TECHNICAL SESSIONS

MONDAY, FEBRUARY 26
AFTERNOON

1:30 PM | ROOM L100A

Dreyer Lecture

Recipient and Lecturer: *Robert Schafer*

Lecture: TBD

MONDAY, FEBRUARY 26
AFTERNOON

2:00 PM | ROOM 200ABC

6th North American Iron Ore Symposium: Mining & New Projects

Chairs: *G. Hudak, University of Minnesota*
D. Gagnon, DRA Americas

2:00 PM
Introduction

2:05 PM
Advantages of Using UAVs in Pueblo Viejo
J. Ozoria; Mining, Dominican College Of Engineers, Architects and Surveyors (CODIA), Santo Domingo, Santo Domingo, Dominican Republic

The time in projects of any kind has always been a fundamental issue from the start of construction to the operation itself, when it comes to earthworks on a large scale such as an open-pit mining operation; it is when we realize how valuable it's the time. The main objective of this presentation is to expose the advantages that make the UAV technology in mining a valuable and important tool for the management of geospatial information more efficiently and the control of the different material types in a mine with space limitation asPV. it will show the benefits of managing a mining operation with UAV. Substantial improvements in Pueblo Viejo from the area of safety, efficiency, quality and planning once implementation began. Today in Pueblo Viejo there are many applications that are carried out day by day with the use of UAVs. From the end of month report, stockpile inventory, construction monitoring, mine plans, slope monitoring, blast analysis, chess reporting. Undoubtedly, the UAVs in Pueblo Viejo came to stay, since the limitation of space and having different material types being dumped on top or beside each other. With the incorrect tracking the control of grades will be lost.

2:25 PM
An Evaluation of Rock Weathering Experiments at the MN DNR Hibbing Laboratory and Field Research Site and Their Importancein Developing Geochemical Models
S. Koski and Z. Wenz; Minnesota Department of Natural Resources, Hibbing, MN

Since the mid 1970's, a focus of the DNR Hibbing laboratory and field research site has been the development and evaluation of the humidity cell kinetic test procedure and field scale rock weathering experiments. These experiments have allowed for the assessment of the relationship between sulfur concentrations, leachate pH and solute release rates for varying rock types and mine wastes along with the ability to understand rock weathering geochemistry over decades of monitoring. In 2014 an experiment was initiated to develop a laboratory rock weathering procedure that would allow leachate solute concentrations to become limited by mineral saturation and sorption. The experiment consisted of standard humidity cells, a variant of the humidity cell, and 4 kg rock filled columns. The different experiment methods using the same two rock types have shown that similar rock types may generate different leachate compositions when following different experiment protocols. This can provide insight into geochemical processes occurring in these experiments and may allow for more accurate representations of full scale mine waste weathering and data to be used in geochemical modeling.

2:45 PM
Automation Application Realities for North American Iron Ore Laboratories
B. McBain; IMP Automation Canada Ltd., Oakville, ON, Canada

Extensive experience has been gained in the mechanization and automation of iron ore laboratories since the mid-2000s, when the first series of IMP automated labs gained a foothold in the Australian mining sector. Because of the large scale operations that often handled sample streams from several mines, these labs feature front-to-back automation that manage several hundred to a few thousand samples per day. In addition, a stringent focus on safety and regulatory compliance resulted in design strategies to limit worker access and ergonomically-challenging demands. IMP's first North American iron ore lab opened in 2014 at the TATA Steel Mineral Canada site near Schefferville, Quebec, but for various reasons this lab is a hybrid of manual and pseudo-automated processes. For the North American market, there are automation considerations to be made on the basis of lessons learned in both Australian and Canadian labs. This presentation will review the practical importance of such factors as mine output and ore type, labour factors, safety requirements and specialty iron production. It will also discuss some of the aspects to be considered in port laboratory specifications.

3:05 PM
Dominga Iron Project Update – Andes Iron
M. Rojas[1], H. Alegria[1], F. Porcile[1], M. Mlinar[2] and B. Eisenbraun[3]; [1]Dominga Project, Andes Iron, Saniago, Las Condes, Chile; [2]Coleraine Labratories, Natural Resources Research Institute, Coleraine, MN and [3]Barr Engineering Company, Hibbing, MN

A Chilean mining company Andes Iron SpA owns and is developing the Dominga Mine and associated port project. This is a greenfield project located in La Higuera, some 70km from La Serena in Chile's Coquimbo region. Andes Iron SpA, founded in 2011, acquired the Dominga project from its former owner, Minería Activa. The mine design will be consist of two open pits and include a processing facility for the extraction and beneficiation of magnetic iron ore, with copper as a byproduct. The Dominga project is expected to have a 26-year project life span. The initial investment is expected at $2.5

billion (USD). Dominga is currently planned to have an annual production of 12 million m. tons of high value iron concentrate with an additional 150,000 m. tons of copper concentrate as a by-product. The technical-economic feasibility study, was completed in April 2016. Additional testing was accomplished to optimize the flowsheet in the concentrator that will improve operating costs. The iron concentrate is to be exported while the copper concentrate will have the option to be treated domestically or exported internationally. Andes Iron is in the process of finalizing environmental permits.

3:25 PM
ERP Iron Ore – Forging a New Direction in High-Quality Iron Ore Prodcution
T. Roth and R. Bigelow; ERP Iron Ore, LLC, Grand Rapids, MN

Newly formed ERP Iron Ore, LLC (ERPI) is owned and operated by Tom Clarke of Roanoke, Virginia. ERPI along with partners have recently purchased two bankrupt iron ore companies in Minnesota, Magnetation and Mesabi Metallics/Essar Minnesota as its first ventures into the iron ore industry after successes in the coal mining industry. ERPI's goal will be to offer a bold new direction for the production of iron ore and a sustainable future for our employees and the communities we serve. ERPI will provide an update and summary of its progress to restart the existing oxide mine and associated processing sites along with the construction and development of a new iron ore facility in Nashwauk, Minnesota. The Nashwauk mine will process magnetic iron ore to produce high grade iron concentrate and pellets for the production of value added iron. They will also provide updates on the existing pellet plant located in Reynolds, Indiana, and subsequently produce pig iron for the JV with Republic Steel's Lorain, OH blast furnace facility. ERPI has the potential to produce nearly 11 million tons of iron ore in Minnesota annually, quickly becoming a major player in the North American iron ore market.

MONDAY, FEBRUARY 26
AFTERNOON

2:00 PM | ROOM 200DE

Accessing Capital in Mining Today

Chairs: *T. Alch, Vice Chair NY Section of SME and Co Chair of SME's Mining Finance Conference, Edgewater, NJ*

2:00 PM
Introduction

2:00 PM
Accessing Capital in Mining Today
T. Alch; Chair of New York Section of SME, Edgewater, NJ

Join our experts who will speak about key issues and latest trends and answer your questions about raising capital in mining today. What has changed in the past year? Is the ability of miners to secure capital easier, or more difficult? If you are in the exploration and mining business, an investor or owner, you will want to hear our group of speakers discuss: What can you do to help raise capital? Is the capital available suitable? How do technical, non-technical, legal, and societal issues and risks impact raising capital? What should you know about debt, equity, or other sources of capital such as private equity, hedge funds, royalty, and streaming companies? Is M&A, consolidation or restructuring the best option? Look for updates about our speakers who will discuss these issues and answer your questions.

MONDAY, FEBRUARY 26
AFTERNOON

2:00 PM | ROOM L100C

Coal & Energy: Best of Ground Control

Chairs: *B. Mishra, West Virginia University, Morgantown, WV*
M. Murphy, National Institute for Occupational Safety and Health, Pittsburgh, PA

2:00 PM
Introduction

2:05 PM
Addition of ARMPS-HWM and AHSM into the Web GroundControl Application
C. Newman, Z. Agioutantis and N. Schaefer; University of Kentucky, Lexington, KY

The webGroundControl application (webGC) provides the mining industry with a means of accessing NIOSH ground control design software packages (ARBS, ALPS, ARMPS, etc.) through any web browser. Taking advantage of current Internet technologies, increased internet availability (even underground), data security for cloud computing, and cross-platform compatibility, webGC provides users with the ability to instantaneously access ground control designs for on-site analysis with respect to site-specific conditions as well as a means of project collaboration between multiple users. Overall, these features of the webGC application will aid in the development of safer mining environments making webGC a forerunner of many such apps that will be shortly available to the mining and geotechnical community. This paper will introduce two new modules implemented within webGC; ARMPS-HWM and AHSM. Through introductions to and discussions of current developments within the webGC application will provide the industry with a first hand look at the capabilities of the application as well as its ability to increase project efficiencies and collaborations before launching the product in the Fall of 2018.

