF). In more recent research, it was shown that ARMPS-LAM with an improved overburden loading model can classify the deep caver cases in the ARMPS database better than the original ARMPS program. In the research presented in this paper, the development of a similar computer code that implements the laminated overburden model into the Analysis of Longwall Pillar Stability (ALPS) has been discussed. This program takes the basic ALPS geometric input for defining the mining plan and loading condition and then automatically develops and runs the laminated model and outputs the ALPS stability factor, all without further user input.

3:25 PM

Intrinsically Safe Mine Rescue UAV Development: Phase 1 - Design

S. Cotten and M. Trevits; Xtraction Science and Technology, Inc., South Park, PA

An impediment to unmanned aerial vehicle (UAV) use to assist mine rescue operations is MSHA approval for use in hazardous mine atmospheres. A prior investigation established the requirements for a mine-worthy mine rescue UAV and identified the primary approval obstacle as the electrical power required to operate the commercial UAV brushless motors. This Phase 1 design effort investigated two parallel approaches to overcome the power obstacle: employ small commercial motors with a constrained power supply and (2) develop a new intrinsically safe motor design larger than the small commercial motors to enable development of a more capable rescue UAV.

3:45 PM

Adaptation of Coal Mine Floor Rating (CMFR) to Eastern U.S. Coal Mines

S. Cicek[1] and I. Tulu[2]; [1]Geotechnical Engineer, Nevada Gold Mines, Elko, NV and [2]Assistant Professor, West Virginia University, Morgantown, WV

Floor heave—the excessive deformation and failure of floor strata—is a serious problem for many underground coal mining operations in the U.S. and there is not any systematic design method to assess floor heave potential for Eastern U.S. coal mines. In this study, the Coal Mine Floor Rating (CMFR) system, a rock mass classification system recently developed by Mo (2019) in Australia to four Eastern U.S. coal mines that intermittently experienced floor heave. The CMFR system is adopted to Eastern U.S. coal mines through modifications such as such orientation coefficient, horizontal stress magnitude, and elastic modulus of the strong floor layer. After modifications, better separation of failure and non-failure cases from one another is observed and an applicable rock mass classification system capable of predicting potential floor failures in the U.S. is proposed.

TUESDAY, MARCH 1

AFTERNOON

Room 02 | 2:00 PM

COAL & ENERGY: RESEARCH AND INNOVATIONS IN RESPIRABLE CRYSTALLINE SILICA (RCS) MEASUREMENT TECHNOLOGIES

Chairs: ***K. Raj****, CDC NIOSH, Spokane, WA*

D. Parks, *CDC NIOSH, Spokane, WA*

2:00 PM

Introductions

2:05 PM

Silica Classification in Respirable Coal Mine Dust Using Optical Microscopy and Image Processing

N. Santa[2], C. Keles[2], J. Saylor[1] and E. Sarver[2]; [1]Department of Mechanical Engineering, Clemson University College of Engineering Computing and Applied Sciences, Clemson, SC and [2]Department of Mining and Minerals Engineering, Virginia Polytechnic Institute and State University College of Engineering, Blacksburg, VA

The resurgence of lung diseases in coal miners has emphasized the need for advanced dust monitoring technologies. Prior work has indicated that optical microscopy and image processing can be used to classify respirable coal mine dust (RCMD) particles into two primary fractions: coal and minerals. In this study, we aim to demonstrate further classification of mineral particles by specifically separating silica based on its characteristic optical properties. The experimental approach involves, first, building a library of microscope images containing variable distributions of respirable-sized particles that are representative of the primary dust types in RCMD (i.e., silica, silicates, carbonates, and coal). Then, an image processing routine is used to identify particles and extract feature data (i.e., size, optical characteristics). Finally, a model can be built using the feature data from known particles to classify silica in unknown samples. Here, we present results of the silica classification on lab-generated dust samples. We additionally discuss an envisioned field application based on portable microscopy.

2:25 PM

Investigation of RCMD Characteristics in Western and Eastern Underground Coal Mines in the US

M. Hovingh[2], Y. Shekarian[2], P. Roghanchi[1] and M. Rezaee[2]; [1]Mineral Engineering, New Mexico Institute of Mining and Technology, Socorro, NM and [2]The Pennsylvania State University, University Park, PA

Coal worker's pneumoconiosis (CWP) has been on the rise in recent years, especially in the Appalachian region of the US. Several studies have shown the striking effect of contributing factors such as mining method, and geographic location in the prevalence of coal worker's pneumoconiosis (CWP). The purpose of this study is to investigate respirable coal mine dust (RCMD) characteristics such as size, shape, mineralogy, crystalline silica content, and bioavailability. Multiple techniques were used to characterize the collected dust samples; automated SEM-EDX to determine the size, shape, and mineralogical content, FTIR to determine the crystalline silica content, and dissolution coupled with ICP-MS to yield the bioavailability of the dust. Furthermore, the characteristics of RCMD dust in western and eastern underground coal mines in the US were compared. While RCMD dust characterization is not the complete answer as to the difference in CWP occurrence between these two regions of the US, it is a significant piece of the puzzle.

2:45 PM

Calibration of Low-cost PM Sensors for Coal Dust Monitoring

N. Amoah, A. Kumar and G. Xu; Mining Engineering, Missouri University of Science and Technology, Rolla, MO

Exposure to mining-induced coal dust is linked to the recent resurgence of coal workers' pneumoconiosis (CWP) in the US mines. Accurate personal exposure monitoring can protect coal miners from overexposure. However, currently used coal dust monitors are expensive, heavy, and only measure mass concentration. These drawbacks limit them for regulatory sample monitoring purposes that require only a few miners to wear it. As a result, most miners could be exposed to elevated coal dust unknowingly. Low-cost PM sensors offer a high spatiotemporal resolution of coal dust monitoring. However, these sensors require accurate calibration before they can be applied in mining environments. This study calibrates a low-cost PM sensor for coal dust monitoring. A complete monitor is fabricated using the low-cost sensor to display coal dust concentrations in real-time and store data. PDM3700 is used as the reference monitor to calibrate the low-cost sensor at varying coal dust concentrations, temperature and relative humidity. Multivariate calibration models are used to calibrate the sensors following the experiments to ensure high performance, accuracy, precision and robustness in its operation.

3:05 PM

Portable FTIR for Rapid Silica Analysis in Coal Mine Dust: A Demo Video as Outreach

B. Jones, N. Pokhrel and E. Sarver; Mining and Minerals Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA

Respirable crystalline silica (RCS) represents a serious health hazard for miners, and has been associated with the dramatic resurgence of lung disease among US coal miners. Improved monitoring technologies and programs are accordingly a top priority. NIOSH has been working to develop a direct-on-filter (DOF) analysis method that uses portable Fourier Transform Infrared (FTIR) transmission spectroscopy. It is intended as an "end of shift" method that would enable more rapid assessment of RCS exposures—and thereby more rapid interventions. Research surrounding the DOF FTIR method for coal mine dust samples has yielded favorable results in terms of RCS measurement reliability. However, significant adoption by the coal mining industry is not yet underway. To facilitate interest and learning, we created a video tutorial to explain the DOF FTIR method purpose and procedures, and outline the required sampling materials and equipment, analytical instrumentation, and NIOSH-developed silica analysis software; and the video includes demonstration of all method steps from start to finish. In this presentation, we will discuss this outreach effort and feedback from interested stakeholders.

3:25 PM

Analysis of Dust Concentration Data from Helmet-CAM and Reduction of Miners' Dust Exposure

S. Jayaraman Sridharan[1], P. Tukkaraja[1] and E. Cauda[2]; [1]Mining Engineering and Management, South Dakota School of Mines and Technology, Rapid City, SD and [2]PMRD, NIOSH, National Institute for Occupational Safety and Health, Pittsburgh, PA

Real-time personal dust monitoring is helpful in identifying miners' dust exposure. However, this will not provide the information on dust source or activity. The Helmet-CAM and Enhanced Video Analysis of Dust Exposure (EVADE) software, developed by researchers at the National Institute for Occupational Safety and Health (NIOSH), is a technique that uses video from the camera worn by the worker concurrently with data collected by a real-time personal dust monitor. The EVADE software program merges video files and logged data files, allowing the user to view them simultaneously. In this study, the dust concentration levels are tagged based on the activity and the working area to identify the dust exposure source or activity. Engineering and administrative solutions can then be implemented to reduce dust exposures. The ability of the Helmet-CAM and EVADE technology to reduce miners' dust exposure is evaluated using available data. The outcome of the study will help the mining industry to reduce the miners' dust exposure.

3:45 PM

Wearable Respirable Dust Monitor (WEARDM) for Real-Time Gravimetric Monitoring of Concentrations of Coal and Silica Dust in Underground Coal Mines

I. Paprotny and M. Hajizadehmotlagh; Electrical and Computer Engineering, University of Illinois at Chicago, Chicago, IL

Exposure to respirable coal and silica dust in underground coal mines can cause etrimental airway diseases such as coal worker's pneumoconiosis (CWP), silicosis, and lung cancer. In this paper, we present the design, fabrication, and experimental evaluation of a wearable respirable dust monitor (WEARDM) which uses a dual-resonator gravimetric sensing approach for continuous measuremen of respirable airborne particulate matter (PM) concentrations. WEARDM use a novel dual-resonator mass sensor which is composed of a quartz crystal microbalance (QCM) and a film bulk acoustic resonator (FBAR) allowing measurement of PM mass concentration in real-time. The QCM measures the mass concentration of particles generated from coal mining operations (typically >2.5 µm A.D.), separated using inertial impaction. Then thermophoretic precipitation is used to deposit the fine and ultrafine particles (typically <0.1 µm A.D.) on FBAR. This allows the WEARDM system to maintain large dynamic range and uniform collection efficiency across the entire respirable fraction.

TUESDAY, MARCH 1

AFTERNOON

Room 07 | 2:00 PM

ENVIRONMENTAL: GREEN MINING PART III - CRITICAL MINERALS

Chairs: ***A. Persico****, INTERA, Inc, Walla Walla, WA*

E. Vahidi*, University of Nevada Reno, Reno, NV*

D. Reed*, Idaho National Laboratory Research Library*

2:00 PM

Introductions

2:05 PM

Environmental Aspects and Impacts of Rare Earth Mining and Processing

D. Talan and Q. Huang; Mining Engineering, West Virginia University, Morgantown, WV

Many research initiatives have been funded to identify alternative sources to meet the industrial deficit that arose due to supply constraints and the lack of minable concentrations of rare earth minerals in recent years. However, toxic and radioactive elements are frequently seen in the same mineralization as rare earths regardless of their primary or newly identified sources. The concentration of these hazardous elements may be elevated as a result of extraction and beneficiation processes. They produce extremely high occupational radiation exposures and large amounts of hazardous waste, which may develop cancer risk for workers, severely damage surface vegetation, cause water pollution, and affect agricultural output. The environmental prospect of rare earth mining was not thoroughly considered until recent years. Within that context, this presentation aims to provide insightful information on the environmental impact of rare earth mining arising due to the association of toxic and hazardous elements considering both conventional and unconventional sources. Moreover, a brief introduction to the potential separation techniques for these radioactive materials will be given.

2:25 PM

Utilizing an Existing Uranium Mill to Create a New, Low Cost U.S. Rare Earth Supply Chain Based on a Monazite

M. Chalmers; Energy Fuels Inc., Lakewood, CO

Energy Fuels' White Mesa Mill is a licensed & operating uranium mill in Utah which may hold the key to restoring a low-cost rare earth (RE) supply chain in the US. Monazite is a RE mineral recovered at heavy mineral sand (HMS) operations in the US & elsewhere. Monazite is contains concentrations of Nd, Pr & "heavy" RE's that are superior to Bastnaesite, the other main RE mineral mined in the US. However, the "problem" with Monazite is that it contains higher levels of uranium & other radionuclides than Bastnaesite. As a result, HMS operators need to sell their monazite to China or dispose of it. Energy Fuels solved this issue. In 2021, Energy Fuels began buying Monazite from a HMS operation in Georgia (US). We are recovering the uranium for nuclear power, evaluating recovering the thorium, and producing mixed RE Carbonate. In July 2021, we began shipping RE Carbonate to a RE separation facility in Estonia. As a result, Energy Fuels is now producing a RE product more advanced than any other US company. We are also planning to install RE separation, and possibly metals/alloys capabilities, at Mill in the coming years, thereby creating a fully integrated RE supply chain in the US.

2:45 PM

Rare Earth Elements Recovery From Coal Refuse Using Organic Acids Converted from Food Waste

B. Jones, Q. Li and W. Zhang; Mining and Minerals Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA

Rare earth elements (REEs) are critical materials to the United States due to the imbalance between their supply and demand. Considerable research and development efforts have been devoted on REE recovery from coal refuse using inorganic acids as lixiviants, however, the cost of inorganic acids is normally high, and the environmental friendliness is low. As alternatives to inorganic acids, organic acids of small molecules such as lactic acid and succinic acid have been used as efficient and green lixiviants for metal extraction. In addition to the supply risk of REEs, food waste generation and disposal is another emerging and critical issue since nearly one-third of the edible food is lost or wasted each year. In this research, organic acids were microbially converted from food waste and used as lixiviants to leach REEs from density fractions of an Illinois Basin coal. Experimental results indicate that REE recovery increases of up to 15 absolute percentage points were obtained using organic acids relative to inorganic acids. The conversion of food waste into value-added, renewable, and environment-friendly chemicals promotes the economic viability of REE recovery from coal refuse.

3:05 PM

Recovery of REE from Magnet Waste Using Microorganisms Grown on Food and Agriculture Wastes.

C. McNamara[1], M. Alipanah[2], K. Lyon[1], M. Greenhalgh[1], L. Aldana[1], Y. Fujita[1], H. Jin[2], V. Thompson[1] and D. Reed[1]; 1Energy Environment Safety and Technology, Idaho National Laboratory Research Library, Idaho Falls, ID and [2]Department of Systems & Industrial Engineering, The University of Arizona Graduate College, Tucson, AZ

REE are used widely in many different industrial, communication and green-energy technologies. Agriculture and food wastes were shown to serve as a substrate for biolixiviant production to bioleach REE from magnets obtained from magnetic swarf, mobile device speakers, and computer HDD. Design of experiment modeling driven by net present value was used to optimize the bioleaching conditions and showed >60% neodymium and 100% dysprosium recovery. Preliminary experiments conducted to separate REE from non-REE in the bioleachate suggested opportunities to improve the process and purify REE. These data suggest that Bioleaching can be used effectively as a green technology in recycling REE.

3:25 PM

Bioleaching of Tellurium from Mine Tailings with Iron and Sulfur Oxidizing Microorganisms

Y. Fujita[1], D. Gazzo[2], J. Busboom[3], M. Guzman[4], D. Park[4] and D. Reed[1]; [1]Idaho National Laboratory, Idaho Falls, ID; [2]Chemical and Biomolecular Engineering, University of Notre Dame College of Engineering, Notre Dame, IN; [3]Chemical and Biological Engineering, Colorado State University, Fort Collins, CO and [4]Lawrence Livermore National Laboratory, Livermore, CA

Tellurium is used in thin-film photovoltaic cells and is primarily obtained as a byproduct of copper production. We investigated the use of iron- and sulfur-oxidizing microorganisms to leach Te from mine tailings. Constructed microbial consortia were tested for their ability to solubilize tellurium in batch leaching experiments. Average Te solubilizations ranging from 32 to 57% after two weeks were observed, depending on the tailings and culture combinations. The data also suggested that native microbes in tailings likely contributed to leaching. The results are promising with respect to the potential for development of new and more environmentally friendly sources of tellurium.

3:45 PM

Challenges and Green Opportunities in Direct Lithium Extraction and Recycling

Y. Smith; Metallurgical Engineering, University of Utah, Salt Lake City, UT

Lithium and its compounds have found numerous applications in glass and ceramics, energy storage, nuclear energy, and pharmaceuticals. The need to meet our rapidly growing demand for lithium motivates extraction from unconventional resources such as low-grade brines (e.g., The Great Salt Lake or geothermal brines) and secondary resources (e.g., end-of-life lithium-ion batteries). In this presentation we will review methods of lithium extraction, their current challenges, and new green extraction (i.e., direct lithium extraction from aqueous resources) and recycling (carbon-free processing of end-of-life lithium-ion batteries) approaches developed in our group.

4:05 PM

Comparative Life Cycle Analysis for Critical Materials Recovery from Spent Li-ion Batteries

S. Mousavinezhad[1], S. Kadivar[2] and E. Vahidi[3]; [1]PhD student of University of Nevada, Reno, NV; [2]Master student of University of Nevada, Reno, NV and [3]Mining and metallurgical engineering, University professor, Reno, NV

Recent studies predict a global demand for Li-ion batteries (LIBs) of $129 billion by the year 2027. Developing new generations of electric vehicles is expected to drive the growth of LIBs' global market however, the lifetime of batteries on electric vehicles is about 10-15 years. Therefore, it is imperative to develop means of both diverting these batteries from the solid waste stream and recovering critical materials from spent LIBs to meet growing future demand. This study aimed to analyze the environmental impacts associated with various hydrometallurgical methods utilized in the recovery of critical materials from LIBs' cathode powder. According to the results, not all of the organic acids utilized in the recycling of LIBs can enhance the environmental performance and leaching with some organic acids such as citric, succinic, and ascorbic acids will even lead to higher environmental impacts in most environmental categories compared to inorganic acids like sulfuric and nitric acids. However, organic acid leaching of LIBs using formic, acetic, and DL malic acids can significantly improve the environmental performance of the recovery process in most environmental categories.

TUESDAY, MARCH 1

AFTERNOON

Room 08 | 2:00 PM

ENVIRONMENTAL: SUSTAINABILITY AND ESG DISCLOSURES

Chairs: ***K. Awuah-Offei****, Missouri University of Science & Technology, Rolla, MO*
K. Brantingham*, ARCADIS, Phoenix, AZ*

2:00 PM

Introductions

2:05 PM

Relationship Between Sustainability Performance and Disclosure Policies of Mining Firms

M. Fikru[2], L. Eng[3], E. Gyawu[1] and K. Awuah-Offei[1]; [1]Mining & Explosives Engineering, Missouri University of Science and Technology, Rolla, MO; [2]Department of Economics, Missouri University of Science and Technology, Rolla, MO and [3]Department of Business & Information Tech., Missouri University of Science and Technology, Rolla, MO

Investors and other stakeholders are increasingly concerned about the quality and quantity of sustainability disclosures as well as the extent to which such disclosures correlate with sustainability practices of mining firms. This is because disclosure policies widely vary across firms in terms of extensiveness, materiality, and disclosed topic. In this paper, we conduct a preliminary examination of the relationship between sustainability performance and disclosure. We use sustainability performance indicators that include fatalities, and water and energy use and SASB's standards to evaluate disclosures. Analysis based on 81 publicly traded companies shows a shift in firms' disclosure policies from boilerplate statements in 2014 to either not-disclosing or using more precise language in 2018. Our preliminary results also show that some measures of sustainability performance are correlated to the amount and quality of disclosures while others are not. Thus, investors should not judge sustainability performance based solely on the amount and quality of sustainability disclosures.

2:25 PM

Exploring the ESG Ecosystem with a Focus on Mine Water Management

C. Perdeli Demirkan and T. Braun; SRK Consulting (US), SRK Worldwide, Vancouver, BC, Canada

With the rising focus of stakeholders on ESG principles, this paper explores how ESG commitments in the mining industry can impact water-related studies for existing and new projects, and whether a better job can be done with reflecting the implications of these commitments in mine water management. Our perspective is the water-focused practitioner involved in characterizing pre-mining baseline conditions, estimating water consumption and quality for proposed projects, and managing mine water at active operations. We investigate the frameworks within the evolving and expanding ESG ecosystem and the connections to water management in mining. We first create an inventory of ESG frameworks by reviewing 28 mining companies' sustainability disclosures and the ESG literature. We then classify these frameworks and identify water-related components of particular interest to the water-focused practitioner. Finally, we examine how the ESG commitments can influence the inputs, methods and outputs related to mine water management.

2:45 PM

A Quick Evaluation Tool for Capex and Opex Applied to Mining Operations and ESG Mitigation

C. Petter, V. Araujo, F. Cantini, R. Petter, J. Oppermann, T. Fernandez, R. Darrigo, I. Guazelli da Costa, V. Lenz, V. Juchen, H. Souza and L. Wives; UFRGS, Porto Alegre, Brazil

There are many methods to estimate costs in a quick way. One of these methods is the Parametric Method, where costs are derived from general algorithms (or curves). Derived from an original tool based on the O'Hara model, a software called MAFMINE was developed. MAFMINE is based on parametric models to estimate the investment and operational cost in mining. The software itself is based on the use of a computer model known as client-server. However, the model needs new inputs from advances made by the mining industry, mainly in terms of electrification, automation and ESG concerns. Thus, this work was to collect data from preliminary economic assessments, preliminary feasibility studies, feasibility studies and technical reports on the mineral resource and mineral reserve estimates available online, to incorporate operation and capital cost associated with environmental impact mitigation. The tool generates an order of magnitude for CAPEX and OPEX to establish a very first Discounted Cash Flow (DCF) in a mining venture. For quick evaluations, in a business plan level, the results are very promising.

3:05 PM

Environmental and Economic Effects of Sand Mining: A Case Study of Pakdasht, Tehran-Iran

E. Moosavi, M. Shokri and K. Tolouei; Department of Petroleum and Mining Engineering, South Tehran Branch, Islamic Azad University, Tehran, Iran, Tehran, Iran (the Islamic Republic of)

The present research scrutinizes the environmental and economic effects caused by mines on local communities. The evaluation of effects on these three views predicts the probable environmental factors triggered by implementing development projects. The present research aims to analyze and figure out the influence of any one of these factors in order to decide on either bringing to a halt or keeping on the activities of mines. A questionnaire including 32 questions was prepared to achieve necessary information about economic and environmental issues. For the next step, the reliability of the questions was assessed by SPSS software. Then, some suggestions were presented through benefit-cost analysis about the situation of sand and gravel mines activities. After the model was applied in economic and environmental aspects, the results of costs were 0% and 52.67%, respectively. Outcomes of incomes were 100% and 47.33%, correspondingly. Hence, the income obtained from the understudy activities is more than the costs intended in the three mentioned aspects.

3:25 PM

Urban Mining: An alternative for E-waste Recycling

L. Velasquz-Yevenes[2] and M. Risso[1]; [1]Electrical and Electronics Engineering, Universidad del Bio Bio, Concepcion, Bío Bío, Chile and [2]Universidad de Talca, Talca, Region del Maule, Chile

Faster technical advancements and a culture of constant upgrades in electronic devices is generating an accelerated production demand, which leads to shorter technology life times. This creates increasing volumes of waste from electrical and electronic equipment (WEEE, or e-waste) which is becoming an environmental problem that cannot be ignored. The trend of constant growth of WEEE in recent decades puts the global community on alert, causing both public and private organizations and global NGOs to work together to promote new policies that allow capturing the value global e-waste and turn them into sustainable models. It is noted that only 20% of WEEE is formally recycled, and that the amount generated will double by 2050, with 120 million tons per year. E-waste contains highly valuable metallic elements, but also toxic and potentially dangerous pollutants for the environment and human health. In this work we present an approach for a mobile e-waste recycling plant with community engagement, which uses sustainable methods to recover valuable minerals from e-waste using a hydrometallurgy approach.

3:45 PM

A method to Eliminate the use of Hydrocarbons in Artisanal Mining Using an Energy Transition to Renewable Energy Sources

J. González Guzmán, I. Cerchiaro Sanchez and O. Restrepo Baena; Materials and Minerals, Universidad Nacional de Colombia, Medellin, Antioquia, Colombia

Frontino, a municipality in western Antioquia, Colombia, has more than 200 years of mining tradition. Currently, mining activities are carried out for vein gold using subterranean tunnels, where the grinding of the material is done in "cocos", whose power depends on internal combustion engines and ACPM, environmentally polluting and inefficient methods. In this paper authors present a method to eliminate the use of hydrocarbons in artisanal mining using an energy transition to renewable energy sources that take advantage of the topography and water resources in the area, bringing advantages to the communities that live there, like illumination, electricity to cook, ventilation for mines, etc.

4:05 PM

Sustainability in Artisanal Gold Mining in an Afro-Descendant Community in the Department of Chocó – Colombia

S. Fernandez Rodriguez, L. Klinger Mosquera, T. Vallejo Lopez and O. Restrepo Baena; Materials and Minerals, Universidad Nacional de Colombia, Medellin, Antioquia, Colombia

In the municipality of Rio Quito, department of Chocó, Colombia, alluvial gold has been illegally exploited by suction dredging. The project consists of using geospatial techniques to identify degraded areas and analyze the viability of remediation dredging to mitigate environmental liabilities. The area has sediments contaminated by mercury and cyanide, so it is necessary to reconform the riverbed with the remediated material. The work is part of the Mine Closure Plan that seeks to jointly articulate the communities, academia, the company and the state.

4:25 PM

Implementing a Sustainability Program for Small-Scale Artisanal Gold Mining in Antioquia, Colombia.

L. Martinez Mendoza and O. Restrepo Baena; Materials and Minerals, Universidad Nacional de Colombia, Medellin, Antioquia, Colombia

The present work aims to define the concepts of sustainability and relate them to small artisanal gold mining. For this, a qualitative approach with a descriptive scope was used, for which the documentary or bibliographic review technique was carried out. In this sense, articles, theses, books, and institutional documents, and any contribution related to the research topic, were taken into consideration. Likewise, this documentation contributed to delimit aspects that allowed a contrast between the proposed definitions and small artisanal mining in the Northeast Antioquia. Based on the sources reviewed, different needs were recognized in artisanal small-scale gold mining in the Northeast Antioquia that still need action. In conclusion, through the exposition of sustainability theories, three common factors were identified within the various positions raised, which are the environmental, economic, and sociocultural dimensions.

TUESDAY, MARCH 1
AFTERNOON

Room 19 | 2:00 PM
Geosynthetics in Mining
*Chair: **S. Calendine**, hydroGEOPHYSICS Inc., Tucson, AZ*

2:00 PM
Introductions

2:05 PM
Successful Tailings Dewatering Design Using Multi-Linear Drainage Geocomposites
A. Jung; Western GeoSystems, Golden, CO

Tailings Storage Facilities (TSFs) are used for the long-term disposal of mining tailings. This storage method can cause large scale casualties and environmental devastation in the case of a dam failure. Tailings Dewatering has emerged as a method to naturally thicken and stabilize slurry tailings in order to make it both less likely for a dam failure to occur and easier to reclaim in the future. Tailings Dewatering process is done by enabling the drainage of liquid from the tailings and into a water management facility. Multi-Linear Drainage Geocomposites (MLdG) have been successfully used in several low pH dewatering designs with high compressive loads and high contents of fines. In high fines applications, a filter geotextile component is designed and tested before being used to reduce mineral clogging. It is therefore advised that, with site specifics in mind to specify the correct product, laboratory gradient ratio tests need to be performed to determine which filter is suitable. Project examples will share the proper lab techniques to be followed to evaluate product and technology selection. Case studies will also be shared.

2:25 PM
Geomembrane Hippos: Design Considerations and In-situ Repairs
M. Isola[1] and J. Dean[2]; [1]Wood Group USA Inc, Houston, TX and [2]Potash Corporation of Saskatchewan Inc, Saskatoon, SK, Canada

Geomembranes are a critical component in the design and performance of impermeable lining systems in the mining industry. Heap leach pads, water and wastewater management and tailing impoundments are among the most common uses of lining systems. The performance of these impermeable barriers is essential to prevent the release of harmful materials into the subsoil and the local aquifer. However, the presence of an impermeable layer on top of the subgrade represents an anomaly to the ground at its natural state and can lead to the rise of gases trapped underneath it, developing enough uplift fluid pressure to deform the geomembrane and leading to the development of liner bubbles, also known as hippos or whales. Geomembrane hippos can lead to several issues, such as: a) loss of effective pond storage volume, b) increased susceptibility of the geomembrane to mechanical damage, c) excessive deformations in the geomembrane. Design considerations to capture and release raising gases and/or to ballast the lining system should be accounted for during the design of the impoundment. Case studies and design details will be discussed in the paper.

2:45 PM
Geosynthetics In Mining – How Zero Leaks Impacts the Bottom Line
G. Toepfer; CQA Solutions, Ltd., Toledo, OH

The use of geosynthetic liners as a barrier system has continued to grow in the mining industry. In order to achieve the maximum benefit (Return on Investment) from these liner systems, a series of owner-driven cost-impacting decisions must be made: design and specifications, material selection, and vendor selection. Each decision/cost can greatly impact the quality of the installation, which in turn impacts the Owner's bottom line. This presentation will examine the critical decisions required to approach zero-leak liner systems and the Return on Investment a zero-leak liner system can offer.

3:05 PM
Geosynthetics Construction Quality Assurance in Mining – An Intangible Asset
G. Toepfer; CQA Solutions, Ltd., Toledo, OH

Construction Quality Assurance (CQA) has been viewed by many as "the necessary evil" because regulations dictate this additional cost the owner must comply with. However, the benefits of competent, proactive CQA have been substantiated repeatedly proving that CQA is not a "necessary evil" but rather a Mine Owners Insurance Policy. This presentation will look at lessons learned from over twenty years of CQA experience on projects throughout the world, identify common installation pitfalls, and provide recommendations for the best practices in CQA that will minimize the potential for both short-term and long-term issues.

3:25 PM
Mining Construction Project Risk Mitigation Using Geosynthetics
A. Maskal; Technical Services, Solmax, Varennes, QC, Canada

With mine throughput often more than $10,000 per hour, the financial burden of construction delays can be staggering. Although often prolific on mine properites, drainage aggregates and compacted clay often have variability and processing constraints that can cause significant construction delays. Geosynthetic materials have been used extensively to mitigate the effects of these issues in deep canyon landfill applications, but have seldom been used to full benefit in mining infrastructure. Material issues that cause construction delays in earth-fill mine structures were examined to establish the most valuable failure modes associated with earthen materials. Performance parameters were then established for geosynthetics to replace the riskiest and most costly earthen materials. The resulting parameters were then compared with commercially available geosynthetic materials and a cost/risk tradeoffs was conducted. A range of appropriate geosynthetic materials was established for common mining structures along with rules of thumb to efficiently determine when cost and risk warrant the use of geosynthetics in specific mining applications.

3:45 PM
Puncture Mechanics and Examination of Critical Physical Properties for Exposed Geomembrane Liners Placed on Run-of-Mine Aggregate
A. Maskal; Technical Services, Solmax, Varennes, QC, Canada

Milled mine tailings slurry is often handled as slurry stored in large impoundments. Tailings impoundments are typically lined with geomembrane on structures constructed from waste rock. The top fill often needs to be crushed/screened to mitigate risk of aggregate puncturing geomembrane. This fine aggregate is often available only in limited quantities due to crusher issues and other needs. Traditional puncture protection assumes compaction of cohesive soil over geomembrane with exposed aggregate below the membrane. However, the lack of shear strength in tailings slurries and heavy equipment on overliner create a different set of loading conditions than seen in landfills. Puncture protection models for geomembranes are traditionally derived empirically. However in this study, the critical stress elements were examined analytically for a geomembrane conforming to 4-inch-minus run-of-mine aggregate under hydrostatic loading conditions. A geomembrane's out-of-plane elongation capacity and threat of abrasion were the key variables. Aside from increasing abrasion resistance, tailings impoundment geomembrane thickness was much less important than previously thought.

TUESDAY, MARCH 1
AFTERNOON

Room 06 | 2:00 PM

HEALTH & SAFETY: INTERVENTIONS AND TRAINING THAT INFLUENCE SAFETY AND EMERGENCY MANAGEMENT

Chairs: ***V. Seppala****, Freeport-McMoRan Inc*
E. Haas*, National Institute for Occupational Safety and Health, Pittsburgh, PA*

2:00 PM
Introductions

2:05 PM

Evaluation of the Perception and Implementation of Ground Control Management Plans in the Colombian Mining Industry

L. Sierra, A. Gelvez, J. Monsalve and J. Monsalve; Facultad de minas, Universidad Nacional de Colombia Sede Medellin, Medellín, Colombia

Ground Control (GC) related accidents are the main cause of accidents and fatalities in Colombian underground mining industry. Between 2005-2020, 28% of mining fatalities have been reported to be caused due to GC related issues. After conducting a literature review of GC best practices in Australia, the United States and Peru, it was determined that Ground Control Management Plans (GCMP) are the most effective tool to control GC related risks. A survey was developed to understand the Colombian industry's perception about GCMP and the level of implementation these plans. A total of 181 stakeholders related to this topic responded the survey. The survey showed that even though GCMP are enforced by law in Colombian mining regulation, there is not a unified criterion about the technical content of the GCMPs. This survey also indicated that there is a significant amount of operations that do not comply with the minimum recommended GCMP best practices. This work proposes a standard that regulates the GCMP's technical content using as a reference frame the GC risk management model proposed by the Department of Mines, Industry Regulation and Safety from Western Australia.

2:25 PM

Miner-Centered Approach to Understanding Technology Needs for Self-Escape in Underground Coal Mine Emergencies

E. Gyawu[1], K. Awuah-Offei[1] and D. Baker[2]; [1]Mining Engineering, Missouri University of Science and Technology, Rolla, MO and [2]Psychological Science, Missouri University of Science and Technology, Rolla, MO

Several underground coal mining disasters, such as Upper Big Branch in 2010, have revealed technological and organizational shortcomings related to self-escape. Efforts to address these gaps have primarily been top-down, that is, identified and implemented by upper management or external governing bodies. In contrast, this study employs a novel miner-centered approach to identify perceived technological boundaries to self-escape. Using a semi-structure scenario-based survey, we elicit direct feedback from miners about current, emerging, and hypothetical technologies aimed at improving self-escape during mine emergencies. Preliminary results suggest miners' belief about efficacy are related to instrumental needs, usability, and comfort. For example, a high percentage of early respondents indicated self-contained self-rescuers that allow you to talk while wearing them would be extremely useful in an emergency. Other results are surprising and counter intuitive. The work will be helpful to inform decisions by miners, operators, technology providers, and regulators on technologies to facilitate self-escape in underground coal mines.

2:45 PM

Tactical Medicine in Mining Rescue – A New Condensed Teaching Curriculum for Qualification of Medical Non-professionals in Advanced Preclinical Emergency Treatment in Mining.

F. Reuter[2], A. Fichtner[3] and H. Mischo[1]; 1Mining & Special Underground Construction, Technische Universitat Bergakademie Freiberg, Freiberg, Sachsen, Germany; [2]FLB Research and Teaching Mine, TU Bergakademie Freiberg University, Technische Universitat Bergakademie Freiberg, Freiberg, Sachsen, DE, academic, Freiberg, Germany and 3Kreiskrankenhaus Freiberg gGmbH, Freiberg, Sachsen, Germany

Today's underground mines are highly mechanized operations with limited workforces and often do not have specialized medical teams on site. Public emergency medical professionals are not trained to go underground so mines must rely on mine rescue teams for initial care and patient transport to the surface. The remoteness of underground mine workings also creates increased response times in medical emergencies that often exceed the "golden hour" during which a trauma patient can be saved. To improve the likelihood of survival and recovery, researchers at Bergakademie Freiberg and the Freiberg Regional Emergency Room have developed a new, standardized tactical medical approach for mine rescuers along with mining-specific life support equipment. The new approach includes a training curriculum for mine rescue team medics to elevate their medical emergency skills in relevant fields within a short period of time. By applying focused teaching methods, researchers could demonstrate that the trained mine rescuers achieve a competency comparable to that of advanced paramedics in Germany.

3:05 PM

Evaluation of Mine Safety and Health Training Programs Using a Pretest-Posttest-Control Design

R. Reed, L. Brown and J. Burgess; Mel & Enid Zuckerman College of Public Health, The University of Arizona, Tucson, AZ

Measuring the impacts of training interventions remains a substantial challenge in health and safety applications. In this study, we evaluated the effectiveness of training interventions at three mine sites using a pretest-posttest-control design. Partner A implemented an active learning guide for annual refresher and a tabletop card game for hazards training. Partner B deployed a warm-up exercise training program. Partner C used the active learning guide and a computer-based serious game. For the pre- and post-intervention periods, average quarterly injury and days lost rates were obtained from MSHA and compared for each partner, our partners' sister sites, and all other active mines of the same type. Partner A reported decreases in average injuries (-6.3%) and days lost (-75.5%), respectively, as compared to increases (95.1% and 54.5%, respectively) for Company A. Partner B observed decreases in average injuries (-39.8%) and days lost (-71.3%), compared with decreases in both (18.6% and 35.6%, respectively) for Company B. Partner C reported decreases in average injuries (-38.4%) and days lost (-40.9%), while Company C observed increases in both (28.1% and 1,814%, respectively).

3:25 PM

Use of Cognitive Task Analysis to Inform Future Research and Identify Solutions for Haul Truck Safety

J. K. Hrica, NIOSH

Each year, haul truck accidents account for a large portion of mining injuries and fatalities. To better understand why these accidents continue to occur, NIOSH utilized cognitive task analysis methods to identify the task requirements of surface haul truck operators and assess differences in perceptions between operators, managers, and maintenance personnel. A part of these analyses also focused on better understanding cognitive demands, decision-making, and problem solving during nonroutine incidents. Preliminary results identify and explore challenging situations routinely faced by operators and provide detailed accounts of non-routine incidents such as near-misses, loss of control due to environmental conditions, and collisions involving property damage. These accounts reveal insights into operator decision-making and establish precise event timelines that can then be used to build more realistic training scenarios and address hidden hazards and root causes. These results, along with potential solutions offered by study participants, can inform NIOSH research and help identify creative interventions that can be used by mine operators to address haul truck safety issues.

3:45 PM

COVID-19 Impact On Mine Rescue Team Readiness, Mine Emergency Risk, Readiness, and Preparedness

W. York-Feirn[1], J. Kravitz[2] and D. Stalfort[3]; [1]Colorado Department of Natural Resources, Colorado Division of Reclamation Mining & Safety, Denver, CO; [2]Holmes Mine Rescue Association, Carnegie, PA and [3]American Bureau of Shipping, Houston, TX

The readiness of mine rescue teams is vital to effectively respond to a major mine emergency. The COVID-19 pandemic has impacted team readiness due to the reduction in mine rescue training and contests. MERD exercises in realistic environments have not been possible, and risk and readiness assessments are difficult to acheive. People often ask: "Why Do We Need To Do A Risk Assessment?" Organizations and their management are often lulled into a false sense of security due to complacency, and a feeling that "Everything is Great" and ask "What Could Possibly Go Wrong?." This presentation will illustrate where some things have gone terribly wrong at some mines, leading to several major mine disasters in the past. Risk Assessments for major mine emergencies could have helped mitigate potentially dangerous situations. Preparedness and readiness assessments are necessary to assure proper responses can be made in the event of an emergency. These assessments pinpoint individual mine risk and readiness deficiencies for mine emergencies and help mine management prioritize the gaps and devise action plans to quickly address them.

4:05 PM

Training in the Field During the Digital Age

S. Penmetsa; SME, Milpitas, CA

Ensuring that employees are trained correctly and are competent to operate equipment and complete tasks unsupervised is one of the biggest challenges facing employers. And even once an employee has been trained, documenting, and tracking that training and staying in compliance is another set of challenges. New digital Learning Management Systems (LMS) and apps are solving these challenges and allowing companies to not only improve how they train and manage their employee's training but ensuring that paperwork like 5000-23s are completed correctly. Such systems help companies ensure that each employee is sufficiently trained to perform an assigned This technology also enables companies to implement career advancement systems which help with employee morale and retention. In this paper, we will discuss best practices to use when building training plans, use the LMS and apps to ensure that the correct training documents are issued and how these systems can be used to create career advancement systems.

TUESDAY, MARCH 1

AFTERNOON

Room 09 | 2:00 PM

INDUSTRIAL MINERALS & AGGREGATES: RESOURCE ESTIMATION, MINE PLANNING & OPERATIONS

Chairs: ***H. Patel****, University of Nevada Reno, Reno, NV*

S. Chatterjee*, Michigan Technological University, Houghton, MI*

2:00 PM

Introductions

2:05 PM

Detection of Drill Holes Using Aerial Image Analysis and Machine Learning

A. Jha, J. Valencia and J. Sattarvand; Mining and Metallurgical Engineering, University of Nevada Reno, Reno, NV

This study aims to detect snow-covered drill holes on images obtained from unmanned aerial vehicles (UAV's) using convolutional neural networks. Each of the images was sliced into 400 × 225 pixels from its original size to optimize memory usages and then annotated with a bounding box in case of an existing drill hole. The annotated images were inputted as training data for the machine learning algorithm. Initially, 500 best annotations were used to train the model and additional samples were later added. Mask RCNN object detection technique with ResNet101 architecture is used for this study. A convolutional feature map is generated for the original image using a convolutional neural network (CNN), which is then acted upon by the region proposal network to suggest the region of interest within the image. The region of interest is reshaped to a fixed size and fed into a fully connected layer, thereafter a classification layer predicts the object class and regression layer the coordinates of the bounding box. Data preparation pipeline, model architecture, and its performance in detecting the snow-covered drill holes are discussed in this study.

2:25 PM

Short-term Production Planning Algorithm for IPCC based Open-Pit Mines

H. Askari-Nasab, N. Habib and A. Afrapoli; Civil and Environmental Engineering, University of Alberta, Edmonton, AB, Canada

Open-pit mines are getting deeper with time and transportation expenses are increasing because of the increasing haulage distance. This resulted in popularity of In-pit Crushing and Conveying (IPCC) material handling systems as a suitable alternative to the conventional truck and shovel material handling system because it offers a significantly lower operating cost and requires a smaller fleet of trucks. Semi-mobile IPCC, currently the most popular IPCC system, is relocated every two to five years and this relocation has direct impact on production schedules of all time horizons including the short-term production schedule. Careful review of existing literature revealed that no existing short-term production scheduling model can generate short-term extraction sequence accommodating presence and relocation of IPCC. This research work proposes a short-term production scheduling model to optimize shovel allocation and minimize shovel movement cost for an open-pit mine that incorporates existence and relocation of IPCC. We implemented our proposed short-term production scheduling model in a real mining case study and presented the results in this paper.

2:45 PM

Fleet Management Script for Short Scale Mines Using Python

O. Palomino and V. Tenorio; Mining, Student, Tucson, AZ

The large-scale mine industry is facing the arrival of the 4th Industrial Revolution, characterized by a fusion of the Industrial Internet of Things (IoT) and the disruptive technologies, which carry the promise of improved safety and productivity, within a sustainable and integrated framework. Even though this idea of smart mine was extended to the short-scale mine industry, they struggle with scarce budgets to integrate the physical and IoT. Even more, they do not have the budget for having software to plan the mine activities; for example, there are on the market expensive software focused on fleet management that can determine the fleet productivity based on simulations that are not affordable for the short-scale mine industry. In this work, we try to provide a basic script in Python to determine the fleet size and fleet productivity. Thus, this script can calculate the cycle time and the required time to move the target. Also, this script can give several scenarios based on each parameter including, distance, loading time, and grade, etc. Thus, we link ideas of smart mine to potential application in the short-scale mine industry which may allow more efficient production.

3:05 PM

An Integrated Simulation and Optimization Model to Solve Truck Dispatching Problem in IPCC-Based Surface Mines

H. Askari-Nasab, M. Kazemi Ashtiani and A. Moradi Afrapoli; School of Mining & Petroleum Engineering, Department of Civil & Environmental Engineering, University of Alberta, Edmonton, AB, Canada

High raw material demand in the world market drives mining companies to mine existing surface mines deeper and wider. As the demand will continue to increase in the future, the surface mines require to have In-Pit Crushing and Conveying (IPCC) systems to reduce material handling costs due to long-distance haulages. Despite the economic and environmental advantages of the IPCC material handling systems, mine planning has fallen behind IPCC. There is a huge gap in operational mine planning with IPCC-based mining operations. None of the thus far developed operational planning models have addressed the impact of IPCC on surface mining production and operational decision-making processes. Herein, we introduce a simulation-and-optimization operational planning model that makes near-optimal operational decisions for surface mines where IPCC is one of the main subsystems of material handling operation. The developed model uses mixed-integer linear programming to solve the truck allocation problem and implement discrete event simulation to capture uncertainty associated with the surface mining operation. Results of the verification of the model on a case study are presented in this paper.

3:25 PM

Recoverable Reserve Estimation in an Indian Copper Deposit through Copula based Simulation Model

K. Dinda[2], B. Samanta[1] and D. Chakravarty[1]; [1]Mining Engineering, Indian Institute of Technology Kharagpur, Kharagpur, West Bengal, India and [2]Advanced Technology Development Centre, Indian Institute of Technology Kharagpur, Kharagpur, West Bengal, India

Copula functions are widely used for modeling based on multivariate dependence. Since the dependence in multivariate cases may not be necessarily linear, the copula model is brought into picture for modeling of such multivariate data. Copula based model and its application is introduced to simulate the recoverable reserve of an open-pit copper deposit in India. In this paper, three theoretical copula-based simulation models are presented: Gaussian, student's t and v-transformed copula. The efficiency of the copula-based simulation models is assessed by comparing the estimated reserve by these techniques with that of actual reserve determined using blast hole sample information. The statistical error analysis on the estimated values indicate the v-transformed copula-based model provides improved accuracy in estimation in comparison with Gaussian and t copulas.

3:45 PM

PixelMPS: A Python Toolbox for Multiple-Point Geostatistics

K. Menon[1], A. Asadi[3], P. Kadrolli[2] and S. Chatterjee[2]; [1]Mining Engineering, National Institute of Technology Karnataka, Surathkal, Karnataka, India; [2]Michigan Technological University, Houghton, MI and [3]Tufts University, Medford, MA

Multiple-point (geo) statistics (MPS) have wide-scale applications in mineral resource modeling for different commodities. MPS proves effective in capturing the spatial continuity of orebody, lithology, and mineralogy, compared to two-point geostatistics. Although significant large numbers of software packages are available for two-point geostatistics, there are not many options for MPS.This research aims to develop an open-source Python package for MPS. The implementation of the novel method has been done in the Python language through the use of several free and open-source libraries. The realizations of the training image are generated by a pixel-based method in contrast to the multiple pattern-based methods. Patterns extracted from the image are subject to a clustering process using the t-stochastic neighbors embedding algorithm followed by a dbscan clustering algorithm. The unique dimentional reduction and pattern classification approach aimed to reduce the sampling time from conditional distribution during the simulation. Results show the method is efficient, and performs well for both two- and three-dimensional geostatistical data for conditional and unconditional simulations.

4:05 PM

An Aggregate Project in Southwest Texas Gets an Unexpected Surprise – A Case Study in Deposit Optimization

M. Lee; Westward Environmental, Boerne, TX

As we all know, there are several basics to opening an aggregate mine anywhere. Match the market need with perfectly placed high volume logistics and put a darn good geological deposit in the mix and you have a recipe for a great project. A group that is new to the aggregate mining realm did just that. After locating what "appeared" to be a good concrete aggregate producing location on over 8,000 acres in southwest Texas; with a major rail line and highway access, a backlog of potential clients in Houston, maybe a passage to the neighboring country, far from everyone in an area that has a few operating mines already, on a lesser dry river that every now and then replenishes its limestone gravel and three additional formations that can make other viable products; the pieces were in place for a mega mine that could serve several markets. Westward was brought in during the initial due diligence and quickly identified the additional potential for other possible products. The project is in its infancy stage and there are still hurdles in place, like enough data to adequately define the deposit(s), but the early indications are promising.

TUESDAY, MARCH 1

AFTERNOON

Room 13 | 2:00 PM

MINING & EXPLORATION: GEOSCIENCES: GEOMETALLURGY: INPUTS FOR PREDICTING RECOVERY: A PANEL DISCUSSION

Chairs: ***C. Young****, MT Tech, Butte, MT*
D. Palo*, Barr Engineering*
Sponsored by Barr Engineering

2:00 PM

Introductions

2:05 PM

Using Geometallurgy to Predict Mill Performance at Doe Run's Higdon Property

S. Ripke, J. Uhrie, B. Clark and J. Burton; Exploration & Development, Doe Run, Viburnum, MO

The Higdon Project is a development project wholly owned by The Doe Run Company and located in Missouri's East Flank Mining District. The deposit is a classic Mississippi Valley Type (MVT) deposit with economic mineralization consisting of galena (PbS), sphalerite (ZnS) and chalcopyrite (CuFeS2); however, the Higdon Deposit also contains significant values of the critical minerals cobalt and nickel in the form of siegenite ((Ni,Co)3S4)and bravoite ((Fe,Ni) S2). Gangue mineralogy of Higdon, while very similar to the better known Viburnum Trend is dolomitic hosted and contains significant quantities of the pseudomorphs of marcasite and pyrite (FeS2) and also contains significant clay. Current processing flowsheets consist of concentration through flotation followed by hydrometallurgical refining of the metals. Bench testing is showing that gangue mineralogy dramatically effects both grinding and flotation response and has resulted in the generation of a geometallurgical model of the deposit which may be potentially used as an operational tool for ore blending to explain critical operational variables of grind size, throughput, flotation response, concentrate grade, etc.

2:25 PM

Optimization of the Ore Routing at the Carlin Complex using Deswik.Blend

B. Pearson and K. Murphy; Metallurgy, Nevada Gold Mines, Spring Creek, NV

The formation of Nevada Gold Mines (NGM) unlocked ore routing synergies by allowing the possibility of ore movement across NGM to a variety of process plants. This created an exponentially complex blending scenario. Using plant constraints and targeting life of mine NPV, a linear optimizing scheduler, Deswik.Blend, was employed at the Carlin Complex to improve ore routing and make better wholistic business decisions. Assumptions in the model have been continuously improved through lab and mineralogy test work to improve the understanding of the fundamental differences between ore sources, primarily focusing on the Goldstrike and Gold Quarry Roasters, the largest gold producers in the Carlin Complex and NGM.

2:45 PM

Geometallurgy: Inputs for Predicting Recovery

D. Palo[1], S. Izatt[2], R. Kappes[3], k. murphy[4], S. Schwarz[5] and S. Shoemaker[6]; [1]Barr Engineering, Murrieta, CA; [2]IBC Advanced Technologies Inc, American Fork, UT; [3]Newmont USA Ltd., Englewood, CO; [4]Nevada Gold Mine, Elko, NV; [5]Rio Tinto, South Jordan, UT and [6]JT Boyd, Tooele, UT

Aside from a panel discussion, this session offers 2 papers as a follow-up to the 6-paper session on Geometallurgy: Preventing Ore Deposit Mineralogy from Wreaking Metallurgical Havoc. The panel will offer their thoughts on geometallurgy and draw from the papers as points of discussion. Each panel member though has different viewpoints about what is the best way promote the integration of geological and mineralogical data into extractive processing operation and design and enhance communication and collaboration between geologists and process engineers. Is it a discipline or is it a link? Come listen to the great debate!

TUESDAY, MARCH 1

AFTERNOON

Room 10 | 2:00 PM

MINING & EXPLORATION: GEOSCIENCES: UNDERGROUND GEOTECHNICAL: STRATEGIES FOR DESIGN & OPERATION I

*Chair: **L. O'Connor**, Sibanye-Stilwater, Absarokee, MT*

2:00 PM

Introductions

2:05 PM

Pillar Stability Assessment of an Underground Stone Mine Using the Reliability Theory, Continuum Numerical Modeling and Empirical Pillar Strength Equations

J. Monsalve, A. Soni and N. Ripepi; Mining and Minerals Engineering Department, Virginia Polytechnic Institute and State University, Blacksburg, VA

Pillar design is one of the most important tasks in underground mine design. Not only should pillar design maximize the reserves, but also ensure the mine's global stability. Current best practices indicate that this process should integrate different analytical, empirical, numerical, and observational methods to reduce potential risks during the design. However, some of these methods only consider deterministic results neglecting the intrinsic variability in the rock mass, and increasing the uncertainty in the design process. This work evaluates the stability of pillars of an underground dipping stone mine by integrating multiple design methods for strength and stress estimation. Variability obtained in laboratory tests is used to estimate probability distributions for both pillar stresses and strength for the different levels of the mine. A reliability analysis considering such distributions is performed, and pillar probability of failure is estimated for different scenarios. Results from this assessment will be used as a reference to validate numerical modeling results obtained from stochastic discrete element modeling.

2:25 PM

Inclined Pillar Strength Considerations Using Numerical Modeling

R. Flattery, C. Cardenas Triana, C. Gerwig and Z. Agioutantis; Department of Mining Engineering, University of Kentucky, Lexington, KY

Coal and rock pillar design is important not only for mineral extraction but also for the safety of the mine operators. Pillar strength can be estimated through numerous empirical formulas that are available in the literature, which are typically based on statistical analysis of case study data. The limitation of the majority of these equations is that they only considered the width to height ratio and in situ rock or coal strength for pillars in horizontal seams. The adoption of such equations to estimate pillar strength in inclined seams may overestimate the pillar strength and ultimately lead to a poor pillar design. This presentation will discuss different techniques that can be used to estimate pillar strength in inclined seams as well as present preliminary modelling results for stress redistribution around inclined pillars. Factors in the parametric analysis include pillar shapes, geometry and seam inclination.

2:45 PM

Corrosion of Ground Support in Underground Mines: A Review

C. Stazick, C. Sunderman and G. Feagan; Spokane Mining Research Division, National Institute for Occupational Safety and Health, Washington, DC

Corrosion of ground support structures in underground mines leads to loss of integrity with eventual safety concerns for mine workers. It is important to understand the mechanisms and factors that affect corrosion in underground mines to engineer solutions that prevent accidents. Laboratory and field research methods for this industry, however, remain sparse and underdeveloped. This paper investigates the more documented mechanisms influencing corrosion in civil, pipeline, and marine environments and how these mechanisms might be adapted to understand corrosion processes in underground mines. Often, mining environments introduce a larger and more variable spread in the observable corrosion parameters stemming from the wide range in minerology, geochemistry and environmental conditions encountered. An expanded scope of research into measurements and monitoring techniques is warranted to create a foundation for future engineering solutions.

3:05 PM

Effects of Foam Additive on the Ductility of Cemented Paste Backfill

D. Sweet, T. Emery, J. Seymour, J. Bourgeois, G. Feagan and S. Murray; CDC/NIOSH, Spokane, WA

For traditional underhand cut and fill mine operations, determining a suitable cemented paste backfill (CPB) mix design that can meet strength requirements and maintain ductility is a challenge. The CPB material must be ductile enough to withstand high strain experienced from squeezing ground, while also reaching a high enough strength to remain competent under high stress conditions that develop as mining operations continue under filled stopes. To eliminate ground falls that result in injuries and fatalities, the Spokane Mining Research Division (SMRD) of the U.S. National Institute for Occupational Safety and Health (NIOSH) has partnered with a metal underground mine and producers of concrete additives to study the effects of foaming additives on the strength and ductility of CPB. This study looks at the impact to strength and ductility of mix designs using various amounts of foam additive.

3:25 PM

Changes in Elasticity and Ductility of Cemented Paste Backfill due to Variations in Binder Content

T. Emery[1], W. Johnson[2], M. Armatys[2], J. Seymour[1], D. Sweet[1] and J. Bourgeois[1]; [1]Mining Research Division, CDC/NIOSH, Spokane, WA and [2]Hecla Mining Co, Coeur d'Alene, ID

The Spokane Mining Research Division (SMRD) of the U.S. National Institute for Occupational Safety and Health (NIOSH) has partnered with a hard rock mine to research the effects of the binder content on the elasticity and post peak ductility of cemented paste backfill (CPB). In high stress, underground mines utilizing cut and fill mining methods, the cemented paste backfill design requirements also have upper limits in strength due to brittle behavior. As mining advances deeper and stresses increase, CPB mix designs will need to be modified to handle higher levels of strain. This portion of the research examines the impact of reductions in binder content as preliminary work in a larger study.

3:45 PM

Calculating Stone Mine Pillar Concentric Ring Zone Capacities for Boundary Element Modeling

S. Escobar and I. Tulu; Mining Engineering, West Virginia University, Morgantown, WV

In the USA, empirical pillar strength equation and S-Pillar program developed by Esterhuizen et al., (2011) are used to assess the global stability of stone mines. This study shows the derivation of the empirical pillar strength equation of stone pillars to obtain the stress gradient equation as a function of the pillar's width-to-height ratio. This function provides the stress distribution within the pillar and is used to derive concentric rings of zones to simulate stone mine pillar yielding in boundary element software. The application of this equation in boundary element code is demonstrated by the analysis of a pillar layout from a case study mine.

4:05 PM

Raise Caving – A New Cave Mining Method

T. Ladinig[1], M. Wimmer[2], H. Wagner[1] and J. Bergström[2]; [1]Mining Engineering, Montanuniversitat Leoben, Leoben, Steiermark, Austria and [2]LKAB, Kiruna, Sweden

Raises are the central element of the new cave mining method. Machinery is operated remote-controlled or automated in raises and utilized for drawbell construction, undercutting, pre-conditioning and controlling of cave progression. Moreover, raise caving enables to make use of an active stress control approach in which the deposit is de-stressed with minimum amount of infrastructure prior to production. De-stressing slots separated by massive pillars are used therefore. The massive pillars may be extracted during subsequent production. Overall, raise caving is a considerable alternative to widely used block caving and sublevel caving. Amongst others, advantages comprise an improved safety, efficiency, controllability and flexibility. Hence, the risks of cave mining can be reduced significantly. A study regarding a potential application of raise caving for a depth extension in Kiruna mine underpins the advantages. In order to develop the raise caving method further a joint research and development program between LKAB and Montanuniversität Leoben was launched. The presentation will describe the method and background of raise caving. Moreover, the chances and advantages are discussed.

TUESDAY, MARCH 1

AFTERNOON

Room 12 | 2:00 PM

MINING & EXPLORATION: INNOVATION & TECHNOLOGY: AUTOMATED MINING: MAKING AN IMPACT

Chairs: ***C. Gilbert****, Caterpillar Inc., Tucson, AZ*

L. Velasquez Acero*, University of Kentucky, Lexington, KY*

2:00 PM

Introductions

2:05 PM

How People and Process are Unavoidable Factors of Successful Mine Automation

T. Berens and C. Blignaut; Epiroc, Garland, TX

Blasthole Drills have made profound developments in safety, efficiency and productivity through the benefits that automation enables. With the potential value seeming limitless, we asked ourselves the question of what key factors contribute to unlocking a maximum return on the implementation and optimization of autonomous technology. Whilst those focused on software and hardware are paramount, less direct factors around people and process consistently presented opportunities targets in Automation projects. We challenged ourselves to explore some answers to questions like; What organizational behaviors lead to successful change management during technology implementation? What processes enable a true value chain approach in optimization? and how does automation and data encourage positive long term change in decision making practices? We find that automation and the data-driven methodologies it exposes, not only yields higher returns from a culture focused on people and process, it also acts to mature it.

2:25 PM

Autonomous Mining in Extreme Conditions

K. Guebert; Caterpillar Inc, Peoria, IL

Caterpillar's Command for Hauling™ (CfH) is currently operating at gold, copper, iron, coal, and oil sands sites globally that present extreme conditions from altitude over 4000m above sea level to 100-degree Celsius temperature changes. All these unique mine sites present a variety of challenges. Caterpillar provides onsite support that delivers continuous improvement and value creation specific for customer's needs. The seasonality of these sites is matched by the functionality delivered with CfH. The ability to retrofit different truck class sizes provides new and existing customers the functionality to scale operations depending on the mine plan.

2:45 PM

Wireless Lock-Out-Tag-Out Scheme for Autonomous Haul Trucks

B. Miller; Autonomous Correct, LLC, Littleton, CO

On May 24th of 2021, a significant incident occurred at an iron mine involving two Autonomous Haulage System (AHS) technicians and two autonomous haul trucks (AHTs). The two AHS technicians were exposed to potentially serious injury when the two AHTs they were attempting to board unexpectedly drove forward. The direct causes include: attempting to board an AHT while not under their control; the technicians did not identify that the AHTs were in exception mode when attempting to board; and critical safety systems had been deactivated that would have prevented the incident. A scheme is presented that provides a wireless Lock-Out-Tag-Out system, which could be rated under Functional Safety Standards. The primary intent of the system is not for full teleoperation control of the AHT but to allow personnel on foot to approach an autonomous machine safely. Approaches are required during refueling, inspections, transitions to manual control, and returning an AHT to autonomous operations that has stopped due to an exception such as an object detection or communications loss. Use cases have been defined for the scheme and incorporate safe work procedures for utilizing the system.

3:05 PM

Automatic Entry Driver: Autonomous Control of a Face Drill Using Lidar Imaging

M. Usama and A. Teator; Research and Development, J H Fletcher & Co, Huntington, WV

Optimal entries in the traditional drilling and blasting process are often hard to achieve. Variances during the drilling process can oftentimes lead to inadequate production, an irregular face, or divergence from the planned excavation. This paper discusses a two-stage solution for this problem. The first includes scanning the working face, gathering topological information of the face, and generating a modified drill plan to guarantee a hole trajectory that would ensure an ideal post-blast face. The second utilizes autonomous drill control with active collision mitigation to accurately execute the drill plan to achieve the desired result.

3:25 PM

Value Added Drilling Automation in Surface Mining

J. Stinson; Caterpillar Inc, Peoria, IL

Drilling automation has existed for two decades and yet the industry is only now integrating this technology into their day to day operations. The paper explores the value drilling automation could create, the changes needed to deliver positive outcomes and the technology adoption challenges Caterpillar is addressing within Caterpillar Rotary Blasthole Drills and the MineStar product suite. More specifically, the discussion will focus on how to assist customers in obtaining more value from drill automation and it's associated data to mine their orebodies more accurately even as the overall grade changes due to its geological nature.

3:45 PM

Automation – A Journey to Underground Improvement

T. Cressman; Komatsu, Franklin, PA

Implementing automation is a phased and unique journey that has different levels and milestones for each customer. Finding the right solution for a mine generally starts with studying current operations. This takes the form of a time study with a productivity model. The model will help identify the gap between current operations and future goals. By identifying these gaps, discussions can be had regarding what levels of automation and features can be applied to meet the needs of the mine. Once a feature has been installed, data analytics play a key role in the overall assessment of progress toward the desired goals. With different levels and options, our goal is to work with mine sites to identify specific challenges and understand how targeted features can be applied to improve operations. Implementing these features come with technical and organizational challenges that through the right roll out plans can be managed. Starting with a collaborative effort to build a plan, getting equipment with the right features, and data analytics to support implementation and optimization, this can be a smooth transition to improve safety, increase productivity, and reduce operating cost.

4:05 PM

The People Behind Autonomous Drilling

G. Scott; Caterpillar Inc, Peoria, IL

Blast hole drilling requires human care and calculation. Its evolution to digital controls & on-board computer processing greatly enhances overall performance. Connectivity and HP GPS, to position over target and track drilling production with strata-logging supports precision drilling, and tailors blasting to specific ground conditions. An autonomy program including safe processes and related hardware plus infrastructure is essential. However, to successfully drill, it's crucial that humans monitor and interact with the drill (manually or remote) tuning auto functionality (namely auto drilling) and machine working parameters to align with (cutting tools) (ever-changing ground) and environment. This paper discusses drilling inputs and parameters integral in traditional "manned operations" thus must be managed when working autonomously to optimize performance.

4:25 PM

Adapting Open Pit Mine Design Fundamentals to Leverage the Advantages of Autonomous Haulage Systems

R. Owens[2], C. Roos[1], B. Hill[3] and S. Rosenthal[1]; [1]Mining Engineering, Montana Tech, Butte, MT; [2]Climax Mine, Freeport-McMoRan Inc, Climax, CO and [3]Electrical Engineering, Montana Tech, Butte, MT

It is common practice, and even legally required in many jurisdictions, to design two-lane haul roads in open pit mines to three and a half times the widest dimension of the haul trucks operating on the road. In open pit gold mines with high strip ratios, the road width has a significant impact on the economics of a design. It is possible to minimize the flattening of the highwall if the road width is reduced, assuming the width used is not needed to flatten the slopes for geotechnical purposes. With the use of autonomous haulage and pull-outs, it may be possible to operate safely and efficiently on a reduced road width of two times the width of the hauling equipment.

TUESDAY, MARCH 1

AFTERNOON

Room 14 | 2:00 PM

MINING & EXPLORATION: INNOVATION & TECHNOLOGY: SPACE AND SEA MINING: INNOVATIONS FOR THE NEXT FRONTIERS

*Chair: **D. Christensen**, University of Utah, Salt Lake City, UT*

2:00 PM

Introductions

2:05 PM

Ramp Design Fundamentals for the Excavation of Icy Regolith on the Moon

V. Tenorio[2], K. Kingsbury[2], K. Brown[2], J. Nickels[2], D. Tolmachoff[2] and G. Nail1[1]; [1]Aerospace & Mechanical Engineering, The University of Arizona, Tucson, AZ and [2]Mining and Geological Engineering, The University of Arizona, Tucson, AZ

A major design feature from the initial pioneering works until reaching full mine production of icy regolith at the surface of the South Pole of the Moon will be the ramp. This will allow the access of equipment and personnel in and out of the excavation area. Although most of the requirements considered when designing a ramp on the Earth are similar, the fact of working in low gravity and zero atmosphere, with the potential exposure to high radiation, extreme temperature levels, the impact of dust, and drastic changes of illumination, from intense light to total darkness, are new factors to be included. Transversal sections are obtained according to the progression sequence of the production levels, with changes in length, gradient, friction factor of the terrain and curvature when required by the location characteristics and the specification of the equipment utilized. A MATLAB script was developed to calculate all the variables, in order to obtain 3D generated surfaces from the range of possible profiles.

2:25 PM

Systematic Approach For Stripping the Uppermost Crust of Regolith at the Lunar Surface

O. Palomino and V. Tenorio; Mining and Geological Engineering, The University of Arizona, Tucson, AZ

The process of extracting water from deposits of icy regolith located at the Permanently Shadowed Regions at the South Pole of the Moon will require the preliminary task of stripping the top crust material. This consists of a layer of soft material of relatively low hardness, which can be treated as a thin seam, like the non-metallic deposits found on Earth. With a thickness of 20 centimeters, it is expected to be extracted using a continuous surface miner with design modifications for working in autonomous mode at the Lunar surface under minimum supervision. The purpose is to expose the valuable material in synchrony with the production schedule, without exposing the ore to potential sublimation with the direct sunlight and other external conditions. A Python-based algorithm has been developed to demonstrate the effectiveness of this approach on a case study scenario, using the existing topography of an area nearby the South Pole region of the Moon.

2:45 PM

Sourcing Seabed Minerals Essential to Meet Energy Transition Goals

H. Smit; Texas A&M University System, College Station, TX

Ocean Minerals is a seabed minerals exploration and development company focused on sustainable and responsible commercial mineral supply chains for multiple critical metals required for 21st century high tech and green tech applications. We recently completed a campaign to recover Cook Islands nodules and subsequent results of mineral process extraction testing. We delve into our future plans to achieve "first cobalt" by 2026, and in particular we discuss our core project fundamentals, our eco-system based environmental work program and hands-on community involvement used to develop a commercially successful project with positive impacts for the Cook Islands local economy and population.

3:05 PM

Mining on the Moon

M. Nakagawa; Mining Engineering, Colorado School of Mines, Golden, CO

Mining on the Moon as currently perceived may involve a shallow excavation of lunar regolith (lunar soil). Reliable excavation requires a good understanding of how the forces exerted by the excavation machines are transmitted to undisturbed layers of regolith. The excavated regolith then needs to be transported to a processing and/or storage point. This requires knowledge about the stability of a heap of excavated lunar regolith against external vibrations under the Moon gravity. This paper will review our attempt to understand the impact of irregularly shaped lunar agglutinates on the mechanical behavior of regolith.

3:25 PM

Deploying Hyperspectral Satellite Technology for Enhanced, Persistent Mining Stewardship and Improved Sustainability

R. Weaver; Business Development, Orbital Sidekick, San Francisco, CA

With the arrival of a rapidly evolving space economy, the mining industry is well-positioned to benefit from new monitoring technologies. The persistent collection of hyperspectral imagery (HSI) by micro-satellite is one such technology offering improved environmental stewardship, site monitoring, contamination alerts, and mineral identification capabilities. In this presentation, Orbital Sidekick will discuss the state-of-the-art for delivering sustainability solutions and actionable insights to the sector. It will outline how this data combined with advanced analytical processes can detect subtle physical changes and threats to operations while providing low-threshold leak detection and chemical and mineral speciation services. The latest HSI satellite imagery from OSK's Aurora satellite will be shared alongside observations derived using the company's Spectral IntelligenceTM analytical platform. These capabilities are global in scale, allow revisit as often as daily, and have never before been as simple, affordable, and sustainable. Satellite-based hyperspectral imaging is now a reality and offers an ultramodern approach to those driving innovation in the mining sector.

TUESDAY, MARCH 1

AFTERNOON

Room 11 | 2:00 PM

MINING & EXPLORATION: MANAGEMENT: MINE FINANCING & INVESTING

Chair: ***R. Barickman****, Orion Resource Partners, Englewood, CO*

2:00 PM

Introductions

2:05 PM

Assessment of the Real Economic Feasibility of Potential Critical Raw Materials Mining Projects in the US: Implementation of a Newly Developed Smart Computational Tool

M. Islam, G. Barakos and H. Mischo; Institute of Mining and Special Civil Engineering, Technische Universitat Bergakademie Freiberg, Freiberg, Sachsen, Germany

Among the thirty-five declared critical raw materials (CRM) in the United States, there is no sustainable domestic production for the fourteen of them, while for some others domestic supply does not meet the national demand. Numerous potential critical raw material projects are in the advanced exploration stage. However, the price uncertainties of many of these commodities put potentially feasible production into question and come into contrast with overly optimistic price forecasts published in all feasibility studies related to such exploration projects. Thus, in this paper, a newly developed smart computational tool is used to evaluate the real perspectives of several future CRM projects regarding actual commodity prices and conduct reverse calculations to find the prices at which each project can be viable.

2:25 PM

Natural Resource SPACs 101

K. Taylor; American Resources Corporation, Fishers, IN

Special Purpose Aquisition Companies (SPACs) have seen a dramatic rise in popularity over the past several years. The number of SPACs in the first two quarters of 2021 have nearly matched the number of SPACs from 2019 and 2020 combined. A SPAC is a company with no operations that is formed to raise capital through an initial public offering in order to buy another company. These "blank check companies" have been around for quite a while but are just now becoming more common place in the mining and natural resource industry. An overview of SPACs will be given, specifically related to the mining industry.

2:45 PM

Digital and Technological Trends Enabling Supply Chain Transparency and How This could Impact Mine Finance and Projects

P. Rogers and A. Young; Mining Engineering, University of Utah, Salt Lake City, UT

Modern markets of mineral commodities are a complex network of explorers, developers, and financiers. These networks can be formal and/or informal structures based on regional geology, the strength of governing institutions, commodity type, and a variety of other economic drivers. Many critical minerals have underground, or informal markets driven by bad actors and/or desperation, which drive human rights violations, environmental degradation, and economic disruption. As there is significant diversity in approaches to mineral development and a market shift toward "green" technology, many manufacturers are insisting on "certified" or sustainably sourced raw materials. Investments funds are pushing ESG incentives for the extractive industries and digital tools, such as blockchain-enabled technology, are being deployed to enhance supply chain transparency and sustainability. A review of these technology trends in this area is provided as well as, potential implications on ESG reporting in mine finance.

3:05 PM

Current Industry Trends: Impact on Mine Finance

C. Urda Kassis; Shearman and Sterling LLP, New York, NY

How are current industry and broader market trends such as (a) the greening of the mining and other industries, (b) the climate change driven EV revolution and implementation of transition technologies, (c) the growing need for critical minerals and thus ensuring the certainty of their supply and the use of ethical sourcing practices and (d) the role of new participants in the mining industry impacting mine finance? Are the types of projects needing funding changing? If so, in what ways? What challenges do these new projects present to financiers? Is the result a need to rethink traditional financing approaches and structures? If so, why and in what ways? How are the diligence process, availability of funding and structure/terms being affected? These are the topics this presentation will seek to address.

3:25 PM

Financing Options for Small Mines—What We Learned in Our Senior Design Project

G. Campbell[1], O. Holdsworth[2] and M. Nelson[1]; [1]Mining Engineering, University of Utah, Salt Lake City, UT and [2]Nevada Gold Mlnes, Elko, NV

A senior design project is required by all accredited mining engineering degree programs. Often referred to as the capstone of a student's education, this project is expected to include all the important components of the preliminary economic assessment of a mineral prospect, including orebody modeling, grade and reserve estimation, selection of mining and processing methods, preliminary mine design, access and utilities, environmental compliance and reclamation, and financial analysis. In the authors' experience, most senior design projects use a marginal cutoff grade and a discounted cash flow analysis to assess the financial viability of the project under consideration. These analyses usually assume direct sale of the product or products over a range of market prices, and capital financing from corporate reserves or equity investors. Capital and operating costs are estimated using the Mining Cost Service, provided by Western Mine Engineering, Inc. The analysis described here used Lane's method to calculate cutoff grade, and looked at five types of project financing— streaming, offtake, royalty, debt, and equity—and calculated net present value for the mine operation in each case.

TUESDAY, MARCH 1

AFTERNOON

Room 05 | 2:00 PM

MINING HISTORY: 150 YEARS OF AIME

Chair: ***G. Luxbacher,*** *NIOSH, Prosper, TX*

2:00 PM

Introductions

2:05 PM

Immigrant Miners in North America 1820-1920

E. McCarthy; Performance Minerals LLC, Morgan Hill, CA

From anthracite coal mining in Pennsylvania, to gold, silver and copper mining in the west, the labor force in the mines from 1820-1920, was made up largely of immigrant miners and their children. The Cornish were the best known; most were miners before they emigrated and they brough their water pumps, contrcat ming system and pasties with them. Less well known were the Chinese who were the largest nationality in the west and suffered great discrimination from both American and immigrant co-workers. The Finns had similar experiences in the iron and copper mines of the upper midwest and that culminated in a series of better strikes. This paper highlights their stories as well as the triumphs and tribulations of the Germans, Irish, Welsh, Italians and Eastern Europeans who came, mined and built an industry.

2:25 PM

The Forgotten Copper Kings of Butte, America

C. Anderson; Colorado School of Mines, Golden, CO

Butte, America in Montana is recognized the the Richest Hill on Earth. Mining fortunes were made and lost there in a fury of activity beginning in 1864. Over one billion tons of copper, silver and gold were mined there for just shy of a century. Commonly, historians focus on the two Copper Kings, W. A. Clark and Marcus Daly, undoubtedly prominent figures in Butte's mining history. However, as is often the case, history forgets or rewrites the true record. This can be an intentional cancel culture phenomenon or simply be a bias based upon the availability and popularity of information. So, others such as Heinze, the Lewisohns, Largey, Davis, Farlin, Murray, Baggely, Tuohy, Cole, Wolvin, the Rothschilds, Ryan, Rogers, Rockerfeller and Washington are largely overlooked or diminished. This presentation will broaden the perception of Butte's Copper Kings and provide a glimpse at a more inclusive mining history directly from the perspective of a native Butte Rat. Tap er light !

2:45 PM

The U. S. Uranium Boom 1950-1980

T. McNulty; T. P. McNulty and Associates, Inc., Tucson, AZ

In 1938, the uranium isotope, U-235, was found to be fissionable. Nearly all prior uranium production was from pitchblende concentrates made in Czechoslovakia, the Belgian Congo, and Canada, with only about 5 percent extracted in the U. S. from carnotite ores being processed in Colorado and Utah for their vanadium content. On August 2, 1939, reacting to the Nazi's seizure of the Czech uranium deposits, Albert Einstein wrote President Roosevelt, warning that a nuclear bomb using enriched uranium was "... within reach." In August 1942, the U. S. Army Corps of Engineers formed a top-secret program code-named Manhattan Engineer District with the responsibility for securing necessary raw materials and developing a bomb. The military need temporarily ended in 1945, but developments in the Soviet Union and China soon ignited the nuclear arms race. In early-1950, Paddy Martinez found a "yellow rock" while herding sheep on Haystack Butte near Grants, NM, and the Boom was on! This paper lists the domestic uranium mills and their owners, and describes the prevalent metallurgical technologies. It recites some anecdotes and memorializes some of the men and women who contributed to the Boom.