2:25 PM
Analysis of Monitored Ground Support and Rock Mass Response in a Longwall Tailgate Entry
I. Tulu, G. Esterhuizen, D. Gearhart, T. Klemetti, K. Mohamed and W. Su; Pittsburgh Mining Research Division, NIOSH, Pittsburgh, PA

A comprehensive monitoring program was conducted to measure the rock mass displacements, support response, and stress changes at a longwall tailgate entry in West Virginia. Monitoring was initiated a few days after development of the gateroad entries and continued during passage of the longwall panels on both sides of the entry. Monitoring included overcore stress measurements of the initial stress within the rock mass, changes in cable bolt loading, standing support pressure, roof deformation, rib deformation, stress changes in the coal pillar, and changes in the full three-dimensional stress tensor within the rock mass at six locations around the monitoring site. The monitoring results have provided valuable data for the development and validation of support design strategies for longwall tailgate entries.

2:45 PM
Upwards Surface Movement Above Deep Coal Mines After Closure and Flooding of Underground Workings
A. Vervoort[1] and P. Declercq[2]; [1]Department of Civil Engineering, KU Leuven, Leuven, Belgium and [2]Geological Survey of Belgium, Royal Belgian Institute of Natural Sciences, Brussels, Belgium

After the mass closures of entire coal mine districts in Europe at the end of

the last century, a new phenomenon of surface movement was observed—an upward movement. Although most surface movement (i.e., subsidence) occurs in the months and years after mining by the longwall method, surface movement still occurs many decades after mining is terminated. After the closure and flooding of underground excavations and surrounding rock, this movement is reversed. This presentation focuses on quantifying the upward movement in two neighboring coal mines (Winterslag and Zwartberg, Belgium). The study is based on data from a remote sensing technique: interferometry with synthetic aperture radar (INSAR).

3:05 PM

Tekcrete Fast®: Fiber-Reinforced, Rapid-Setting Sprayed Concrete for Rib and Surface Control

S. Tadolini[1], P. Mills[1] and D. Burkhard[2]; [1]Minova USA Inc, Georgetown, KY and [2]San Juan Coal Company, Waterflow, NM

Fiber-reinforced spayed concrete has been used for several years in civil and tunneling operations. Research conducted to reduce cure times and increase compressive and flexural strengths resulted in the development of Tekcrete Fast®, a cementitious product capable of obtaining 41 MPa (6,000 psi) compressive strength and 8 MPa (1,200 psi) flexural strength in only 3 hours and reaching 7 day strengths of 62 MPa and 11.7 MPa (9,000 and 1,700 psi), respectively. A single bag product that uses conventional shotcrete and gunite application systems make it a natural crossover product for mining applications. The discovery of incredible adhesion properties and high resistance to chloride permeability helps ensure long-term stability and increases the ease of application. Project results from Disaster City® in Texas and the application for rehabilitating a coal mine belt entry are presented. The case study illustrates the effectiveness of the product in stabilizing a coal mine beltway and adjacent cross-cuts that were subjected to progressive sloughage due to humidity and cyclical loading.

3:25 PM

Evaluation of Seismic Potential in a Longwall Mine with Massive Sandstone Roof Under Deep Overburden

M. Van Dyke[1], W. Su[1] and J. Wickline[2]; [1]Pittsburgh Mining Research Division, NIOSH, Pittsburgh, PA and [2]Coronado Coal LLC, Beckley, WV

A seismic event was recorded by a deep longwall mine in Virginia at 3.7M_L in July 2016, which had no impact on the mining operations. Further investigations by NIOSH and Coronado Coal have shown that this event was associated with geological features that have also been associated with similar mining-induced seismic events in Virginia. Mapping and geological exploration in the area has made it possible to forecast possible locations for future seismic activity. In order to use the geology as a forecaster of mining-induced seismic events, two primary components are needed. The first component is a long history of recorded seismic events with accurately plotted locations. The second component is a high density of geologic data within the mining area. In this case, 181 events of 1.0M_L or greater were recorded by the mine's seismic network between January 2009 and October 2016. Geophysical logs were analyzed from gas wells, core holes were drilled and logged, and fiberscope holes were examined by mine geologists. It was found that overburden thickness, sandstone thickness, and sandstone quality contributed greatly to seismic locations and could be forecasted to unmined areas.

3:45 PM

Development Process for a Greater Capacity Propsetter® System

C. Brown; Strata Worldwide, LLC, Acme, PA

Proper ground stability in gateroads has been a critical aspect of success in longwall mining. In particular, the tailgate has proven to be one of the more active mine areas that needs to be managed. As longwall tailgate support technologies continue to be developed and improved, Strata Worldwide has worked to design and manufacture a revised Propsetter to provide additional support capacity and enable applications at greater mine heights. The support is targeted for tailgate applications; however, it can also be used for roof support in various types of mining environments. This presentation describes the design changes for enhancing the support capacity of the Propsetter to more closely align its performance with other support technologies currently being employed in longwall tailgates. Balancing changes to each design aspect of the Propsetter was key to successfully improving the roof support load capacity while maintaining controlled deformation. Test results from the NIOSH Mine Roof Simulator verified that these design changes were successful in increasing the capacity of the Propsetter to the 80- to 100-ton range at two inches of deformation.

MONDAY, FEBRUARY 26

AFTERNOON

2:00 PM | ROOM L100E

Coal & Energy: Dust Control I

Chair: *T. Beck, NIOSH – Pittsburgh Mining Research Division, Pittsburgh, PA*

2:00 PM

Introduction

2:05 PM

A Field Study of a Re-designed Roof Bolter Canopy Air Curtain (2nd Generation) for Respirable Coal Mine Dust Control

W. Reed[1], S. Klima[1], M. Shahan[1], G. Ross[2], A. Bailey[2], K. Singh[3], R. Cross[3] and T. Grounds[3]; [1]DVTSB, NIOSH, Pittsburgh, PA; [2]JH Fletcher & Co. Inc., Huntington, WV and [3]Prairie State Generating Company LLC, Lively Grove, IL

A 2nd generation roof bolter canopy air curtain (CAC) was tested at a Midwestern underground coal mine by NIOSH. Analysis was completed 3 ways: 1 comparing operator concentrations underneath the CAC to operator concentrations outside the CAC, 2 comparing operator concentrations underneath the CAC to concentrations at the rear of the bolter, and 3 comparing concentrations directly underneath the CAC to concentrations at the rear of the bolter. Dust control efficiencies ranged from -53% to 60% for method 1, -150% to 52% for method 2, and 40% to 91% for method 3. Reasons for negative and low dust control efficiencies are due to incorrect sampling locations, large distance between CAC and operator, and contamination of intake air from line curtain, and low dust concentrations of the study. However, low dust concentrations encountered made it difficult to discern whether differences dust control efficiencies were due to the CAC or due to variances in experimental dust measurement. The analyses, especially the method (3) analysis, show the CAC can be an effective dust control device. However, additional studies correcting the deficiencies mentioned in this study are recommended.

2:25 PM

Silica Surfaces on Respirable Dust Particles in Central Appalachian Coal Mines

L. Frost, C. Keles and E. Sarver; Virginia Polytechnic Institute and State University, Blacksburg, VA

Since the mid 1990s, there has been increased incidence of severe lung disease amongst Appalachian coal miners. While the underlying cause of this trend has not been proven, increased respirable silica exposures have been implicated in many cases. Separately, some evidence suggests that particles with free silica surfaces can induce a more severe biological response than particles with occluded surfaces (i.e., covered by other minerals, such as

alumino-silicates). In order to better understand the nature of silica particles in Appalachian coal mines, 32 respirable dust samples collected in eight mines across three sub-regions were examined by SEM-EDX. For each sample, 15 silica particles were identified and their EDX spectra were gathered at 20 then 5 kV to observe whether the atomic percentage of Si decreased with voltage – which would imply occlusion. Results are discussed with respect mine region and dust sampling location.

2:45 PM

A Mathematical Model to Simulate Drilling Process for Reducing Noise and Respirable Dust during Roof Bolting Operations

Y. Luo and H. Jiang; Mining Engineering, West Virginia University, Morgantown, WV

The respirable dust generated during the bolt-hole drilling could present serious health problems to the miners involved in the roof bolting operations. A proactive dust control approach, different from conventional passive approaches, has been analyzed theoretically. By properly controlling the drilling parameters, the purpose of reducing quartz-rich respirable dust from its generation source could be achieved. A mathematical model has been proposed to simulate the rotary drilling with sharp and blunt cutter conditions. The functions for area of total friction, resultant cutting force and specific energy have been given in the model. According to this model, the area of total friction, drilling bite depth, bit wear condition and Torque-Thrust (TW) ratio have been identified as direct factors influencing respirable dust generation. Through the analysis of each factor, it is found that by achieving a low specific energy with proper drilling bite depth, TW ratio and avoid using worn-out bit, less respirable dust and noise can be realized simultaneously. The model can be used as a tool to develop a comprehensive drilling control algorithm for dust and noise control purpose.