3:05 PM

Antimony in the Twentieth Century: The Global and Mobile Story of a Critical Metalloid

M. Hendrickson; History, University of California San Diego, San Diego, CA

Globally, the primary production of antimony is now isolated to a few countries and is still dominated by China. Global resources and reserves are being depleted while demand is growing. Hence, antimony is currently deemed a critical and strategic material. My paper begins by describing how China—and specifically Hunan Province—went from producing no antimony at the turn of the century to assuming the role of unquestioned global leader by WWI. The story of this transformation is one of mobility. The mobility of metallurgical processes, experts, and technology that circulated between the Hunan Province, the United States, and France in the opening decades of the twentieth century. The paper ends in the inter-war period with American policymakers—with the assistance, interestingly, of Chinese mining experts—for the first time deliberating on the consequences of mineral resource dependence.

3:25 PM

Kentucky's Coal Heritage Trail

J. Gardner; SynTerra Corp., Lexington, KY

Coal mining began in Kentucky in the 1800's and development of railroads led to tremendous expansion in the early 1900's. Tens of thousands of people came to the Appalachian Mountains to work the mines including many immigrants fleeing Europe plus thousands of African Americans seeking a better life. Coal camps sprung up through out the coal fields with ones in the mountains by necessity having to be self-sufficient communities that depended on one thing, COAL. With the decline of coal in recent decades Kentucky coal fields communities turn their eyes to tourism to help fill the void left by closed mines. There are numerous attractions throughout the region that already exist. The Kentucky Coal Heritage Trail is designed to become the link between these attractions and sites giving those that are looking for their heritage numerous places to go while visiting Kentucky. Linkages with similar trails in West Virginia and Virginia will be included. This presentation will showcase several recent projects that are designed to help bolster the economy of the region and honor those who helped build the economy of this nation.

3:45 PM

AIME 150 Years Later – Professionalism in the Mineral Industries

G. Luxbacher; OMSHR, NIOSH, Prosper, TX

In 1871 a circular went out calling for a meeting to form the American Institute of Mining Engineers (AIME), identifying issues that would be addressed by a professional society through the accumulated knowledge of the participants: "…consideration of more economical systems of mining in our coal and metalliferous mines, improved methods of transportation above and below ground, unwatering and ventilating mines, the mechanical preparation of coal and other minerals, the various metallurgical processes, and, in fact, every question tending to the attainment of two great objects: 1st. the more economical production of the useful minerals and metals and 2nd. the greater safety and welfare of those employed in these industries." This paper looks at the legacy of the 22 individuals of diverse background, education, and experience who met on the evening of May 16th, 1871 to establish AIME, now represented through its four Member Societies with a combined membership of 200,000 professionals worldwide and continuing the "great objects" focus 150 years later - as applicable today as at the call for that first meeting.

4:05 PM

The Influence of Mining and Metallurgy on the Early History of Mineral Science

I. Barton; Mining & Geological Engineering, University of Arizona, Tucson, AZ

This talk will describe how mining and metallurgy contributed to changing scientific views of minerals over time. Ancient Western philosophers saw minerals as a form of plant with two uses, metals or medicines. Most of their data came from mines and ore minerals are overrepresented among described ancient mineral species, but medicinal uses (unlike metallurgy) were prestigious and were the main focus of early mineral literature. As mining diminished in the Dark Ages, mineral literature shifted from metallurgy and medicine to gemstones, mysticism, and medicine. Starting in the 800s AD in the Middle East, alchemical experiments focused on metal ores and showed that minerals were inorganic, differing from plants in being dissociable into separate elements through chemical processes. Theory and practice of the time, including the sulfur-mercury model, again reflect a disproportionate emphasis on metal ores. As mining rates increased again in Europe after the 10th century, this alchemical concept of minerals caught on and European mineral literature refocused on ores. The concept of living minerals declined and the inorganic model evolved into the modern chemical classification.

TUESDAY, MARCH 1

AFTERNOON

Room 17 | 2:00 PM

MPD: CHEMICAL PROCESSING: PRESSURE HYDROMETALLURGY

Chairs: ***R. Frischmuth****, Hatch, Mississauga, ON, Canada*
J. Baron*, Newmont, Weston, FL*

2:00 PM

Introductions

2:05 PM

Pressure Oxidation Vessel Design - A Historical Review 1985 - 2021

R. Frischmuth[1] and K. Fraser[2]; [1]Hatch, Mississauga, ON, Canada and [2]The Fraser Mining Group Inc., Mississauga, ON, Canada

High temperature pressure oxidation (>190°C) is a well recognized and versatile metallurgical oxidative pre-treatment process commonly used to liberate gold from refractory sulfide ores and concentrates. The process has also been applied for the pressure leaching of base metal concentrates and iron sulfides for acid production within a base metal recovery plant. The pressure oxidation of refractory gold ores was first applied in 1985, at the McLaughlin mine California. Since that time numerous refractory gold and other high temperature pressure oxidation facilities have been installed throughout the world. The design of each facility was met with unique challenges and opportunities which have led to an array of plant configurations, pressure oxidation autoclave sizes, and sulfide oxidation capacities. This paper presents a historical review of high temperature pressure oxidation operations and current projects with a focus on the autoclave vessel design, circuit configuration, and sulfide oxidation intensity as a basis for characterization and comparison.

2:25 PM

Testing and Development Of Acoustic Emission Condition Measurement for POx and HPAL Autoclave Severe Service Ball Valves

J. Scheepers[1], D. Ryce[2] and P. Smith[2]; [1]Service, MOGAS Industries, Houston, TX and [2]MOGAS Australia, MOGAS Industries, Perth, WA, Australia

High pressure acid leach (HPAL) and pressure oxidation (POx) processes occur in autoclave vessels operating at elevated temperature and pressure, acidic conditions with abrasive mineral slurries. The harsh process conditions require specialized severe service metal seated ball valves to support operation of the vessels. Ultrasonic acoustic emission measurement has historically been used to detect and measure leakage through closed valves in pressure piping systems. Indirect and inaccurate non-destructive testing diagnosis techniques are often used to assess the condition of severe service valves in POx and HPAL applications. Accurate and reliable measurement of the severe service ball valve conditions allow maximum valve utilization, avoid premature changeout, and identify the need for changeout prior to significant valve damage or failure. In 2019, MOGAS embarked on laboratory and field testing of potential POX and HPAL autoclave solutions. This paper will discuss the experimental workshop results, field trials, client integration and learnings from incorporating ultrasonic sensor technology to monitor valve internal seal integrity as an inference of the actual valve condition.

2:45 PM

A Novel Corrosion Resistant, Metallurgically Bonded Coating for HPAL and POx Mining Applications

G. Qiao[1], J. Scheepers[2] and P. Smith[3]; [1]Research and Development, MOGAS Industries, Houston, TX; [2]Service, MOGAS Industries, Houston, TX and [3]MOGAS Australia, MOGAS Industries, Perth, WA, Australia

High pressure acid leach (HPAL) and pressure oxidation (POx) or pressure leaching extraction processes occur in autoclave vessels operating at elevated temperature and pressure, acidic conditions with abrasive mineral slurries. The harsh process conditions require specialized severe service metal seated ball valves to support operation of the vessels. Over several decades thermally sprayed titanium dioxide (TiO2) and chrome oxide (Cr2O3) coatings have been applied to extend the service life of the ball valves and other high wear critical components. Variability in the coating application quality control and severe process conditions can result in spalling, coating failure and premature failure of the component resulting is decreased autoclave circuit availability. In 2012 MOGAS, together with BRENCO, initiated research and development for ML-381, metallurgically bonded coating. This paper includes the historical development of severe service ball valve coatings, success of the trials and increasing industry adoption of the ML-381 coating for ball valves and other critical autoclave circuit components.

3:05 PM

Near-Technical Limit Gold Recovery from a Double Refractory Carlin-Type Ore after Pre-Treatment by High-Temperature Pressure Oxidation

D. Dyson[2], J. Langhans, Jr.[1] and S. Yopps[1]; [1]Growth & Strategy, Nevada Gold Mines, Elko, NV and [2]Minerals Division, FLSmidth USA Inc. - Salt Lake City Operations, Salt Lake City, UT

A recent Nevada Gold Mines (NGM) test program conducted at FLSmidth focused on pressure oxidation (POx) pretreatment of a Carlin-type double refractory ore from the Turquoise Ridge (TR) Mine at temperatures between 270-300 °C. The program found that both arsenian pyrite and carbonaceous matter can be oxidized to a high degree in less than an hour when using a benchtop reactor. The gold recovery from these POx residues can approach the technical limit set by the amount of gold encapsulated by silica at the target grind size. A POx temperature of 300 °C yields robust performance when treating the TR whole ore without additives. However, certain additives can catalyze the oxidation rate of carbonaceous matter allowing a lower reactor temperature to be considered for ore pre-treatment. Gangue minerals are susceptible to dissolution at 300 °C, and aluminum precipitates can trigger poor gold recovery. This problem is mitigated by the proper operating conditions during POx.

3:25 PM

Iron Precipitation Control in Total Pressure Oxidation Processes

D. Dyson; Hydrometallurgy, FLSmidth, Salt Lake City, UT

Total pressure oxidation of bulk copper concentrates is an effective processing method for copper extraction, especially in cases where refractory precious metals are also contained within iron sulfide minerals. As previously determined, iron precipitation is heavily dependent on temperature and free acid concentrations during the oxidation process. However, the stability of iron precipitates that are formed in the presence of other metal sulfates, such as copper sulfate, can potentially be underestimated. Copper concentration in solution could be a significant driver in predicting iron precipitation. Data from various continuous pilot plants conducted at FLSmidth are examined in greater detail. Mineralogical X-ray diffraction analyses indicated dominant crystalline iron precipitate phases present in various residues after oxidation. Trends were observed that could significantly impact process optimization and project economics.

3:45 PM

Separating Excess Acid From Leach Streams: Improve Processing And Put Acid Where It is Needed

P. James; Blue Planet Strategies, Madison, WI

Facilitated oxidative leaching approaches such as Pressure Oxidation (POx) and Rapid Oxidative Leaching (ROL) are gaining wider market adoption. They often result in substantial net acid generation and yield Pregnant Leach Solutions (PLS) that have highly elevated acid content that may be well over that preferred for the subsequent Solvent Extraction (SX) step. Electrolytic acid separation has been demonstrated for such high acid tenor PLS and can provide economic benefits over conventional mitigation of the excess acid or compensation for the excess acid on the copper extraction at the SX step. The fundamental aspects of the innovative separation process will be discussed. Results illustrating the basic separation process will be presented for an example case. Noted performance will be used to develop an economic comparison for separating the acid, leaving the acid in the PLS and compensating during SX metal extraction, and neutralizing the excess acid ahead of SX. Options for site tailoring and streamlining the targeted acid separation to optimize the relevant treatment performance and economics plus the site production will be discussed.

4:05 PM

The Golden Rules of Pressure Oxidation and Pressure Leaching Operations

R. Frischmuth; Hatch, Mississauga, ON, Canada

Pressure oxidation (POX) and pressure leaching (PL) introduce unique, high severity hazards to typical mineral processing facilities including elevated temperature, pressure, high purity oxygen and acidic slurry conditions. The hazards and controls are typically identified and controlled from project implementation however detailed knowldege of the hazard and control intent may wane over the life of a project. During operations, minor incidents or near-misses can quickly escalate if a decision to shutdown is postponed. The following "golden rules of POX and PL operations" include a list of critical conditions that can be used for pre-approved immediate shutdown and correction with the support of operations management.

TUESDAY, MARCH 1

AFTERNOON

Room 16 | 2:00 PM

MPD: FLOTATION CHEMISTRY AND REAGENTS

Chairs: ***B. Vaziri Hassas****, Penn State, State college, PA*
W. Zhang*, Virginia Tech, Blacksburg, KY*

2:00 PM

Introductions

2:05 PM

Effect of Al3+ and Mg2+ on the Flotation of Apatite Using Fatty- and Hydroxamic-Acid Collectors – A Multiscale Investigation

A. Eskanlou[2] and Q. Huang[1]; [1]Mining Engineering, West Virginia University, Morgantown, WV and [2]Energy and Mineral Engineering, The Pennsylvania State University, University Park, PA

An original multiscale approach has been developed involving flotation experiments, electro-kinetic and adsorption density measurements, XPS studies, and AIMD simulations to unravel the effect of Al3+ and Mg2+ on the flotation of apatite using fatty- and hydroxamic-acid collectors. Results showed that fatty acid establishes a stronger interaction with the bare apatite surface compared to the hydroxamates. Na+ counter-ion contributes to the adsorption of fatty acid on bare apatite. Both Al3+ and Mg2+ ions are beneficial for the adsorption of fatty acid, and thereby the apatite flotation. For octanohydroxamic acid, the presence of Al3+ results in a stronger collector-apatite interaction, and therefore an enhanced flotation. For fatty acid and hydroxamates, adsorption of Mg2+ leads to a stronger collector-apatite interaction. Benzohydroxamic acid is more strongly adsorbed than octanohydroxamic acid in the presence of Mg2+. Fatty acid establishes a stronger interaction with bare and Al3+/Mg2+-treated apatite, as opposed to hydroxamates. Mg2+ is more favorable than Al3+ in apatite flotation using both fatty acid and the hydroxamates.

2:25 PM

Eco-Friendly Surfactants for Fine-Particles Flotation

V. Slabov, E. Larsen, I. Chernyshova and H. Rao Kota; Geoscience and Petroleum, Norges teknisk-naturvitenskapelige universitet, Trondheim, Norway

Secure supply of raw materials calls for technological innovations of the mineral separation industry toward increased resource and energy efficiency guided by sustainable-by-design principles. One of responses to this challenge is to substitute toxic or hazardous petroleum-based flotation reagents by environmentally-benign alternatives. Another one is to valorize tailings, which requires their reprocessing and can be done by flotation. However, liberation of target minerals requires ultrafine grinding which results in a complex of issues related to fine-particle flotation. Hence, the goal of our study was to test efficiency of select biosurfactants (eco-friendly surfactants produced by benign yeasts from food waste) as collectors in flotation of hematite and malachite fines (-20 µm) in comparison with conventional surfactants. Our results demonstrate the ability of the biosurfactants to separate the mineral fines from quartz in miniflotation tests. To interpret the results, we study the adsorption mechanisms and compare flotation of the mineral particles of various sizes and iron and copper oxide nanoparticles.

2:45 PM

Functionalized Biopolymer for Non-Sulfide Gangue Suppression in Froth Flotation Cleaner Stage at NGM Phoenix Mine

L. Kuri[1], B. Arthur[2], B. Wilson[3] and G. Benthen[4]; [1]Integrity Mining and Industrial, Humble, TX; [2]Brian Arthur Consulting Metallurgy, LLC, Elko, NV; [3]Quadra Chemicals, The Woodlands, TX and [4]Nevada Gold Mine, Elko, NV

Fine particles in froth flotation are difficult to selectively float, resulting in low recoveries, concentrate grades, and additional cleaner stages. Complex ore mineralogies- such as swelling and/or friable clays can create slime films and gangue agglomerates that also limit recovery and concentrate grade.

The CleanMax biopolymer is optimized with substituents designed to encapsulate these fine, charged particles. CleanMax prevents non-sulphide gangue from adhering to the bubbles in the froth, yielding higher grade cleaner concentrate. Matched pair bench studies were conducted on rougher concentrate samples from the Nevada Gold Mine Phoenix Mill. The tests indicate improved kinetics and overall recovery of both gold and copper. Gold recovery was 10.8% higher and copper recovery was 14.8% higher in 9-minute bench tests with the CleanMax vs the baseline in the cleaner circuit. The overall recovery of copper was improved by 2.61%, and gold recovery was improved by 3.76%.

3:05 PM

Towards the Concentration of Gold-Rich Arsenopyrite and Rejection of Gangue Pyrite from an Auriferous Concentrate

P. Forson[1], R. Asamoah[1], M. Zanin[1] and W. Skinner[2]; [1]Future Industries Institute, University of South Australia, Adelaide, SA, Australia and [2]ARC Centre of Excellence for Enabling Eco-Efficient Beneficiation of Minerals, University of South Australia, Adelaide, SA, Australia

In spite of the seeming benefits decoupling pyrite and arsenopyrite minerals present in practice, little success has been achieved to date. The present study presents possible process routes for attaining selective flotation broadly capitalising on differential oxidation between pyrite and arsenopyrite, and the use of chelating collectors with arsenic ion specificity. Dithionocarbamate application following copper activation yielded 86.9% arsenopyrite and 31.8% pyrite recovery accounting for 86.7% of the total gold recovered. Pre-aeration followed by staged addition of xanthate produced 76% arsenopyrite and 28% pyrite recovery while reverse flotation of pyrite after hydrogen peroxide addition gave rise to the rejection of 76% pyrite accompanied with 33% arsenopyrite. Thus, dithionocarbamate addition after copper activation gave superior flotation performance and selectivity.

3:25 PM

Selective Flotation of Bastnaesite in the Presence of Calcite Using Organic Acids as Depressants

E. Muhoza[1], K. Gibson[1], H. Amini[1] and W. Zhang[2]; [1]Mining Engineering, West Virginia University, Morgantown, WV and [2]Mining and Minerals Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA

Flotation of bastnaesite suffers from high reagent consumption and complex stages of high-temperature conditioning due to the similar surface characteristics of bastnaesite and associated gangue minerals, including calcite and barite. This research seeks to develop a sustainable flotation reagent scheme for the optimal recovery of bastnaesite using organic acids as depressants and sodium oleate as the collector. As such, systematic flotation experiments were conducted to investigate the impact of pH, collector dosage, and organic acids concentration on the flotation performance of bastnaesite when calcite exists as the primary gangue mineral. The results of flotation tests indicated that the addition of lactic and succinic acids dramatically reduced the recovery of calcite with no influence on the bastnaesite recovery. The data demonstrated that both organic acids are selective depressants for calcite. At the optimal level of pH, sodium oleate, and organic acid dosages, the recovery of calcite was reduced to below 10%, where bastnaesite recovery remained above 95%.

3:45 PM

New Insights into the Pre-Concentration of Alunite from a Siliceous ore using Ba2+, Ca2+, and F- in Froth Flotation

F. Dehghani and T. Ghosh; Department of Mining & Mineral Engineering, University of Alaska Fairbanks, Fairbanks, AK

Alunite is the main non-bauxite source of aluminum. Due to the low Degrees Of Freedom (DOF) of alunite, froth flotation, as a preconcentration method, is a viable alternative to increase selectivity in downstream processes. The current study was aimed at investigating the pre-concentration of alunite using micro-flotation. In the first step, optical microscope studies were done to determine the DOF of alunite. In the next step, flotation tests were designed. The experiments were performed based on the surface charge differential between alunite and quartz using direct and reverse flotation. In the reverse flotation, Ca+ 2 and Ba+ 2 were used to activate the quartz surface. An anionic collector was used to float the gangue minerals. The highest grade and recovery using reverse flotation were 34.96 and 81.33%, respectively. In the direct flotation, the surface of alunite was activated using Ba2+, Ca2+, and F-. The optimum condition was achieved using F-as an alunite activator for particles ranged-37+ 25 µm with a grade of 31.47%. The grade and recovery were 50 and 89%, respectively. During the experiments, several parameters were controlled.

4:05 PM

Innovative Sulfides Depressant for Cu/Mo Separation

A. Pejlovas; OMS, Clariant Corporation, Tucson, AZ

Several reagents are involved in the flotation process of copper and molybdenum sulfide ores to produce a bulk copper and molybdenum concentrate. Following the production of the bulk concentrate, many operations continue processing the bulk concentrate to further separate the copper sulfides into a copper concentrate and the molybdenum sulfide into a molybdenum concentrate. This separation is carried out by using depressants to depress the copper sulfides while the molybdenum sulfide can be floated. Typical depressants for the copper sulfides used in this separation process are NaHS solution and Noke's reagent. Depressants such as NaHS solution generally have a very high consumption, have inherent safety risks related to the toxicity of the chemistry, and possess a foul odor. We present the results of the joint development with a global producer of an innovative sulfide depressant to be used in the separation of copper sulfides and molybdenum sulfide to result in a more effective and safer separation process. The outcome is a depressant that is very effective at depressing the sulfides, does not have any odor, is non-hazardous, and is readily biodegradable.

TUESDAY, MARCH 1

AFTERNOON

Room 18 | 2:00 PM

MPD: PHYSICAL SEPARATION II

Chairs: ***A. Cavendor****, Weir Minerals, Reno, NV*
M. McCaslin*, FL Smidth, Murray, UT*

2:00 PM

Introductions

2:05 PM

Sensor-Based Sorting Technology and the Pre-Concentration of Ores

J. Rutledge and H. Cline; Tomra Sorting Mining, Lakewood, CO

Challenges to the mining industry only continue to grow. There is pressure to be more financially streamlined, radically more efficient than in the past, while being conscious of environmental and sustainability concerns. Sensor-based sorting proves to be an increasingly more important tool, both to formulate optimal solutions for greenfields projects and to help conquer challenges for keeping brownfields operations viable. Current sorting technology, advantages and limitations, and examples of operations and case studies in the field will all be discussed.

2:15 PM

Benefit of Scalping Feeder

T. Schoultz[2] and G. Davis[1]; [1]Metso Outotec, Sandy, UT and [2]Screening BL, Metso Outotec, Columbia, SC

Mesto Outotec offers a series of robust, mining duty feeders designed to fit the process flowsheet needs. Our presentation focuses on scalping or vibrating grizzly feeders suitable to feeding ROM to crushers or crushed feed to screens. We will briefly present operating principles, recommended duty within the process flowsheet, while also reviewing the process and cost benefits of protecting the down steam, higher capex equipment: crushers, screens, and material handling systems Physical Separation Flowsheet Exhibit Floor Walkabout session.

2:25 PM

CAVEX® 2 Hydrocyclones and the Benefits of Turbulence Reduction

D. Switzer; Weir Minerals, Cody, WY

CAVEX® 2 hydrocyclones reduce turbulence through the utilization of the advanced laminar inlet, LIG+. This reduction in turbulence allows for increased volumetric capacity and improved separation efficiency in the equipment. An example of the impact of these improvements in a mill circuit application will be given.

2:35 PM

The application of the REFLUX™ Classifier in Heavy Mineral Applications

N. Boonzaier; GPLM, FLSmidth and Co A/S, Valby, Denmark

The REFLUX™ Classifier combines a conventional fluidized bed with a series of inclined lamella plates to achieve enhanced separation of high density particles with the ability to accommodate high throughput. The technology reduces footprint and improves recovery compared to traditional density separation, which leads to attractive value propositions. Historically the technology was deployed in coal and has since proven itself highly effective in several heavy mineral applications. This presentation highlights the key features which makes it unique and also covers opportunities for the REFLUX™ Classifier in various markets outside of those already established.

2:45 PM

Productivity and Recovery Improvements by Closing Grinding Circuits with Fine Screens

B. Zhang; Derrick Corporation, Buffalo, NY

Metallurgists worldwide are adopting innovative technologies to overcome the challenges of falling metal prices, high energy costs, low-grade ores, and increasing environmental constraints. Technology advances have made it practical to close grinding circuits with screens instead of conventional hydrocyclones or in combination with hydrocyclones, enabling operators to benefit from improved grinding efficiency, higher production rates, and negligible over-grinding, and a better particle size distribution for downstream processing. This paper highlights recent success stories of screen classification in various ore beneficiation plants, including, platinum, copper, lead-zinc, and tin.

TUESDAY, MARCH 1

AFTERNOON

Room 15 | 2:00 PM

MPD: PLANT DESIGN I

Chairs: ***M. Spicher****, Montana Tech of the University of Montana, Meridian, ID*
A. House*, Forte Dynamics, Helena, MT*

2:00 PM

Introductions

2:05 PM

Opportunities For Pre-Concentration: Development Of A Lab-Scale Evaluation Test

A. Dance; Metallurgy, SRK Worldwide, Vancouver, BC, Canada

Pre-concentration opportunities are available for most operations to improve the grade of their mill feed and eliminate fine/soft contaminants or coarse/hard material. As an industry, we are obliged to ensure our plant feed requires the lowest power and water consumption and the smallest footprint tailing-management facility. Every opportunity to reject waste when it's still coarse, dry and conveyable should be assessed. So here's the dilemma: we cannot include pre-concentration stages in flowsheet design without some level of demonstration and yet, we never get the opportunity. For a greenfield project, we cannot evaluate pre-concentration due to a lack of standardised testing methods and sample top-size constraints. It's exacerbated by our current testing practices where sample preparation involves stage-crushing down to a manageable size – destroying the opportunity to evaluate coarse beneficiation methods. This paper covers recent progress by the author to develop a standardised ranking test using ½ drill core samples. The objective is to consider pre-concentration at an early study stage and quantify the impact on project economics.

2:25 PM

Review of Richmond Hill Copper Elution Operations

S. Dixon; SND Consultants, Tucson, AZ

The selective elution of copper from gold and silver on carbon is a common practice. The process was evaluated at Richmond Hill Heap Leach operations in 1990. The data resurfaced after decades in a box. The use of warm (40-50 C) solution for the selective elution (pre-strip) of copper cyanide from gold and silver cyanides adsorbed on activated carbon was found to elute +90% of the adsorbed copper compared to the use of ambient (20 C) solution eluting 50-70% of the adsorbed copper. The warm solution pre-strip elution did have higher co-elution of gold (1-4%) and silver (10-18%) with the copper. The use of ambient solution pre-strip elution co-eluted less gold (0.2%) and silver (2%). The use of warm (40-50 C) solution for the selective elution (pre-strip) of copper cyanide from gold and silver cyanides adsorbed on activated carbon was found to elute +90% of the adsorbed copper compared to the use of ambient (20 C) solution eluting 50-70% of the adsorbed copper. The warm solution pre-strip elution did have higher co-elution of gold (1-4%) and silver (10-18%) with the copper. The use of ambient solution pre-strip elution co-eluted less gold (0.2%) and silver (2%).

2:45 PM

Development of a Flotation Simulation Including Reliability Based Maintenance Model and a Multi-Compartment Model for Metallurgical Performance and Quality

R. Rodrigues Silva[1], P. Mendonza[1], D. Rivera[1], C. Canaza[1], R. Siwale[1], M. Richards[1], V. Ngcoza[1], R. Richards[1] and H. Amini[2]; [1]FLSmidth, Midvale, UT and [2]West Virginia University, Morgantown, WV

Development of a realistic flotation model to predict its peformance is of paramount importance to the processing plant and operators. A model that accounts for predictive and non-predictive maintenance simulating individual equipment downtime and the effect on metallurgical peformance of the flotation bank with final recoveries and grades has huge benefits on circuit optimization. Developed in a dynamic enviroment, the model allows for improved and more realistic simulation of the flotation bank. The maintenance model accounts for the Failure rate, Mean Time Between Failures, Mean Time To Fail, Mean Time to Repair, and Reliability. These features are combined with a multi-compartment process model that consist of a slurry recovery model having options of froth recovery, entrainment, and carry capacity as a final check for the simulation In addition to the maintenance and process model, a dynamic dart valve model was added to the simulation in order to have a realistic control of the slurry level of the flotation cell. The paper goes over a case study for a current flotation operation, trying to explore all the elements of the simulator to optimize the flotation bank.

3:05 PM

High-Pressure Slurry Ablation (HPSA) – A New Particle Attrition Technology

J. Lee[1], G. Buckingham[2] and A. Halverson[2]; [1]Mining Engineering, The University of British Columbia, Vancouver, BC, Canada and [2]Disa, LLC, Casper, WY

Of the total energy consumed by the mining industry, more than 50% is spent on ore comminution. Disa seeks to prove that it provides significant energy savings with its High-pressure slurry ablation (HPSA) technology. HPSA is a new particle attrition technology that works on the principle of particle-to-particle collisions between two or more high-pressure slurry jets. Particle disassociation is realized through the intense collisions created by high-pressure pumps moving slurry through a series of nozzles within the collision chamber. Preliminary testing using both lab and pilot-scale HPSA units has demonstrated promise to effectively be applied to a diverse group of materials, specifically soft to medium hard ores. Disa is currently testing materials at its four research centers; Forte Dynamics, Dundee Sustainable Technologies, University of British Columbia, and Montana Tech. Materials include oil sands, potash, iron, molybdenum, copper, gold, uranium, vanadium, phosphate, lithium, rare earths, graphite, nickel, and others.

3:25 PM

Mill Sump Design

M. Webb; Weir Minerals, Madison, WI

Suction sump and piping design is crucial to the success of a typical ore grinding circuit. The sump and suction piping feed the mill circuit pump that sends the mill product to the cyclones for classification. A general understanding of how the sump, the suction piping, and the pump interact is essential for designing an effective system. A poorly designed suction system can affect pump performance, reliability, and wear life of the internal pump components. Guidelines and general considerations regarding proper sump and suction piping design are discussed in this presentation.

3:45 PM

The Use of Dynamic Heap Leach Recovery Modeling to Optimize Plant Design and Operation

S. Guidi; Forte Dynamics, Inc., Fort Collins, CO

Plant design and operations are key factors to a successful Heap Leach Project. Optimization of the Heap Leach Facility (HLF) and ancillary facilities can mitigate operational downtime and maximize Net Present Value (NPV) for the life of the project. Utilization of dynamic systems models that track key process indicators (KPIs) that relate to heap leach operations give us the opportunity to optimize plant design and operation for a HLF. These models utilize a full mine-to-heap approach to understand how variations in mine plans and HLF operations impact recovery and project NPV. These models incorporate best practices for optimization; evaluating changes of the mine plan, ore placement, changes in PSD, and changes in planned leaching operations. This discussion will focus on the use of dynamic heap leach modeling to improve plant designs by optimizing flow rates, sizing and optimizing the processing facilities, and improving the phasing of capital. Additionally, this will include discussion of optimization of operations for a HLF, including maximizing recovery, maximizing NPV, minimizing liability into closure, optimizing leaching, and reduction of inventory.

4:05 PM

Optimizing the Dry Tailings Transportation Method for Lowest CO_2 Emission, Water Recovery and Energy Consumption

J. Kruyswijk; Weir Minerals Netherlands, Venlo, Limburg, Netherlands

Following several recent catastrophic TSF failures, tailings storage has become vital in maintaining the social license to operate. The preferred tailings storage method optimizes water preservation with sustainable long-term stability at much lower emissions. A comprehensive approach must, therefore, consider energy, water and footprint preservation, as well as the process flow from dewatering through to deposition in the TSF. The benefits of upgrading dilute tailings deposition to thickened tailings or paste tailings have been studied by several authors. Both high density paste and filtered tailings are considered dry tailings. There are different approaches to the way filtered tailings are handled, deposited and compacted; however, they are all energy intensive, resulting in higher emissions compared to thickened or paste tailings systems. The transportation of filtered tailings also results in higher CO_2 emissions. This paper expands on previous research and provides a framework to decide between hydraulic or filtered tailings deposition. The benefits, in terms of consumed energy and related CO_2 emissions, are qualified at a high level.

TUESDAY, MARCH 1

AFTERNOON

Room 04 | 2:00 PM

VALUATION II- LESSONS LEARNED

*Chair: **D. Noll**, Earthtech, Inc, Somerset, PA*

2:00 PM

Introductions

2:05 PM

Pitfalls of Retrospective Appraisals of Oil and Gas Interests

B. Suppes; IIMA, Johnstown, PA

Retrospective appraisals are sometimes requested by attorneys when settling an estate. However, the mineral owner may not realize that their property was not worth much at that time and the cost to appraise it could potentially exceed the value of the property. The appraiser may not be aware of the relatively modest value of the property this until they are halfway into the appraisal. Examples of retrospective appraisals and mitigating techniques are discussed.

2:35 PM

What About the Word "Comparable" Do You Not Understand?

A. Stagg; Stagg Resource Consultants, Inc., Cross Lanes, WV

One of the three Approaches to Value an appraiser is to consider is the Sales Comparison Approach. Although somewhat more difficult to use for mineral appraisals than for real estate, it can be done with appropriate reconciliatory techniques. One not so subtle nuance frequently overlooked is the fact sales of mineral properties can involve differing interests. A passive investor seeking royalty income can be expected to make a different investment decision than an investor that is to operate the property. This distinction is particularly significant when the property in question is producing. Two notable misuses of this approach i am encountering frequently involve the selection of an indication of value for reserves and the selection of a discount rate. Recent examples of each are provided in this presentation.

3:05 PM

The Financial Phase Diagram Approach to Project Valuation

L. Hutson; Mining Engineering, University of Arizona, Tucson, AZ

Mining is a capital-intensive industry, where strategic decisions to buy, sell, develop, expand, or close a project require a strong understanding of the economic value and financial risks involved. However, conventional discounted cash flow (DCF) and real options methods of analyses either fail to consider many combinations of variables or are difficult to execute and opaque. This talk will describe a new, analytics-based approach to financial valuations that showcases myriad potential project outcomes in a way that explicitly defines the 'boundary conditions' of a successful project with respect to multiple variables. The approach is analogous to a geochemical phase diagram, which uses a field or surface to define the region of stability of a chemical compound with respect to different physicochemical conditions. This approach is more comprehensive than DCF and more transparent than real options analysis. It also provides a useful evaluation framework to aid technical staff in project evaluation, including a robust set of interactive visualizations.

3:35 PM

To Before and After?

D. Falkenstern; Appraisal, Society for Mining Metallurgy and Exploration, Englewood, CO

While most texts and accepted appraisal practice on the subject dictate that partial acquisitions of mineral properties be valued with the Before and After technique; specifically using royalty income, is it always appropriate? Do different site specific situations necessitate a different appraisal approach to partial acquisitions: Permitted/active and non-permitted/reserve mineral properties Acquisition involves part of an eminently mineable section within a well defined mine plan Separate royalty/mineral owners within the mine If the partial acquisition is a significant percentage of an active operation Is royalty income the only damage? Reserve replacement New permitting costs Do juries grasp Before and After? The goal of this presentation is to present different examples of partial acquisitions and facilitate an open dialog of our appraisal experiences on the subject.

4:05 PM

A Baseline Market Analysis of the New England Aggregate Industry

D. Werthessen; Mineral Engineering, New Mexico School of Mines, Bridgewater, MA

A relevant and reliable market analysis is the basis for appropriately valuing any property interest. The northeastern United States has experienced accelerated levels of construction over the past several years and there are many projects partially completed or within the development pipeline as of Q3 2021. The aggregate industry supplies the raw materials used in residential and commercial construction projects as well as road and highway development. This presentation will provide an overview of producing aggregate mines within New England, production volumes and the construction markets they primarily serve. Primary focus will be placed on three of the largest core market areas in New England as measured by population; Boston (630,000), Providence (180,000), and Worcester (180,000). This information will then be contrasted with the demand figures developed through study of the construction projects in progress, permitted and approved, and other relevant construction figures such as highway construction and residential construction (new housing starts). The culmination of this presentation will be an assessment and forecast of the vitality for the New England aggregate industry.

4:35 PM

Applying the Reasonableness Standard Early in a Property Evaluation

D. Abbott; David Abbott Consulting, Denver, CO

I propose adoption of a "Reasonableness" standard for all types of geoscience reports. I'm further suggesting that early application of some reasonably estimated modifying factors to property evaluations provides a basis for valid conclusions without acquiring and analyzing large amounts of supporting data. The "Reasonableness" standard in the IMVAL Template (2021) is modified for general application, "'Reasonableness' means that other qualified and experienced geoscientists with access to the same information for the same date and basis would consider the author(s)'s interpretations and conclusions to be with a reasonable range of variation. Any standards used, assumptions applied, and any method relied upon should be reasonable within the context of the purpose of the report or presentation." The "Modifying Factors" of the CRIRSCO Template apply throughout the property delineation process. A number of "laws of exploration" illustrate this point. Examples of the application of the modifying factors are provided including two examples comparing unjustified and justified extrapolation of inferred mineral resource estimates.

WEDNESDAY, MARCH 2

MORNING

Room 03 | 9:00 AM

COAL & ENERGY: APPLICATION OF MODELING IN COAL MINING OPERATIONS

Chairs: ***A. Choudhury****, Montana Tech*

S. Arya*, University of Alaska, Fairbanks, AK*

9:00 AM

Introductions

9:05 AM

Effective Demonstration of Monitored Natural Attenuation using Geochemical Models

P. Nolan and R. Verburg; Golder, Redmond, WA

Monitored Natural Attenuation (MNA) presents an economically favorable strategy for long-term management of potential groundwater impacts from coal combustion residuals (CCR) impoundments. However, some traditional approaches to demonstrating MNA, such as use of a single partition coefficient (Kd), do not adequately predict long-term stability of constituents that are sensitive to geochemical changes. In this presentation, we discuss how to effectively utilize geochemical models (the USGS codes PHREEQC and PHAST) together with advanced laboratory methods (e.g., sequential extraction) to provide a robust MNA demonstration. Modeled scenarios also include examples of MNA combined with other corrective actions, such as semi-permeable caps, wall emplacement, geochemical manipulation, or source control. The potential for reversible attenuation will be also described. Most notably, a sequential approach to modeling will be presented, which will identify when a basic 1-D geochemical model or a full reactive transport model would be more appropriate to demonstrate that MNA is a viable remediation strategy.

9:25 AM

Numerical Snalysis of the Effect of Lamination Properties on Roof Failure in Coal Mines using Coupled FDM-DEM

Q. Shi, B. Mishra and Y. Zhao; Mining Engineering, West Virginia University, Morgantown, WV

In the present study, a 3D numerical model coupled with the finite-difference method (FDM) and the discrete-element method (DEM) was created to simulate the laminated roof failure in an eastern coal mine in the US. In the FDM-DEM coupled model, the laminated roof of the entry is represented by an assembly of bonded particles using PFC3D. The laminated roof is simulated by adding parallel discontinuities. The ribs, floor, and far-field surrounding rock are represented by continuum zones using FLAC3D. The strength of the discontinuities is varied sequentially and the fracturing of the laminated roof was analyzed with respect to entry advance. The results show that increasing the strength of discontinuity could enlarge the tensile zone inside the laminated roof and hence change the crack distribution. In addition, the crack quantity in the laminated roof behind the advancing face decreases with the increment of discontinuity strength while this trend is not occurring ahead of the advancing face. The simulation demonstrated that coupled methods using PFC3D/FLAC3D can reproduce the laminated roof failure in underground coal mines.

9:45 AM

Numerical Investigation of the Size Effect on the Compressive Strength of Laminated Shale

Y. Zhao, B. Mishra and Q. Shi; West Virginia University, Morgantown, WV

Laminated shale is considered as a leading factor in causing roof falls. It exhibits anisotropic mechanical behavior due to the presence of bedding. However, little attention has been paid to the anisotropic behavior of the size effect on the strength of laminated shale. This paper uses the bonded-particle discrete element method to study the size effect on the strength of laminated shale under the uniaxial stress state. The anisotropic behavior of laminated shale is characterized by the shale matrix with embedded bedding planes, while the size effect is introduced by flaws. The developed model of laminated shale is scaled to different sizes and then tested in the direct tension test and the uniaxial compression test. The test results demonstrate that the uniaxial compressive strength decreases when the specimen size increases. However, the size effect on the direct tensile strength depends on the direction of bedding planes. When the loading direction is perpendicular to bedding planes, the size effect is not prominent. When the loading direction is parallel to bedding planes, the direct tensile strength decreases when the specimen size increases.

10:05 AM

Numerical Simulation of Pore-Pressure and Parallel Joints on Laboratory Rock Specimens

G. Zhao, B. Mishra and Q. Shi; Mining Department, West Virginia University, Morgantown, WV

Strength of rock specimen is significantly affected by the presence of joints and pore pressure, however the hydro-mechanical response of the rock to different stress regime is not clear. Therefore, seven three-dimensional numerical models with parallel oriented joints of 0°, 15°, 30°, 45°, 60°, 75°, 90° was developed in 3DEC. Uniaxial ($\sigma_2 = \sigma_3 = 0$) and triaxial ($\sigma_2 = \sigma_3 =$ 10, 20, 30, 40 MPa) compression tests of each model were conducted under uncoupled state with Mohr-Coulomb constitutive model and coupled hydro-mechanical state under different fluid pressure (0.5, 1.0, 2.0, 3.0 MPa). The simulation results showed that the uniaxial strength varied with different orientation producing the classic "U"-shaped curve. However, when fluid was coupled with the mechanical simulation the strength changed from the "U" shaped curve to a non-linear curve. Further analysis of the model showed that at 30°orientation showed that due to the combination of the pore pressure and the orientation of joints, a reaction strength was developed in the joints causing a slight increase in the strength.

10:25 AM

Coupling Numerical Modeling and Rock Burst Potential Indices to Predict Coal Bursts

C. Cardenas Triana, R. Flattery and Z. Agioutantis; Department of Mining Engineering, University of Kentucky, Lexington, KY

Coal bursts involve rapid and violent ejection of coal or rock into an underground excavation. They can occur without warning during longwall or pillar extraction, but they can also occur during development. This phenomenon typically occurs under a complex set of conditions, and this has made it extremely difficult to predict. In the last decades, different researchers have aimed to understand the sources and mechanisms of failure of coal bursts. Several indices have been proposed to predict rock bursts considering the rock properties, stress conditions, elastic-energy storage, and dissipation of energy after failure. As coal bursts are considered dynamic events, numerical modeling provides a tool to analyze the process of rock deformation. The present work presents a first-order approximation to estimate the burst tendency of coal pillars in a longwall gateroad system, using a combination of rock burst potential indices and numerical modeling. Results show that if a coal pillar accumulates sufficient elastic strain energy, the burst potential increases unless mitigation measures are taken to reduce the strain build-up.

10:45 AM

Geometallurgical Model Using Analysis of Covariance (ANCOVA) at Toromocho Mine

G. Giarnelly; Universidad Nacional de Ingenieria, Callao, Peru

In the mining industry where every day it is more frequent to work with a large amount of data that makes managing it complicated. As consequense, new concepts such as Business Intelligence, Data Science, Big Data and others have emerged. In Toromocho mining operation, there was a problem, the equation for the metallurgical recovery of copper was made up of 20 variables and did not represent reality. In this research, a statistical model was built using the analysis of covariance, technique allows combining categorical and continue covariates, the R statistical software was used. As result, it was reduced the number of variables in the copper recovery equation which were values close. In addition, this methodology helped to replicate in other mining processes.

WEDNESDAY, MARCH 2

MORNING

Room 01 | 9:00 AM

COAL & ENERGY: INNOVATIVE ENGINEERING SOLUTIONS FOR MINING OPERATIONS

Chairs: ***S. Baker****, Rosebud Mining, State College, PA*
A. Patterson*, LCT Energy, LP, Latrobe, PA*

9:00 AM

Introductions

9:05 PM

CONSOL Energy – Itmann No.5 Mine Project Development Update

B. Williamson, CONSOL Energy Inc., Wyoming County, West Virginia

The Pocahontas No. 3 (P3) seam in Central Appalachia (CAPP) has been one of the largest sources of high-quality metallurgical coal for 100+ years. CONSOL Energy has recently re-entered the CAPP region and is developing a new metallurgical coal project, the Itmann No. 5 mine, to produce low-vol metallurgical coal from the P3 seam in Wyoming County, WV. The Itmann No. 5 mine continues a legacy of successful mines in the region dating back to 1916 with the inception of the Itmann No. 1 mine. This paper will discuss the process of the Itmann mine development over the past 2-years, including considerations associated with the mine layout, permitting, site construction, and initial underground mining operations. In addition, CONSOL will provide an update on the Itmann coal preparation plant construction, a unique project in which an existing state-of-the-art preparation plant is being disassembled, transported 220 miles, and reassembled at the Itmann site, a substantial benefit to the project overall.

9:25 AM

Schedule Optimization for Large-Scale Coal Operations with Blending and Destination Constraints

A. McBrayer and A. Brickey; Department of Mining Engineering and Management, South Dakota School of Mines and Technology, Rapid City, SD

With the current economic climate, many coal companies are seeking avenues to improve efficiencies. For large-scale area mines, using scheduling optimization tools is often deemed unnecessary. In the Powder River Basin (PRB), blending manages qualities to achieve a saleable product. A PRB company desired to quantify the impacts of abandoning low-quality coal with specific allowances. This research presents a mathematical model used to determine a production schedule for a large area mine with blending re-quirements. The results provide a schedule of when and if coal is mined and processed or left insitu along with the impacts to the operation's economics.

9:45 AM

Estimation of a Blasting Induced Vibration Prediction Model of Mid and Far Fields for the Structure Care on an Open Pit Mine in Closure Process

P. Cornejo; Mining, Pontificia Universidad Catolica del Peru, Lima, Lima, Peru

Blastings always generates induced vibrations through seismic wave, these are lost energy from the blasting and therefore causing the disturbance of slopes and structures near the blast source. Most of the components of an open pit mine have to reach a physical stability, especially during its closure process. Aiming to develop a vibration prediction model using the historical records from an open pit mine located on Peru, this research has two main focuses depending on the distance from the blast source to the structure: to protect the final slopes and to protect the villagers houses. Both are based on the Devine model of the Square Root Scaled Distance (SRSD) to predict the Peak Particle Velocity (PPV). The Mid field model, where is found mainly final slopes from the pit, limited by the failure criteria of McKenzie based on the geo mechanical properties of the rock mass. The Far field model ranges distances where are located the most community households, limited by the German rule DIN 4150 for highly sensitive structures. Both scenarios resulted on a distribution abacus to limit the weight of used explosives to get the best operational advantage and structure safety.

10:05 AM

Constant Torque Results of a Medium Voltage AFD using Output Transformer

S. Simms; Medium Voltage Motor Controls, Eaton Corp, Cleveland, OH

This paper describes an installation of a medium-voltage adjustable frequen-cy motor drive on a constant torque friction load that includes a long cable and gear box speed reducer. The AFD electrical architecture is introduced from line to load. The type of closed loop encoder feedback motor control algorithm is briefly described. The results of the AFD motor identification au-to-tuning are compared against the manufacturer's supplied data. The motor drive performance results are shown for pre-Start DC fluxing, high start-ing torque with overload current, excessive load torque stall condition, and blocked rotor. The instrumentation and arrangement for the two Watt-meter method to capture low frequency data are presented. The data shown is from the input power quality meter, the AFD computer tool, the output motor protection relay, an oscilloscope, and load shaft connected strain gauge (for torque). These types of constant torque friction loads are found in Mining and Process Industry Applications employing AC adjustable frequency drives. Us-ing these real field results will demystify the use of voltage matching output transformers in AFD applications including constant torque loads.

10:25 AM

Stieber and Svendborg Brakes Combined Their Expertise to Provide Integrated Systems

T. Kretschmer, Stieber GmbH, Germany

Stieber torque limiting and releasable backstops (series RDBK and RDBR) add a fundamental safety feature and a release function to conventional backstops, which prevent from reverse rotation in countless conveyor applications. The integrated torque limiter slips when reverse torque exceeds a predefined value and so protects the drive system. With the integrated hydraulic release system, the torque limiter can be opened in a quick and controlled way and so allows revers rotation when ever needed without dismounting the backstop.

The SOBO® iQ from Svendborg Brakes provides a controlled and repeatable braking sequence designed to mitigate the risk of torsional shock (and enable a consistent stopping profile) in variable load applications. As a standalone unit, the SOBO® iQ is capable of controlling up to four independent hydraulic power units. All brakes can be controlled by the single unit in a single mechanical chain.

Stieber and Svendborg Brakes have combined their expertise to offer customers an intelligent solution for their application. Recently, the RDBK backstop including a complete SOBO® iQ System was used to protect the emergency auxiliary drive on a cement kiln.

WEDNESDAY, MARCH 2

MORNING

Room 02 | 9:00 AM

COAL & ENERGY: MINE DESIGN CHANGES TO MAXIMIZE SAFETY AND PRODUCTIVITY

Chairs: ***J. Haughey,*** *Joy Global, Warrendale, PA*
J. Hirschi*, Komatsu, Mt. Vernon, IL*

9:00 AM

Introductions

9:05 AM

OptimalSlope: A Slope Optimization Software Applied to the Design of Coal Open Cast Mines for Improved Profitability and Reduced Carbon Footprint

S. Utili; School of Engineering, Newcastle University, Newcastle University, Newcastle upon Tyne, UK

We showcase substantial increases of the financial returns for coal open cast mines obtained by the adoption of steeper non-linear in elevation ge-otechnically optimal pitwall profiles which are determined by a novel slope optimization software, OptimalSlope. The optimal profile is defined as the one maximizing the overall steepness of a pitwall given the geotechnical properties of the rock/soil formations encountered and a prescribed Factor of Safety (FoS). We considered a case study of a deep coal mine currently in development. We redesigned the mine adoopting optimal pitwall profiles featured by the same FoS as the planar pitwalls of the original design. To this end a depth varying angle, obtained as output from OptimalSlope, was prescribed instead of a depth constant overall slope angle. From our analysis it turns out the design employing the optimal pitwalls exhibits significant increases of NPV which are mainly to be ascribed to a similar reduction percentagewise of rockwaste volume. Such a reduction of rockwaste in turn results in a substantial reduction of the mine carbon footprint.

9:25 AM

The Future Off-Highway Haul Truck: Balancing Charging and Productivity

J. Bollini, J. Wientjes, K. Miles and C. Watters; Komatsu America Corp, Morton, IL

The global decarbonization movement has generated industry attention to al-ternative off-highway vehicle power systems including hydrogen and battery technologies, which require energy infusion methods to maintain continuous operation. A key emerging question is the ability to supply adequate energy to the alterative power system through efficient charging alternatives while ensuring effective productivity will be a key metric mining operations must consider. Understanding a precise balance between haulage fleet charging options while minimizing cycle time impact will be a crucial step for an ef-ficient and cost-effective electrified haulage fleet. This paper will include a review of key current and future electrification alternatives for off-highway trucks and the potential performance impact due to respective charging re-quirements.

9:45 AM

Total Systems Approach – Optimized High Productivity Mining System for Future Mine Design in a South African Underground Coal Operation

S. Burich; Komatsu Mining Corporation - Underground, Kabushiki Kaisha Komatsu Seisakusho, Minato-ku, Tokyo, Japan

This paper summarizes the multi-phase, total system approach to optimized mine design for the integration of high productivity mining equipment sys-tems in a South African underground coal operation. Adverse geologic con-ditions and increased depth of mining required a mine design with increased pillar dimensions. At current, a place-change miner and shuttle car haulage mined a 7-entry room and pillar development. For a period of three weeks, data were collected on-site and utilized to develop a base productivity model which matched the average production of 1,090 tonnes per shift. Production delays were identified in the cutting and loading cycle, shuttle car cycles, and bolting. A total system approach was taken to identify a system to minimize delays and increase prodcution. The system is a 6.6-meter-wide continuous miner, bunker car with roof and rib drills, and 20-ton battery haulers. The model demonstrated simultaneous cutting and bolting, elimination of haul-age delays, reduced number of miner relocations, and increased production of 1,900 tonnes per shift.

10:05 AM

Innovation and Monetization of Mine Methane Destruction

B. Apple, Environmental Commodities Corporation

Carbon Credits, Alternative Energy Credits, Renewable Natural Gas Credits, Methane Offset Credits, Tax Credits… Increasing interest in methane emissions continues to create opportunities to monetize methane destruction. The first mine methane control projects in the U.S. utilized flaring systems to generate carbon credits for voluntary programs. While flaring is still the most common method of abatement, increasing values of environmental attributes enables more capital-intensive applications including on-site thermal utilization, electricity generation, physical pipeline delivery, virtual pipeline delivery, and material production for both regulated and voluntary programs.

This presentation will highlight technical innovations employed throughout the mining industry that compliment and improve ventilation systems to extract, capture, utilize, and monetize methane abatement.

WEDNESDAY, MARCH 2

MORNING

Room 07 | 9:00 AM

ENVIRONMENTAL: MINE CLOSURE AND RECLAMATION

Chairs: ***K. Doran****, Northeast Technical Services, Inc., Babbitt, MN*
J. Keller*, USA Environment L.P, Littleton, CO*
E. Schlenker*, Arcadis, Highlands Ranch, CO*

9:00 AM

Introductions

9:05 AM

Characterization of Background and Mining-Related Impacts on Groundwater, Red Devil Mine, Alaska

M. Longtine; Earth and Environment, WSP USA Seattle, Seattle, WA

For BLM, WSP (formerly Ecology and Environment, Inc.) performed a CERCLA RI/FS at the Red Devil Mine, an abandoned mercury mine in Alaska. Underground and surface mining targeted the structurally-controlled deposit. Leaching of mine waste resulted in metals contamination in groundwater and other media. Impacts are also derived from mining and natural mineralization. Impacts of natural mineralization on groundwater were challenging to characterize because the mining-impacted area overlaps the narrow mineralized zone. Detailed geological/hydrogeological analysis and precisely targeted monitoring wells facilitated estimation of impacts of natural mineralization on groundwater concentrations that were used to inform remedial goals in the FS.

9:25 AM

Mine Closure, Practices to Avoid Re-doing Your Technical Work Again

G. Barreda; Civil, CIP 56910, Lima, Lima, Peru

Closure is an important stage to consider during the planning of the mine life cycle. Although during the last years, several standards have been developed, and more mines are adopting their recommendations; many times, closure seems to be such a distant stage, that the importance of proper planning and designing since early stages, unnoticedly, gets minimized or postponed for a later time, when "more data is available". When that time arrives, frequently, the technical data developed during exploration, construction and operation is not longer available to be used for closure planning and design, generating knowledge voids; and thus, increasing closure project costs and risks for the mine. This paper will summarize recommended practices that mines can adopt during the exploration, construction, and operation phases, to take advantage of the technical information they typically developed during these stages for later use during closure planning and design. The technical information recommendations will be focused on the civil, hydrological, hydraulic, geotechnical and geochemical aspects with the intention to avoid efforts/expenditure "duplication" during the closure stage.

9:45 AM

Water Balance Evaluation of Field Acid Rock Drainage (ARD) Test Pads at the Bagdad Mine in Arizona

M. Raghav, J. Szaro, T. Graham and B. Callen; Freeport-McMoRan Inc, Phoenix, AZ

Characterization of acid rock drainage (ARD) and metal leaching (ML) potential through predictive tests is critical for closure planning and implementation of effective water management strategies at a mine site. Major differences exist between actual field conditions and standard laboratory methods used to test ARD/ML potential. Hence, field studies with constructed test pads are likely to simulate more closely, the interplay of various physical, chemical, and biological processes controlling the evolution of ARD/ML from mined materials. The ARD test pad study at Bagdad, Arizona has been conceived and designed to better understand the ARD potential and evolution of future seepage water quality from development rock and leached ore stockpiles under field conditions. The overall water balance in a rock pile and related parameters such as internal moisture content and flow regimes strongly influence mineral reaction rates and the evolution of long-term seepage chemistry. Authors will present the main findings from the water balance evaluation, including timing and magnitude of seepage, development of preferential flow paths, internal water storage, and evaporation from the test pads.

10:05 AM

SME Conference Rain Mine Acid Mine Drainage Treatment with Advanced Vapor Recompression Technology

G. Hukill; South Dakota School of Mines and Technology, Rapid City, SD

The Rain Mine, located near Carlin, NV operated from 1988-2002 under Newmont Mining Corporation and consisted of two open-pit facilities. A joint venture in 2019 was created between Newmont and Nevada Gold Mines (NGM) to assist with closure activities. The North Waste Rock Disposal Facility consisted of 70 million tons of waste rock generating acid rock drainage from leachate since 1990. Seeking an active solution to comply with the Nevada Division of Environmental Protection, NGM retained the services of Purestream. A boil-down test was conducted to determine the treatment options. The Avara was selected, a modular skid comprised of two separate containment chambers: the evaporator and the high-pressure condenser. Initially, water is heated to boiling by immersion heaters generating steam that is pushed through the cores where it condenses to a clean distillate. The evaporation process leaves all solids in solution. To prove the capabilities of the system a 1-month pilot was conducted with a mini Avara in 2020. The Avara ran at a 3 GPM rate with an average of 14000 ppm TDS in the feed, while producing a distillate of 25 ppm TDS, achieving the discharge standard of < 1000 ppm TDS.

10:25 AM

Assessing the Impact of a Residential Metals Abatement Program on Child Blood Lead levels in Butte, MT

R. Schoof, C. Van Landingham and A. Bailey; Ramboll USA Inc, Arlington, VA

A residential metals abatement program has been underway in Butte for more than 20 years. More than 1,350 yard and attic cleanups were completed by the end of 2018; most triggered by lead. While the focus is on remediation of residential soil and house dust, the program also includes a blood lead monitoring program with identification and abatement of additional sources of exposure for children with elevated blood lead levels (BLLs). As specified in the remediation program, studies are being conducted every 5 years to assess BLL data collected from Butte children. The first two studies have evaluated over 6,000 BLLs from 2003 through 2017 and evaluated trends over this time period, by Butte neighborhood, and as compared to areas outside of Butte. These studies showed that rates of elevated BLLs (i.e., those above 5 µg/dL) in Butte children have declined dramatically since 2002 but have been declining much more slowly since 2011. Improved rates of confirmation testing are needed to verify the rates of elevated BLLs. While the RMAP likely has contributed to these declines in BLLs the magnitude of impact cannot be quantified.

WEDNESDAY, MARCH 2

MORNING

Room 08 | 9:00 AM

ENVIRONMENTAL: MINE WATER TREATMENT

Chairs: ***J. Aulbach****, Brown & Caldwell, Meridian, ID*
D. Levitan*, Barr Engineering, Minneapolis, MN*

9:00 AM

Introductions

9:05 AM

Improving Leach Operation Sustainability

P. James; Blue Planet Strategies, Madison, WI

Conventional copper acid leach operations both add (sulfuric acid, H2SO4) to and generate ("natural" ore sulfur) large amounts of sulfate into recirculated leach solution, creating a sustainability challenged which must be mitigated upon shut-down. Together these sources create high sulfate tenor metal impacted water (MIW) that is often treated by costly lime neutralization, yielding high sludge volumes due to pervasive gypsum (CaSO4 * 2 H2O) formation. Advanced electrolysis technology using membranes can separate sulfate from targeted MIW while treating the MIW in various ways and concurrently regenerating sulfuric acid for re-use. This lessens feedstock sulfuric acid consumption and the resultant added sulfate load in the resultant MIW via sulfate recycle by sulfuric acid regeneration and reuse. By putting less sulfate in, there is less to remove and less sulfate needs to be sourced from elsewhere à both of which improve the operation sustainability. Results illustrating such concurrent sulfate separation and sulfuric acid regeneration in conjunction with selected treatment of MIW will be discussed along with treatment economic projections for a representative scenario.

9:25 AM

Meeting Mine Closure Goals through Integration of Habitat and Aesthetics into a Functioning Treatment Wetlands for Zinc and Manganese

R. Thomas[1], J. Bays[1], R. Bitely[1], A. Lewis[1], J. Preis[1], A. Pia[2] and J. Strunk, Jr[3]; [1]Jacobs Engineering Group Inc, Atlanta, GA; 2USA Enivronmental, Montclair, NJ and 3DOW, Philadelphia, PA

A challenges of mine closure is creating sustainable remedial systems that will provide low-cost, low-maintenance treatment post-closure. Passive treatment systems (PTS) offer one option for achieving these goals; however, in the post-closure environment there is a secondary desire to provide a benefit to the future landowner beyond simple water treatment. This presentation describes two PTS designed to meet these expectations at a mine closure site in the south-central United States. The first PTS reduces zinc concentration/loading and increases hardness of the effluent of a pit lake. The second PTS includes three separate wetlands that reduce iron, manganese, and zinc concentrations/loadings from groundwater seeps. Both PTS include open water and subsurface flow components designed for long-term hardness addition and metal retention. The surface flow marshes were planted with native vegetation and designed with diverse habitat features that create a natural aesthetic that blends into the surrounding environment. Both systems meet treatment goals: zinc is reduced below detection limits in the first system and manganese is reduced by more than 90% in the second system.

9:45 AM

Remediation of Uranium-Mining Impacted Waters Using Glycolipid-Based Ion Flotation

D. Hogan[1], R. Stolley[2], C. Boxley[2], M. Amistadi[1] and R. Maier[1]; [1]Environmental Science, University of Arizona, Tucson, AZ and [2]GlycoSurf, LLC, Salt Lake City, UT

Mining has left a substantial legacy of uranium impacted waters in the arid southwest. As water resource demand and water scarcity issues become more pronounced, the development of remediation strategies to remediate uranium contamination will become increasingly important. Ion flotation is one technology with the potential to remove uranium and recover water resources for beneficial use. Green, bio-inspired glycolipids bind uranium and were investigated for their efficacy as collectors in ion flotation using uranium-contaminated groundwaters from the Four Corners Region of the US. Under some conditions, glycolipids reduced uranium concentrations to near or below the Environmental Protection Agency's maximum contaminant level.

10:05 AM

Process Development for Recovering Critical Elements from an Acid Mine Drainage

Q. Li and W. Zhang; Mining and Minerals Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA

The rapid development of advanced technologies such as electric vehicles has increased the demand for critical elements. A systematic study was performed on a natural AMD to develop a process for producing high-purity Mn, Co, and Ni products. A pre-concentrated slurry containing 3,794 ppm Mn, 59 ppm Co, 127 ppm Ni, and 300 ppm Zn was obtained by collecting the precipitates formed in the AMD in the pH range of 6.5 to 10.0. The pre-concentrated slurry was re-dissolved by reducing the pH, and as a result, most of Co, Ni, and Zn were dissolved into solution, while more than 50% of Mn and 95% of Al remained undissolved, resulting in an Mn product with Mn content of 30%. After re-dissolution, greater than 90% of Co, Ni, and Zn were selectively recovered from the re-dissolved solution through sulfide precipitation. The sulfide precipitate was calcined at 200 degrees Celsius for 2 h and dissolved in 1.2M HCl, followed by solvent extraction (SX). Around 60% Mn and 100% Zn were extracted using D2EHPA in the first stage SX, and Co and Ni were separated using CYANEX 272 in the second stage SX. Based on these findings, a process flowsheet was developed to recover the critical elements from AMD.

10:25 AM

Bench-Scale BioChemical Reactor Removes Selenium from Mineral Processing Effluent

T. Fazio[1], J. Gusek[2], S. White[1], J. Renner[1] and D. Stanton[1]; 1Titanium Technologies, The Chemours Company, Wilmington, DE and [2]Linkan Engineering, Golden, CO

Selenium is a trace constituent of sediments and ground water accessed for heavy mineral sands in southeast Georgia. Re-use of water to separate the desirable minerals concentrates dissolved constituents, necessitating a blowdown. pH adjustment and flocculation remove suspended humates and most metals, but selenium in the effluent exceeds the NPDES limit of 5 ppb. A bench-scale biochemical reactor has been operated for 2 years. Various recipes of organic materials and bacteria reduce soluble selenite and selenate to insoluble elemental selenium which precipitates in the reactor cell. Se concentration in the BCR discharge is consistently less than 5 ppb.

10:45 AM

Removal of Thallium from Mining-Influenced Wastewater using Permanganate Oxidation

A. Karunanayake[1], L. Berwick[1], D. Skutt[1], J. Wang[1] and H. Heath[2]; [1]Carus LLC, Peru, IL and [2]OceanGold, Kershaw, SC

Thallium (Tl) is a highly toxic heavy metal, and soluble over a wide range of pH. Tl levels may exceed discharge limits in mining-influenced water associated with processing gold, lead, cadmium, zinc, and copper ores. In this case study, the effect of Carus permanganate products on Tl removal from mining wastewater was studied. Factors influencing Tl removal, namely permanganate dosage, coagulant use, order of chemical addition, temperature, and co-existing metal ions were examined. The results show that permanganate addition was very effective at removing Tl to less than target limits and can provide a unique option for improving wastewater quality and reducing overall chemical costs.

11:05 AM

A Glycolipid Based Non-Traditional Method of Generating Metals and Rare Earth Elements From Mining Impacted Waters

A. McCawley, D. Hogan and R. Maier; Environmental Science, The University of Arizona, Tucson, AZ

Recovery of rare earth elements (REE) from non-traditional resources will become increasingly important to meet future resource demands. Green, bio-inspired glycolipids selectively bind valuable metals and REEs over common water cations (e.g., Mg, Mn, Ca). Utilizing this characteristic, a two-step recovery process utilizing centrifugation or filtration of glycolipid-metal complexes was investigated using simple model and complex mining-impacted solutions. The potential environmental benefits of this process include remediation of mining-impacted waters and development of under-utilized resources to recover REE.

11:25 AM

Evaluation of Heavy Metal Removal From Contaminated effluents using Phragmites australis (Cav.) Trin. Ex Steud. and Schoenoplectus californicus (C.A. Mey.)

M. Guzman, M. Romero Arribasplata, M. Flores Obispo and S. Bravo Thais; Mining Engineering, Pontificia Universidad Catolica del Peru, Lima, Lima, Peru

One of the greatest environmental issues related to the development of the mining activity is the generation of Acid Mine Drainage (AMD). Many methods have been developed for AMD treatment, being wetlands a good option for heavy metal removal. In this sense, the implementation of artificial wetlands for the treatment of mining effluents would seem to be an environmentally friendly alternative. In this paper, we present the results on the elimination of heavy metals (Cu, Zn, Pb and Fe) using two Peruvian native species such as Schoenoplectus californicus (C.A. Mey.) and Phragmites australis (Cav.) Trin. Ex Steud. The results show that Schoenoplectus californicus preferentially removes copper (82 and 90%), lead (88 and 92%) and iron (28 and 69%), whereas Phragmites australis removes copper (68 and 87%) and zinc (53 and 95%). Likewise, it is observed that the Schoenoplectus californicus mainly retains the ions in its root, copper (89%), zinc (84%) and iron (76%). While the Phragmites australis accumulates iron (62%) and copper (74%) in the steam and root part respectively. Keywords: heavy metals, Phragmites Australis, Schoenoplectus Californicus, phytoremediation, artificial wetlands.

WEDNESDAY, MARCH 2

MORNING

Room 06 | 9:00 AM

HEALTH & SAFETY: HOT TOPICS IN FRONTLINE WORKER H&S

Chairs: ***M. Savit****, Husch Blackwell, Denver, CO*

K. Walster*, Prairie State Generating Company*

S. Moore*, NIOSH, Pittsburgh, PA*

WEDNESDAY, MARCH 2

MORNING

Room 05 | 9:00 AM

HEALTH & SAFETY: NORA: RESPIRABLE CRYSTALLINE SILICA DUST IN METAL, NON-METAL AND COAL MINING

Chairs: ***L. Saperstein****, Missouri University of Science and Technology, Nantucket, MA*

R. Reed*, NIOSH, Pittsburgh, PA*

9:00 AM

Introductions

9:05 AM

An Investigation of Respirable Crystalline Silica Particle Characteristics in 15 US Underground Coal Mines

C. Keles and E. Sarver; Mining and Minerals Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA

Crystalline silica is widely recognized as one of the most hazardous components of respirable coal mine dust and chronic exposures can lead to severe lung disease. Mass concentration of respirable silica (measured as quartz) has long been tracked as part of compliance dust monitoring in coal mines. However, little is known about silica particle characteristics such as size or surface condition (i.e., presence and manifestation of occluding mineral), even though some evidence indicates these characteristics can affect the physiological response. Indeed, a better picture of silica characteristics in the mine can support the current understanding of health outcomes, as well as efforts to improve exposure controls. In this study, a computer-controlled scanning electron microscopy (SEM) routine was used to determine silica particle size and relative abundance by number and mass for samples collected in several key locations of 15 underground US mines. Moreover, the same instrument was utilized manually at low and then high voltage to investigate the surface condition of silica particles in the same samples. Results will be presented and discussed.

9:25 AM

Respirable Crystalline Silica Exposures Among United States Metal and Non-Metal Miners, 2000-2019

A. Sussell and S. Misra; National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, Atlanta, GA

In United States Metal and Non-Metal (MNM) mines, respirable crystalline silica (RCS) exposures are prevalent and a leading indicator of respiratory disease. 55,265 full-shift personal air samples from a public dataset maintained by MSHA were analyzed over the years 2000-2019. Descriptive statistics for RCS, percent silica, and dust concentration in respirable dust samples were examined by explanatory variables. The overall geometric mean (GM) for RCS exposures was 28.9 µg/m3 (GSD: 2.5) and the 95th percentile was 149 µg/m3. Personal exposures varied significantly by sector, year, state, occupation, location, and commodity ($P<0.001$). Overall, the percentages of RCS exposures above the MSHA Permissible Exposure Limit (100 µg/m3) and NIOSH Recommended Exposure Limit (50 µg/m3) were 11% and 27%, respectively. Forty of 53 occupations with >50 samples each, had a NIOSH REL exceedance fraction of >20% (range: 20 to 57% exceedance). GM concentrations in 2018 (45.9 µg/m3) and 2019 (52.9 µg/m3) were significantly higher than the GM for all years prior (28.2 µg/m3). The prevalence of high exposures to RCS among MNM miners continues and may be increasing in certain settings and occupations.

9:45 AM

Resuspension of Airborne Submicrometer – and Nanometer-Sized Particles at the Underground Coal Mine Associated with Common Work Practices

C. Tsai, J. Brune and S. Duzgun; University of California Los Angeles, Los Angeles, CA and Colorado School of Mines, Golden, CO

We measured and characterized airborne coal dust and evaluated the performance of sampling methods. The Tsai diffusion sampler (TDS) is for collecting nano/respirable particles with >95% collection efficiency. We used TDS and 37 mm close face PVC filter cassettes for particle collections, PDM for measuring mass concentration and dual particle spectrometers for counting particles in the sizes of 10 nm-10 µm. The airborne particles collected on TDS and 37 mm cassettes showed similar level of mass concentrations and are below coal exposure limit. The samples taken at the background had low mass concentrations (<0.5 mg/m3), with the total particle counts of ~14,000 particles/cm3 in 10-420 nm sizes. A large number of small particles were identified, showing many small individuals and agglomerates of coal airborne particles mixed with various contaminants. PDM data showed a lower mass concentration. We found that resuspension of those particles at this size range was within a minute from disturbance. Resuspended sub-micrometer particles were undermeasured by PDM. Our sampler and characterization method were very efficient for determining the actual airborne particles in the air.

10:05 AM

Respirable Coal Mine Dust Research: Dissolution of Silica and Heavy Metals in Simulated Lung Fluids

V. Salinas, M. Das, G. Rubasinghege, M. Rezaee and P. Roghanchi; Mineral Engineering, New Mexico Institute of Mining and Technology, Socorro, NM; Chemistry, New Mexico Institute of Mining and Technology, Socorro, NM and The Pennsylvania State University, University Park, PA

Further research on coal dust characteristics and toxicity is needed to com-prehend the adverse effects of exposure to respirable coal mine dust (RCMD). This study investigates the toxicity of RCMD based on their total metal con-tent and total metal dissolved in the simulated lung fluids (SLFs). Dissolution experiments of coal dust samples were carried out in gamble's solution and artificial lysosomal fluid (ALF) for different particle sizes. Dust samples were characterized using Fourier transform infrared spectroscopy (FTIR), dynamic light scattering (DLS), X-ray photoelectron spectroscopy (XPS), BET method, and scanning electron microscope (SEM), and microwave total digestion. ICP-MS experiments were conducted to determine the concentrations of the metals dissolved in the lung fluids. Dissolutions of iron, aluminum, copper, zinc, strontium, barium, and lead were obtained using gamble's solution and ALF. The concentrations of the dissolved metals were higher in the ALF com-pared to the gamble's solution. Finally, the dissolution of each metal and its health effects were also analyzed from the dissolution results.

10:25 AM

Portable FTIR as Tool to Support Coal Mine Dust Source Apportionment

N. Pokhrel, C. Keles and E. Sarver; Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA

To enable rapid measurement of crystalline silica in respirable coal mine dust, NIOSH has developed a direct-on-filter (DOF) analysis method using portable Fourier Transform Infrared (FTIR) transmission spectroscopy. The method has been designed with "end-of-shift" measurements on personal dust samples in mind, though it can be readily applied to other types of samples for engineering or research studies. Moreover, in addition to crystalline silica (i.e., as ' -quartz), the DOF FTIR method can be used to estimate other dust constituents including kaolinite and calcite. While tracking these constituents has heretofore not been a primary goal of dust monitoring, the ability to do so can provide mines with valuable information regarding the major dust sources influencing particular locations or occupations—and how those sources change with operational conditions including dust controls. Here, we used DOF FTIR on area dust samples collected in 16 coal mines to determine quartz, kaolinite, and calcite. To demonstrate basic source apportionment, we also analyzed samples of major dust source materials (ROM coal and rock, rock dust products) collected in the same mines.

10:45 AM

Characterizing Respirable Dust Generated from Cutting a Potash Rock with Picks at Different Stages of Wear

S. Slouka, C. Tsai, M. Ishaq, J. Brune, J. Rostami and E. Sidrow; Colorado School of Mines, Golden, CO; Statistics, The University of British Columbia, Vancouver, BC, Canada and University of California Los Angeles, Los Angeles, CA

Respirable rock dust poses serious long-term health effects to workers in underground hard rock tunneling and mining environments. When inhaled, the respirable silica particles, commonly found in quartz and other minerals, will scar sensitive lung tissue and cause irreversible lung diseases. With understanding rock dust characteristics, mine and tunnel operations will possibly be able to implement effective controls more appropriately to protect their workers. Therefore, in this study, full scale cutting tests on potash rock were performed with radial picks to generate dust. Three stages of pick wear were tested: new, moderately worn, and severely worn. Comparisons between different stages of pick wear to dust concentration, size distribution, and particle shape characteristics are drawn from this study to determine the scenarios when the released airborne dusts become potentially most hazardous for workers. It is concluded that the moderately worn pick, or the pick with the most uniformly blunt tip, is potentially the most dangerous because it releases the highest concentration of dust and particle shapes with the highest aspect ratio when compared to the other two picks.

11:05 AM

Detection and Characterization of Nanoparticles in Respirable Coal Mine Dust

S. Assemi, T. Akinseye, F. Sime, X. Wang, L. Pan and J. Miller; Materials Science and Engineering, The University of Utah, Salt Lake City, UT and Department of Chemical Engineering, Michigan Technological University, Houghton, MI

Respirable coal mine dust (RCMD) comprises particles of various sizes and compositions, which can impart different toxicological effects to coal miners. In almost all studies on RCMD, nanoparticles have been bundled with particles < 10 µm in diameter as the "respirable fraction". However, recent toxicology studies have demonstrated that ultrafine particles can result in significantly greater pulmonary inflammation than micron-sized particles, warranting a more comprehensive study of nanoparticles in RCMD samples. RMCD samples collected at different coal mines were characterized for size and composition using scanning electron microscopy (SEM), dynamic light scattering (DLS), and asymmetrical flow field-flow fractionation (AsFlFFF). Methodologies were developed for SEM and AsFlFFF analyses of both micron-sized and nano-sized particles. Results obtained from the three techniques clearly demonstrated the presence of nanoparticles in RCMD samples. The mass concentration, composition, and size distribution of nanoparticles varied with the sampling duration and locations within a coal mine. The challenges, potentials, and limitations of each technique will be discussed.

WEDNESDAY, MARCH 2

MORNING

Room 09 | 9:00 AM

INDUSTRIAL MINERALS & AGGREGATES: DIGITAL APPLICATIONS, ANALYTICAL DATA, AND BENEFICIATION OF INDUSTRIAL MINERALS

Chairs: ***R. Raitani****, USG CORPORATION, Buffalo Grove, IL*
R. Dube*, Outotec, Centennial, CO*

9:00 AM

Introductions

9:05 AM

Fast-Froth Minerals Beneficiation Using ACE Hydrocyclone

H. Fayed; R&D, Narmer-engsim LLC, Blacksburg, VA

A new aerated cyclonic extraction technology (ACE) developed at Narmer-engsim LLC to enhance separation efficiency and economics of fine and ultrafine minerals. The new technology consists of an aerated cylindrical hydrocyclone that contain a new air-bubbles generation system. This air-bubbles system has been designed to pump air into hydrocycone and prevent clogging problems of air-feeding system. We tested the ACE hydrocyclone for a coal sample that has a particle size of less than 50 microns. The experiments showed a recovery of 80% of the given sample and separation efficiency of 99%. We kept the device running for more than 24 hours and the air feeding system showed no signs of clogging, whereas the feeding air pressure remained constant for the same air flow rate through the course of experiment. The experimental data of our ACE hydrocyclone shows similar performance to ASH hydrocyclone without suffering from clogging problems.