3:05 PM

Preliminary Laboratory Testing of a Shuttle Car Canopy Air Curtain

W. Reed[1], Y. Zheng[1], M. Yekich[1], G. Ross[2] and A. Salem[3]; [1]DVTSB, NIOSH, Pittsburgh, PA; [2]JH Fletcher & Co., Inc., Huntington, WV and [3]The Weisburg Division of Engineering, Marshal University, Huntington, WV

Canopy air curtains (CAC) have been developed by the National Institute for Occupational Safety and Health (NIOSH) for use on roof bolting machines in underground coal mines to protect those operators from overexposure to respirable coal mine dust. The next logical progression is to develop a CAC for shuttle cars to protect shuttle car operators. NIOSH conducted laboratory testing to determine the dust control efficiency of a shuttle car CAC at three different ventilation velocities — 120, 400, and 850 fpm. The lowest, 120 fpm, represented the velocity encountered during loading, while the 850 fpm velocity represented airflow over the shuttle car while tramming against ventilation airflow. Results showed dust control efficiencies ranging from 74–83% for 120 fpm, 39–43% for 400 fpm, and 6–16% for 850 fpm. Minor modifications to the shuttle car CAC design and placement improved the dust control efficiency to 51–55% for 850 fpm with minimal impact on the efficiencies for lower ventilation velocities. These laboratory tests demonstrate that the newly developed shuttle car CAC has the potential to successfully protect shuttle car operators from coal mine respirable dust overexposures.

3:25 PM

Field Investigation to Measure Airflow Velocities of a Shuttle Car Using Independent Routes at a Central Appalachian Underground Coal Mine

M. Shahan and W. Reed; Dust Control, Ventilation, & Toxic Substances, NIOSH - PMRD, Pittsburgh, PA

Canopy air curtains (CAC) on roof bolters have been proven, through laboratory and field investigations, to protect miners from respirable dust, and prevent dust overexposures. Another desired application of a CAC system was to develop a CAC that is mounted in the cab of a shuttle car to protect the operator from dust. The challenges faced with this design include mine ventilation rates in conjunction with the shuttle car tram speeds, causing cab airspeeds to exceed 638 fpm as found in this study of a Central Appalachian underground coal mine. During this study, dust concentrations of the shuttle car operator were measured, while also measuring the airflows experienced by the operator using a recording vane anemometer. Results from the survey indicate that the highest exposure to respirable dust (2.22 mg/m^3) occurs when the shuttle car is loading at the miner, which had an average airspeed of 156.75 fpm. While tramming, the operator was exposed to 0.77 mg/m^3 with an average airspeed of 203 fpm.

3:45 PM

Frequency Distrubutions of Diesel Particulate Matter (Dpm) Concentrations in Underground Mines

M. Khan and K. Homan; Mining and Nuclear Engineering, Missouri S&T, Rolla, MO

Underground miners are exposed to different levels of DPM. Miners' exposure to DPM concentrations is variable as it depends upon many factors. Generally, face workers are exposed to the highest levels of DPM. At or near work faces, due to the changing levels of diesel activities, DPM concentrations can vary drastically even over a short duration. Miners' do not necessarily spent full eight hour shift at one specific mine location, in addition, some miners' visit high DPM areas only for a short duration. Thus the evaluation of Frequency Distributions (FD) of DPM at potentially high DPM concentration mines zones is significant. FD patterns can allow us to estimate the likelihood of DPM levels faced by miners during their stay at a certain mine location. This study identifies FD patterns of DPM concentrations encountered at underground mines work faces and in exhaust air drifts. Thousands of measurements were recorded, results were analyzed by Wolfram Mathematica 10.4. It was observed that the DPM concentrations at mines work faces and in exhaust air drifts were not normally distributed. However, lognormal and Weibull distributions were able to present these measurements adequately.

4:05 PM

Coal and Mineral Mass Fractions in Personal Respirable Dust Samples Collected by Central Appalachian Miners

K. Phillips, C. Keles, M. Scaggs and E. Sarver; Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA

Over the past two decades, the apparent incidence rate of severe lung disease amongst US coal miners has increased significantly – particularly in central Appalachia. However, this trend is squarely at odds with compliance rates for respirable dust limits. The juxtaposition between available health surveillance and dust surveillance data begs for a better understanding of exposures. The conventional approach to respirable dust monitoring is based on personal samples from workers in designated occupations, and two primary metrics are evaluated: mass concentration of dust and mass percentage of crystalline silica in the dust. In order to learn more about the whole composition of dust, thermogravimetric analysis (TGA) can be used to estimate the mass fractions of coal and total minerals. The latter can be further broken down into carbonate and non-carbonate minerals, which might be loosely associated with rock dusting activities and cutting of roof strata, respectively. Here, TGA results are presented and discussed for 59 personal dust samples collected by volunteers at seven central Appalachian coal mines. For four mines, results are also compared with those from area samples.

MONDAY, FEBRUARY 26

AFTERNOON

2:00 PM | ROOM L100D

Coal & Energy: Rare Earth Elements

Chairs: *A. Noble, West Virginia University, Blacksburg, VA*
M.Mosser

2:00 PM
Introduction

2:05 PM
Comparison of Rare Earth Element Results from a Hand-Held Portable XRF Spectrometer with Fused ICP-MS Results for Coal and Coal Related Materials in Select Western States

D. Richers[1], R. Bryan[1], H. Andersen[1], F. Wood[2] and T. Gray[2]; [1]Nexus Geos LLC, Thornton, CO and [2]Tetra Tech, INC, Pittsburgh, PA

Portable XRF spectrometers provide a fast and inexpensive means to screen samples for their elemental content. These units are generally considered to be fairly accurate for qualitative metal identification but tend to be generally semi-quantitative at best in measuring the actual concentrations. This study compares a data set (> 300 samples) where rare earth elements (REE) have been determined in coal and related materials by both XRF and ICP-MS from a DOE/NETL sponsored study in the Piceance-Uinta, Raton basins and the Canon City Embayment. Certain ranges of concentrations in specific rock types show a high degree of relative correlation with both methods, but discrepancies appear in others. Careful cataloging of rock type, freshness of samples, and overall matrix heterogeneity may explain deviations found between the analytical methods. It was also noted that high temperature ashing may reduce the REE content due to mobilization from ammonium compounds released during the coking process. Still, with careful sample preparation and diligence, XRF can provide a useful tool in identifying samples with elevated REE content for submission for more exacting chemical analysis.

2:25 PM
Monte Carlo Simulation of Dynamic Compositing for Rare Earth Element (REE) Concentrations within Raton Basin Colorado Coal and Associated Non-Coal Strata

R. Bryan[1], D. Richers[1], H. Andersen[1], F. Wood[2] and T. Gray[2]; [1]Nexus Geos LLC, Golden, CO and [2]Tetra Tech, INC, Pittsburgh, PA

Generating effective and realistic mining simulations of rare earth elements (REE) from coal and associated materials requires composite thickness be dynamically changed. Traditional protocols blended physical samples from each rock type proportional to their thickness. This produces a physical sample which represents the average REE concentrations for that thickness. This result is a fixed mixture that cannot be used to explore the effect of additional composite lengths. This is much like the children' rhyme where once a composite is blended, "all the King's men and horses" cannot put "Humpty Dumpty back together again". Instead of physical compositing, the authors propose the use mathematical compositing. With mathematics one can produce an unlimited number of length-weighted averages which will change as different coal and bounding strata units are modeled. This study will develop a simple strata REE and coal model based on observations from an ongoing study of the Raton Basin Colorado coal fields. Monte Carlo simulation will be utilized to analyze any advantage in exploiting both REE in coal and non-coal simultaneously

2:45 PM
Design and Evaluation of an Acid Leaching-Solvent Extraction Process to Extract Rare Earth Elements from Acid Mine Drainage Precipitates

A. Noble[2], P. Ziemkiewicz[3], C. Vass[1], X. Liu[4] and P. Ren[4]; [1]Mining Engineering, West Virginia University, Blacksburg, VA; [2]Mining & Minerals Engineering, Virginia Tech, Blacksburg, VA; [3]Water Research Institute, West Virginia University, Morgantown, WV and [4]Mechanical and Aerospace Engineering, West Virginia University, Morgantown, WV

Over the past two years, researchers at West Virginia University and Virginia Tech have identified acid mine drainage (AMD) and the associated treatment precipitates (AMDp) as attractive sources of Rare Earth Elements (REEs), particularly heavy and critical REEs. Acid forming coal spoils, tailings, and underground mines act as heap leach reactors, where the sulfuric acid produced through pyrite oxidation leaches REEs from the surrounding shales. Conventional AMD treatment captures nearly 100% of REEs and concentrates them by a factor of 2,000x. Extensive sampling efforts (n = 74 at the time of publication) have shown that AMDp samples contain an average of 635 g/t REE, with a 95% confidence interval of 549 to 724. This sampling effort has identified 292 tons of REEs in 58 existing AMDp storage ponds sampled thus far, and ongoing AMD production in Appalachia generates about 800 tons of REE per year. Noting this promising resource, an acid leaching-solvent extraction flowsheet was developed and tested at the laboratory scale using a single mixer/settler. Early testing has produced a mixed REE concentrate of 4.6%, and further scale up is expected to improve this performance.

3:05 PM
Production of Critical Rare Earth Element Concentrates from Coal Sources

R. Honaker[1], R. Yoon[2], G. Luttrell[2] and A. Noble[2]; [1]Mining Engineering, University of Kentucky, Lexington, KY and [2]Mining & Minerals Engineering, Virginia Tech, Blacksburg, VA

The supply of rare earth elements (REEs) is a significant issue nationally and internationally due to their importance in renewable energy and military technologies as well as the manufacturing of general consumer products. Recent research has found that coal is an excellent source of REEs, especially those identified as being critical. The treatment of coal sources containing around 0.03% of REEs using a combination of physical and hydrometallurgical separation processes has generated concentrates containing as high as 50% total REEs. The concentrates were comprised of relatively large amounts of neodymium and yttrium among other critical elements. A process circuit has been developed and preliminary assessments indicated the potential for economic recovery of the REEs.

3:25 PM
Rare Earth Elements from Coal-Based Materials

M. Alvin; NETL, Pittsburgh, PA

In 2014, the Department of Energy, Office of Fossil Energy and the National Energy Technology Laboratory performed an initial assessment of the feasibility of economically recovering rare earth elements from coal and coal by-product streams, such as fly ash, coal refuse, and aqueous effluents. After reporting its findings in the DOE 2015 Report to Congress, the Department initiated a multi-year research and development program to demonstrate the technical feasibility and economic viability of separating and extracting REEs from domestic coal-based resources. Research projects include identification of domestic field-site locations and reserves containing elevated REE concentrations, design and construction of bench- and pilot-scale facilities to ultimately produce 90-99wt% rare earth oxides, development of in-situ, field sensors, and development of advanced REE separation concepts. This paper provides a summary overview of DOE-NETL REE program's technical accomplishments, and the projects being conducted to achieve the REE program goals of validating the technical and economic feasibility of prototype, salable, high-purity, REE systems, using coal-based materials, by 2020.

3:45 PM

Rare Earth Element Associations in Product Streams of Coal Preparation Plants

G. Luttrell[1], A. Noble[1], R. Yoon[1], M. Rezaee[2], a. bhagavatula[3] and R. Honaker[3]; [1]Mining & Minerals Engineering, Virginia Tech, Blacksburg, VA; [2]John and Willie Leone Family Department of Energy and Mineral Engineering, Penn State University, University Park, PA and [3]Mining Engineering, University of Kentucky, Lexington, KY

A field study of 20 coal preparation plants was undertaken to determine the concentrations of rare earth elements (REEs) present in the product streams. For each plant, samples were taken from the clean coal, coarse refuse, and fine refuse streams. Each sample was subdivided into size and density classes that best reflected the process circuitry in each plant. The data set was used to establish statistical correlations between coal qualify indicators, such as ash and sulfur contents, and concentrations of REEs reporting to the product streams. Statistical associations were also established between the various elements. The statistical analyses indicate a strong correlation between ash content and total concentration of REEs for all plants evaluated in the study. However, some notable and insightful exceptions were observed when evaluating the data on an element-by-element basis. This article discusses the results of the statistical analyses obtained from the plant fleet study and provides generic recommendations for correlating elemental concentrations of REEs in coal plant products for predictive purposes.

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AFTERNOON

2:00 PM | ROOM L100DF

Cyber Security and Mining? Things to Consider When Building a Security Program

Chair: *J.Faxon, Newmont C.Dooley*

2:00 PM

Cyber Security and Mining? Things to Consider When Building a Security Program

J. Ward; Security Risk & Resiliency (SR&R), Black & Veatch, Denver, CO

This presentation will provide and discuss several key considerations for implementing a Cyber Security Program for Business Entities such as Mining that include significant operational components within their business models. To the stated rule that "security needs to be built in, not added on" there are several key aspects that should be recognized and considered from the very beginning in order to achieve an effective and sustainable Cyber Security Program, that include but are not limited the following: - Delineations between IT and OT systems - An accurate, up to date, and comprehensive Asset Inventory system(s) - Identification, classification, and protection of associated data - The complementary physical security controls - Impact Assessment Criteria - Security Control Frameworks - The different organizations that own, operate, and manage the various business assets and associated OT/IT cyber systems - Governance Models that include direct participation and ownership of applicable organizations - The required policies, processes, and procedures - The importance of detail upfront planning that includes participation from the various stakeholder organizations

MONDAY, FEBRUARY 26

AFTERNOON

2:00 PM | ROOM L100H

Environmental: International Environmental Regulations

Chairs: *J. Craynon, Export-Import Bank of the United States, Washington, DC*
S. Parsons, Export-Import Bank of the United States

2:00 PM

Introduction

2:05 PM

International Lending Institutions' Sustainable Development Frameworks

S. Parsons; Export-Import Bank of the United States, Fairfax, VA

In addition to host country environmental and social (E&S) requirements, lending institutions providing financial support to mining projects seek to manage the E&S risks of their involvement by requiring alignment with one or more E&S sustainable development frameworks. Commercial banks, multilateral development banks, export credit agencies, and development financial institutions may apply sustainable E&S frameworks of their own or use standards developed by other institutions. Implementation of mining project-specific plans to meet the applicable framework requirements is generally ensured by binding provisions included in the financial agreements.

2:25 PM

IFC Performance Standards and Mining

J. Craynon; Engineering & Environment, Export-Import Bank of the United States, Washington, DC

The World Bank Group and the International FInance Corporation (IFC) have established guidelines and performance standards that have long been applied to mining operations. The various requirements include both general and sector-specific issues and provide a generally-accepted "level playing field" for operations. Over recent years, other international financial institutions have adopted these frameworks to ensure performance and expand sustainable development in the mining industry.

2:45 PM

Social Performance and Mining

K. Dunbar; Office of Investment Policy, Overseas Private Investment Corporation, Washington, DC

The Overseas Private Investment Corporation (OPIC) is among the many financial institutions implementing international frameworks to require that projects appropriately implement social safeguards, including those related to worker rights, human rights, public consultation, and grievance redress for communities that may be impacted, and sufficiently avoid, mitigate and manage other potential social impacts of development projects such as when projects need to negotiate land acquisition with neighboring communities. These frameworks and OPIC's internal requirements have helped improve the social performance of mining operations around the world. This presentation addresses the social aspects of the international frameworks and the role of financial institutions such as OPIC in furthering sustainable development.

3:05 PM

The Model Mine Development Agreement Project

R. Bassett; Holland and Hart, Denver, CO

Over the past decade, the International Bar Association recognized the need for guidance on mining agreements (post-exploration phase) between governments without mature mining codes and mining companies wanting to construct operating mines. The group established a committee which collected over 80 existing Mine Development Agreements and deconstructed and analyzed common provisions of those agreements. The project committee then assembled example provisions and drafted generic provisions, with a goal of providing a template for agreements with state owned mining enterprises, an agenda for mine development negotiations based on a sustainable development objective, a guide where the mining code must be supplemented by private agreement, and a tool for use in drafting mining agreements. Many of those provisiions reflect the need for adopting standards for environrmental, health and safety and social performance.

3:25 PM

Drainage Geocomposite System Applied Tailing Dam in Perú

C. Torres; Lima-Perú, Maccaferri, Lima, Lima, Peru

Year by year the mining production in Peru has been growing and with it comes the requirement of higher projected capacity of the tailings dams; the use of the drainage geocomposite provides potential advantages, as it manages to increase the download speed of water, productive time, use of the capacity of the dam, drying of the sludge, the reuse of the deposited materials dry and reuse of the water in the mining process with immediate responses of the geosynthetics and without the need for costly pumping systems. The present paper show the feasibility of using geocomposites that accelerate the process of consolidation by drying, through the assessment of the design criteria, methods of analysis and the application of the results obtained from this solution to a real case in the development of mining projects in Peru. To study the behavior of the tailings and the filling process, it is used the drainage geocomposite in all the slopes of the tailings dam, in order to optimize most of the drainage area, extending the requirement for construction of new dams. The drainage geocomposite system increasing approximately a 15% storage capacity of the tailing dam.