9:25 AM

Designing Beneficiation Plants from a Holistic Standpoint: Incorporating both Proper Beneficiation and Materials Handling Design

T. Holmes and C. Hartford; Jenike & Johanson, San Luis Obispo, CA

During the design phase of a beneficiation plant, planners focus on the proper beneficiation steps to produce maximum return on the ore. However, often missed in the design is the importance of planning ahead with regards to the solids handling aspects of the plant. Planners frequently "copy and paste" techniques for equipment selection rather than consider the properties of the actual material that the system will handle. Not taking a holistic approach and considering the material leads to something less than maximum return. This paper identifies the beneficiation plant with multiple physical handling steps and connects testing and solid design techniques with successful throughput.

9:45 AM

Using Digital Tools and Data Analytics to Achieve ESG/Net Zero Goals

D. Johnson; Eco-Edge, Phoenix, AZ

Mining companies are under increasing pressure to make rapid progress to achieve commitments to Carbon Neutrality, as well as raise the bar relative to ESG's "S" and "G". These goals are cascading from the C-Suite through every level of the organization, meaning that if mines are not operationalizing ESG, overall performance is likely to fall short of the commitments. 2020 proved technology adoption was necessary to enable remote workforces and ensure business continuity. It also proved that miners were better at these new ways of operating than most thought. Now is the time to leverage those wins into scalable digital initiatives to support ESG strategy at all levels. Harnessing the next generation of digital tools like AI/ML, Digital Twins, IIoT, and VR/AR, will enable mines to reach beyond standard data collection, reporting and analysis to gain clear, actionable insights. This will not only drive positive operational results, but also extend to ESG-related issues such as safety and energy efficiencies, thereby delivering triple bottom line benefits and social license. This session will explore linkages between evolving digital tools and positively impacting ESG/Net Zero metrics.

10:05 AM

Literature Review, and the Challenges for Adaptation, Implementation of Digitization, Data Analytics for Operational Excellence in the Cement and Aggregation Production Industry

K. Boakye and S. Simske; Systems Engineering, Colorado State University, Fort Collins, CO

The application of digitization for operational excellence is becoming popular. From advanced data analytics to intelligent networks, this offer tremendous opportunity to create value, raise the efficiency of production processes and reduce emissions. Several manufacturing industries have already implemented solutions to good effect by using digitization. Mining companies, for example, are using historic data about equipment health to predict potential failures, while aeronautics and automotive companies are using robotics and end-to-end digital twins to improve their design and production processes. Not surprisingly, first adopters in many industries have gained an edge over their competition. The cement and aggregate industry can better manage the enormous energy consumption, rising cost challenges, inefficient used of raw material, logistic problems, emissions, and overall process complexity that are inherent in their operations by ado. This paper presents the results of a literature review, challenges for adaptation and implementation, of digitation, data analystics in the cement and aggregate production industry.

10:25 AM

The Benefits of Integrating Existing Technologies into a Decision Support System in the Mining Environment

R. Tamir; Seekers Strategy, Boynton Beach, FL

This paper will describe the benefits of implementing the methodology of structured decision-making process by utilizing the decision support system, DSS, and its applicability to the mining environment. It will outline the layers of the mining related decision making – Creation of "one truth" situational awareness utilizing existing planning, ERP, operational and monitoring agents, Expressing plan verse performance across mining phases and functions compered with the actual and trends to evaluate performance. Creating alternate courses of action and the implications up and downstream. It will review the current condition were although a multitude of technologies resolve multi variable issues they do not interact in a way that assists decision makers throughout the organization in making high-quality decisions that will push the overall performance envelope. The paper will show the benefits of integrating military methodologies resolving multi variable complexed issues, operating in changing environments in order to meet time sensitive objectives with restricted resources by creating a shared situational awareness. The paper will discuss the implementation and suggest a path.

WEDNESDAY, MARCH 2

MORNING

Room 04 | 9:00 AM

INDUSTRIAL MINERALS & AGGREGATES: HEALTH & SAFETY IN INDUSTRIAL MINERALS & AGGREGATES

Chairs: ***P. Roghanchi****, New Mexico Institute of Mining and Technology, Socorro, NM*

H. Amini*, Morgantown, WV*

9:00 AM

Introductions

9:05 AM

Review of Challenges and Evacuation Models for Underground Mine Fire Disaster

O. Salami and G. Xu; Mining and Nuclear Engineering, Missouri University of Science and Technology, Rolla, MO

The interest in underground mine fire has increased enormously in recent decades due to its life-threatening danger to mine works, as well as the financial losses associated with the destruction of underground facilities. When a fire occurs in the underground, it produces heat and toxic gases, and the magnitude of this heat and toxic gases. The main challenge to evacuate miners in the underground is poor visibility due to smoke and inhalation of toxic carbon monoxide. Another challenge is the complex and complicated geometry of the underground mine environment. Currently, only a few studies have considered developing efficient evacuation models in underground mines despite the laudable success this type of approach has recorded in building fires and other high rising structures. This inadequacy, therefore, necessitates that a thorough review of mine fire disaster and evacuation challenges be conducted. The aim of this work is to present a review of underground mine fire disaster and evacuation models that can be applied to assist self-escape. It will identify critical factors that could substantially increase fire safety, thus optimize the management of emergency evacuation plans.

9:25 AM

Small Mine Activities Reporting Tool: A Lightweight App to Improve Compliance Reporting and Track Outcomes

L. Brown[1], N. Pham[1], K. McCormick[2] and J. Burgess[1]; [1]Mel & Enid Zuckerman College of Public Health, The University of Arizona, Tucson, AZ and [2]Mining Engineering & Management, South Dakota School of Mines and Technology, Rapid City, SD

Small operators face a variety of challenges to implement the reporting requirements of 30 CFR Parts 46, 48, and 50. Working with MSHA personnel, state grants programs, and mine operators, we have developed the Small Mine Activities Reporting Tool (SMART). SMART addresses key pain points, including 1) timely filing of hours worked, 2) efficient record-keeping and reporting for accidents and injuries, and 3) proper notification of activity commencement and closure. SMART provides a secure, light-weight app that runs on Android and iOS-based smartphones, with intuitive workflows to guide users via tutorials, templates, and context-specific Q&A. The app also provides integrated record keeping, storage for supplemental photos and audio, and reminders to stay on track with filing deadlines. A dashboard visualizes key metrics, such as numbers and types of reports filed, to provide a high-level snapshot of health and safety trajectory. In this talk, we outline the development of SMART, discussing key interaction design characteristics and the evolution of requirements via our discovery process. A rapid prototype is presented, with feedback from usability and UX testing.

9:45 AM

Analysis of U.S. Surface Mining Haul Truck and Mobile Equipment Accidents

J. Homer, J. Bickson, C. DeGennaro and M. Girman; Pittsburgh Mining Research Division, National Institute for Occupational Safety and Health, Pittsburgh, PA

Industry organizations developed guidance on scenarios to address surface mining haul truck and mobile equipment collision-related accidents. There is a need to investigate accident data to prioritize these scenarios and identify factors relevant to developing validation methods for evaluating collision warning/avoidance technologies and determining performance limitations and abilities. Targeted developments concerning standards and validation methods are also necessary to achieve effective system validations relevant to improving their efficacy within mining operations and in-turn, promoting industry adoption. To address these needs, NIOSH researchers investigated available powered haulage and machinery-related accident reports documented by the Mine Safety and Health Administration. Their objective was to gain perspective for informing the development of test protocols and validation methods through determining the most prevalent scenarios and related factors. Our summary findings afford direction to ensure research and evaluation efforts are aimed to address, more effectively, the most prevalent of accident scenarios and relevant factors within U.S. surface mining environments.

10:05 AM

An Overview of Methods and Parameters to Evaluate Detection Performance and Validation of Collision Warning and Avoidance System in Surface Mining

J. Bickson, J. Homer, C. DeGennaro, M. Girman and C. Jobes; National Institute for Occupational Safety and Health, Pittsburgh, PA

Between 2010 and 2019, powered haulage accidents resulted in a total of 52 fatalities at surface mines in the United States and were the leading accident classification. Haul truck collision warning and avoidance systems (CXS) can prevent accidents at surface mines. CXS use technologies to detect entities and alarm to alert haul truck operators. System performance must be validated using robust methods. Validation would increase confidence in and encourage implementation of CXS. NIOSH researchers reviewed documents related to the evaluation and validation of CXS with two objectives: (1) to identify methods and parameters used to evaluate detection performance and (2) to identify gaps in CXS test methods and in detection performance. Stakeholders can use the findings from this research to guide implementation of CXS to improve safety at surface mines.

10:25 AM

Statistical Analysis of Diesel Particular Matter and Silica for Underground Stone Mines

M. Harris[1], E. Rubenstein[1], K. Raj[2] and V. Gangrade[1]; [1]PMRD, National Institute for Occupational Safety and Health, Washington, DC and [2]SMRD, National Institute for Occupational Safety and Health, Spokane, WA

Large-opening stone mine ventilation is characterized by high ventilation quantities with low resistances. Stone operation ventilation systems differ with large variations in numbers of entries, depths of operations, slopes of deposit, use of benching, and use of natural ventilation. Past research suggested these mines face three primary ventilation challenges: moving adequate volumes of ventilation air, directing the airflow, and planning ventilation systems that work well with production requirements. Given these challenges, underground workers in large-opening stone mines may be exposed to respirable crystalline silica (RCS) and diesel particulate matter (DPM) at levels above the regulatory limits set by the Code of Federal Regulations. This paper examines the MSHA collected data to see if RCS and DPM may be an issue in underground stone mines. Out of 522 sampled mines, there were 108 resulting RCS violations during 2000 – 2020. DPM was more prevalent than RCS in these mines with 382 citations when 929 mines. With this knowledge, appropriate prevention and mitigation techniques can be utilized to prevent stone miners' exposure to RCS and DPM and subsequent respiratory diseases.

10:45 AM

Applicability of Low-Cost Dust Monitors in M/NM Mining

A. Louk and J. Patts; Health Hazards Prevention Branch, CDC/NIOSH, Pittsburgh, PA

NIOSH is currently testing the efficacy of real-time, low-cost dust monitors for M/NM mining applications. A number of low-cost monitors are currently available that are designed for the air quality and pollution market. These monitors are similar in operation to the technology currently employed in mining for wearable dust exposure monitoring, but at a fraction of the cost. Lower costs should allow for the implementation of dust sensing networks, resulting in increased spatial and temporal data, and driving more informed decision making to improve miner health. Testing includes introducing different dust types and concentrations typically found in the mining industry to a number of low-cost dust monitors in a laboratory aerosol chamber and comparing the response to reference-grade instruments. Selected monitors were also demonstrated in mining environments to estimate the corrections needed to co-located gravimetric measurements. Ultimately, the goal is to determine if low-cost dust monitors can be integrated with existing engineering controls to improve their efficiency while enabling the use of smart control technologies which respond to a dynamic environment in real-time.

11:05 AM

Hot Surface Ignition of Liquid Fuels Under Ventilation

W. Tang, Pittsburgh Mining Research Division, National Institute for Occupational Safety and Health, Pittsburgh, PA

Mine equipment fires remain as one of the most concerning safety issues in the mining industry, and most equipment fires were caused by hot surface ignitions. Detailed experimental investigations were conducted at the NIOSH Pittsburgh Mining Research Division on hot surface ignition of liquid fuels under ventilation in a mining environment. Three types of metal surface materials (stainless steel, cast iron, carbon steel), three types of liquids (diesel, hydraulic fluid, engine oil), four air ventilation speeds (0, 0.5, 1.5, 3 m/s) were used to study the hot surface ignition probability under these conditions. Thermocouples attached on the metal surface were used to indicate the hot surface ignition from the measured temperatures. Results show that the type of metal has a considerable effect on the hot surface ignition, while ventilation speed can shift the hot surface ignition temperature by several hundred degrees. Different types of liquid fuels also have different ranges of ignition temperature. Results from this work can help understand equipment mine fires and develop mitigation strategies.

WEDNESDAY, MARCH 2

MORNING

Room 14 | 9:00 AM

MINING & EXPLORATION: GEOSCIENCES: RESOURCE GEOSCIENCE: INNOVATION IN EXPLORATION TECHNOLOGY

Chairs: ***R. Parratt****, Renaissance Exploration Inc*
A. Young*, Student Member, Porto Alegre, Brazil*

9:00 AM

Introductions

9:05 AM

Optimal Exploration Drill Hole Planning using Algorithms for Sequential Decision-Making and Value of Information

T. Hall[1], C. Scheidt[2], D. Yin[1], T. Mukerji[2] and J. Caers[1]; [1]Geological Sciences, Stanford University, Stanford, CA and [2]Energy Resources Engineering, Stanford University, Stanford, CA

We determine optimal sequences in exploration drilling by optimizing the dollar value of sequential information. The user inputs the existing and proposed drillholes, the geological model, drilling cost, and the target resource volume. The output is a set of exploration sequences, which are ranked by their value. The sensitivity of these sequences to the drilling cost and volume threshold is shown. This research draws from decision theory and algorithms for sequential decision-making, which are commonly applied in autonomous navigation. We demonstrate a test case using real data from a metal deposit in the Midcontinent Rift System.

9:25 AM

Quantitative Assessment of Mineral Resources by Integrating Geostatistics and Machine Learning Algorithm in the Darreh-Zereshk Cu Deposit (Iran)

E. Moosavi[1] and Z. Bagheri[2]; [1]Department of Petroleum and Mining Engineering, South Tehran Branch, Islamic Azad University, Tehran, Iran, Tehran, Iran (the Islamic Republic of) and [2]Department of Mining Engineering, Isfahan University of Technology, Isfahan, Iran, Isfahan, Iran (the Islamic Republic of)

For this research, a machine learning algorithm will be used to generate geological/ spatial estimates at unsampled locations while reducing the amount of human interaction required in the modeling process. The hybrid algorithm leads to an estimate that outperforms the traditional spatial estimations methods in scenarios complex with geological domains. In this study, results obtained from 3D geological modeling of the Darreh-Zereshk Cu deposit and geostatistical and machine learning are combined to assess the mineral resources quantitatively and to delineate potential exploration targets at substantial depths, revise certain interpretations of the Darreh-Zereshk fault that were poorly correlated with borehole data, improve the understanding of the geological history of the Darreh-Zereshk district, and serve as a guide during detailed exploration. The construction of the 3D geological model links sample observations to geostatistical analysis and subsurface grade estimation using a borehole dataset.

9:45 AM

Efficacy of Information in Acquiring Downhole Geophysical Data for Mineral Exploration

D. Yin[1], C. Scheidt[1], J. Edman[2] and J. Caers[1]; [1]Stanford University, Stanford, CA and [2]KoBold Metals, Berkeley, CA

We introduce a new measure to steer the planning of future downhole geophysical data acquisitions for mineral exploration. This measure, named Efficacy of Information (EOI), directly quantifies how much the future geophysical surveys can reduce the uncertainty in key deposit parameters, such as orebody volume and depth. We applied this approach to explore a metal deposit in the Mid-Continent Rift system. We will show that maximizing the EOI can lead to optimal decision-makings in planning geophysical data acquisitions. It will guide us to obtain the most informative signals to reduce the deposit exploration uncertainty.

10:05 AM

Digging Up Old Dirt The Challenges of Bringing a Historic Mining Property into NI 43-101 Compliance

A. Schappert; Mining, Stantec Consulting LLC, Chandler, AZ

This paper chronicles the challenges encountered and solutions developed when a newly formed mining group decided to acquire, explore, and develop an abandoned mine site for eventual economic extraction of mineral resources left behind by the previous operator. In operation from 1972 to 1984, the mine site had undergone environmental remediation when acquired in 2020. This entrepreneurial mining group had to ensure that their exploratory work and as much of the historical data available could meet CIM best practices guidelines and thus be used in NI 43-101–compliant technical reports. The solution involved working with old paper logs and plots, re-logging core, using stored pulps, and developing tools to efficiently convert analog data to digital records.

10:25 AM

Trace Element Signature of Pyrite and Fluid Inclusion Petrography from Quartz-Calcite-Sulfide Veins: Implications on the Genesis of the Nazca-Ocoña Deposits

J. Crespo[1], E. Holley[1], K. Pfaff[2], A. Fulton[2], C. Jilly-Rehak[3], R. Huamani[4], M. Guillen[5] and J. Thompson[1]; [1]Mining Engineering, Colorado School of Mines, Golden, CO; [2]Department of Geology and Geological Engineering, Colorado School of Mines, Center for Mineral Resources Science, Golden, CO; [3]Stanford University, Stanford Nano Shared Facilities, Stanford, CA; [4]Department of Metallurgical Engineering, Universidad Nacional de San Agustin de Arequipa, Arequipa, Arequipa, Peru and [5]Department of Geology and Geophysics, Universidad Nacional de San Agustin de Arequipa, Arequipa, Arequipa, Peru

One of the most important economic activities in Peru is gold mining. More than 70 gold deposits have been recognized in the Nazca-Ocoña metallogenic belt, southern Peru where mining activity is focused on gold-bearing quartz veins hosted in Cretaceous rocks. The aim of this study was to combine geological field observations, petrographic observations, LA-ICP-MS trace element analyses in pyrite, and fluid inclusion petrography, in order to decipher the genesis of this metallogenic belt. Based on field work, we identified that veins are hosted in intrusions of granodioritic to dioritic composition. Petrographic observations of quartz veins show that the ore mineralogy is characterized by pyrite, chalcopyrite, arsenopyrite, galena, sphalerite, native gold and electrum. Trace element data for pyrite show Au concentrations range from 0.01 to 13,000 ppm with a median content of 0.43 ppm. Fluid inclusion petrography shows that the quartz contains an abundance of healed micro-fractures defined by secondary fluid inclusions forming wispy arrays. Based on these observations, we conclude that these gold-bearing quartz veins represent intrusion-related gold deposits.

WEDNESDAY, MARCH 2

MORNING

Room 10 | 9:00 AM

MINING & EXPLORATION: GEOSCIENCES: UNDERGROUND GEOTECHNICAL: STRATEGIES FOR DESIGN & OPERATION II

*Chair: **W. Robertson**, Golder Associates Ltd*

9:00 AM

Introductions

9:05 AM

Optimizing Underground Mining Sequence Through Geotechnical Stress Modelling

I. Traore; Mining, Mining, Kibali, Congo (the Democratic Republic of the)

Defining the optimum mining sequence is one of the most important step of the underground mine design and scheduling process. The underground mine when not adequately sequenced result in significant dilution & ore losses, considerable production loss and major geotechnical stability issue. In this paper, a rigorous iterative approach of defining the mining sequence is presented for defining the optimum mining sequence. Its consists of sequencing the stopes for a series of option considering the productivity, the dilution and ore loss factors. Furthermore, geotechnical stress modelling is performed to understand the stress regime overtime follow by mine production scheduling Even though various mining sequence result in different productivity profiles, it is critical to undertake a life of mine geotechnical stress modeling in order to holistically assess the induced stress impact for optimizing the mining sequence and the net present value of the overall project.

9:25 AM

Strength Evaluation of Compartmentalized Pillar Zones using Drone LiDAR Mapping in an Underground Limestone Mine

A. Soni, R. Bishop, J. Monsalve and N. Ripepi; Mining and Minerals Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA

Assessing pillar strength and optimizing pillar design is essential in karst-affected underground limestone mines. The karst formations may lead to ground control issues such as inrush of water and excessive spalling during and after mining operations. The affected pillars may indicate deterioration visibly at one place but may not show signs of yield or complete failure. Hence, along with evaluating the overall pillar's strength, stability analysis should be carried out individually for compartmentalized zones of a pillar. This study demonstrates the benefit of conducting this research for improving the designs of karst-affected stone pillars. For mapping the discontinuity network around the tall pillars, drone-based LiDAR surveys were conducted. Distinct-element modeling using 3DEC software simulates the presence of discontinuities and karst voids inside the pillar. The results are interpreted to improve the design and dimensions of pillars in an underground limestone mine with a karst terrane to prevent local instability and optimize excavation.

9:45 AM

Wet Shotcrete Transition in a Narrow Vein MIne

J. Marjerison; Project Engineer, Stillwater Mining Co, Littleton, CO

Stillwater MIne is a steeply dipping narrow vein ore body. Stoping ground conditions vary, from good to very poor, and thus require the application of varying degrees of rock reinforcement and surface support. The narrow vein nature of the stopes has limmited operations to using dry shotcrete application techniques. This exposes operators to many different hazards. The focus of this paper is to discuss the mines initiative to transition to new remote shotcrete equipment, and to producing, delivering, and applying wet shotcrete on the mine.

10:05 AM

Stress Measurement and Monitoring in Anisotropic Rock

W. Pariseau; Mining Engineering, University of Utah, Salt Lake City, UT

This contribution describes a procedure for reducing stress measurement data obtained in anisotropic rock. The procedure is based on the well-known finite element method and fills a long-standing gap in stress measurement technology. Measurement and monitoring data at three underground hard rock mines in Precambrian meta-sediments and one soft rock mine in Cretaceous strata are used to demonstrate the ease and accuracy of the procedure. Devices used include the popular Australian triaxial cell (HI Cell), borehole stress meters (BSM), and U.S. Bureau of Mines borehole deformation gauges (BDG). The role of cement in case of HI Cell use is quantitatively addressed. Although all devices may be used for stress measurement and for monitoring stress change, not all were used for both purposes. The new procedure overcomes deficiencies in the error-prone and seriously flawed complex variable procedure for stress measurement in anisotropic rock and, moreover, is readily available to the mining community at large. The procedure is independent of the strength of anisotropy and, in fact, is equally applicable to weakly anisotropic and isotropic rock, as well.

10:25 AM

Using Fibercrete as Temporary Wall Support in Shaft Sinking at Turquoise Ridge #3 Shaft Project

R. Wu, Rocky Mining Consultants Inc, Toronto, ON
J. Dase and R. Howell, Turquoise Ridge Mine, Nevada Gold Mines, Golconda, NV

A temporary wall support with fiber shotcrete only was developed for the #3 shaft sinking project at Barrick Turquoise Ridge in Nevada, to replace the traditional mesh/bolting wall support. The shaft is 3250ft deep and 24ft net diameter. The shaft sinking is completed in July 2021 as scheduled. The average daily sinking rate is approximately 12ft per day. No incident of fall of ground occurred during shaft sinking. The shaft sinking productivity and safety have been significantly improved by reducing miner exposure and the ground support cycle time with traditional mesh/bolting temporary wall support. The ground control management system is based on accurate geotechnical investigation and rock characterization, site mapping and design according to the real ground conditions encountered, effective quality control and assurance etc. This is the first successful case in the world of using shotcrete only as temporary wall support throughout in the whole shaft sinking from top to the bottom. The innovation and practices may result in revolutionary changes in the shaft sinking technology and engineering.

10:45 AM

Utilization of Geostatistical Methods to Estimate Localized Cemented Rock Fill Strength in Underground Mass Placements

D. Porter and S. Chatterjee; Mining Engineering, Michigan Technological University, Houghton, MI

During the production and placement of large quantities of backfill, it is nearly impossible to measure the mechanical properties of each ton of material produced. Typical quality control sampling occurs at a predetermined frequency, and the test results from the sample are applied to material produced between the sampling intervals. The Unconfined Compressive Strength (UCS) test is used to measure the 28-day strength of the material after placement. At each sampling interval important data is recorded including the sampling time, production quantity, and location underground the material is being placed. Based on the data recorded from production and a two-dimensional map of the underground void to be filled, the CRF strength at a single geolocated point can be determined. Utilizing block kriging, a heat map of the UCS strength can be produced to estimate the strength of material produced between sampling intervals. This information can assist engineers to design future stopes and predict future geotechnical issues related to previously placed backfill.

WEDNESDAY, MARCH 2

MORNING

Room 12 | 9:00 AM

MINING & EXPLORATION: INNOVATION & TECHNOLOGY: LEVERAGING TECHNOLOGY TO IMPROVE MINING EFFICIENCY AND SAFETY

Chairs: ***K. Tew****, Cementation USA Inc., Herriman, UT*
M. Thyagarajan*, Colorado School of Mines, Golden, CO*

9:00 AM

Introductions

9:05 AM

Progress: Lithium-Ion Cell Thermal Runaway Cascade Prevention Technology

K. Roth[1] and T. Dubaniewicz[2]; [1]High Performance Materials, ADA Technologies, Inc., Littleton, CO and [2]National Institute for Occupational Safety and Health, Washington, DC

Mining vehicle manufacturers are developing lithium-ion (Li-ion) battery electric vehicles as an alternative to diesel-powered vehicles. Large-format Li-ion batteries of hundreds of volts sourcing hundreds of amperes are constructed from series and parallel connections of smaller cells or modules. Electrical faults and mechanical damage that can initiate thermal runaway at the cell level can potentially cascade to other cells, leading to a larger scale thermal runaway and fire risk. The National Institute for Occupational Safety and Health (NIOSH) contracted with ADA Technologies Inc. to develop Li-ion battery thermal runaway cascade prevention technology. Progress towards development of cascade prevention technology will be reviewed during this presentation.

9:25 AM

Making the Smart Mine Safer

J. Savit; Hexagon Mining, Tucson, AZ

Safety technology is an important part of the Smart Mine ecosystem. Currently these technologies run in parallel with side by side computers, sensors, cameras, GPS, and screens. These redundancies in hardware and data can muddy the overall output. The solution is the Smart Device Ecosystem, combining systems and sensors when possible. The move to integrated systems, away from systems running in parallel offers a new level of context and corelative data. The unification of systems such as the Collision Avoidance, and Operator Alertness, and Fleet Management streamlines the hardware and removes the redundant data points being fed to Business Intelligence but also provide visualization to what was once only operator, date and time displayed on a graph. This allows for less effort in joining the data and more direct usable data. further enabling predictive analytics, decreasing risk, and increasing safety and efficiency in the mining operation.

9:45 AM

Evaluation of Ground Control Stability in Underground Stone Mines Using GIS-Based Tools

H. Dougherty[1], N. Evanek[1], M. Murphy[1] and A. Iannacchione[2]; [1]National Institute for Occupational Safety and Health, Pittsburgh, PA and [2]University of Pittsburgh, Pittsburgh, PA

The underground stone industry faces challenges in the collection, storage, analysis and display of geospatial data. NIOSH has found it has the potential to be used in the prevention of falls of ground, improving safety conditions in underground stone mines. Multiple level and steeply dipping conditions can be better recognized when utilizing technology to view and analyze the data in a more effective manner. Geographic Information Systems (GIS) have the advantage of managing large collections of geospatial data in ways not possible using traditional geotechnical analysis. Surveyed and geological data has helped NIOSH researchers to establish areas of potential high risk overburden and interburden thicknesses and help to identify factors impacting hazardous ground conditions. NIOSH researchers present three case studies where a detailed GIS analysis has been used to identify complex ground control interactions. The GIS analysis used in this research may facilitate further ground control stability evaluations at the case study sites and could be applied to other operations, potentially reducing falls of ground and creating a safer working environment for underground stone miners

10:05 AM

Interoperability in Block Cave Remote Equipment Operation

P. Marshall; The University of Queensland Faculty of Engineering Architecture and Information Technology, Saint Lucia, QLD, Australia

Remote and autonomous operations of underground mining equipment has advanced such that there are now several OEM specific solutions available. However, creating an integrated mine will require such technologies and solutions to be compatible with one another so that mining equipment from different OEM's can be remotely operated together. Collaboration from OEM's is required in software interfaces and hardware integrations that enable seamless interoperability of the production zone safety systems, traffic management systems, localization systems and equipment remote control systems. Epiroc and MacLean Engineering have joined forces to make their respective systems work together. With close alignment on creating value through interoperability, the two OEM's have developed an environment where MacLean vehicles (a water-cannon and a secondary reduction drill) are remotely operated inside of an Epiroc Scooptram Automation Total installation at a block cave mine in Australia. This white paper explores the details of how to setup technology collaboration for success, how the engineering development process unfolded, how the system was deployed and the operation results at the mine site.

10:25 AM

A Disruptive Platform to Integrate Mining Data and Augment Knowledge for Real-Time Decision Making

R. Rojas and B. Marsh; Product Management, Eclipse Mining Technologies LLC, Tucson, AZ

The mining industry today utilizes a vast array of technologies that produce a constant stream of multi-faceted data. However, most mines underutilize this potential knowledge to optimize their operations. True agile mining and optimization cannot take place without the integration and full understanding of data across the mine-to-market operation. This paper addresses a case study on how a data platform could integrate the data silos of multiple areas through a common ontology and mine data model regardless of the type and origin of the datasets. SourceOne® is a designed data hub/platform created specifically for the mining industry that attributes "context" at each business process and the holistic system level, ensuring that the back end is built to be compatible with existing and future third-party applications and providers for full integration into the platform. The goal is to enable transformational and disruptive real-time critical decision making in the field based on insights, from business intelligence and data analytics, to facilitate multidisciplinary teams' true collaboration at the "tactical" and "strategic" levels of the organization and reengineering processes.

10:45 AM

21st Century Fleet Studies and Solutions: Mobile Apps

C. Watters, J. Wientjes, J. Bollini and K. Miles; Ultra-Class Electric Drive Haul Truck Division, Komatsu America Corp, Peoria, IL

Recent technological innovations ranging from automated equipment to battery technology to real-time data analytics are making big marks on the mining industry. In the face of advances like these, Komatsu has developed a suite of mobile and web apps that can evaluate their impacts on fleet performance and economics. This paper will review how Komatsu is leveraging the cloud-based Microsoft Power Apps platform to create tools that account for time-tested surface mining principles. One tool will even get put to the test to evaluate a fleet performance case study and showcase the versatility and accessibility of the apps in the field. Don't miss out on the chance to learn about 21st century fleet solutions and how they can impact the way we work.

11:05 AM

Video Data Analytics for Qualitative Measurement of Feeder Ore Flow Characteristics in Underground Systems

J. Fastle; Freeport-McMoRan Inc, Phoenix, AZ

The block cave mining method utilized by PT Freeport Indonesia (PTFI) generates fines and allows the inflow of water. Both constituents have contributed to unfavorable characteristics: ore material plasticity and fluidity passing through feeders that draw from intermediate ore stockpiles. We describe an implementation of several Video Data Analytics (VDA) algorithms on smart cameras to qualify the potential fluidity and plasticity by measuring the apparent velocity and agglutination of material flowing through ore feeders. This approach to VDA on smart cameras is a cost effective, self-contained solution to identify these unfavorable characteristics. The solution allows the operators to manage the related operational risks, maintain safe production and govern feeder rates when material is unfavorable, which is expected as PTFI precedes deeper into the underground orebody.

11:25 AM

Implementing Interactive VR for Safety Training and Underground Rescue Scenarios

E. Saygin; Mining Engineer, Hacettepe Universitesi, Ankara, Ankara, Turkey

Al Masane Al Kobra (AMAK) underground mine is located in Saudi Arabia. Actual gallery openings length is more than 40 km in underground. It becomes more difficult to understand UG working locations due to complexity of mine openings for employees. For these reasons, three-dimensional (3D) interactive underground training in virtual reality (VR) environment takes an important role for the all underground employees. Amak VR-UG project aims to increase understanding of UG in VR environment related with all working levels, safety standards. In addition, VR-UG has different mine emergency real scenarios which are UG truck fire and level entrance roof caving. Saadah (11 levels), Al Houra (19 levels) and Moyeath (1 level) were 3D modelled and developed into an interactive desktop software by using a game engine. It was further developed into an interactive VR software. User experience, navigation in 3D and realism were the main concerns throughout the development process. It can be concluded that using VR-UG training helps employees to improve underground knowledge and safety discipline under consideration of subjects such as increasing manhour, awareness and navigation in underground.

WEDNESDAY, MARCH 2

MORNING

Room 13 | 9:00 AM

MINING & EXPLORATION: MANAGEMENT: SUSTAINABLE DEVELOPMENT ACROSS THE ENTIRE MINING VALUE CHAIN

Chair: ***N. Smith****, Colorado School of Mines, Golden, CO*

9:00 AM

Introductions

9:05 AM

Building a Global Community: The Creation of the Global GeoForum

M. Sorensen[1], J. Baar[1], C. McClung[1], S. Jergenson[1], B. Griffiths[1], J. Marshall[2], S. Adam[1], R. Ibanez[1], W. Riemer[1], C. Schultz[1], H. McLean[1], D. Arnott[1], J. Gluchowska[1], C. Harman[1], M. Judge[1], A. Latscha[1], C. Matthews[1], D. Robinson[1], D. Sargent[1], N. Spurway[1], K. Trappitt[1], R. Bartlett[1], N. Halsall1 and L. de Nysschen[1]; [1]Rio Tinto, South Jordan, UT and [2]Rio Tinto Plc, London, London, UK

Feeling connected and informed is a major problem among employees of large global mining companies. Even more strained are the opportunites for development and global sharing of innovations and access to information that can improve the workforce. Enter the global GeoForum- Rio Tinto's first interconnected, multidisciplinary, biannual, internal conference that seeks to connect geoscientists from across the world and create a more innovative and informed workforce. The GeoForum helps give internal opportunites for employees of all skill levels to report on their work and findings, as well as learn and network from others around the globe, creating opportunites for networking that might not have been available previously. The Geoforum is open to anyone, targeting geoscientists who range in careers from exploration to closure, covering hydrology, environmental, finance, production, and geomet- to name a few, and includes all commodities. To date, we have had four GeoForums, starting in 2019, and going global in 2021. In addition to the conference itself, we are working on creating more mentoring and networking opportunities for our global workforce as well.

9:25 AM

The 5.7 Magnitude Magna, UT Earthquake and the Rio Tinto Kennecott Tailings Storage Facility Response

E. Hover; Hydrology, Rio Tinto Plc, London, London, UK

On March 18, 2020, a 5.7 magnitude earthquake shook the Salt Lake Valley. The epicenter of the earthquake was located near the northeast corner of the South Impoundment of the Rio Tinto Kennecott Tailings Storage Facility (RTK TSF). Over the course of the successive months, over 2,500 additional aftershocks were felt in the area surrounding the 10,000 acre impoundment. Immediately following the initial earthquake and additional aftershocks, the team of RTK TSF Geotechnical Engineers as well as qualified internal and external site representatives preformed in field inspections once deemed safe to do so. Drones were used after the initial earthquake to help determine safe access for field investigations of geotechnically sensitive areas. In addition to field inspections, the substantial amount of geotechnical monitoring equipment installed throughout the currently operational North Impoundment and no longer operating South Impoundment were monitored extensively. This instrumentation includes piezometers to monitor pore pressures, inclinometers to measure subsurface displacement, and accelerometers to measure earthquake acceleration.

9:45 AM

Using the Sustainable Livelihoods Framework to Understand Artisanal and Small-Scale Mining in Colombia

A. Delgado-Jimenez, E. Holley and N. Smith; Mining Engineering, Colorado School of Mines, Medellin, Antioquia, Colombia

This research applies the sustainable livelihood framework (SLF) to understand the activities of artisanal and small-scale gold mining (ASGM) in a municipality in Colombia. ASGM is a critical livelihood in the rural global south, where few alternative economic opportunities exist; however, ASGM often operates on or near large-scale mining concessions and conflicts between the two sectors are common. The sustainable livelihoods framework (SLF) is suitable for large-scale mining companies to improve their relationships with ASGM and identify methods for coexistence among the two sectors. The SLF allows us to examine various forms of capital available to or held by miners and how these forms of capital intersect with policies, institutions, and processes to influence the vulnerability of ASGM livelihoods. The application of the SLF to the ASGM context can indicate to what extent proposed interventions can contribute to the sustainability of ASGM livelihoods and better coexistence strategies.

10:05 AM

A New Mining View

P. Altamirano Soto, B. Bustamante, J. Manrique, J. Mendoza and J. Reyes; Mining, Society for Mining Metallurgy and Exploration, Lima, Lima, Peru

A proposal to move mining projects forward and the opportunity to achieve sustainable development in Peru. With no doubt, Peruvian mining potential is great as well as the energetic one. Unfortunately, this potential is threatened by social unrest. A number of methods and strategies from different standpoints have been rehearsed with respect to unrest in Peru. The mining unrest dates from ancient times and has not always had the same stages nor the same demands. In the 20s and 30s, conflicts focused on workers' rights and demands. It is very important to highlight that transversal demands such as land purchase, agricultural property, impacts and water reduction as well as pollution, impact on water systems and disappearance of springs have always been present over the historical period. Seeking peaceful coexistence, sustainable development, public participation, social license to operate (among the State and foreign investment), legitimacy, development projects, social investment, sustainable engagement, successful roundtable, and so on, without a strategic approach of participatory development planning, is a very subjective claim that will not get good results in the long term.

10:25 AM

Interdependencies Between Legal and Illegal Flows in the ASGM Supply Chain in Peru

L. Jaramillo Urrego and N. Smith; Mining Department, Colorado School of Mines, Golden, CO

The activities involved in the production of a good or service and the associated input and information flows constitute, roughly, what we know as supply chains (SC). SC is related to any economic sector, from the food to the fashion industry, using, directly and indirectly, minerals as raw materials. Thus, responsible SC for minerals is important since they impact the downward chains of other industries. Globally, conflict minerals have promoted the creation of standards that guarantee the responsible production of minerals such as gold. However, the complexity surrounding gold SCs have prevented this from being achieved. This study, therefore, focuses on artisanal and small-scale mining (ASM) gold SCs in Peru, a country with strong gold mining in different scales and legal forms, where many ASM activities are illegal impacting the transparency and traceability of the SC since they involve the violation of human rights, money laundering, and environmental contamination. As result, we aim to glimpse how and why ASM's SC is so complex moving between illegality and legality, showing the interdependencies between illegal, legal, informal, and formal flows.

10:45 AM

The Permitting and Public Relations of Controversial Projects in Mining

M. Akers[3], C. Roos[1], S. Rosenthal[1] and C. Okrusch[2]; 1Mining Engineering, Montana Tech, Butte, MT; [2]Interdisciplinary Arts & Sciences, Montana Tech, Butte, MT and [3]Pogo Mine, Northern Star Resources, Delta Junction, AK

Modern mining, especially developing new mines, consistently faces controversy so a quality public relations (PR) program for mining companies may improve society's impression of the mining industry. Two case studies were selected based on the type of public controversy they face to demonstrate how pervasive permitting issues are in industry. Both Pebble Mine, owned by Northern Dynasty Minerals (NDM), and Black Butte, owned by Sandfire Resources America Inc (SRA), experienced difficulties with their water permitting due to potential risks their mine developments posed to local fish populations. The local history, mine setting, prevalent culture groups, technology development, and intercultural communication competence (ICC) of these two projects will be discussed. The mining industry needs to evaluate its ICC skills since ICC directly determines the effectiveness of PR. Based on Barna's Stumbling Blocks for intercultural communication, methods for improving the mining industry's PR will be suggested in the hope of easing the permitting process for future mines by developing ICC.

WEDNESDAY, MARCH 2

MORNING

Room 11 | 9:00 AM

MINING & EXPLORATION: OPERATIONS: OPTIMIZING DRILL AND BLAST

*Chair: **J. Thuringer**, Nevada Gold Mines*

9:00 AM

Introductions

9:05 AM

Mine to Mill – A Successful Case Study at SPCC – Cuajone Mine

R. Vivas; Technical Services, Hexagon Mining, Tucson, AZ

Over the past decades we have become accustomed to the term "mine to mill". It is a simple term to describe a complex process in the mining cycle. Cuajone Mine has two different-sized mills with different throughputs. In addition, ore materials have a variable tonne per hour milling rate for each mill that depends on several factors, such as the mineral type, rock type, rock hardness and fragmentation. The mill hours associated with processing ore blocks at the big mill and the small mill are set up as variables in the orebody model. The challenge is finding the optimum blend of hard and soft rock at the mills to maximize throughput without exceeding the operating hours available in each period for each mill. In addition to monitoring mill throughput and fragmentation, SPCC must monitor several other factors, such as safety and slope stability. At SPCC the execution of the mine plan and the monitoring of its implementation is assisted with fleet management and other mine monitoring systems. This presentation will bring to light a case study that shows how to optimize a mine plan with variable mill throughputs and how these mine-to-mill efforts are paying huge dividends.

9:25 AM

Managing Continuous Improvement of Mine to Mill Begins with Measurement

J. Loeb and R. Ramanathan; Mining, Hexagon, Vancouver, BC, Canada

All mining operations, including iron ore, maintain a focus of continuous improvement and asset optimisation in their operations. As all the operations in the Mine-to-Mill value chain are inter-dependent, available technologies that address efficiencies across the value chain are once again in the spotlight as companies are driven to improve productivity and maximise mine site profits to increase return on capital invested. Core to continuous improvement is the need to understand the baseline and the impact of changes to the process. In this paper, we discuss some of the key attributes in the mine to mill process, including their influence on productivity and cost, the need for direct measurement and areas where they should be applied. Measurement of the key attributes establishes the baseline for Mine to Mill (or Pit to Plant) performance which is necessary to understand the impact of any proposed improvements to the process design and execution and to monitor the outcomes on an ongoing basis to sustain the improvements that have been implemented. We have focused this paper on two types of measurement – blast movement and particle size of materials through the mine to mill process.

9:45 AM

Drill and Blast Optimization Through an Unbiased Audit

J. Heiner; Technical Services, Forte Dynamics, Bountiful, UT

In mining, drilling and blasting seem to be a simple process in an extensive cycle, but their effects are far-reaching. Drill and blast set the pace for digging productivity, truck fill factors, crushing, recovery, maintenance, and so much more. With one process that has such effects on the rest of the value stream, why do we pay so little attention to it? If you could improve this one process, it can enhance multiple downstream processes. Having an unbiased audit is the first step is to better understanding and improving the process.

10:05 AM

A Holistic Approach to the Drill and Blast Process

T. BoBo, S. Gering and J. Loeb; Mining, Hexagon, Tucson, AZ

Without a holistic approach built on an integrated solutions portfolio, it can also be the hardest and most costly. D&B impacts the entire mining process, from mining equipment efficiency, through crushing and grinding circuit performance, to recoveries and final product quality. Costs and energy usage increase throughout the comminution process. Efforts targeted at optimizing the blasting process can pay huge dividends downstream, reducing costs and energy consumption. But how does a mine harness and harmonize the technology necessary to accomplish all of this? "A Holistic Approach to the Drill and Blast Process" will cover the importance of a well-designed blast pattern and the effective execution of the blast plan using high-precision drills; proven fragmentation analysis and blast monitoring solutions that minimize loss and dilution and deliver the data necessary for the next blast pattern design; and a continuous D&B feedback loop underpinned by technology that not only increases profit from every blast, but also increases a mine's purchasing power over one of the most expensive part of the process – explosives.

10:25 AM

Case Study: Blasting with Air Decks to Maintain Performance While Saving Costs

D. Schnell, RESPEC

Blasting is the primary and most effective method for breaking and moving material at most mine sites. The blast design is often adjusted in efforts to optimize the effectiveness of the blasts' explosive energy while minimizing costs. The goal of this case study was to reduce the mine site's bulk explosive consumption and blasting costs. The authors observed and analyzed the effect of test blasts utilizing various air deck designs on the overall blast performance. The authors also measured and verified the proposed changes in the blast design in addition to verifying all other designed parameters remained constant prior to all test blasts. After each test blast the authors analyzed the blast results to determine if there were any significant changes in the blast performance associated with the individual test blasts. Recommendations are made for future test blasts for further potential reductions in drill and blast costs associated with the site.

WEDNESDAY, MARCH 2

MORNING

Room 18 | 9:00 AM

MPD: CHEMICAL PROCESSING: MODELING, SIMULATION, AND MACHINE LEARNING FOR HYDROMETALLURGY

Chairs: ***J. Werner****, University of Kentucky, Sadieville, KY*
S. Koermer*, Virginia Tech, Blacksburg, VA*

9:00 AM

Introductions

9:05 AM

Gaussian Process Modeling of Hydrometallurgical Separations with Uncertain Dynamics

S. Koermer and A. Noble; Virginia Tech, Blacksburg, VA

Metallurgical models are often used to streamline the design and optimization of hydrometallurgical processes. These models rely on experimental data for parameter estimation; however, discrepancies between observed data and model predictions are common. The reason for such divergence can be intractable. For complex processes, a full factorial experimental design can quickly become infeasible, and noisy data can be misleading in cases where successive experiments are being used to optimize operating conditions. One approach to resolve this challenge is through the use of Gaussian Process (GP) regression – a statistical approach for modeling an uncertain function. GP functional uncertainty quantification provides a framework for reducing laboratory experiments through use of experimental designs for optimization or improving prediction accuracy which leverage active learning criteria. Methods related to GP regression can simultaneously improve prediction accuracy while reducing expenses related to data collection. This paper will provide an overview of GPs and active learning, as well as advantages, disadvantages, and application in hydrometallurgy.

9:25 AM

Design of Multi-Stage Solvent Extraction Process for Separation of Rare Earth Elements

V. Srivastava and J. Werner; Mining, University of Kentucky, Sadieville, KY

Flowsheet design and stage determination of the rare earth elements (REEs) solvent extraction (SX) process is a challenging task. Low separation factors between the elements and complex equilibrium chemistry makes it very difficult to analyze the separation results and design an efficient separation flowsheet. The multi-stage nature of the SX process adds further complexity, making assessment of products for a proposed design and stage combination difficult. This work attempts to address the challenge by utilizing equilibrium and process modeling approach. Bench-scale studies performed were used in studying the extraction/stripping behavior and develop equilibrium models. The results obtained allowed the development extraction/stripping models which was integrated in a process framework of a SX cascade in Matlab/Simulink environment. To identify optimum stage combination particle swarm optimization (PSO) routine was developed and implemented to each SX cascade. Recovery and purity of element of interest was used as objective function criteria. The stage combination leading minimum value of objective function was identified as optimum stage combination.

9:45 AM

A Lattice-Boltzmann Simulation Approach for Design Analysis of a Heap Bioleaching Model of Copper Sulfides Ores

A. Videla; Mining Engineering, Pontificia Universidad Catolica de Chile, Santiago, Chile

Lattice-Boltzmann Methods (LBM) has gained more and more popularity for the simulation of complex flow and transport phenomena. These methods are in their infancy and are in a state of evolution as they are becoming better understood and are extended to new applications. In this paper we address the application to a two dimensional heap bioleaching model for process design and analysis. The novel approach shows how the porours solution trasnport, solute transport, and micro-organism driven chemical reactions are inccorporated in the model. The advantages and limitations of the method are shown.

10:05 AM

Bayesian Mass Balancing of Hydrometallurgical Processes

S. Koermer and A. Noble; Virginia Tech, Blacksburg, VA

Unconventional resources for rare earth elements (REE) have gained popularity as their development can prompt greater feedstock diversity and a more robust supply chain. Unfortunately, many of these resources are relatively low grade and thus require innovative processing approaches. While error and uncertainty are pervasive challenges in process engineering, these issues are compounded when processing a low-grade material, as standard sampling and assaying techniques can be limiting. To mitigate these issues, engineers often employ mass balancing or data reconciliation techniques, whereby noise is filtered from raw plant data to gain a better understanding of a process under steady state conditions. Conventional data reconciliation models do not succinctly provide uncertainty quantification for estimates. Alternatively, Bayesian methods intrinsically provide full uncertainty quantification, as well as a framework for statistical simulation and model selection using machine learning. Model results from REE solvent extraction pilot plant data, the utility of this machine learning powered model, and its implementation using the BayesMassBal package for R will be discussed.

10:25 AM

Kinetic Study of Copper Leaching from E-waste using Ammoniacal Solution

P. Lin and J. Werner; Mining Engineering, University of Kentucky, Lexington, KY

Leaching copper by ammoniacal lixiviants has been known and practiced for over 100 years in various processes yet adoption of this interesting and potentially green chemistry has not seen widespread adoption. Potential benefits of this chemistry are alkali leaching, and lower electrowinning power consumption, and closed loop oxidizer regeneration. Owing to the oxidation states of copper in ammoniacal solutions, this work seeks to provide additional insights into the use and control of a copper/ammonia lixiviant utilizing Cu(II) as an oxidizer on metallic copper and printed circuit boards. To provide data for the design of copper leaching for metallic recycling, several affecting factors were studied, including the particle size, Cu(II) concentrations, and various Cu(II)/Cu(I) ratios in high Cu(I)-ammine solution. The study, as far as possible, performed experimentation to understand the relationship of recovery, residence time and Cu(II) consumption for the purpose of evaluating the feasibility of direct electrowinning coupled with leaching.

10:45 AM

Oxalic Acid Precipitation of Rare Earth Elements at High Contaminant-to-REE Ratios

A. Nawab, X. Yang and R. Honaker; Mining Engineering, University of Kentucky, Lexington, KY

Oxalic acid precipitation is a common step in the purification of rare earth elements (REE) from a concentrated pregnant leach solution (PLS). However, the presence of contaminants such as Al, Fe, and Ca decreases the REE precipitation efficiency and product purity while also increasing the amount of oxalic acid needed to maximize recovery. A statistically designed test program was performed to identify the optimal conditions needed for the treatment of a relatively low REE content PLS containing elevated concentrations of contaminant ions. The resultant model suggested that oxalic acid dosage and solution pH are the most significant factors for the prediction of RE precipitation efficiency followed by the interaction of oxalic dosage and Fe concentration. Oxalate speciation diagrams were developed for various oxalate anion and Fe contamination levels using MINTEQ software. The results from the speciation study were found to be in agreement with the experimental findings.

WEDNESDAY, MARCH 2

MORNING

Room 16 | 9:00 AM

MPD: COMMINUTION

Chairs: ***O. Arafat****, Metcom Technologies, Hamilton, ON, Canada*
M. Larson*, Molycop, Ewen, MI*

9:00 AM

Introductions

9:05 AM

Replacement of Wet Ball Milling Ahead of Mineral Separation with High-Pressure Grinding

R. McIvor[1], C. Gagnon[1], S. Makni[1], A. Rosa[1], B. Klein[2], A. Kumar[2] and C. Wang[2]; [1]COREM, Quebec, QC, Canada and 2UBC - Keevil Institute of Mining Engineering, University of British Columbia, Vancouver, BC, Canada

In response to the Natural Resources Canada "Crush It Challenge", Corem partnered with UBC and led a project to develop and demonstrate the use of high-pressure grinding to replace the workhorse of the industry, wet ball milling, with high-pressure grinding. Two plant case studies, a small tonnage gold recovery operation, and a large tonnage copper recovery operation, were carried out. Plant circuit performances were compared to pilot plants operated on the same circuit feed set up to represent the novel equipment and flowsheet that was developed to produce downstream circuit feed. Numerous obstacles to industrial implementation of high-pressure grinding in this role which were recognized at the outset of the work were successfully addressed. In both cases, comminution equipment energy savings alone, and final stage total circuit energy savings, exceeded 60% and 50%, respectively.

9:25 AM

HPGR – Technology Basics & Looking Forward

T. Lundquist; HPGR, Weir Minerals, Madison, WI

This paper will cover the basics around High Pressure Grinding Rolls including how it works, benefits, incorporation into layouts, and the most common circuit types. It will also review HPGR circuit simplification options, remote monitoring and diagnostics, and incorporation into the wider comminution circuit.

9:45 AM

Upgrading of a Cerro Verde HPGR with the Metso Outotec Flanged Roll and Mechanical Skew Sontrol Assembly

L. Biggs[1], A. Aradhya[2], J. Bublitz[3] and B. Knorr[3]; [1]FMMC Project Group, Freeport-McMoRan Inc, Phoenix, AZ; [2]Sociedad Minera Cerro Verde, Arequipa, Peru and [3]Metso Outotec, York, PA

HPGRs have shown significant performance gains when operating with a flanged roll design at previous Freeport installations. Flanges help mitigate edge effect to provide increased specific throughput and improved power efficiency. A single HPGR at our Cerro Verde 2 concentrator was recently upgraded with a Metso Outotec flanged roll design and a mechanical skew control retrofit package. This upgrade was aimed providing mechanical control of the crushing forces to avoid excessive skew events, which in turn allows for a successful implementation of the flanged roll design to expand capacity of the tertiary crushing system. This paper will discuss the need for flanged rolls at the Cerro Verde operations to meet projected throughput increases and the performance of the mechanical skew control system to prevent high skew events. The construction, commissioning, operational successes and learnings are also discussed.

10:05 AM

Exploring the Speed Limit of Flanged HPGRs in Tertiary Crushing

P. Byra[1] and N. Elkin[2]; [1]Freeport-McMoRan Inc, Phoenix, AZ and [2]Metso Outotec USA, York, PA

It is generally accepted that the maximum nominal circumferential HPGR roll speed is a function of the roll diameter, and should be limited to a factor of 1.0 to 1.2 times the diameter to prevent slippage and avoid excessive wear and reduced specific throughput. As roll diameter has increased so has circumferential speed. Lim (1997) published data showing a turn-over in the speed-throughput relationship above 2.5 meters per second circumferential speed using a 0.25 meter lab HPGR operating at speed factors from 1.5 to 12.4. This suggests there is either an upper speed limit as the circumferential speed pushes past 2.5 to 3.0 meters per second thus limiting the capacity of HPGR's above 3 meters, or HPGR's are capable of substantially higher speed factors which has upside capacity and capital efficiency implications. This paper will review test data from operating a 3.0 m diameter, flanged HPGR operating at a circumferential roll speed of up to 3.6 m/s, explores the relationships between specific throughput, specific energy, and gap, and considers possible explanations for the observed behavior.

10:25 AM

Catastrophic Mill Failure—A Case Study in Mitigating Major Unplanned Outages

D. Steiner[1] and R. Oros[2]; [1]Metallurgy, Nevada Gold Mines, Elko, NV and [2]Maintenance, Nevada Gold Mines, Elko, NV

In May of 2021, Nevada Gold Mine's Goldstrike Roaster experienced unplanned component failure in the North Mill with potential major ounce loss. This case study will explore the multifaceted effort to shorten and mitigate the outage from the perspective of Safety, Environmental Protection, Maintenance, Production, Procurement, and Metal Planning. In the end, the North Mill was brought back into production under plan with no environmental impacts, no lost time injuries, and minimal ounce loss.

10:45 AM

Coarse Particle Retention Testing on a Ball Mill at Lundin's Eagle Mine Humboldt Concentrator

K. Bartholomew, R. McIvor and O. Arafat; Metcom Technologies, Hamilton, ON, Canada

Media size investigations were carried out for the ball mill circuits grinding -12.5 mm crushing plant product at Lundin's Eagle concentrator in Humboldt, MI. Grinding tests were conducted on mill feed with a torque-metered pilot mill with the same ball charge sizing as the plant. Calculated grinding rates of the coarsest particles were approximately 4X higher for the plant mill than the pilot mill. One explanation is that coarser particles are retained in the continuous plant mill longer and exposed to more energy. This challenged the assumption used in PBM that particles of all sizes, as well as liquid, have the same residence time, as characterized by liquid tracer tests. A literature review showed that this assumption is false, and residence time as a function of particle size is indeterminant. A plant test was carried out by dosing a mill with particles, coarser than any in the normal circuit feed, in conjunction with liquid residence tracing using salt and a conductivity probe. The test showed that the coarse particles were retained approximately twice as long as the liquid. It also showed that abrasion of these particles contributes significantly to their size reduction.

11:05 AM

Development of a Dynamic Model-based Platform for Tumbling Mills

W. Xie; Chemical Engineering, University of Minnesota Duluth, University of Minnesota Duluth, Duluth, MN, US, academic, Duluth, MN

Although using steady-state mathematical models for plant simulation still dominates in the minerals industry, there has been growing interest in dynamic modelling for these systems. In fact, dynamic models are far more useful in the tuning and optimization of control systems than steady state models. Due to tumbling mills taking the biggest section of the energy consumption pie in comminution, it is necessary to develop a dynamic model-based platform for them. It has been developed with the sub-models such as appearance functions, breakage rate functions, energy distribution, transport, and multicomponent grinding interaction model. It can assist dynamic simulation of plant operation, and further potential process optimization and control.

11:25 AM

Acoustic Measurements of Different AG/SAG Mill Slurry Densities and Performance

K. Owusu, G. Abaka-Wood, W. Skinner and R. Asamoah; Future Industries Institute, University of South Australia - Mawson Lakes Campus, Mawson Lakes, SA, Australia

The hostile nature of industrial AG/SAG mill operation necessitates the need for an enhanced online measurement. Mill slurry density is regarded as a critical variable and requires a suitable range for grinding efficiency. In this work, mill acoustic sensing of five different pulp densities (50, 60, 70, 80 and 90 wt.%) was investigated using a laboratory-based AG/SAG mill. The results showed that slurry density of 70-80 wt.% gave highest mass of -75µm particles and similar acoustic intensity. The mill acoustical level increased continuously coupled with energy reduction as a function of increasing slurry density, an indication of potential real-time measurement. Keywords: Slurry density, acoustic emission, laboratory-based AG/SAG mill, real-time measurement

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WEDNESDAY, MARCH 2

MORNING

Room 17 | 9:00 AM

MPD: Evolving Technology in Flotation Equipment: Panel Discussion

Chairs: ***T. Bhambhani****, Cytec Industries Inc., Stamford, CT*

J. Gebhardt*, FLSmidth Inc, Midvale, UT*

9:00 AM

Introductions

9:05 AM

Evolving Technology in Flotation Equipment

D. Meadows[1], D. Lelinski[2], G. Jameson[3] and T. Banerjee[4]; [1]Bechtel Corp, Reston, VA; [2]FLSmidth Inc, Midvale, UT; [3]The University of Newcastle, Callaghan, NSW, Australia and [4]Woodgrove Technologies Incorporated, Toronto, ON, Canada

A panel of experts from the flotation equipment supply chain will provide their perspectives on flotation equipment technology and where the future might lie. Are flotation cells as large as they can be? Will smaller cells allow for more flexible flowsheets? Do we need cells to be more versatile to manage different ore types? Where do flotation cells fit in the concentrator of the future? How can we expect the mining industry's drive towards sustainability, as defined by reduced energy and water usage affect future flotation technology? Each panel participant will deliver a short presentation on the current state and future of flotation equipment in the mineral processing flowsheet, followed by a 90-min discussion and Q&A with the panel.

WEDNESDAY, MARCH 2
MORNING

Room 15 | 9:00 AM

MPD: FRANK F. APLAN: BETWEEN THEORY AND PRACTICE I

Chairs: ***B. Arnold****, The Pennsylvania State University, Apollo, PA*
C. Young*, MT Tech, Butte, MT*

9:00 AM
Introductions

9:05 AM
Coal Froth Flotation and Remembrances of Frank F. Aplan
T. Olson; T Olson Consulting, Gold River, CA

From a study of the response of coal, mineral matter, and locked particles in a coal flotation system to laboratory scale froth flotation scale up, Frank F. Aplan influenced many aspects of my career. This led to many advances in conventional flotation cell technology, including tank design and rotor stator design. The eventual use of computational fluid dynamics (CFD) allowed the rapid prototyping of multiple designs for flotation cells. This presentation will cover lessons learned and applied throughout my career.

9:35 AM
Thermo-Adhesive Separation – A Novel Dry Coal Beneficiation Technique
B. Parekh[1] and D. PatiF[2]; 1FGX SepTech LLC, Lexington, KY and [2]Alden Resources, Corbin, KY

Water is the mainstay for beneficiation of fine size coal and minerals; however, it is also the least desirable constituent in the final product. The basic concept of the novel process described in this paper is based on the differential surface heat absorption capacity of individual particles, which differs for different species of mineral. When a mixture of fine material is exposed to a radiant energy source, the various solids components present in the mixture will absorb heat energy depending on their composition and there will be difference in the surface temperature of the particles. When this differentially heated solid mixture is placed on a moving belt, which is coated with low temperature melting resin, the hotter component of the mixture will stick to the belt and relatively cooler will stay free on the belt and fall off at the end of the belt run. Experiments were conducted with pyrite, coal and quartz of 6 x18 mesh particle size. The goal of the test program was to find the optimum conditions at which there exists a required temperature difference between minerals and coal particles by controlling the operating and system variables.

10:05 AM
Confronting the Inherent Complexity in Flotation Systems
D. Nagaraj and R. Farinato; Earth and Environmental Engineering, Columbia University, New York, NY

Fundamental studies of flotation sub-processes have yet to give plant operators adequate guidance in solving practical problems in plants. If flotation research is ever to be genuinely useful to plant practice, we need to incorporate increasing levels of complexity that approaches and eventually matches that of practical systems. Elements of this complexity include: (i) multiple interacting composite and heterogeneous ore particles, aquatic mineral species and added chemicals; (ii) time and process dependent changes in surface chemistry and environmental parameters, and (iii) bubble-particle interactions giving rise to a dynamic and transient froth zone that separates value from gangue. These are characterized by a hierarchy of interactions and responses, often exhibiting emergent properties. In this paper we provide several examples of confronting and probing flotation system complexity at several levels. These examples serve to demonstrate the importance and utility of this type of approach in bridging theory and practice, providing a deeper understanding of flotation, and enhancing the knowledge base with the appropriate information to provide better guidance to plant operators.

10:35 AM
Use of Benign Reagents in Processing of Minerals
P. Somasundaran and P. Patra; Columbia University, New York, NY

Many of the flotation reagents used are toxic and have repugnant odors. There is a current need to employ benign reagents in flotation and other processes in general. In this regard, biodegradable greener reagents have generated considerable interest for the benefit to society. Considerable work has been done during the past few decades on interfacial properties and applications of reagents produced from natural reagents rather than petroleum derived products, particularly in the personal care and health care fields. Attempted use of greener reagents in the mineral processing area will be reviewed along with needs and opportunities to reduce toxic reagents. Importantly, opportunities to reduce energy consumption in the production and use of reagents need to be considered to help mitigate climate chaos issues.

11:05 AM
Use of Modeling to Characterize and Optimize Froth Flotation Performance – Laboratory to Industrial Practice
B. Arnold[1] and E. Dowling[2]; [1]The Pennsylvania State University, University Park, PA and [2]Independent, University Park, PA

Initiated and overseen by Professor Aplan, this paper is a retrospective of a series of research and development projects for optimizing the flotation of copper and coal. A variety of flotation models were evaluated to determine which models most reliably described the flotation process so that modifications to the overall system could be statistically characterized as improvement, or not. A wide variety of reagent and operating conditions were then tested to optimize performance. This work was then extended to the industrial scale where techniques to characterize residence time distributions and mass balances were developed. Finally, a case study is presented where these approaches were used to justify and execute the expansion of an industrial copper flotation circuit.

Room 19

Tailings: I&D: Women in Tailings – The Road So Far and the Path Forward

Chair: ***Amanda Adams****, Stantec, Denver, CO*
Kim Morrison*; Newmont, Katie Kruger; Freeport-McMoRan,*
Kate Patterson*; Klohn Crippen Berger, Michelle Theron; Stantec*

The SME Tailings Dams Committee, in collaboration with the Inclusion and Diversity Committee, presents a session highlighting exceptional women in the field of tailings management. Each speaker will share their "journey to tailings" and then join a discussion panel. The panelists will uncover unexpected challenges they faced, why this segment of the industry is so interesting and important to them, and strategies for attracting more engineers and operators, including new and diverse candidates, to join the field.
Panel Facilitators: Rachel Jansen, Dean Gehring

WEDNESDAY, MARCH 2
AFTERNOON

Room 02 | 2:00 PM

COAL & ENERGY: AUTOMATION AND INNOVATION IN MINE PRODUCTION OPERATIONS

Chairs: ***J. Sottile****, University of Kentucky, Lexington, KY*
Z. Agioutantis*, University of Kentucky, Lexington, KY*

2:00 PM
Introductions

2:05 PM

Autonomous Trucks VS Humans: How to Obtain Better Results

O. Lazo Pazce; Resource Industries Sales, Services and Technology Division, Caterpillar Inc, Peoria, IL

The autonomous hauling system has allowed reaching safer, efficient, and more productive mine operations in the whole world. The advantages of this technology are a lot, but a high percentage of operations doesn't make the decision to invest in this technology, and the operations that have invested in this technology has two big challenge: the work culture and habits. And this situation generates a waste of time during the troubleshooting of autonomous operations, and doesn't allow to have a better operation. And that environment generates a scenario that I'm describing as "Autonomous trucks VS Humans: How to obtain better results."

2:25 PM

A Discussion of the Design and Development of an Intrinsically Safe Drone for Underground Coal Mining Applications

P. Roghanchi[1], M. Hassanalian[1], D. Wetz[2] and J. Lehr[3]; [1]New Mexico Institute of Mining and Technology, Socorro, NM; [2]The University of Texas at Arlington, Arlington, TX and [3]University of New Mexico, Albuquerque, NM

This study discusses the challenges in developing an intrinsically safe drone platform for underground coal mining applications. Our team is currently working on a research project to design a permissible propulsion system for a multi-rotor drone. The Mine Safety and Health Administration has not developed specific guidance for testing and approval of a flying vehicle. Therefore, the design of an intrinsically safe drone should be based on the general MSHA's guidelines and the requirements for the intrinsic safety level for Class1-Division1 and Class2-Division1 classifications. The design of a permissible propulsion system must include a systematic feasibility study on the drone platform sizing to ensure the flyability of such design. An intrinsically safe machine is usually much heavier than its non-intrinsically safe counterpart. Increasing the weight of a drone drastically decreases its efficiency. Therefore, the two main challenges in designing an intrinsically safe drone for indoor applications are (1) to demonstrate the permissibility and intrinsic safety of the vehicle and (2) to design a propulsion system that provides sufficient lifting power and reasonable flight time.

2:45 PM

Longwall Shearer Operation from the Surface

C. Weese; Administration, Arch Resources, Morgantown, WV

The Leer Mining Complex currently operates their longwall shearer from the surface of their underground mine in a designated automation room. The goal was to eliminate the dust exposure of the shearer operator on the longwall mining system when cutting the pass from the head side of the longwall face to the tail side. Implementation of the technology and process to make it all work began with shearer automation in July of 2020. A few months later Leer purchased and installed the Komatsu Landmark Guidance System. Then with the addition of fiber optics added to the shearer power cable it became possible to install cameras making the move of the operator to the surface a reality. Utilizing shearer automation, strategically located cameras, and the Komatsu Landmark Guidance System (Landmark), the shearer operator has been relocated to a remote surface location. By operating the shearer in a longwall automation room on the surface, the operator is completely removed from any dust exposure.

3:05 PM

Concepts for Development of Shuttle Car Autonomous Docking with a Continuous Miner Using 3-D Depth Cameras

S. Miller[1], J. Sottile[1], H. Chiu[2], S. Schafrik[1], A. Krasner[2], M. Sizintsev[2], A. Rajvanshi[2] and Z. Agioutantis[1]; [1]Mining Engineering, University of Kentucky, Lexington, KY and [2]SRI International, Princeton, NJ

In recent years, a great deal of effort has been put into automating mining equipment with the goal of improving worker health and safety and increasing mine productivity. Significant progress has been made in automating mining equipment such as load-haul-dumps and drills in underground environments where global positioning systems are unavailable. This paper addresses automating the task of positioning the shuttle car (SC) under the continuous miner (CM) coal-discharge conveyor during cutting and loading operations. A stereo depth camera is mounted on the SC. Machine learning based algorithms are applied on the camera's output to identify the CM discharge conveyor and segment the scene into various regions such as roof, ribs, and personnel. This information is used to plan the shuttle car path to the CM discharge conveyor. The approach currently uses a 1/6th scale continuous miner and shuttle car in an appropriately scaled mock mine.

3:25 PM

Concepts for the Development of an Autonomous Roof Bolting Module for Enhancing Miner Safety

A. Xenaki[2], H. Zhang[1], S. Schafrik[2], S. Nikolaidis[1] and Z. Agioutantis[2]; [1]Computer Science, University of Southern California, Los Angeles, CA and [2]Mining Engineering, University of Kentucky, Lexington, KY

Equipment operators, especially, roof bolter operators are often exposed to dangerous conditions. This research is developing an automated process within the roof bolting cycle removing humans from hazardous environments. The study focuses on the concept of the development of a robotic assembly capable of carrying out the entire sequence of roof bolting operations in a full or partial autonomous manner. A bolting module has been set up with programmable hydraulic controls and connected to an industrial robot to develop and demonstrate this automation methodology. Computer simulations enable the control and motion of the hydraulic system, the drill steel, roof bolts, and resin cartridges. Various considerations for calibration-diagnostics and a self-monitoring system have been incorporated. The autonomous system is supervised by a human-machine interface enabling manual approval of the tasks and overriding of the system in the event of unpredicted or unsafe actions.

3:45 PM

Developing a Semi-Autonomous Shuttle Car: Performance of a Lab-Scale Prototype

S. Schafrik, University of Kentucky, Lexington, KY & J. Sottile, University of Kentucky, Lexington, KY & V. Androulakis University of Kentucky, Lexington, KY & Z. Agioutantis, University of Kentucky, Lexington, KY

Delegating hazardous tasks from humans to machines can be critical for improving personnel safety and mine productivity. Integrating autonomous vehicles in the mining cycle is undoubtedly a necessity for the mining industry of the future. Employing autonomous solutions in the multi-disciplinary field of mining engineering is a cutting-edge trend of the last few decades.

This paper presents and discusses the challenges in the development of a semi-autonomous shuttle car for room-and-pillar coal mining operations that can tram between the continuous miner and the feeder breaker. Performance results of a 1:6 scale shuttle car equipped with various sensors and a custom navigation system are presented and evaluated. Performance metrics have been collected through experiments with a 1:6 scale shuttle car in a scaled mock mine section for inby and outby tramming across several pillars. Extensive testing was performed in preparation for equipping a full-scale production shuttle car and demonstrating the use underground.

WEDNESDAY, MARCH 2
AFTERNOON

Room 01 | 2:00 PM
COAL & ENERGY: VENTILATION INNOVATIONS

Chairs: ***P. Tukkaraja****, South Dakota School of Mines and Technology, Rapid City, SD*
V. Gangrade*, National Institute for Occupational Safety and Health (NIOSH), Pittsburgh, PA*

2:00 PM
Introductions

2:05 PM
A Direct Derivative Method to Calculate Resistance Sensitivity for Mine Ventilation Networks
L. Zhou and D. Bahrami; NIOSH, CDC, Pittsburgh, PA

A stable ventilation system is essential to the safe operation of underground mines. The stability of a mine ventilation system becomes extremely critical while responding to a fire since an unstable ventilation system will pose a risk of airflow reversal. There has been a growing interest in the study of ventilation network stability using resistance sensitivity, which is described as an indicator of how the airflow in an airway is reacting to a resistance change of other airways. Several methods have been carried out by researchers around the world. However, those methods heavily rely on vast amount of mine ventilation simulations, which is very time consuming. In this paper, a direct derivative method calculating the resistance sensitivities with a single mine ventilation simulation has been developed and implemented into a mine fire simulation software, MFIRE. The direct derivative method was carefully verified using an example ventilation network and the results indicate that the proposed method can calculate resistance sensitivities accurately. The biggest advantage of this method is that it only requires a one-time mine ventilation simulation compared to other methods.

2:25 PM
Optimization of Auxiliary Fan Placement for Large-Opening Underground Stone Mines
E. Watkins and V. Gangrade; Mining System Safety, NIOSH, Pittsburgh, PA

Large-opening stone mines often rely on natural ventilation and a network of auxiliary fans to produce adequate ventilation conditions in the mine. Large air volumes in underground stone mines, poor ventilation practices, and low operating budgets for mine ventilation potentially leave mine workers at risk to dust, silica, and diesel particulate matter (DPM) emissions exposure. To help improve mine ventilation practices, the optimal auxiliary fan location for maximum airflow production from a ventilated intersection was determined using a combination of field measurements and computational fluid dynamics (CFD) modelling. A six-foot diameter auxiliary propeller fan was introduced into the validated CFD model at three locations around an intersection with established ventilation flow perpendicular to the fan direction. The findings summarized in this paper show how an optimized auxiliary fan placement may increase the net effective ventilation flow rate by 70,000 cfm and reduce recirculation by 30%, which maximizes the potential output of large-opening stone mine ventilation systems and decreases mine worker exposures to airborne contaminants.

2:45 PM
Identifying the Location and Size of an Underground Mine Fire with Simulated Ventilation Data and Random Forest Model
Y. Xue, D. Bahrami and L. Zhou; National Institute for Occupational Safety and Health, Pittsburgh, PA

The timely determination of the location and size of an underground fire is important for the safety and health of mine workers. Machine learning was used to develop a predictive model for fire location and size in an underground mine. The ventilation data were obtained by simulating different fire scenarios with MFire. The ventilation data of all airways were used as features to predict the fire location. Based on the feature importance, five airways were selected to monitor, and the airflow data of the selected airways were used to predict the fire location and fire size. An accuracy score of 0.920 was obtained for fire location prediction. Also, in-depth analyses were conducted to characterize the wrong predictions. The results show that the occurrence of fire at closely connected airways at some locations can generate misleading ventilation data for each other and the model performance can be further improved by grouping them. Fire size is another factor affecting the model performance and the model accuracy increases with increasing fire size. The result from this study can help mine safety personnel make informed decisions during a mine fire emergency.

3:05 PM
Evaluation of Parameters Influencing Potential Gas Flow to the Mine in the Event of a Nearby Shale Gas Well Casing Breach
K. Ajayi, Z. Khademian and S. Schatzel; NIOSH, Pittsburgh, PA

The integrity of shale gas well casings positioned in the abutment pillar of a longwall mine could be jeopardized by longwall-induced deformations. In event of this, the surrounding fracture networks could provide pathways for gas flow into the mine creating safety concerns. Hence, this study evaluates the impact of parameters that could affect potential shale gas flow to the mine using a Discrete Fracture Network (DFN) model. These parameters are evaluated using a defined DFN realization that is representative of the fractured zone in the overburden and the range of parameter variations are within values validated with field measurements. The results show that a 50% decrease in aperture from the breach location could reduce the potential gas flow to the mine by over 70% for the condition simulated. It is also observed that changes in the fracture water saturation level could significantly affect the gas flow. These findings provide critical information regarding the impact of each parameters associated with gas flow in the event of a shale gas casing breach near a longwall mine and could help towards the development of guidelines to ensure a safe co-existence of both industries.

3:25 PM
Estimating Airway Friction Factors from LiDAR Scans
H. Ayaz, J. Brune, S. Duzgun, G. Bogin and A. Juganda; Colorado School of Mines, Golden, CO

Ventilation modeling requires accurate data on airway resistance. Ventilation software often use Atkinson friction factor to calculate airway resistance. Atkinson friction factor values rely on surface roughness calculated from measurements of entry geometry and pressure differential. This method cannot be applied to short sections of mine airways where pressure differential is small and close to detection limits of handheld micro-barometers. In this research, LIDAR scans are used to calculate airway friction factors from surface roughness of entry walls and compared with pressure measurements and CFD analysis to arrive at a useful conversion of LIDAR wall roughness to Atkinson friction factor.

3:45 PM
A Method of Ventilation Network Simplification
C. Strong and S. Schafrik; University of Kentucky, Lexington, KY

Mine ventilation systems are represented by networks comprised of idealized elements. There are several numerical methods which vary in both computation time and ability to solve used to design these networks. In all cases, these solvers work faster and more reliably on smaller networks. Often specialized software tools could be used on smaller networks or specific areas of a mine. These tools could be used if the rest of the mine network was simplified to boundary conditions. This paper demonstrates a mathematical technique of network simplification that creates reversible simplified synthetic networks. Comparing the original and simplified networks shows little to no change in characteristics such as the fan operating point. Future work with this method includes applying the technique to typical large ventilation networks, piping networks and comparison of simplification techniques currently in practice with this synthetic simplification technique.

WEDNESDAY, MARCH 2
AFTERNOON

Room 07 | 2:00 PM

ENVIRONMENTAL: ENVIRONMENTAL POLICY AND REGULATION

Chairs: ***L. Sunna****, Freeport McMoRan, Phoenix, AZ*
A. Patel*, Barr, Salt Lake City, UT*
Sponsored by Barr Engineering

2:00 PM
Introductions

2:05 PM

Status of Waters of the U.S. in the Arid West

B. Lindenlaub; WestLand Resources, Inc., Tucson, AZ

The definition of waters of the U.S. (WOTUS) remains an enduring source of confusion and debate for mine projects, particularly in the arid west. The presence of WOTUS can significantly impact permitting timelines and compliance obligations for mine projects. Three administrations in a row have attempted to clarify the definition of WOTUS and a fourth has announced yet another change. Despite the advertised clarity, the result has been persistent uncertainty for the mining community. In light of the ever-shifting political landscape, we provide a brief review of WOTUS history and a discussion of the current and potential future status of WOTUS in the arid west.