MONDAY, FEBRUARY 26

AFTERNOON

2:00 PM | ROOM L100G

Environmental: the Politics of Mining: Emphasis on Government Policy and the Mining Industry

Chairs: *A. Martin, Foth Infrastructure & Environment, LLC, De Pere, WI*
A. Kipper, GHD, Rhinelander, WI

2:00 PM

Introduction

2:05 PM

The View of a Former Regulator: Politics, Policy and Mining

A. Kipper; GHD, Rhinelander, WI

Ann Kipper will speak to the politics of mining from a former regulator's viewpoint, including sharing her experiences implementing mining policy, drafting mining legislation, permitting mine sites, and working with elected officials, mining companies, interested parties/stakeholders, and the public. Political control and influence are ever changing. One thing that seems to remain constant: politics and policy often collide, especially relative to mine sites in many areas of the United States. Ann will provide a concise overview of politics and policy in Wisconsin mining – the pressures agencies, elected officials, mining companies, and stakeholders face. Policy development varies, as do perceptions regarding policy and policy development. Ann will advocate for the importance of absolute regulator neutrality – decision making based upon policy rather than opinion or perception. She will close by encouraging mine developers and operators to know their elected officials, regulators, and interest group, not forgetting the ever-important social license to mine.

2:25 PM

The Minnesota Sulfate Rule to Protect Wild Rice – the Story of a Decade Long Rulemaking

R. Walker; Barr Engineering Co., Minneapolis, MN

In 1973, Minnesota adopted a sulfate standard to protect wild rice. For many years following its passage, the standard was largely ignored. In 2009, with the introduction of proposals for several new mining projects in northern Minnesota, concerns regarding potential impacts from mining on important natural resources emerged. Specifically, concerns regarding potential impacts to wild rice, a plant of significant cultural significance to Minnesota American Indian Tribes, were raised. Several stakeholders discussed whether the Minnesota sulfate standard was sufficiently protective. In response to these concerns, the Minnesota Legislature earmarked over one million dollars requesting that the Minnesota Pollution Control Agency study how sulfate affects wild rice. In 2018, the MPCA is set to begin rulemaking based on the outcomes of that study. As a member of the MPCA Advisory Committee since its inception, we present an overview of the history, key questions, and key scientific outcomes of this study and rulemaking process. We discuss some of what has been unique about this case both in Minnesota's and the U.S.'s environmental regulatory history.

2:45 PM

The Grand Challenges of Social Licensing in Mining

B. Teschner, E. Holley and N. Smith; Mining Engineering, Colorado School of Mines, Golden, CO

Conflicts between mining companies and communities increasingly account for delays or stoppage of mining projects worldwide. Companies have invested millions of dollars into projects around the world only to find that they remain stonewalled by social opposition or challenged by legal issues. Gaining and maintaining a social license to operate is an increasingly important activity. But what are the most significant challenges that this generation of companies needs to solve in order to build sustainable relationships with stakeholders? Through a survey of reports, white papers, and online media, this talk examines the recommendations and focal points of intergovernmental organizations (i.e. International Finance Corporation and the United Nations]), governments (US and Canada), and the mining industry (International Council on Mining and Metals and individual companies). The authors highlight the priorities of these stakeholders and identify points where research advances could improve the implementation of the mining industry's social licensing goals. The presentation concludes by offering a list of "social licensing grand challenges" for the mining industry in the next decade.

3:05 PM

Prospects for a Renewal of the Mining Industry in Wisconsin

S. Donohue; Foth Infrastructure & Environment, LLC, De Pere, WI

Northern Wisconsin is host to numerous known polymetallic resources that were discovered between the 1960's and 1980's. Based on this mineral potential, Wisconsin passed comprehensive legislation regulating nonferrous mineral development. Beginning in 1991, the first mine permitted, operated, and closed under Wisconsin's nonferrous mining law was Flambeau Mine in Ladysmith Wisconsin. The Crandon Project attempted to navigate the regulatory process in Wisconsin but was closed down in

2003 due to changes in state law in the late 1990's. Since 2003 there has been little exploratory or development interest by the mining industry in Wisconsin despite active development in neighboring states. This presentation will trace the regulatory history of Flambeau and Crandon and evaluate prospects for changes to Wisconsin's Mining Law that could perhaps reopen Wisconsin to interested miners.

3:25 PM

Social & Political Influence a Risk that Can Be Managed

T. Champo and S. White; Strategic Communications, Salt Lake City, UT

NIMBY - not in my backyard - is a term of the past. Communication technology has changed so dramatically in the last few years that public awareness, and public activism, is shifting. Today's backyard is the entire globe and the public demands transparency, brevity, and a voice in what happens to it. These dramatic changes have created an environment where social and political influence is swift, powerful, and difficult to manage. Every person is wielding a smart phone with instant access to millions of viewers. Yet many corporations continue to use traditional public relations approaches. The modern world requires a comprehensive approach to strategic communications planning, long before a public relations crisis presents itself. Consider the Keystone Pipeline project, the symbolic campaign for activists arguing against environmental impacts vs proponents pushing for economic stimulation. This presentation will highlight key lessons from Keystone and other high-profile projects and current events and offer a strategy for how to thoughtfully prepare for – and manage – social and political risk in the age of instant news and viral influence.

3:45 PM

Regulatory Trends in Water Discharge Requirements and Strategies for Managing Discharge

S. Truby; Mining, Black & Veatch, Denver, CO

The USA Federal governments as well as states have been tightening water discharge standards over the past few years. This presentation will review the trends, how they impact existing operations, and briefly look at technologies and strategies that can be used to meet the new discharge requirements.

4:05 PM

The Crucial Role of Coalition Building to Obtain Your Social License

N. Norr[1], J. Byers[4], J. George[2] and D. Lislegard[3]; [1]Minnesota Power, an ALLETE Company, Duluth, MN; [2]International Union of Operating, Minneapolis, MN; [3]Lake Head Constructors, Aurora, MN and [4]Minnesota Chamber of Commerce, St. Paul, MN

It's no longer enough to provide facts and comply with the environmental review process. Resource development projects such as mines and pipelines have become magnets for media coverage and high-profile opposition by environmental groups. To gain insights into the importance and impact of building public support, we'll discuss how to build coalitions utilizing partners such as local elected leaders, suppliers and unions, who are able to make the case for a project based on its importance to jobs and local economies and to refute the false choice between jobs and the environment. We will share the experience of the Jobs for Minnesotans coalition that is supporting the PolyMet and Twin Metals projects

MONDAY, FEBRUARY 26

AFTERNOON

2:00 PM | AUDITORIUM ROOM 2

Health & Safety: Plenary Session: What Really Works in Safety Management in the Mining Industry

Chairs: *W. Rogers, University of Utah, Marana, AZ*
E. Clausen, TU Clausthal, Clausthal-Zellerfeld, Germany

2:00 PM

What Really Works in Safety Management [PR1] in the Mining Industry

W. Rogers; University of Utah, Salt Lake City, UT

The global mining industry interfaces with a wide variety of health and safety regulatory frameworks and management systems. Whether in response to catastrophic events that drove legislation and regulation, economic strength of a region, or even cultural aspects of the workforce, it is worth considering the effectiveness of the regulatory frameworks in place to manage health and safety. Although the overarching regulations may be generally considered dated, the internal aspects of these frameworks are continuously evolving. The adequacy and future of various health and safety frameworks or management systems will be discussed in this panel discussion. Several high-profile speakers from the global mining industry will provide insights regarding prescriptive approaches, risk-based approaches in an era of technology enhanced smart mining, and varying levels of government involvement and operator accountability. Perspectives will be provided from academia, industry, government, union organizations, and other non-governmental groups.

MONDAY, FEBRUARY 26

AFTERNOON

2:00 PM | ROOM L100J

High Level Certifications and Education (by invitation only)

Chair: *M. Anderson, Colorado School of Mines, Golden, CO*

2:00 PM

High Level Certifications and Education (PhD, PE, CMSP, etc.)

M. Anderson; Colorado School of Mines, Elko, NV

Discussion and advice on obtaining various high level certifications and education. Descriptions on certifications, how to get them and what is the best way to prepare for obtaining certifications

MONDAY, FEBRUARY 26

AFTERNOON

2:00 PM | ROOM 101H

Industrial Minerals & Aggregates: Adaptive Reuse of Pits and Quarries

Chairs: *S. Stokowski, TEC Services, Lawrenceville, GA*
J. Giddens, Oil-Dri

2:00 PM
Introduction

2:05 PM
Mined Out Pits and Quarries — An Underappreciated Resource

D. Bieber; Rocky Mountain Division, Martin Marietta, Lakewood, CO

Mined out pits and quarries have for too long been viewed by the public as a nuisance at best and a liability at worst. However, these features can also be an asset or resource with their own intrinsic value. Some of the ways that mined out or abandoned pits and quarries have been repurposed include water storage vessels, stormwater detention basins, aquifer recharge facilities, music venues, wildlife areas, parks and other recreation facilities, and agricultural facilities. In some cases, the mining activity that forms a pit or quarry is a secondary economic activity and the pit or quarry end use is the primary activity. Examples of adaptive reuse strategies along with example social, environmental, and economic benefits are presented to illustrate these the points made in this presentation.

2:25 PM
An Aggregates Producer's Perspective on Post Operational Land Uses

F. Lieth; Geological Services, Vulcan Materials Company, Birmingham, AL

With over 300 reserves bearing operations, Vulcan Materials Company employs a number of uses for property once mining has ceased. The complete life of a mine involves a circumspect approach for the profitability of the operation both during the aggregates producing stage and the value of the remaining asset for the community during the decommissioning/repurposing phase. An early planning approach yields new opportunities for the community and avoids excessive asset retirement obligations. The void that is created by the mining can yield an asset that has as much or more economic and community outreach value than the resource that was originally extracted. The general categories for post operational land use that add value include water reservoirs, large scale stormwater management, clean construction debris landfills, industrial and residential development, and recreational areas. Specific examples and related mine planning methods will be discussed.

2:45 PM
Boston's Ongoing History of Adaptive Reuse of Quarries and Pits

S. Stokowski; TEC Services, Lawrenceville, GA

Boston, MA, has a rich legacy of adaptive reuse of aggregate and dimension stone mining sites. The oldest sites are the Tri-mount hills developed into the Beacon Hill area in the early 1800's and the large part of Needham developed during excavation for the Back Bay Fill project of the Civil War. One of the stone quarries for the Massachusetts State Rock, the Roxbury Puddingstone is now a park in the Mission Hill neighborhood. The Old Colony Broken Stone quarry in Quincy now hosts office buildings and nearby Quincy quarries are now a park and housing. The Rowe quarry in Malden/Revere is now the Quarrystone condos. The Mass Broken Stone property in Weston hosts Biogen IDEC's offices, which are cooled with deep quarry water, host a solar power array, and have a 42 acre nature area. In Scituate, the Boston S&G property is now the Widow's Walk Golf Course. The numerous quarries for Milford Pink stone host an interstate, the Quarry Square Shopping Center, and commercial properties. Currently, there are redevelopment plans for operating crushed stone quarries in Ashland (Bayer-Mingolla/Trimount/Agg. Ind.), West Roxbury (W. Rox. Cr. Stone/SM), and in Saugus (Lynn S&S/Agg. Ind.).

3:05 PM
The Butchart Gardens, Brentwood Bay, Bristish Columbia

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

The Butchart Gardens, designated as a national Historic Site of Canada in 2004, had quite a different beginning over 100 years ago. In 1903, Jennie and Robert Pim Butchart, along with their two daughters, came to Vancouver Island from Ontario. Robert was a pioneer in the production of portland cement and he supervised the building of a cement plant in 1904 and production began in 1905. The plant was located near Tod Inlet, home to a rich limestone deposit. When parts of the quarry were exhaused in 1909, Jennie began her beautification project to turn the former quarry into what is now one of the most recognized gardens in the world, the famous Sunken Garden. Jennie's vision in replacing the scars left by the quarrying with a garden of beauty and imagination, stands today as a magnificant example of a reclamation site.

3:25 PM
Abandoned Mine Reclamation's Role in Improving the Perception of Mining

M. KORB; Tetra Tech, Inc, Wapwallopen, PA

Many of our friends and neighbors are unaware of the essential part mining has played in the country's growth and economy. Their view of mining is likely a negative view of its environmental, social and human legacies. Few have any idea of the scale of mining's progress and mine closure and Abandoned Mine Reclamation (AMR) projects have little exposure The issue of AMR is important because past land and water abuse associated with coal and metal mining is a major cause of the negative perception of mining Post-reclamation land uses are seldom creative, often because of the additional work needed has no funding or the additional steps that need to be taken. AMR Programs do some "innovative" reclamation, but one department secretary described our role as "they fill holes." The public would like to see reclamation used for community revitalization In recent years, some regulations and funding have encouraged reclaiming the energy of communities affected by legacy mining This presentation will look at and discuss some AMR projects in progress, some past projects, and will touch on some "out-of-the-box" ideas for helping mine closure and AMR Improve the Perception of Mining

3:45 PM
Bridging Sinkholes, Soft Soils and Voids When Reclaiming Abandon Quarries

M. Isola[2] and E. Michiels[1]; [1]Maccaferri Mining Solutions, Lithia, FL and [2]Maccaferri Inc, Rockville, MD

Quarrying often occurs in urban areas, leaving abandon mines an eyesore and a dangerous site claiming 20-30 lives per year in the US alone. (MSHA*) These mines are often left as massive holes in the ground or cuts into mountainsides. Falling debris is often a significant threat as is falling from a vertical highwall or drowning in a pool of water that has developed. Reclaiming of abandon quarries presents an opportunity for development of commercial, residential and recreational activities, but first one must address these ever present threats. Many developers are looking to stabilize the foundation, bridge any potential sinkholes and fill in these areas. Structural fill is often expensive and often times less care is employed when installing organic or other materials. This backfilling practice often creates voids in the backfill making the material susceptible to settlement. Ultra High Strength (UHS) geogrids allow for an increased design safety factor of embankments, the reduction of differential settlements and a faster construction rate. These geogrids have been used to reclaim abondon quarries, bridge sinkholes on highways and transfer the loads in pile caps.

MONDAY, FEBRUARY 26

AFTERNOON

2:00 PM | ROOM 101I

Industrial Minerals & Aggregates: Fundamentals & Best Practices in Industrial Minerals Processing

Chairs: *V. Gupta, EP Minerals, Reno, NV*
N. Gupta, Virginia Tech, Blacksburg, VA

2:00 PM
Introduction

2:05 PM
Breakthroughs in Commercializing Two Mineral Separation Devices for Dramatic Reduction in Energy and Water Consumption

J. Zhang[1], W. Xiao[2], D. Zhang[2] and D. Yang[3]; [1]Florida Industrial and Phosphate Research Institute, Bartow, FL; [2]Hubei Bonan Tech, Yichang, China and [3]Mineral Technologies International, Morgantown, WV

Recent technological breakthroughs have been achieved, paving the way for commercializing two innovative mineral separation devices, the packed column jig (PCJ) and packed flotation column (PFC). Major breakthroughs include eliminating the column plugging problem and developing a remote process control system. This paper presents some pilot testing results and recent commercial activities in utilizing these technologies. Pilot testing of PCJ on a high-dolomite mining tailings recovered 87% of the P2O5 value with the concentrate analyzing 28%P2O5 and less than 1% MgO. A packed flotation column (PFC) of 12 meters in height and 3 meters in diameter at a dolomite flotation plant was demonstrated to be capable of replacing 11 mechanical flotation cells of 24 cubic meter each, showing eight (8) folds saving in electricity use and over 90% reduction in water consumption. Three commercial plants are being constructed, where heavy media separation is replaced with PCJ and mechanical cells are replaced with PFC.

2:25 PM
Faster and More Efficient Beneficiation of Hydrophobic Particles

K. Galvin, J. Dickinson and K. van Netten; Centre for Advanced Particle Processing and Transport, University of Newcastle, Callaghan, NSW, Australia

With the decline in the quality of accessible resources, there is the need to re-consider conventional approaches used to achieve beneficiation, and to establish ways to increase the speed of separation while achieving higher quality separation. This paper examines two approaches being developed by our group, namely a novel agglomeration technology referred to as 3D Binder Technology, and the Reflux Flotation Cell. The agglomeration technology utlisers a novel hydrophobic binder that reduces oil consumption by an order of magnitude, delivering recoverieis that are virtually independent of the particle size. The flotation technology utilisers a system of inclined channels to promote the segregation of the bubbles from the tailings, thus permitting up to an order of magnitude increase in processing rates. By operating with a bubbly zone rather than a trditional froth zone most of the problems encountered in flotation are overcome, with a much higher product grade.

2:45 PM
Interactions Between Water Droplets and Solid Surfaces for Dust Control Applications

Y. Gao[1], S. Jung[2] and L. Pan[1]; [1]Chemical Engineering, Michigan Technological University, Houghton, MI and [2]Department of Biomedical Engineering and Mechanics, Virginia Tech, Blacksburg, VA

Suppression of airborne dusts is commonly achieved by spraying water into the dust cloud during the mining and mineral processing operations. The process involves collision and attachment of dust particles onto water droplets and agglomerates fall out from the air. In the present work, the attachment process was fundamentally studied by measuring both interaction and separation distance between a water droplet and a flat cantilever beam in air using a modified force apparatus for deformable surfaces (FADS). Force measurements were conducted with water droplets of different sizes and solid surfaces of different hydrophobicities. The result shows that water droplets wet the hydrophilic surfaces spontaneously, and the attachment occurs at a separation distance of above 500 nm. The force measured with the hydrophobic surface is much smaller than that obtained with the hydrophilic surfaces due to the weaker capillary force. The present result will be useful for improving the performance of water spray systems and facilitating the development of novel chemical aids for dust control applications.