2:25 PM

Implications of Operating in an Environmental Justice Community

A. Feldpausch; Health Sciences, Ramboll USA Inc, Arlington, VA

The U.S. Environmental Protection Agency (USEPA) established the Office of Environmental Justice following the creation of Executive Order 12898 in 1992 with the intent of reducing environmental and health disparities for low income and people of color and improving overall environmental quality. Since then, USEPA has endeavored to meet the challenge of addressing environmental and health disparities. The current U.S. administration is elevating environmental justice issues by increasing investments in disproportionately impacted communities identified using USEPA's EJScreen tool. Similar investments are being seen at the state and local levels. With increased public participation, pressure from investors and other stakeholders, and initiatives pushing the regulated community to account for cumulative impacts or meet lower risk thresholds, managing mining operations, meeting regulatory obligations, and maintaining a social license to operate is becoming increasingly dynamic and complex. In this talk, we explore the implications of changes in policy and regulations on mining in environmental justice communities.

2:45 PM

Real-Time Monitoring and Data Management of a NEPA Draft EIS Public Comment Period

J. Joyner; Brown and Caldwell, Boise, ID

As part of the United States Forest Service's National Environmental Policy Act (NEPA) process, the public has the opportunity to comment on proposed project alternatives and impacts assessed in a draft environmental impact statement (EIS). Past comment periods have focused on community outreach efforts to gather proposed project support prior to the comment period. To create a real-time collaborative process, Brown and Caldwell (BC) combined efforts with its client to develop a series of tools for data capture, data analytics, and communication that included tailored status reports. BC's use of a shared platform provided the client with 24/7 access to the nearly 10,000 letters over a 75-day period and instantaneous feedback on the effectiveness of public outreach efforts. Early indications of public concern allowed for immediate adjustments to planning and agency interactions. The use of real-time monitoring and data management of a NEPA draft EIS public comment period enables multiple departments of the proponent to collaborate and improve respective strategies, ultimately leading to an improved project with overwhelming public support.

3:05 PM

Decarbonization Strategies For Miners

R. Miller; Reliant Energy Solutions LLC, Highlands Ranch, CO

Lowering our globe's emissions is a major effort as we move toward a future net-zero-carbon environment, and will require significant investment in new low-carbon infrastructure, along with key market incentives to change. The mining industry will play a key part in this transformation, requiring expertise in both energy and emissions. Key elements of the decarbonization strategy are: energy data, emissions reporting method, governance, decarbonization project generation and drivers, the MACC, electrification, and the decarbonization checklist. For a zero carbon future, it will be key for mining leaders to understand decarbonization, anticipate technological changes, and implement new business methods and processes to remain good stewards of the environment.

WEDNESDAY, MARCH 2
AFTERNOON

Room 06 | 2:00 PM

HEALTH & SAFETY: ADVANCES IN HEALTH EXPOSURE AND MONITORING

Chairs: ***C. Tsai****, University of California Los Angeles, Los Angeles, CA*
T. Bauerle*, NIOSH/SMRD, Spokane, WA*

2:00 PM
Introductions

2:05 PM

Wavelength Selective Portable Device for Quantifying Organic and Elemental Carbon in Diesel Particulate Matter

D. Parks and K. Raj; CDC NIOSH, Spokane, WA

A device based on narrow bandpass optical filters was designed to target infrared absorbance bands associated with diesel particulate matter (DPM). The five optical passband filters were chosen based on previous work quantifying DPM using Fourier-transform infrared (FT-IR) spectrometry. The resulting device, referred to as a filtometer, is optimized to exclusively determine DPM as a cost-effective, field-portable alternative to laboratory-grade FT-IR analysis and instrumentation. The performance of the filtometer is investigated by calibrating thermal/optical DPM (dependent variable) to the filometer spectra (predictor variables) using a partial least-squares (PLS) approach. The calibration is then validated by quantifying DPM in a separate set of samples (i.e., a test set). Method performance is judged on test set figures of merit including R^2, root-mean-square error, and median bias.

2:25 PM

Electromagnetic Emission Measurement of the Shielded Metal Arc Welding (SMAW) Process

L. Yan, B. Lambie and J. Carr; CDC/NIOSH, Pittsburgh, PA

Electromagnetic emissions from electrical and electronic devices may interfere with electronic safety systems or other devices in the mining environment. To reduce the risk of EMI, the National Institute for Occupational Safety and Health (NIOSH) is conducting research to quantify the electromagnetic emission of several types of equipment which may be used in mining environments. Welding is essential and prevalent in the mining industry. In this study, the electromagnetic emission of the shielded metal arc welding (SMAW) process was monitored and measured. Several factors including operating mode, current setting, and electrode type were investigated to compare their effect on emission levels. The test shows that the emission levels from the welding process can be affected by each of these factors. The test data also show that among these factors, the operating mode has the most significant influence on emission levels. The information in this paper can be useful for the mining industry to better understand the emission in the microwave and radio wave range from SMAW.

2:45 PM

A Study of Temporal Trends in Respirable Coal Mine Dust Characteristics

S. Ghaychi Afrouz, C. Keles, A. Cueller and E. Sarver; Mining, Virginia Tech, Blacksburg, VA

The resurgence of severe lung disease among US coal miners beginning in the late 1990s is well established. Although radiographic and pathologic evidence strongly suggest respirable crystalline silica exposure as a key factor, the available mine dust monitoring data does not paint a clear picture about when or where such exposures occurred. This situation has naturally prompted questions about whether other dust constituents or characteristics (e.g., particle size) have played a critical role in disease, and speculation about how dust might have changed with specific changes in mining conditions. However, data on historical dust characteristics is scarce. The aim of this study is to investigate temporal trends in particle size and mineralogy distributions of respirable coal mine dust using samples collected in 2003-2005 and 2018-2020. Both sample sets were collected using virtually identical sampling equipment, procedures, and filter media, and both are being subjected to the same preparation and analytical methods including Fourier-transform infrared spectroscopy (FTIR) and Scanning Electron Microscopy with Energy Dispersive X-Ray (SEM-EDX)—enabling direct comparison of results.

3:05 PM

Quantifying Environmentally Persistent Free Radicals (EPFRs) of Submicron Coal Dusts

S. Azam[1], S. Liu[1], V. Kurashov[2], J. Golbeck[2], S. Bhattacharyya[1] and R. Zhang[3]; [1]Energy and Mineral Engineering, Pennsylvania State University, State College, PA; [2]Department of Biochemistry and Molecular Biology, The Pennsylvania State University - University Park Campus, University Park, PA and [3]Chemical Sciences Division, Oakridge National Laboratory Biosciences Division, Oakridge, TN

Free radicals (FRs) present in coal dust directly influence the interaction behavior between lung cells and dust particles. FRs are atoms or groups containing unpaired electrons, with strong chemical reactivity and a short lifespan. FRs which are quite persistent in natural environments, termed environmentally persistent free radicals (EPFRs), have recently received much attention as new environmentally hazardous substances. EPFRs present on coal dust serves as an active intermediary to catalyze reactive oxygen species (ROS) production by oxygen molecules endangering mine workers' health. Many EPFR species may be bonded to the particle surface or trapped within the particle during coalification and can be modified with progressive size reduction through cutting at the mining face or crushing/pulverization in the plant. This study measured EPFRs for lignite, sub-bituminous, and anthracite coal dust at various sizes. We especially focused on EPFRs for submicron coal dust prepared by cryogenic methods. The outcome of this study will directly improve the free radical-dependent toxicity quantification and ultimately contribute to the size-dependent coal dust toxicity quantification.

3:25 PM

Field Demonstration of an Integrated Wireless Respirable Dust Sensing Network Based on Low-Cost Optical Sensors

W. Groves[1] and V. Kecojevic[2]; 1Energy and Mineral Engineering, Penn State University, University Park, PA and [2]Mining Engineering, West Virginia University, Morgantown, WV

This presentation describes the performance of an integrated wireless respirable dust sensing network for surface mines/support facilities. The system employs inexpensive dust sensors interfaced with low-power microprocessors capable of real-time measurement and reporting of dust concentrations and is intended to facilitate timely response to elevations in dust concentrations. Work focuses on field deployment of the integrated system including a wireless LoRa gateway and six dust sensing nodes at a coal loadout facility. One each of two different prototype dust sensing nodes was placed at three locations expected to have the highest respirable dust concentrations, along with reference direct-reading instruments (PDM 3700, Dusttrak DRX, and PDR 1500) and gravimetric samplers. Agreement between the dust sensing nodes and gravimetric sample results was good with an overall error of 20% (n=6, sd=8%) and errors from -0.4-40% for respirable dust concentrations ranging from 0.12-0.64 mg/m3. Data was successfully transmitted over distances up to 600m with minimal packet loss (< 1.5%). Results demonstrate the feasibility of this approach for monitoring respirable dust exposure.

3:45 PM

A Long-Term Field Evaluation of Mining Escape Respirators Conducted from Sept 2019 to July 2020 and the Removal from Service of One Device

S. Moore, G. Walbert, W. Monaghan and J. Simons; National Personal Protective Technology Laboratory, NIOSH, Pittsburgh, PA

Known as self-contained self-rescuers in the mining industry, closed-circuit escape respirators (CCERs) that are deployed to underground coal mines undergo long-term field evaluations (LTFEs) that are jointly performed by the National Institute for Occupational Safety and Health (NIOSH) and the Mine Safety and Health Administration (MSHA). These field evaluations provide performance, reliability, and user maintenance compliance data from the point of use for CCERs. In 2019, NIOSH implemented a revised LTFE strategy that includes, for the first time, the collection and evaluation of units approved to the agency's 2012 update to the regulation, Subpart O. Targeting units approved to both Subpart O and Subpart H, this revised strategy also prioritizes units exposed to more severe conditions (i.e., belt worn or stored on mobile equipment). During this presentation, NIOSH will present its findings for CSE SRLD and CSE SR2000 units that were collected and tested between September 2019 and July 2020 where a device that did not conform to approval requirements was identified and subsequently removed from service by the manufacturer—the CSE SR2000.

4:05 PM

New Underground Communication System for Mine Rescue Operations

F. Reuter[2] and H. Mischo[1]; [1]Mining & Special Underground Construction, Technische Universitat Bergakademie Freiberg, Freiberg, Sachsen, Germany and 2FLB Research and Teaching Mine, TU Bergakademie Freiberg University, Technische Universitat Bergakademie Freiberg, Freiberg, Sachsen, DE, academic, Freiberg, Germany

The common lack of any communication infrastructure after a major mine disaster or on old and abandoned underground mine sites generally does not permit the use of radio-based standard communication technology as used e.g. in the field of firefighting. Therefore, wire-based technologies such as the old-fashioned analogue pit phone, have always been used in mine rescue operations. A number of unsuccessful underground tests with commercially available wireless technology from a wide variety of transmission systems and manufacturers has been conducted by mine rescue departments in Saxony. Consequently, the new tethered system CABLECOM LR has been developed at TU Bergakademie Freiberg specifically for mine rescue operations. It also allows very large transmission ranges of more than 5 km and the connection of multiple transmitters/receivers into one communication system at very reasonable investment and operating costs. The new system is designed to be lightweight, water-resistant (IP68) and can be powered independently by 5V-USB-Powerbank, USB-OTG mobile or 9V monobloc battery and is available on the market through Imtradex Hör- & Sprechsysteme GmbH.

WEDNESDAY, MARCH 2

AFTERNOON

Room 09 | 2:00 PM

INDUSTRIAL MINERALS & AGGREGATES: INNOVATIONS IN INDUSTRIAL MINERALS AND AGGREGATES

Chairs: ***L. Olsen****, Minerals Technologies Inc, Easton, PA*
G. Tomaino*, Minerals Technologies Inc, Easton, PA*
B. Li*, Michigan Technological University, Houghton, MI*

2:00 PM

Introductions

2:05 PM

Biopharmaceuticals to Cat Litter: Product Innovation in the Diatomite and Perlite Industries

S. Palm; Executive, Mineral Strategy Institute, Reno, NV

Diatomite and perlite products are light density, porous industrial minerals which are used in many applications. Although the materials share a number of properties and markets, they have very different origins. Diatomite is a sedimentary rock which consists of the amorphous silica remnants of diatoms, a type of algae, whereas perlite is a natural glass formed through extrusive volcanism and hydration. In the last thirty years, there has been a resurgence of research, product development and new product introductions by diatomite and perlite producers. These innovations included the development of new products for both existing and new markets as well as the introduction of process technologies not previously used in these industries. Many of these new products are patented and provide significant EBITDA to their owners and are used in applications ranging from biopharmaceutical processing to pet litter.. This paper reviews several of the more interesting new products and the key factors of success associated with their technical and commercial success.

2:25 PM

Characterization and Determination on the Degree of Reactivity and Crystallinity of the Pozzolanic Reactions for Specific Natural Zeolites in Combination with Gypsum and Other Cementitious Matrices Following Ambient to Elevated Temperature, Pressure, and Temporal Conditioning

G. Tomaino; Minerals Technologies Inc, Easton, PA

The last three technical presentations provided various experiments and findings that allowed for a general characterization and ranking, for the degree of reactivity and crystallinity of the pozzolanic reaction [AS + CH + H à C-S-H and C-A-H]) along the saturated vapor pressure curve-critical water point from 75C up to 350C-critical point for various natural and synthetic minerals and materials. New experiments and evaluations will be presented and discussed for specificity of CSH (I) and CSH (II) type formations or tobermorite/tobermorite-Al rich formations or combinations thereof for specific natural zeolites when associated with gypsum and other cementitious matrices following ambient to elevated temperature, pressure, and temporal conditioning. As with previous presentations the characterizations will be done using a combination of XRD, TGA-DSC and TGA-DSC with specialized pressure-DSC crucibles (low pressure-100 bar) in addition to actual trialing end-use products.

2:45 PM

Zeolites- Deodorizing the CASE Markets While Cementing Natural Pozzolans in the US

D. Eyde; St Cloud Mining, Tucson, AZ

St Cloud Mining Company (SCM) started aggressively marketing zeolite products into nontraditional applications for filler/extender markets in 2019 to identify properties of zeolite products that would provide specific benefits to CASE, plastics, and rubber applications. Zeolites possess specific chemical and physical properties that can provide unique functionality in a variety of applications. To date, we have identified specific applications in paints where functionality can produce specific benefits. Similar benefits exist for in epoxies, rubber, and plastic applications. With the decision to enter applications utilizing fine particle size products it also made sense to develop an application in which zeolite tuffs have been used since before the time of the Romans. Zeolites/ash as a natural pozzolan has long been used in Asia and Europe. In the US, however, fly ash has been the pozzolan of choice. But, the availability and quality of fly ash pozzolans have consumers of fly ash considering alternative materials. Getting natural zeolites back into the cementitious material supply chain is nearly as challenging as getting it accepted as a new product in non-traditional markets.

3:05 PM

Methodological Proposal to Incentivize the Circular Economy in the Aggregates Industry

S. Escudero; School Mines, Universidad Nacional de Colombia Sede Medellin, Medellin, Colombia

To innovate and make the operation sustainable it is necessary to identify the externalities and impacts completely. This paper presents the results of a proposed methodology to make circular economy initiatives viable in mining operations using these aspects: – Economic, safety, and environmental (HSE) risk analysis – Technology observation – Mineralogical characterization – Identification of potential waste uses – Use of government economic benefits The results of the project can be summarized as follows: – Implementation of new technologies in the aggregates process, efficient use of water, the valorization of waste to convert it into a by-product, and access to tax benefits for investment savings.

3:25 PM

Smart Mining: Leveraging Deep Learning and 3D Imaging for Lip Shroud Monitoring and Boulder Detection for Shovels

C. McKinnon[2], S. Tafazoli[3] and D. Cheng[1]; [1]Marketing, Motion Metrics, Vancouver, BC, Canada; [2]ESG Relations, Motion Metrics, Vancouver, BC, Canada and [3]Executive Team, Motion Metrics, Vancouver, BC, Canada

Crusher obstructions caused by broken lip shrouds and inefficient blasting result in considerable operational downtime. These events are commonplace amongst mines and lead to substantial production loss while jeopardizing employee safety. This paper presents a technology that will tackle these challenges – applying deep learning techniques alongside 3D imaging to detect lip shrouds that have broken off or unwanted boulders in the shovel load. The system immediately alerts the operator to missing lip shrouds and boulders, allowing dispatch to divert the oversized material before it reachers the crusher downstream.

3:45 PM

Biobeneficiation of Spodumene for Decarbonized Lithium

N. Manser; GMES, Michigan Technological University College of Engineering, Houghton, MI

As the green economy takes hold the world depends more upon lithium carbonate as a primary mineral and technologies must be developed to fill the demand for this resource. In addition to brines, there are significant hardrock and clay sources of lithium-bearing minerals globally; however the extraction and/or separation of those minerals from their host minerals can be ecologically unfavorable because of extensive chemical treatment required to support froth floatation, or technologically impossible given the nearly similar densities of the minerals. This work addresses the current knowledge gaps around successful biological beneficiation of lithium-bearing minerals from hard rock and clay sourses by investigating the efficacy of Paenibacillus polymyxa at enhancing the settling characteristics of the ore (spodumene, lepidolite, or petalite) and/or waste (quartz, kaolinite, feldspar) in a manner that promotes more effective separation.

WEDNESDAY, MARCH 2
AFTERNOON

Room 12 | 2:00 PM

MINING & EXPLORATION: GEOSCIENCES: MINE DEWATERING AND HYDROLOGY: LESSONS LEARNED & PRACTICAL APPLICATIONS

*Chair: **S. Douglas**, Piteau Associates, Elko, NV*

2:00 PM
Introductions

2:05 PM
Horizontal Drilling for Depressurization at the Rio Tinto Kennecott Mine

E. Hover; Hydrology, Rio Tinto Plc, London, London, UK

Depressurization of highwalls in an open pit mining environment leads to increased slope performance and overall safety from a geotechnical perspective. Rio Tinto Kennecott Copper (RTKC) utilizes remote controlled horizontal drilling rigs to drill drains into the highwalls in site-wide active mining sectors to further the pit dewatering effort in addition to the dewatering wells and drainage gallery already in place. The use of a remote operated drilling rig greatly reduces the risk of having operators close to the highwall while still gaining the necessary overall pit depressurization needs. The remote-controlled drilling rig utilizes a series of cameras on and around the cab of the rig, which are monitored from a trailer located a safe distance from the pit wall and behind the drill rig itself. Selection of horizontal drilling locations is completed in conjunction with the RTKC Geotechnical team to ensure safe and stable highwall access. This drilling is completed in areas where modelled depressurization needs are present, or in current geotechnically sensitive areas in order to help reduce the potential for slope movement.

2:25 PM
Installation of Elexon Mining Geo4Sight Markers at Rio Tinto Kennecott in an Active Area of Mining and Slope Movement

C. Humphrey[1] and I. Callow[2]; [1]Kennecott Utah Copper LLC, Magna, UT and [2]Rio Tinto Plc, London, London, UK

The ability to maintain consistent data collection from cabled or cased instrumentation in geotechnical areas of concern can present challenges as this equipment routinely shears due to slope movement. In order to mitigate this issue, Rio Tinto Kennecott installed Elexon Mining's wireless Geo4Sight Markers (tilt and pore pressure), which communicate via wirelessly through rock, in an area of active slope deformation. The Markers were installed in a purpose-drilled borehole from surface that was subsequently intercepted by a Marker-equipped underground borehole. This novel approach allows for communication as mining progresses. The purpose of this project was to: 1) Demonstrate and confirm the use of the Elexon Mining's wireless Geo4Sight technology for monitoring pore pressures and slope movement in unstable and active mining areas; 2) Obtain and provide a continuous pore pressure and slope movement dataset in an area of active movement/mining; and 3) Provide an opportunity to monitor over-break pore pressures/ground movement concurrent with mining activities.

2:45 PM
Dewatering Implementation Across Highly Transmissive and Low Permeability Hydrogeologic Settings.

T. Cluff[1], F. Partey[2], M. Geddis[2] and J. Haskell[2]; [1]Piteau Associates, Reno, NV and [2]KGHM Polska Miedz SA, Ely, NV

An open-pit copper porphyry deposit is located across a significant hydrogeologic boundary separating weak, low-permeability mineralized geologic units from a prolific and Carbonate aquifer. Over the past 15 years a comprehensive depressurization and dewatering program has evolved to address the unique challenges arising from the presence of these two systems. This presentation describes the approach and lessons learned while implementing the dewatering systems for both types of hydrogeologic systems. Water levels in the Carbonate system have been dewatered by over 500 ft with total dewatering rates that exceeded 15,000 gpm. Unique challenges to dewatering the Carbonate system include vertical heterogeneity, reduced transmissivity along dewatered fracture planes, pulses of mountain recharge, wellfield and dewatering discharge management, and impacts to municipal water supply. Depressurization of low-permeability and weak in-pit wall rock has been critical to maintaining slope stability. Challenges in the mineralized system include structural compartmentalization, pit lake management, exploitation of historic underground workings, and detailed mine scheduling consideration.

3:05 PM
The Complete Dewatering Cycle at the Lisheen Mine, Ireland

G. Beale; Piteau Associates, Shrewsbury, UK

The Lisheen Mine is located in Co. Tipperary in the Irish Midlands. The mine was operational between 1999 and 2015. The lead-zinc orebody is hosted in karstic reef limestone, mostly at a depth of 700-1,000 ft. A major flooding event occurred as the initial decline was driven through a regional fault zone. A surface wellfield was essential to depressurize the first ore zone ahead of mining, but was superseded by an underground dewatering system after about a year of production mining. The dewatering rate rose quickly to 15,000 gpm and fluctuated between 11,000-19,000 gpm up to the time of closure, showing a strong correlation with precipitation, which reflected the very low storage of the limestone bedrock. Separate dewatering circuits were operated for clean water and dirty water; with the water streams blended prior to discharge to two local river systems. After closure, groundwater levels rose by 400 ft in the first three months, further demonstrating the low storage of the limestone. Full recovery of the water table was confirmed in early 2018, 2 years after shut down of the pumps, when the natural seasonal variation in groundwater levels had re-established.

3:25 PM
Successful Planning and Implementation of Pit Dewatering Through Numerical Modeling at the Penasquito Pit

J. Granados Acoltzin[2], S. Meyerhoff[1] and H. Liu[1]; 1Itasca Denver, Inc., Lakewood, CO and 2Newmont Corporation, Carretera Cedros Mazapil, Zacatecas, Mexico

This paper presents the successful planning and implementation of a pit dewatering system at the Penasquito pit with a groundwater flow model. The dewatering at the pit has achieved its goal of maintaining the water levels two benches below the pit bottom through the constant effort of incorporating the predicted short- to long-term dewatering in the planning and installation of 1,000+ meter deep in-pit dewatering wells. The dewatering operation demonstrates that developing and maintaining a properly calibrated model is critical to provide accurate and realistic dewatering planning and flowrate predictions for the mine to make informed decisions.

3:45 PM
FGR – Challenges and Solutions of instrument installations with Fiberglass Rod

D. Van Eck; Call & Nicholas, Tucson, AZ

The fiberglass rod (FGR) method of piezometer installation has superseded older down-the-hole methods such as tremie pipe. This paper presents the sequential steps involved in a fiberglass rod piezometer installation, benefits and challenges of the method, solutions developed to problems encountered, and lessons learned with reference to actual case studies. Special tools designed and manufactured to make the installation safer and more time and cost efficient are discussed as well as procedures and equipment developed to reduce risk and ensure a successful final installation. CNI has a ninety-nine percent success rate of installations to date and that one percent of failed installations are also discussed, and how the operating procedure was adapted to prevent a re-occurrence.

4:05 PM

Case study: Importance of a Hydrogeologic Conceptual Model to underpin Operational and Closure Decisions

J. Rupp[1], G. Beale[2] and B. Anderson[1]; [1]Hydrologic Sciences, University of Nevada Reno, Reno, NV and [2]Geology, Lancaster University Faculty of Science and Technology, Lancaster, Lancashire, UK

Operational decisions for open pit dewatering, slope depressurization and water supply must rely on a detailed hydrogeologic conceptual model. If the conceptual model is right, there is confidence in the resulting water management decisions. It is therefore important to ensure adequate supporting data and time to develop and support the conceptual model. The current case study draws on the experience of a smaller Nevada mine that required a balance between dewatering and water supply requirements, with no off-site discharge, while at the same time achieving the required pore pressures to support the pit slope designs. Early pumping trials provided the basis for the year-by-year dewatering plan that balanced remaining groundwater storage with future water supply needs. Although the conceptual model has been refined based on 17 years of monitoring data, the actual dewatering rate and observed piezometric responses have been consistent with the original trials. The conceptual model is now being used as the basis for the closure design.

4:25 PM

Mitigating Risk and Preparing for the Unknown: Water Management Through the Mine Lifecycle

D. Richards; Mining, Burns & McDonnell, Kansas City, MO

Whether a mine is situated in a tropical net positive or desert net negative environment, proper planning, design, and stewardship is key to maintain mine site continuity. A proper site water balance requires staff with a thorough understanding of the site's key variables such as environmental seasonal hydrological possibilities, a solid groundwater model, site process demands, and site water treatment standards just to name a few. This presentation discusses the planning, design, and execution phases of a sound water management system. It is easy to fall into the trap of only looking at the current state of the site and not the variable life stages of the mine, from construction to expansion to closure. By asking questions about original mine design intent, water flow and quality parameters, owners can bridge the gap between operators and technical staff for more efficient and effective mine water management systems. Raising these necessary questions unlock the opportunities for savings, improved water quality and mitigates risk involved throughout the process of managing water in a mine.

WEDNESDAY, MARCH 2

AFTERNOON

Room 10 | 2:00 PM

MINING & EXPLORATION: INNOVATION & TECHNOLOGY: SUCCESS IN IMPLEMENTING ADVANCED TECHNOLOGIES TO MINING

Chairs: ***S. Cicek****, Nevada Gold Mines, Morgantown, WV*
L. Nkule Sonkeng*, Caterpillar Inc, Marana, AZ*

2:00 PM

Introductions

2:05 PM

Coordinate Systems 101

M. Maier; Engineering, Empire Southwest, Mesa, AZ

The basics of dealing with coordinate systems. I conduct a lot of survey training for construction and mining clients. In every class I usually start off with a "Coordinate Systems 101" lesson. This is something most clients struggle with. I find that there are a lot of people running GPS survey and machine control systems that may not have a basic understanding for how the coordinate systems relate to their jobsites. There are also experienced surveyors that tend to make these topics overly complex for most people trying to understand the basics. Here are some basic coordinate system rules for clarity. Why is this important? Having one global reference frame (WGS84) makes it easier to convert between localized and other older projections. It means we have one system in common with all other projections. Since the 3rd Century BC, when Eratosthenes first invented the geographic coordinate system, every small country in the world has developed their own ellipsoidal projections. We can now convert between any of those projections, as well your local mine or construction site.

2:25 PM

Development of Matrix-Stabilized Repository Backfill (GESAV II Project) and Further R & D Prospects

L. Schaarschmidt; Underground Mining, Technische Universitat Bergakademie Freiberg, Freiberg, Sachsen, Germany

Since decades, extensive research projects have been carried out about disposal of radioactive waste. In Germany, salt formations were chosen as host rock. In order to seal drifts and openings underground, a commonly used material is magnesia cement. It fully solidifies in an early stage and enables fast sealing but the installation effort is quite high. This is what sparked the idea for the GESAV project. The result was the successful development of a matrix-stabilized salt grit backfill that combines the advantages of an early stabilization and easy application underground. Furthermore, a superior backfill method was developed in order to build the backfill bodies. It turned out that inserting the backfill with a dozer and subsequent compressing with a wacker plate brought promising results. Due to the successful completion of the GESAV project, a number of future R & D projects on this topic are planned to be carried out in cooperation with the institutional sponsor, e. g. the SAVER project. Its main goal is to confirm the application of the wacker plate method to GESAV material as well as salt grit. This could result in tremendous reduction of cost and building effort.

2:45 PM

Blast Modeling and Application with a Kinematic Approach

R. Yang; Orica USA Inc, Watkins, CO

Most current blast models cannot simulate all blast design parameters. Most models are built on first principles of physics - strain/stress constitutive relations. The rock constitutive relations for rock blasting are hard/impossible to define. Consequently, such models can only simulate a small number of blastholes. In fact, simulating millisecond interaction and boundary effects of all blastholes/charges is the most required for blast optimization. This paper presents the blast models that were developed using a kinematic approach, which refers to using kinematic quantities such as the peak particle velocity as controlling parameters to model the process. The kinematic parameters are easy to measure in the field. These models simulate all blast design parameters and complex geometries. The models for 3D muckpile formation (3DMuck), the multiple blasthole fragmentation (MBF), blast damage (MBD), dynamic pressure (MBDP) on charges, and the multiple seed waveform (MSW) blast vibration are all applied widely in the field for blast design optimizations. Blast modeling using the kinematic approach results in easy model calibration and effective applications to practical problems.

3:05 PM

A Disruptive Platform to Integrate Mining Data and Augment Knowledge for Real-Time Decision Making

R. Rojas and B. Marsh; Product Management, Eclipse Mining Technologies, Tucson, AZ

The mining industry today utilizes a vast array of technologies that produce a constant stream of multi-faceted data. However, most mines underutilize this potential knowledge to optimize their operations. True agile mining and optimization cannot take place without the integration and full understanding of data across the mine-to-market operation. This paper addresses a case study on how a data platform could integrate the data silos of multiple areas through a common ontology and mine data model regardless of the type and origin of the datasets. SourceOne® is a designed data hub/platform created specifically for the mining industry that attributes "context" at each business process and the holistic system level, ensuring that the back end is built to be compatible with existing and future third-party applications and providers for full integration into the platform. The goal is to enable transformational and disruptive real-time critical decision making in the field based on insights from business intelligence and data analytics to facilitate multidisciplinary teams' true collaboration at the "tactical" and "strategic" levels of the organization and reengineer processes.

3:25 PM

Using Artificial Intelligence for Predicting Near-Real-Time Methane Concentration in Longwall Coal Mining

D. Demirkan, S. Duzgun, A. Juganda, J. Brune and G. Bogin; Mining Engineering, Colorado School of Mines, Golden, CO

Computational fluid dynamics (CFD) modeling is utilized to predict methane (CH4) and potentially explosive gas concentrations in underground longwall coal mines but CFD modeling requires much computational power and time. Therefore, CFD cannot be used for real-time warnings. Artificial intelligence (AI) in combination with multiple methane sensors can provide reliable near-real-time predictions of explosive gas zones near the cutter drums. Researchers use conducted CFD modeling data for training, testing, and validating the AI results in this study. The findings indicate that AI can predict the CH4 content with a ranging accuracy of 70% to 85% based on the CFD data. Future research will include working mine data as well as data from a 1:40 scaled physical longwall mine model.

3:45 PM

Using the Tenets of The Observational Method in Tailing Storage Facilities Management in the Age of Industrial Internet of Things and Digital Twins.

B. Lowry and A. Pienaar; Bentley Systems Inc, Exton, PA

Recent tragic failures of tailings dams continue to afflict the industry and indicate a pressing need to advance the traditional tool-set of tailings dam management practices to incorporate modern technologies. The concept of asset sensorization using principles of Industrial Internet of Things (I-IoT) and creation of "Digital Twins" present a compelling path forward towards this modernization. Tergazhi's Observational Method require that an order of magnitude increase in data generation from I-IoT sensorization be met with equal increase in engineering activities of "scenario planning and design accommodation for unfavorable conditions." "Digital Twins" of Tailings Storage Facilities (TSF) allows engineers to visualize the asset, track changes, and perform analysis to dynamically recalibrate for improved decision making. TSF Digital Twins fundamentally improve TSF management by (1) establishing bidirectionality and iterative improvement of TSF monitoring, (2) streamlining OT/IT/ET linkage in engineering workflows, and (3) completing the cycle of data acquisition, insight recognition, and decision enablement.

4:05 PM

Utilizing Technology to Improve Mine Asset Health Management

L. Nkule Sonkeng; Solutions & Services, Caterpillar Inc, Peoria, IL

Equipment management can be complex and challenging. Mine sites are interested in preventing failures that lead to lost productivity and costly machine repairs, improving equipment reliability, reducing unplanned downtime, and reducing their overall operating expenses. While trying to achieve these goals, they are faced with many barriers with respect to their equipment KPIs, their maintenance skill level, and the planning and scheduling of maintenance and repair activities on site. This is where Condition Monitoring steps in to evaluate equipment and application data inputs i.e. electronic data, fluid analysis results, inspection results, equipment history and site analysis in order to provide maintenance, component replacement, application and repair recommendations. This paper will explore the case study of a mine site that improved equipment availability and reliability by leveraging Condition Monitoring resources and techniques.

4:25 PM

From Blind to Clear View, Integration of Different Systems and How They Helped to Improve the Mine Planning Strategy

C. Calderon Arteaga and K. Anim; Engineering, Golden Queen Mining, Mojave, CA

Located in Mojave, CA, The Soledad Mountain mine is an Open pit Heap-Leach gold Mine, which is operated by Golden Queen Company LLC. under private capital. In an effort to improve the Mine production, Golden Queen adopted a new fleet management system to monitor the operation and ensure plan execution and compliance. Engineering team also implemented new daily and weekly plans, while the Ore Control process was redefined into a new workflow. Mine production was previously managed based on load count sheets, while the ore was survey/flagged in the field, thus leaving no room for effective mine planning. With the technological upgrades, it was possible to integrate the drilling, ore control, dispatching and mine planning, while increasing the production control and the safety awareness of our team. This integration had brought the mine into the digital era and allowed Golden Queen to make informed decisions based on new reports as a Cycle variance/compliance report, Mine Plan Compliance report, equipment KPIs, among others. This presentation will review the status of integrated solutions, challenges that have been faced, and experiences that we have learned during the process.

WEDNESDAY, MARCH 2

AFTERNOON

Room 11 | 2:00 PM

MINING & EXPLORATION: OPERATIONS: OPERATIONAL PLANNING AND OPTIMIZATION

*Chair: **T. Kosciolek**, Coeur Mining*

2:00 PM

Introductions

2:05 PM

Improvement of the Hauling System Through an Idle Times Approach in Open Pit Mines

C. Estrella; Lima, Caterpillar Inc, Lima, Lima, Peru

Hauling material is the most complex system in a mine and is critical to have the best performance, currently improvement have been done with the Fleet Management Systems, but the mines could get more if they define value generator targets of the system. At this mine, the coeficient of variation for the production is 15%, further analysis shows that 5-7% of this variation is attributed to operational problems but the 8-10% restant is caused by the assignability of the trucks in the system and if the variation reduces to 4-5% the production would increase in 2.9-3.0 Mt yearly. There are very variables that influence in the capacity and performance of a hauling system, but the variables with direct control through the use of a Fleet Management System are the idle times for the loaders and trucks. It was analyzed the data of nine months for the multiple relation between: production, idle times, operative times and productivity, then model the behavior of the system and find the ranges of the variables that maximizes the production. With this ranges of variables the reduction in the coeficient of variation of the production and the increase in the output was 4% and 2.9 Mt respectively.

2:25 PM

A Disruptive Platform to Integrate Mining Data and Augment Knowledge for Real-Time Decision Making

R. Rojas and B. Marsh; Product Management, Eclipse Mining Technologies, Tucson, AZ

The mining industry today utilizes a vast array of technologies that produce a constant stream of multi-faceted data. However, most mines underutilize this potential knowledge to optimize their operations. True agile mining and optimization cannot take place without the integration and full understanding of data across the mine-to-market operation. This paper addresses a case study on how a data platform could integrate the data silos of multiple areas through a common ontology and mine data model regardless of the type and origin of the datasets. SourceOne® is a designed data hub/platform created specifically for the mining industry that attributes "context" at each business process and the holistic system level, ensuring that the back end is built to be compatible with existing and future third-party applications and providers for full integration into the platform. The goal is to enable transformational and disruptive real-time critical decision making in the field based on insights from business intelligence and data analytics to facilitate multidisciplinary teams' true collaboration at the "tactical" and "strategic" levels of the organization and reengineer processes.

2:45 PM

Trucks on Trolley: Is More Always Better?

K. Miles; Application Engineering, Komatsu America Corp., Peoria, IL

With the increased emphasis on reducing fossil fuel usage worldwide, many mining companies are looking for more environmentally friendly alternatives to diesel haulage systems. One common alternative, trolley assist, involves overhead power lines feeding electricity directly to the vehicle drive system, effectively bypassing the engine and reducing fuel consumption as well as providing more propulsion power. In large-scale surface mine operations, this alternative application can greatly address fuel consumption as well as fleet size. But a potential application concern is accessibility and utilization of the trolley assist system for large truck fleets. This presentation will evaluate the potential performance impact caused by variable truck fleet quantities and multiple lengths of trolley assist installations.

3:05 PM

Stochastic Optimization of Long-Term Production Schedules with In-Pit Crushing and Conveyance Systems

L. Findlay and R. Dimitrakopoulos; Mining Engineering, McGill University, Montreal, QC, Canada

In-pit crusher and conveyor (IPCC) systems are used to reduce truck haulage costs for open pit mines. Optimizing a production schedule with semi-mobile IPCC requires integrating extraction sequencing, destination policy, crusher relocation, and truck fleet management while considering both operating and capital costs. Mineral supply uncertainty must be considered to manage risk and provide realistic forecasts. An integrated stochastic optimization framework is proposed to produce long-term schedules for mines using semi-mobile IPCC with multiple crushers, stockpiles, and processing streams while considering material properties and managing risk of not meeting production targets. The method is demonstrated using an iron ore deposit.