3:05 PM
Fluoropolymers – a Solution for the Most Difficult Corrosion Issues in the Mining and Mineral Processing Industry

A. Palovcak[1], G. Fisher[2] and D. Seiler[1]; [1]Technical Polymers, Arkema Inc., King of Prussia, PA and [2]Fisher Company, North Salt Lake, UT

Fluoropolymers are a family of polymers possessing high chemical resistance and high temperature stability. PVDF is one of the most versatile materials of choice for handling acids, chlorides and mixtures of chemicals. Piping systems, pumps, tower packing, tubing, valves, fittings, nozzles, and filter systems are readily available and examples will be shown. A review of case histories of chemical resistant storage and process tanks, linings and coatings in the mining and mineral process industry will be demonstrated. Users have become aware of some shortcomings of common FRP, elastomeric, and urethane linings. With observable and premature failures of these materials the industry is looking for long life solutions. Mixers and agitators heretofore lined with rubber, some up to 8' in diameter, are being lined with thick Kynar® PVDF coatings for slurries and low pH acidic conditions. Similarly to problems with mixers & agitators, Rubber and (FRP), fiberglass reinforced plastics have been used in process filtration, such as in a rotary drum filter, and have been less than satisfactory. New technology for thick Kynar® coatings are available to solve the challenges of corrosion & abrasion.

3:25 PM
Optimizing Cone Crusher Performance

J. Gray; Telsmith Inc., Mequon, WI

There are many operating parameters that factor into optimizing cone crusher performance. Matching the crusher performance to your desired production needs will force you to analyze various aspects of the installation. We will cover all the variables of today's high speed cone and help you understand what affects each variable has on output capacity and gradation. We'll cover machine sampling and benchmarking as key ingredients in the optimization process.

3:45 PM
Re-entrapment of Metal Ions from Seawater Using Lithium Manganese Oxides (LMO) Nanofibers.

S. Choi[1], Y. Han[1], G. Hwang[1], N. Myung[2] and H. Kim[1]; [1]Mineral Resources and Energy Engineering, Chounbuk National University, Jeonju, Korea (the Republic of) and [2]Chemical and Environmental Engineering, University of California-Riverside, Riverside, CA

According to research presently being conducted on selective lithium recovery in seawater, inorganic adsorbents with high selectivity and capacity for capturing lithium ions from liquid lithium resources are called lithium ion-sieves (LISs). Their low toxicity, low cost and high chemical stability make

LISs suitable for lithium recovery from seawater. In the present study, the ultrathin LMO nanofibers with controlled diameter were successfully fabricated by an electrospinning technique with a hypothesis that greater aspect ratio (i.e., smaller diameter) would lead to the enhanced recovery of lithium ion from seawater. Design of Experiment (DOE) and dimensionless analysis were performed to systematically optimize the diameter and morphology of nanofibers. Several complementary techniques including FE-SEM, HR-TEM, XRD, and nitrogen sorption isotherm, were used to evaluate the physical/physicochemical properties of the nanofibers. Lastly, the lithium ion recovery was tested for the nanofibers with different physical properties using artificial seawater; furthermore, the selectivity and stability for lithium ions to the nanofibers were evaluated under different sodium ion contents.

MONDAY, FEBRUARY 26

AFTERNOON

2:00 PM | ROOM 101F

International: Women in Mining

Chairs: *J. Shuttleworth, Fortescue Metals Group, East Perth, WA, Australia*
R. Furey, MWH, Broomfield, CO

2:00 PM
Introduction

2:05 PM
From Graduate Metallurgist to General Manager – Sharing My Story

J. Shuttleworth; Fortescue Metals Group, East Perth, WA, Australia

Julie Shuttleworth shares her career journey from Graduate Metallurgist to General Manager, where she currently manages one of the world's largest iron ore mining operations. Julie has worked in Australia, China and Tanzania, and travelled to over 100 countries for work and recreation. Julie shares her adventures, challenges, lessons learnt, leadership and career tips, demonstrating you can have a very rewarding career and a lot of fun at the same time. This inspiring presentation will especially benefit students, women and young professionals.

2:25 PM
The Readiness of the South African Coal Mining Industry to Support Women in Mining

S. Rupprecht; MiningEngineering, University of Johanesburg, Doornfontein, South Africa

Mining is a significant contributor to the South African nation with 457,698 persons employed in the mining sector in 2015 (COM, 2016). The role of women in this industry has dramatically increased from the period when women were not allowed to work in the mines. In 2002 approximately 11,400 women were employed in the mineral industry. As of 2015, some 53,000 women were employed. Although the working environment is starting to change and adapt for women in mining there is still much work to be done. This paper discusses the readiness of the South African coal mining industry to promote, and support women in mining, as it has become apparent that there are a number of deficiencies regarding facilities and policy that address the employment of women in mining. The paper will comment on the awareness of sexual harassment, the readiness of mining infrastructure for women, research and development around the ergonomics of underground plant and machinery, and pregnancy and maternity issues.

2:45 PM
Gender Gaps, Women's Role and Myths in Artisanal and Small-Scale Gold Mining in Ghana

K. Bansah[1], N. Dumakor-Dupey[2] and E. Assan[3]; [1]Mining Engineering and Nuclear, Missouri University of Science and Technology, Rolla, MO; [2]Mining Engineering, University of Mines and Technology, Tarkwa, Ghana and [3]Community Sustainability, Michigan State University, East Lansing, MI

Women participation in artisanal and small-scale gold mining (ASGM) has increased over the last decade. In Ghana, women participation in the ASGM is at least 40% of the workforce. This study explored the factors accounting for poverty among women in the ASGM. Snowballing and purposive sampling methods and participant observations were used for the study. The authors observed that many women who engage in the ASGM as their only source of livelihood are more than 50% poorer (in terms of income) compared to their male counterparts. The women in ASGM are mostly marginalized and socially-excluded, partly due to certain perceptions or beliefs by their employers, superiors, and male counterparts. Education would engender a change in those beliefs and perceptions and improve the socioeconomic lives of the women and their dependents.

3:05 PM
Exploring Non-conventional Career Paths for Mining Engineers

C. Pomeroy, L. Diaz and K. Boyce; Global Mining, Caterpillar, Peoria, IL

Over the past several years, the mining industry has suffered one of the worst downturns to date. Throughout all of the cost cutting current, mining students and recent graduates are entering the industry at an extremely difficult time. The lack of opportunity presented to undeveloped engineers is discouraging and can result in them leaving the industry entirely. In order to help prevent this pervasive and disheartening attitude, this report discusses the non-conventional ways mining engineers can remain involved in the industry without working as a mining engineer. Pulling from the experiences of the authors and many other recent mining graduates, these non-conventional career paths are compiled and discussed to provide other mining engineers with additional perspective, assistance, and opportunity in the job search.

3:25 PM
Reality Versus Perception: Dissecting the Challenges in Achieving Gender Diversity and Inclusion in the Mining Industry

T. Bame; Sustainable Development – Social Responsibility, Freeport-McMoRan, Phoenix, AZ

In 2016, the Bureau of Labor Statistics reported that only 13% of people employed in the U.S. extractives industry were women, and the sector ranked second to last for the lowest percentage of women. However, the data only tells the story of diversity, which is a simple measure of headcount. Inclusion puts the practice of diversity into action by creating an environment of connection and respect where the variety and richness of perspectives and ideas are harnessed to create business value. Is a lack of inclusion the reason that gender diversity has not advanced and further, is it at the root of stagnant numbers of women in leadership positions? If so, what truly drives a culture of inclusiveness? Explore possible answers to these questions by examining recent survey data gathered from female employees at Freeport-McMoRan's U.S. operations, designed to help the company determine how to accelerate its goal to reach 15% of women in its workforce and leadership ranks. By dissecting industry specific challenges and separating reality from perception, the potential is greater to arrive at solutions and actions that "mine the potential" of women and strengthen the sector.