3:25 PM

Implementation and Scalability of MinePlan Schedule Optimizer (MPSO) for Medium-Term Planning at the Cobre Panama Copper Mine

M. Montenegro Perez[2] and L. Velasquez Acero[1]; [1]Mining Engineering, University of Kentucky, Lexington, KY and [2]First Quantum Minerals Ltd, Vancouver, BC, Canada

Cobre Panama is one of the largest newly developed copper mines with 3.1 billion tonnes of probable and proven reserves. It has achieved commercial production effective Sept 1, 2019. The copper recovery is approximately 90%. The mine is located in the province of Colon, Panama. The complex includes two open pits, one processing plant, two power stations of 150 MW, and one port. During 2020, production was above 205,000 tonnes of fine copper in concentrate, with a projection for 2021 of 330,000 tonnes of fine copper in concentrate. Since the onset of the project, Cobre Panama is testing the MinePlan Schedule Optimizer (MPSO) to assist with the preparation of two-year plans involving multiple pits, multiple destinations, and blending requirements while satisfying comprehensive product quality and quantity requirements as well as physical and technical constraints. MPSO is a new production scheduling tool developed by Hexagon using mixed-integer linear programming (MILP) techniques. This paper provides an overview of the implementation of an MPSO-based mine scheduling process which has been taking on the challenge of producing new schedule scenarios in a minimum amount of time.

3:45 PM

Haul Truck Speed Analysis and Effect on Fleet Optimization

M. Yildirim; Services and Solutions, Caterpillar Inc, Phoenix, AZ

Over the years, truck-shovel operation has been the primary hauling method for open pit mines. According to industry data, numerous studies have addressed optimization of truck-shovel operations. The impact of the haul traffic on the overall productivity, fuel consumption, and other metrics has been difficult to quantify. The misuse of brakes during hauling will cause the trucks to lose efficiency. It will cause extra time and fuel loss which are very critical cost items. This research presents a new intersection passing algorithm based on the priority of each truck at the intersection points. It calculates the criticality based on various parameters such as load status, speed, payload amount, material type, and distance to the intersection. A simulation model is created to measure the effect of the new passing algorithm on productivity, efficiency and fuel consumption. Ad-hoc speed suggestion is also calculated for each truck to use while passing the intersection points. The results of the simulation are compared with other traditional methods such as Loaded Truck First (LTF), First Come First Serve (FCFS), 4-Way stop models.

4:05 PM

Tinguilinta Bauxite Mine Gains 2.23 Truck-Years Through Wenco Centre of Excellence Analysis, Support of Dump Queuing Times

H. Galbraith and D. Wells; Wenco International Mining Systems, Seattle, WA

In March 2020, Wenco International Mining Systems' Centre of Excellence (CoE) commenced its benchmarking analysis of operational technology deployment by DTP Terrassement, contractor miners to Guinea Alumina Corporation S.A.s' Tinguilinta Bauxite Mine. Through its analysis, the Wenco CoE identified significant opportunities to improve operational cycle times through targeted reduction of queueing times at the site's crusher and two ROM dumps. Over the following four-month period, Wenco steered DTP through the additional resourcing and change management of incorporating a second dispatcher exclusively tasked to lost opportunity prevention at dump queues. In October of 2020, subsequent analysis showed the site had reduced dump queue delays by 79.72%, adding 2.23 truck-years in additional productivity. This paper details the scope of the Wenco CoE engagement with DTP Terrassement, the process followed by all stakeholders, and the improved KPIs realized through this benchmarking and change management consultancy.

4:25 PM

Scheduling: Optimisation vs. Field Decisions

A. Wahrer; Mining Engineering, Colorado School of Mines, Golden, CO

Where does optimisation end and mine engineer's knowledge take over? Schedule optimisation results serve a valuable purpose to guide long and mid-range decisions, but sometimes the final, operational plan can't be captured with just logic based conditions. Can software still help to capture the short range needs of a mine planner? What parameters are difficult to optimise based on but still play a role in the short range mine plan and need communicated to operations? A short range mine planner often has a specific sequence in mind and wants to clearly present the logic for that decision. Viewing the sequence in 3D can help both the mine planner and the production team audience understand the reason for the manual sequence which is often based on factors beyond the typical long range optimisation inputs. Examples include specific mill down days, shovel cable moves, community blasting restrictions, and crew shortages. This session will serve as a launching point to discuss what factors are difficult to capture with condition statements alone and require someone with boots on the ground to produce a truly operational plan as well as most effectively present that plan.

4:45 PM

Identifying Best Practices for Improving Mine Design Efficiencies

E. Chmeil[2] and W. Wilkinson[1]; [1]Datamine, Altoona, PA and [2]Fort Hills Energy Limited Partnership, Calgary, AB, Canada

Fort Hills Energy Limited Partnership oil sands mine, located in Alberta, Canada, requires a significant complement of staff to develop accurate mine designs for complex geological conditions. The mine planning business process relies on multiple groups, each with its own expertise, to deliver high-quality and well-sequenced mine plans to mine operations for execution. This paper discusses how the Suncor (Operator of Fort Hills) Fort Hills Mine Technical improved its business processes to meet the demanding challenges of large-scale mining.

WEDNESDAY, MARCH 2
AFTERNOON

Room 16 | 2:00 PM

MPD: CHEMICAL PROCESSING: CHEMICAL PROCESSING OF RARE EARTH ELEMENTS

Chairs: ***T. Larochelle****, Virginia Polytechnic Institute and State University, Sandy, UT*

C. Benson*, University of Virginia, Charlottesville, VA*

2:00 PM
Introductions

2:05 PM

Novel Methods for Bastnaesite Concentrate Leaching

C. Anderson; Colorado School of MInes, Golden, CO

One source of rare earths found in the United States is bastnaesite, a rare earth bearing fluorocarbonate, mined at the Mountain Pass Mine in California. To increase production, it has been essential to optimize existing processes and create new ones to capture current reserves. A research program was run to expand the understanding of the bastnaesite leaching system. With the help of prior knowledge and thermodynamic calculations a novel single stage hydrochloric leach system was created to optimize the rare earth extraction from bastnaesite. Historically, this process has utilized a two-stage leach system involving a high temperature hydrochloric acid leach followed by a caustic crack. A +series of single stage leach experiments were run by reacting locked cycle flotation concentrate with hydrochloric acid to test common leaching parameters. The results of these single stage tests showed rare earth recoveries significantly higher than reported recoveries of historic two stage caustic crack processes, all while decreasing the amount of reagents needed.

2:25 PM

Selective Recovery of Critical Minerals from Acid Mine Drainage (AMD) and Its Treatment Byproducts

Z. Cicek and Q. Huang; Mining Engineering, West Virginia University, Morgantown, WV

Acid mine drainage (AMD) is a long-standing challenge encountered by the mining industry globally, which imposes severe risks to receiving water and soil due to its high acidity and elevated concentrations of metals. However, past and ongoing research have suggested AMD and its treatment sludges are promising sources of various critical minerals (CMs), including rare earth elements (REEs), cobalt, manganese, and lithium. Therefore, if a new treatment strategy is developed, AMD and its treatment byproducts can be turned from a mine waste to a feedstock of strategic, critical elements. In this study, various AMD samples have been characterized for the full range of CMs. Characterization study results indicate that a significantly high content of CMs is seen in several AMD sludge materials. For example, around 2189.5 ppm of REEs, 13.3% aluminum, 2.0% magnesium, 2.8% of manganese, 3229.8 ppm of lithium, 186.8 ppm of cobalt have been detected from one sludge sample collected. Following the identification of promising feedstocks, a separation approach has been under development to recover multiple individual CM pre-concentrates, which are ready for downstream extraction and purification.

2:45 PM

Solvent-Driven Fractional Precipitation for Purification of Lanthanides from Permanent Magnet Leachates

C. Stetson[1], D. Prodius[2], H. Lee[1], C. Orme[1], D. Ginosar[1], I. Nlebedim[2] and A. Wilson[1]; [1]Idaho National Laboratory, Idaho Falls, ID and [2]Ames Laboratory, Ames, IA

Global demand for critical materials required for next-generation technologies is projected to surpass production in the coming years. Lanthanides such as neodymium, praseodymium, and dysprosium face supply shortages due to the increase in production of permanent magnets for electric vehicle motors and wind turbines. Advancements in recycling technologies will contribute to supply security by enabling economical and efficient reuse of strategic rare earth elements. An underexplored hydrometallurgical processing route in permanent magnet recycling is solvent-driven fractional precipitation. In this pathway, a water-miscible organic solvent is dissolved into the magnet leachate, saturating the aqueous system, and driving salt precipitation. Through control of process conditions, selective precipitation is induced, yielding a high separation factor for purification of lanthanide salts from mixed salt solutions. The volatile nature of the solvent facilitates solvent recovery and reuse, circumventing adverse chemical changes to the treated solution. Solvent-driven fractional precipitation presents an opportunity for energy- and reagent-efficient recycling of critical lanthanides.

3:05 PM

Design and Testing of an Integrated Pilot-Scale AMD Treatment and Rare Earth Recovery Process

A. Noble[1], T. Larochelle[1], J. Constant[2] and P. Ziemkiewicz[2]; [1]Virginia Tech, Blacksburg, VA and [2]West Virginia University, Morgantown, WV

Acid mine drainage (AMD) is a promising source of critical minerals and rare earth elements (REEs), particularly the heavy and critical REEs essential for clean energy technologies. Over the last four years, researchers at West Virginia University and Virginia Tech have developed an integrated beneficiation process that first captures and preconcentrates the REEs from raw AMD and then refines those materials to a high purity mixed REE oxide (MREO) and ultimately into individually separated oxide and metal products. Results to date from laboratory and bench-scale testing have shown that the process is highly efficient, with overall recovery values exceeding 90% and final product grades greater than 95% MREO. Current efforts seek to continue the scale up of this technology by constructing an integrated AMD treatment and REE pilot facility at an active AMD treatment site. During the spring and summer of 2021, the team initiated construction activities for the pilot plant at a host site near Bismarck, WV. This presentation will describe the field work along with other ongoing efforts to further develop the technology.

3:25 PM

Scaled-Production of Rare Earth Oxides and Critical Materials from Coal-Based Sources

R. Honaker[1], M. Free[3], J. Werner[1], A. Noble[2], W. Zhang[2] and X. Yang[1]; [1]Mining Engineering, University of Kentucky, Lexington, KY; [2]Mining & Minerals Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA and [3]Metallurgical Engineering, Utah System of Higher Education, Salt Lake City, UT

A projected exponential increase in the production of electric vehicles and high-end advanced technologies including those used in the defense industrial is expected to require nearly double the amount of rare earth elements (REEs) and critical elements currently available worldwide. As such, recovery from secondary sources such as coal and coal byproducts may be needed to meet the increased demand. A project has been initiated to evaluate methods and technologies integrated in an existing rare earth pilot plant that have the potential to improve the economics of extracting rare earths and critical materials from coal-based materials. This presentation will provide details about the technologies and results from pilot plant testing.

3:45 PM

The Effect of Mechanical Grinding and Thermal Treatment on the Recovery of Rare Earth Elements (REEs) from Kaolinite

B. Ji and W. Zhang; Mining and Minerals Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA

REE recovery from a kaolinite sample was conducted in the present study. Mineralogical analyses, salt leaching, and acid leaching test results confirmed that REEs predominantly existed as florencite (REEAl3(PO4)2(OH)6) in the material, and the proportion of ion-exchangeable and ion-substituted REEs were negligible. Mechanically grinding for 4 h completely destroyed the crystal structure of the material, but the recovery of total REEs was less than 20%, indicating that the unsatisfactory recovery was unlikely due to insufficient liberation of the REE-bearing particles. Thermal treatment of the raw material at 600 °C for 2 h largely enhanced the total REE recovery to as high as 92%. The improved recovery was ascribed to the thermal decomposition of crystallized florencite into an amorphous phase, which was proved through transmission electron microscopy - energy dispersive X-ray analysis. Findings from the study will contribute to REE recovery and comprehensive utilization of kaolinite.

4:05 PM

The White Mesa Mill: 40+ Years of Ingenuity in Sustainable Critical Materials Production

P. Keller and D. Kapostasy; Technical Services, Energy Fuels Resources (USA) Inc., Lakewood, CO

Commissioned in 1980, Energy Fuels' White Mesa Mill in southeastern Utah has a storied history of sustainably processing critical materials from many different feedstocks. From processing conventional uranium ores to recovering uranium from various alternate feed sources, the Mill has demonstrated ingenuity and resilience in adapting to the changing landscape of critical materials processing. Energy Fuels is now processing monazite, a radioactive byproduct from heavy mineral sand deposits around the world that contain high rare earth concentrations. Energy Fuels intends to produce separated rare earth products to restore the North American supply chain, leveraging the company's extensive solvent extraction experience.

WEDNESDAY, MARCH 2

AFTERNOON

Room 17 | 2:00 PM

MPD: CHEMICAL PROCESSING: REES AND EVS RECYCLING AND HYDROMETALLURGY OF CRITICAL METALS

Chairs: ***Z. Cicek****, West Virginia University, Morgantown, WV*
D. Talan*, West Virginia University, Morgantown, WV*

2:00 PM

Introductions

2:05 PM

Gold Nanoparticle Synthesis and Design from Gold Chloride and Gold Cyanide Systems

K. Bozer and C. Young; Metallurgical Engineering, Montana Tech of the University of Montana, Butte, MT

Purple of Cassius is a method where gold chloride and tin chloride solutions are mixed to form gold nanoparticles and tin oxide precipitate under acidic conditions. However, it can be modified by adding hydrazine to resolubilize the tin oxide and provide a more stable solution of only gold nanoparticles. A three-factor central composite statistically designed model was created using Design Expert incorporating pH, temperature, and gold concentration as the variables. The response of gold nanoparticle size was measured with both scanning electron microscopy and dynamic light scattering. Comparisons are made to gold nanoparticles made by reacting gold cyanide with oxalic acid under basic conditions in which a similar statistical designed model was used. For both models, tests were conducted in the absence and presence of a thiol stabilizer.

2:25 PM

Physical and Chemical Separations of End-of-Life Lithium-ion Battery Components

Y. Smith; Metallurgical Engineering, University of Utah, Salt Lake City, UT

In the near future, electric vehicles are projected to be the most dominant lithium-ion battery (LIB) application in the market. These end-of-life batteries are high grade and viable secondary resources for numerous battery metals and materials (i.e., lithium, cobalt, nickel, manganese, and graphite). This presentation will focus on physical and chemical methods developed in our group to recover and separate valuable end-of-life LIB components. The hybrid hydro/pyro-metallurgical process developed presents many advantages such as increased recovery of cathode material, carbon-free thermal reduction of transitional metals, and lower processing energy, water, and cost requirements.

2:45 PM

Recovery of Nickel, Cobalt, Iron, and Rare Earth Elements from Low-grade Philippine Laterite Ores using Atmospheric Leaching with Reduction Pre-treatment

E. Daruca, G. Bello, C. Arnejo, C. Naira, R. Perucho and J. Calvez; Metallurgical Technology Division, Mines and Geosciences Bureau, Quezon, Metro Manila, Philippines

Due to the rapid depletion of high-grade laterite ores, methods for processing low-grade ores to obtain high purity leaching products are currently being explored. In this study, reduction pre-treatment is done prior to the atmospheric leaching of limonitic laterite ores to produce a nickel-cobalt-rare earth elements-rich leach solution and iron-rich magnetic residues. The leaching of pre-treated ore resulted in higher recovery of Ni, Co, and REEs, specifically scandium, with minimal recovery of impurities, such as Fe and silica, when compared to the yields from the leaching of untreated ore. Effects of reduction temperature and time, lixiviant type, pH, leaching temperature and time, and solid-to-liquid ratio were also analyzed using a 2k Fractional Factorial Design of Resolution IV. Analysis of Variance showed that all the factors have significant effects on the leaching behaviors of the following, with reduction temperature being the most significant in the recovery of Ni, Co, Fe, and s/l ratio for the recovery of SiO2. Recovery values from the screening experiments ranged from 55-90% Ni, 37-84% Co, 1-58% Fe, and 0-39% SiO2. The parameters will be then subjected to optimization.

3:05 PM

Hydrometallurgical Recovery of Cobalt, Nickel and other Valuable Metals from Primary Lead Blast Furnace Slags

B. Tanda; Research and Development, Doe Run Company, Saint Louis, MO

Doe Run has developed a patented process for the hydrometallurgical recovery of zinc, nickel, lead and copper found in historic smelter slags. Acidified chloride extracts greater than 90% of the metals of interest that could be recovered using a variety of techniques including solvent extraction, ion exchange, electrowinning, precipitation and cementation

3:25 PM

Microwave Processing of End-of-Life Fluorescent Lamp Phosphors for Recovery of Rare-Earth Values

N. Dhawan and N. SHUKLA; Metallurgical & Materials Engineering, IIT-Roorkee, ROORKEE, Uttarakhand, India

In this study, recycling of spent tubular lights comprising about 30 % rare earth (Y, La, Ce, Eu, Tb) elements are explored. Different routes comprising one step, two-step, and acid baking in the microwave were compared based on the recovery of rare earth values. Two-step process consisting of acid leaching followed by NaOH microwave treatment of leach residue was found best concerning overall extraction and separation of Y-Eu and La-Ce-Tb oxides. A novel processing route of microwave-assisted acid baking followed by water leaching of waste phosphor retrieved from end-of-life fluorescent lamps is investigated. It was found that the microwave baking at 800 W for 3 min at 1 mL/g acid ratio yielded 82.5% overall rare-earth dissolution, including 93.6% terbium, 39.6% lanthanum, and ~100% europium and yttrium dissolution. Cerium dissolution was negligible in the investigated experimental conditions. The dissociation of the LaPO4:Ce3+Tb3+ phase governs the overall rare earth dissolution during the baking process. The material balance and cost estimations are also carried out.

3:45 PM

Precipitation of Cobalt and Manganese from Low Concentration Aqueous Solutions

Y. Shekarian, B. Vaziri Hassas, M. Rezaee and S. Pisupati; Energy and Mineral Engineering, The Pennsylvania State University, University Park, PA

Increasing global demands for cobalt and manganese have raised the need to develop processes/technology for economically recovering Co-Mn from low-grade ores and secondary sources. Acid mine drainage (AMD) is a waste stream associated with coal and sulfide minerals, which need to be treated before being discharged to the environment. Depending on the sources, AMD could contain a favorable amount of Co and Mn. However, the removal/recovery of these elements from AMD during the treatment process is challenging due to the required pH and Eh for their precipitation. Various paths including hydroxide, carbonate, sulfide and oxidative precipitation, solvent extraction, and ion exchange have been reported for recovery of these elements from aqueous solutions. This research investigates the most effective process/ligands for the recovery of these elements from AMD and discusses the results.

4:05 PM

The Effect of Combustion on the Leachability and Occurrence Modes of Rare Earth Elements (REEs) in iPhones

B. Ji, Z. Zhou and W. Zhang; Mining and Minerals Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA

Rare earth element (REE) recovery from secondary resources such as electrical waste is critical due to the imbalance between the supply and demand of REEs. The present study aims to investigate the effect of combustion on the leachability and occurrence modes of REEs existing in iPhones. Dissembled iPhones with the battery removed were combusted at 400°C, 600°C, 800°C, and 1000°C, respectively. Sequential chemical extraction (SEC) tests were performed on the original and combusted iPhones. Test results showed that the leachability of total REEs from the original iPhone is minimal (14 mg/kg), however, the leachability was largely improved after combustion, with the highest leachability of 3121 mg/kg being obtained through combustion at 600°C. Most leachable REEs in the 600°C-combusted iPhone occurred as acid soluble and oxidizable forms (2185 mg/kg and 910 mg/kg, respectively). Smaller leachabilities of 2930 mg/kg and 1833 mg/kg were obtained by combusting at 800°C and 1000°C, respectively, primarily due to the conversion of acid soluble REEs into difficult-to-leach forms. The results indicate that combustion at a correct temperature improves REE leaching recovery from iPhones.

WEDNESDAY, MARCH 2

AFTERNOON

Room 14 | 2:00 PM

MPD: FLOTATION: FUNDAMENTALS TO APPLICATIONS II

Chairs: ***Z. Zanetell****, Newmont*

D. Lelinski*, Midvale, UT*

2:00 PM

Introductions

2:05 PM

Full Scale Trial of the REFLUX™ Flotation Cell

L. Christodoulou[1], B. Dabrowski[1], S. Iveson[2] and K. Galvin[2]; [1]FLSmidth Inc, Midvale, UT and [2]Chemical Engineering, The University of Newcastle, Callaghan, NSW, Australia

The REFLUX™ Flotation Cell has previously undergone extensive laboratory and pilot scale investigation, achieving a remarkably high level of separation performance at throughputs vastly higher than considered appropriate in more conventional flotation devices. This performance is achieved by operating with a concentrated bubbly zone, rather than a froth zone, permitting strong counter current washing of the concentrate. A lower system of parallel inclined channels delivers the critical system control, ensuring the bubbles can segregate from the tailings flow, in turn increasing the gas hold-up in the concentrated bubbly zone. This enhanced segregation also permits decoupling of the gas and liquid fluxes reporting to the concentrate, ensuring the concentrate can be recovered at a reduced water recovery. This paper discusses the challenges of delivering a successful full-scale trial of a new technology, recognising that innovation is defined by both the novel device, and importantly the way it is deployed. Results from the recent trial confirming the up-scaling of the system hydrodynamics, and hence the separation performance, are presented.

2:25 PM

Enhanced Flotation of Ultra-fine Apatite and Ca-Al Phosphate from Quartz and Muscovite Using Eriez' Column Flotation Technology

M. Fan[1], A. Hobert[1] and W. van Dyk[2]; [1]Eriez Flotation, Eriez Manufacturing Co., Erie, PA and [2]Itafos, Engineering, R&D and Development, Itafos, Houston, TX

Low flotation recovery and selectivity have been long-standing problems in the treatment of most ultra-fine phosphate ores. This paper investigates the improved flotation of two ultra-fine Brazilian phosphate ores from Itafos' Arraias project. These ores are dominantly composed of quartz, muscovite, apatite and a Ca-Al phosphate. As a result of fine phosphate dissemination and associated grinding requirements, column flotation was selected for the metallurgical test program to address the inherent limitations of fine particle flotation using conventional flotation cells. Accordingly, both benchtop Denver cell and laboratory column flotation tests were conducted to optimize their respective flotation responses. Improved flotation performance was achieved using column flotation as compared to benchtop mechanical flotation. In column flotation, a P2O5 concentrate grade of 30.5-31.0% was yielded at a flotation recovery of 83.7-85.1% for the 38x0µm milled fines. The benefits of Eriez' column flotation technology realized from this study include a higher degree of selectivity, increased recovery, and reduced collector dosage as compared to bench-scale mechanical flotation.

2:45 PM

Rotor Stator Configuration and its Effects in the Laboratory Bench Scale Development of the WEMCO NextGEN

J. Bowden and I. Coltrin; Mining R&D, FLSmidth, Bethlehem, PA

WEMCO flotation cell technology was first developed in the 1930s, updated in 1968 and has been the same ever since. Although this robust and impressive design has been a technology standard for many decades, FLSmidth has set out to improve the design of the rotor and stator configuration for the WEMCO flotation cell for improved metallurgical and kinetic performance. A robust bench scale testing plan via DOE was executed to evaluate the impacts of varying rotor and stator configurations on the hydrodynamic and kinetic performance. Variable factors included rotor geometry, rotor cavity size, number of stator blades, stator width, stator distance, and stator slots. A laboratory bench scale testing unit was setup according to the method established by R. Silva. It is shown that improved pumping, improved air flow, and reduced power draw are achievable. Continuous bench tests were conducted at a copper mine to relate the hydrodynamic effects with the kinetic effects of rotor stator configuration. This information shows promise for an improved rotor stator configuration at larger scales with improved kinetics and metallurgical performance and provides a path forward at the pilot scale.

3:05 PM

Metallurgical Testing and CFD Simulation of StackCell® SC-50 High-Rate Flotation Machine

E. Dohm[2] and H. Fayed[1]; [1]R&D, Narmer-engsim LLC, BLACKSBURG, VA and [2]Product development and commercialization, Eriez Manufacturing Co., Erie, PA

An extensive field test was conducted to evaluate the operability and performance of a StackCell® SC-50 high-rate flotation machine for recovery of copper and molybdenum from flotation tailings. The field test of the 15-m3 StackCell® flotation cell was conducted at a copper concentrator tailings facility in North America. The metallurgical results demonstrate that the StackCell® technology provides a unique solution for recovering metal values from tailings, with excellent selectivity and improved flotation kinetics as compared to conventional mechanical flotation machines. The metallurgical advantages of the StackCell® are particularly pronounced for treating fine tailings, with upgrade ratios greater than 12 achieved at copper and molybdenum recoveries of 20% and 28%, respectively, within approximately one minute of flotation residence time. CFD simulations conducted to explain the fundamentals of the findings from metallurgical measurements. The simulations show high levels of turbulent dissipation rates in the canister that are nearly 5 times that of conventional flotation machines. The high levels of turbulent dissipation enhance attachment rates of fine particles and bubbles.

3:25 PM

Turbulence Profile Study for Pulp Phase in Mechanical Flotation Cells

W. Xie; Chemical Engineering, University of Minnesota Duluth, University of Minnesota Duluth, Duluth, MN, US, academic, Duluth, MN

Turbulence has long been considered an important factor affecting flotation performance since it affects the three main sub-processes: air dispersion, particle suspension and bubble-particle collection interactions. In addition, entrainment of fine particles is also affected by turbulence. However, it has always been an enormous scientific challenge to quantify turbulence in multiphase flows. In this research, the turbulence profiles have been measured by electrical resistance tomography (ERT) in a 3m3 air/water flotation cell and a Metso 3m3 industrial flotation cell. This methodology can be potentially used to minimize energy usage in the mineral industry and maximize the flotation performance.

4:05 PM

Investigation of the Impact of Solid Percent of Pulp on the Flotation Performance

F. Dehghani and T. Ghosh; Department of Mining & Mineral Engineering, University of Alaska Fairbanks, Fairbanks, AK

In the Red Dog Mine due to unfavorable climate conditions replacing freshwater resources with old ones is not affordable. However, water treatment seems to be a reliable solution to recycle a greater percentage of the used water within the flotation cycle, but It is expensive, and the chemical properties of the recycled water are dissimilar to that of freshwater due to remaining a number of chemicals and components after water treatment. The chemistry of water is very critical to the effectiveness of the flotation as there is a great concern about the possible influence of recycled water on the efficiency of flotation. In this research, in order to decrease water consumption in flotation circuits, solid percent in the pulp increased. However, increasing solid percent in the flotation circuits would affect the grade and recovery of the flotation process. In the next step, these effects were investigated and any negative effect was modified. A series of controlled experiments were conducted by various solid percent. To optimize the flotation performance, several parameters were controlled and tested. They include type and dosage of the chemicals, pH/Eh, bubble sizes, and turbulence

WEDNESDAY, MARCH 2

AFTERNOON

Room 15 | 2:00 PM

MPD: FRANK F. APLAN: BETWEEN THEORY AND PRACTICE II

Chairs: ***K. Osseo-Asare****, The Pennsylvania State University*
C. Young*, MT Tech, Butte, MT*

2:00 PM

Introductions

2:05 PM

Influence of Substrate Roughness on Particle Adhesion and Concentration

B. Moreno Baqueiro Sansao[1], J. Kellar[1], W. Cross[1] and A. Romkes[2]; [1]Materials Engineering and Science, South Dakota School of Mines and Technology, Rapid City, SD and [2]Department of Mechanical Engineering, South Dakota School of Mines and Technology, South Dakota School of Mines and Technology, Rapid City, SD, US, academic, Rapid City, SD

The interaction of particles with substrates of different roughness was investigated. Particle surface treatment, relative humidity (RH) and surface roughness levels were controlled in order to achieve separation of different particles. In tests with sanded glass disks, the interfacial energy hydrophilic glass beads was highly variable at 40% RH, showing non-uniformity of area of contact between particles and substrates. For stainless-steel mesh substrates, the asperities and particle dimensions were comparable. The smaller particles had more contact area with the substrate than the larger particles. For the hydrophilic beads the recovery was 92.5% on average, when the RH was between 46% and 85%. For the hydrophobic beads, the average recovery was 19.0% between 46% and 75% RH. The particle's hydrophobicity reduced the interaction with the mesh substrate. The difference in recovery can be exploited to achieve separation of particles based upon adhesive forces.

2:35 PM

X-ray Computed Tomography Evaluation of Crushed Copper Sulfide Ore for Pre-Concentration by Ore Sorting

J. Jin1, C. Lin1, J. Miller1, C. Zhao2 and T. Li3; 1University of Utah, Salt Lake City, UT; [2]Dadi Engineering USA, Inc., Kellogg, ID and [3]Tianjin Meiteng Technology Co., Ltd., Tianjin, China

A large portion of energy consumption in copper concentrators is to reduce the particle size by crushing and grinding. If low-grade particles of cm size can be removed from processing, the pre-concentration of ore will largely reduce the cost of metal production. Two copper sulfide ore samples from Arizona have been analyzed by Micro X-ray Computed Tomography (Micro-XCT) to determine the grade of copper sulfide in each particle. For the 3×1 cm size, Micro-XCT grade results for 35 particles at a resolution of 40 µm are consistent with the results for 500 particles at a resolution of 125 µm. For copper ore A, a significant amount of copper sulfide occurs in grains of mm size and are concentrated in certain particles. A number of particles in sample A contain very low amounts of copper. However, in sample B, distribution of copper sulfide is mostly dispersed in each ore particle, so for the particle size class of 3×1 cm liberation of copper sulfide and gangue minerals is not significant. For copper ore A, a copper recovery of 90% is expected at 50% mass rejection during pre-concentration by sorting. Pilot scale sorting results are compared to the separation based on XCT analysis.

3:05 PM

REE Precipitation and Formations in Presence of Various Ligands

B. Vaziri Hassas, Y. Shekarian, M. Rezaee and S. Pisupati; Energy and Minerals Engineering, Penn State, State college, PA

A recent analysis of Pennsylvania acid mine drainage (AMD) streams that originate from abandoned mines, and coal refuse streams revealed that these streams contain not only favorable quantities of rare earth elements (REE) but also high HREE/LREE ratios. AMD streams, however, pose environmental concerns and hence are treated before being discharged to the environment. A sustainable AMD treatment practice is to recovery REE and other critical elements while treating to address the environmental concerns. However, the REE recovery directly from AMD is challenging due to the very low REE concentration (typically in the order of hundreds of ppb). This paper presents an ongoing work on the recovery of rare earth and critical elements from AMD through staged precipitation process and utilizing various ligands, and discusses the elemental recovery, formation and structure of precipitates, and kinetics of the precipitation.

3:35 PM

Berkely Pit Water: Evolving Chemistry and Estimation of Thermodynamic Data

H. Huang, C. Young, L. Twidwell and D. Tahija; Montana Technological University, Butte, MT

The Berkeley Pit in Butte, Montana is a large open pit mine that began to flood with AMD in 1982 after both mining and pumping were stopped. Since then, its water at various depths has been regularly sampled and analyzed by the MBMG. Metal concentrations have been noted to change with time but trends varied particularly when the water was being processed by copper cementation and/or dual-stage lime precipitation. The concentrations and processes are discussed based on thermodynamic models determined with StabCal using data estimated from NBS data and HKF principles. The models are deemed to be valid and generally illustrate that Fe concentrations are controlled by the precipitation of Schwertmannite, KH-Jarosite, H-Jarosite and K-Jarosite depending on the level of DO.

4:05 PM

The Reprocessing and Revalorization of Critical Minerals in Mine Tailings

B. Arnold and C. Vitti; The Pennsylvania State University, University Park, PA

Mine tailings, the byproduct of mining and mineral processing, are increasingly mass produced as a result of increased demand for metals and minerals as well as the advancement in technology that allows for the exploitation of lower grade ores. As the volume of tailings continues to grow, the possibility of the presence of critical minerals and other valuable metals heightens as well. The practice of reprocessing, while relatively new, is crucial to reducing environmental damages, obtaining valuable critical minerals from waste, and contributing to more sustainable repurposing and disposal methods. With the increase in tailings dam failures in recent years, there is a large motivating factor in remining for the safety of potentially impacted communities. In analyzing the perspectives of various domestic and international studies, this literature review discusses the feasibility of reprocessing and reutilizing mine tailings waste for a more sustainable future while exploring current practices that have benefitted ecosystems and communities.

WEDNESDAY, MARCH 2

AFTERNOON

Room 18 | 2:00 PM

MPD: PLANT DESIGN II

Chairs: ***S. Amini****, West Virginia University, Morgantown, WV*

R. Dube*, Outotec, Centennial, CO*

2:00 PM

Introductions

2:05 PM

Froth Launder Modification in 300m3 Flotation Cells at Kennecott Copperton Concentrator

R. Dube[1], T. Perkins[2] and G. Bermúdez[1]; 1Metso Outotec, Denver, CO and [2]Rio Tinto, Bingham Canyon, UT

The Kennecott Copperton concentrator is currently the bottleneck for the Kennecott operation and thus several steps were taken to increase throughput at the concentrator. This increase in grinding circuit throughput resulted in coarser grind size which then feeds the flotation circuit. 300m3 Metso Outotec flotation tank cells are currently utilized as rougher flotation circuit at the Copperton concentrator. Higher overall recoveries have been observed on the newer Outotec tank cells compared to the original 85m3 self-aspirated flotation cells they replaced. However, coarse particle flotation response on these large forced air cells did not show encouraging results when compared to smaller cells they replaced. This has been attributed to the longer froth transport duration and transport distance on large cells (100m3 and larger). Cell manufacturers addressed the risks of additional coarse particle losses in large cells by installing concentric circumferential launders and crowders (also called center launders). A trial set of the center launder retrofits were installed on the last three tank cells in one of the parallel rougher flotation rows at the concentrator.

2:25 PM

Leveraging Legacy Capacity: Retrofitting Tank Houses To Capture More Value (NOW) and Facilitate Shutdown (LATER)

P. James; Blue Planet Strategies, Madison, WI

Under-utilized EW capacity provides opportunity to increase current production and prepare for improved shutdown treatment of leach solution by leveraging legacy infrastructure. Upgrading existing EW cells can create NEW dual capabilities of profitable EW from low tenor sources (EXTRA PRODUCTION NOW) and advanced wastewater treatment via low-cost neutralizer generation to treat drain down solution (SAVINGS and POTENTIAL REVENUE LATER). The new capabilities afford indirect benefit; extending operation production life and forestalling the transition to closure to delay closure costs and garner substantial value. Focused infrastructure retrofit provides the capabilities at substantially lower implementation cost over a stand-alone system. Modeled application to a representative case for a SX/EW operation will be considered examined at a high-level view to illustrate and quantify what such a conversion might look like and what associated projected revenues and cost saving result. Salient performance results for selected aspects of the treatment on representative target solutions will be noted and used to provide relevant underpinnings for the targeted tank-house conversions.

2:45 PM

Parameter Optimization for the Process Of Green Pellet Formation of Iron Ore Fines Through Kinetic Approach

H. Patel[1] and D. Patra[2]; 1McClelland Laboratories Inc, Reno, NV and [2]ArcelorMittal Nippon Steel India Limited, Surat, India

The growth of the Iron and steel industry in India has been exponential. A kinetic study to optimize different parameters has been carried out with a view of possible applications to utilize low-grade iron ore. The kinetic study is often used to study the rate of a process with optimized parameters and their effectiveness. Different parameters like Moisture, rotations, and angle of the Pelletizers were optimized at the first stage. In the second stage, a time-based study has been carried out to see the effectiveness of the parameters. The major responses selected were moisture, rotation of the pelletizer, Drop numbers and Green Compressive Strength relations were established and studied thoroughly. The importance of the study would help to design future plants and unit operations having a similar characteristic of ore. Finally, the optimized values for the test work obtained were 20 min for palletization time, 0.98 (kg/pellet) for Green Compressive Strengths, 12% for moisture, and 8.1 Mean Diameter Number with 0.5% bentonite as a binder. The results demonstrated that Goethite Iron ore could be used to produce Pellets with Optimal variables.

3:05 PM

Conversion of Copper Cyanide to Cuprite

P. Moyo[1], S. Dixon[3], R. Norcross[2] and J. McPartland[4]; [1]Cyanco, Sparks, NV; [2]Cyanco, Sugar Land, TX; [3]SND Consultants, Tucson, AZ and [4]McClleland Laboratories, Sparks, NV

The separation and recovery of copper from cyanide solution has been investigated since the early 1900's. The precipitation of copper using sulfide ion was patented in 1911 by Williamson, published by Leaver & Woolf of the USBM in 1931 and Cyanamid in 1960's. The current practice of sulfide precipitation is used in various processes such as "SART". The precipitation of copper sulfide requires the pH of the clear solution be in the range of 4-6. The addition of sulfide ion is usually 120% of stoichiometric requirement. The precipitation of copper cyanide requires the pH of the clear solution be in the range of 2-3. Copper sulfide may be sold to smelters. The sale of copper cyanide is a challenge because cyanide content. Past work has focused on the use of boiling sulfuric acid as published by Seracini in 1995. The current paper describes a simple process to convert copper cyanide to cuprite using sodium hydroxide. The cuprite may be sold to smelters or used as feed to an electrowinning circuit to produce cathode.

3:25 PM

Greenfield Project Development for Gold Process Plant in Saudi Arabia

J. Faul; Metso Outotec, Espoo, Finland

Plant Solutions is a key part of the Metso Outotec offering, which encompasses expertise from testwork and research and development, process design and optimization, equipment selection and sizing, plant engineering, and plant productization. Depending on the Plant Solution case, Metso Outotec's offering can extend further to site activities, including installation and commissioning services, production ramp-up and plant performance trials, as well as maintenance and spare part services. The Metso Outotec Plant Solutions presentation provides an overview of the Minerals Processing and Metals areas within the Metso Outotec sphere together with Plant Solutions, and then focuses on a recent gold project in Saudi Arabia where Metso Outotec together with a partner, provided a full rock-to-gold solution." This presentation aims to show the different stages of development of this gold processing plant in Saudi Arabia and challenges associated with the project. It would also show the current status of construction and expected timeline to commissioning the complete processing plant.

3:45 PM

Making Everything Fit! Thickener Retrofits Challenges

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Mineral plants attempt to improve installed thickener's performance will likely include retrofitting with the latest feedwell technology. The design of this fundamental piece is even more critical when the plan includes increased plant throughput, resulting in greater hydraulic capacity. This potentially leads to costly modifications on the tank sidewall and other hydraulic dependent parts of the thickener. Making everything fit, increase performance, and push the capacity of existing tank design is a challenge. This paper presents a case study results of how the patented EvenFlo® feedwell will increase the capacity of multiple thickeners without major tank modifications reducing cost and improving thickener performance.