3:45 PM
How to Attract Young Engineers: The Allure of Travel in the Mining Industry

J. Rutledge; Mining Products, Silvateam Indunor, Tucson, AZ

It's no secret the mining industry has a shortage of skilled engineers as an aging workforce heads into retirement. With a meager dozen schools in the U.S. offering mining engineering programs, the supply of engineers is

bleak. The graduation rate of engineers in mining, geology, and metallurgy has steadily decreased with time. The issue with the pipeline of skilled workforce starts at the source—recruiting students to get involved in the industry and excited for potential opportunities. Many engineering fields offer vast beautiful "campuses" with excellent perks, in bustling cities, in contrast the mining industry can appear stark. However, the mining industry has the distinct advantage of being a truly international industry with an abundance of opportunity for skilled engineers—it's just not often marketed that way. The opportunities for travel within the industry are vast, from study abroad programs at international mining universities, to fly-in-fly-out jobs, or working a "non-traditional" role that allows for extensive travel. With a generation that values travel over purchasing a car or a home, the mining industry has a lot of allure, if we chose present it that way.

MONDAY, FEBRUARY 26

AFTERNOON

2:00 PM | ROOM 101A

Mining & Exploration: Geology: North American Exploration Geology

Chair: *E. Hart, Newmont*

2:00 PM
Introduction

2:05 PM
Comparison of Industrial Sand Areas in Northwestern and Western Wisconsin

d. reed; SEH, Chippewa Falls, WI

Industrial sands are mined from different geological and hydrogeological settings in northwestern and western Wisconsin. The "northwestern" area, located in northern Chippewa, Barron and Burnett counties was influenced by Pleistocene glaciations and possesses more complex Paleozoic bedrock structures, thinning of sandtone units caused by erosion and shallow depths to PreCambrian basement. The "western" industrial sand mining area is bounded to the north by the southernmost Pleistocene glacial ice margins and to the south by the outline of the "Driftless Area" of western and southwestern Wisconsin. The western area occurs in a less complex structural setting that is characterized by a southwesterly stratigraphic dip and more variable overburden thicknesses, Sand quality is excellent in both the northwestern and western sand areas. The Mt. Simon sandstone aquifer produces high quality water for wash plant operations in both areas. The northwestern area is characterized by more surface water features and thinner, high capacity aquifers. The western industrial sand area exhibits thicker, more variable depth, higher capacity Mt. Simon aquifers.

2:25 PM
Bisoni McKay Vanadium Deposit in Nevada and Vanadium Electrolyte Production for Energy Storage

T. Hammond; Hammond Swayne LLC, San Manuel, AZ

Stina Resources' Bisoni McKay vanadium mineral deposit is located in the Vanadium Belt of Central Nevada. The vanadium mineralization is hosted by carboniferous shale and oxidized carbonaceous shale that is part of the Devonian Woodruff Formation. The mineralization is syngenetic and occurs as a single stratabound and strataform body of anomalous vanadium-bearing beds that approaches an estimated 300 feet thick. The Bisoni McKay deposit contains 92 million lbs V_2O_5 Indicated resources and 59 million lbs V_2O_5 Inferred resources at an average grade of 0.40% V_2O_5. The high grade vanadium mineralization is hosted in organic shale in the redox zone. Vanadium hosted in carboniferous deposits is known to produce high level of purity in vanadium electrolyte used in Vanadium Redox Flow Batteries for energy storage. This paper describes the characteristics of the Bisoni McKay deposit and the steps taken by Stina Resources to become North America's first vertically integrated producer of vanadium and vanadium electrolytes for the energy storage industry.

2:45 PM
Do Crystal Morphology and Jasperoid Geochemistry Affect Fe-Oxide (U-Th)/He Cooling Ages in Carlin Systems?

D. Huff[1], E. Holley[1] and W. Guenthner[2]; [1]Geology and Geological Engineering, Colorado School of Mines, Golden, CO and [2]Department of Geology, University of Illinois at Urbana-Champaign, Champaign, IL

Jasperoid is a style of hydrothermal alteration where silica and disseminated sulfides replace carbonate in existing rocks. Although oxidized jasperoids are common in fault zones near Carlin-type deposits in Nevada, they are unreliable indicators of whether economic mineralization exists at depth. This study examines whether Fe-oxide (U-Th)/He thermochronology can distinguish different generations of jasperoids, some of which may be contemporaneous with ore formation. Jasperoids with different Fe-oxide morphologies and whole rock geochemistries were characterized to establish a spectrum of jasperoid styles. Preliminary Fe-oxide (U-Th)/He dating returned ages of 5.73 ± 0.42 Ma to 11.92 ± 0.23 Ma, which are significantly younger than the expected Eocene ages of Carlin-type gold mineralization. The Miocene and Pliocene Fe-oxide ages may represent resetting by younger heating events not recorded by the apatite (U-Th)/He ages. However, it is more likely that the Fe-oxide ages represent the timing of jasperoid oxidation in response to lowering of the water table.

3:05 PM
Integration of Systems on Drill Holes Exploration Logging in the Open Pit Mine of Pueblo Viejo, Dom. Rep.

L. Mosquea; Geotechnical Engineering, Pueblo Viejo Dominicana Corporation, Fantino, Sanchez Ramirez, Dominican Republic

In the first stage of exploration of a mining project, drilling campaigns are traditionally focused on geological research, leaving geotechnical and hydrogeology research for subsequent campaigns, depending on the potential of the resource. This implies potential future expenses on re-drilling. Relatively low cost, easy-to-deploy, down hole multifunction geophysics system are now available, which allow to rethink the initial exploratory work to include a multisectoral approach from the earliest stages and from a unified drilling campaign, thus obtaining crucial information for possible mining planning, at an early stage. PVDC has decided to apply this approach in its new exploratory campaigns, for which it adds to the traditional geological survey geophysical logging systems such as: (i) Acoustical Borehole Image (ABI), (ii) Optical Borehole Image (OBI), and (iii) Constant Head Packer Test. Making possible the creation of fundamental models for mining planning with different uses and more truthful: i) Geological model, ii) Structural model, iii) Model of geotechnical domains and iv) Hydrogeological model from a single exploratory campaign.

3:25 PM
Mineral Potential Modeling: Knowledge-Driven vs Data-driven Models for Regional Exploration

C. Nicosia; Big Rock Exploration, LLC, Minneapolis, MN

Mineral potential mapping is a powerful technique used by exploration geologist to evaluate large regions for mineral resource prospectivity. An extensive geodatabase must be compiled from available data including; geological, geochemical, geophysical, and remote sensing data. These data layers are computed in GIS modeling software to display a singular thematic output that considers all data factors. Typically, geologists will use knowledge-driven or data-driven approaches to calculate or estimate the mineral prospectivity of an area. These approaches assign evidential weights to specific criteria

and integrate evidential maps into a final mineral prospectivity map for a specific style of mineralization. This talk will discuss two common methods used to produce mineral prospectivity maps. The data-driven method, called weights of evidence (WOE) established by Bonham-Carter et al (1989) and the knowledge-driven method known as fuzzy logic modeling, a theory proposed by Zadeh (1965).

MONDAY, FEBRUARY 26

AFTERNOON

2:00 PM | ROOM 101E

Mining & Exploration: Management: Capital Project Management at Operating Mines

Chair: *G. Wilson, Mine Engineer – Barrick Goldstrike Mines Inc., Elko, NV*

2:00 PM
Introduction

2:05 PM
Economic Analysis Tools

K. Miles, R. Kafka and J. Wientjes; Application Engineering, Komatsu America Corp., Peoria, IL

In this evolving age of the mining industry where capital and personnel resources are diminishing, more and more companies are incorporating detailed Total Cost of Ownership (TCO) analyses as a key component in the equipment acquisition process. The Komatsu Mining Division has developed multiple tools to aid in performing and interpreting TCO studies. One such tool incorporates time value of money principles along with comprehensive equipment performance information to perform standard TCO analyses. A recent enhancement to this program is the ability to perform sensitivity analyses for a greater array of cost and performance components that impact TCO results. This presentation will introduce this economic analysis tool and its major design principles. An overview of the new operating enhancements will give the attendee an understanding of the improved functions and capabilities of the program. In addition, a study example will be reviewed to further illustrate the key utilization procedures, data input requirements, and output analysis process.

2:25 PM
Building Northwest Exodus

J. Rahn; Newmont Mining, Elko, NV

The Northwest Exodus expansion has currently added over 800k ounces in reserves to Newmont's Exodus underground mine in Northern Nevada. Due to both the large increase in the size of the mine and the spatial separation of the two ore bodies a large capital project was undertaken to build the Northwest Exodus expansion. This paper will cover the scope and results of the project which include construction of a ventilation shaft, an underground shop, ore passes, a backfill transfer raise system, and commissioning a new ventilation system.

2:45 PM
ESG Matters in Mining

T. Perchiazzi; ERM, Lone Tree, CO

Historically, the return on capital for mining projects has been calculated on specific, measureable line items related to commodity value and its associated economics. As the mining industry begins to show signs of improvement, what drives the flow of capital in today's new normal is broadening. As a result, environmental, social and governance (ESG) considerations are becoming more material in the context of project investments and M&A deals. Companies that are able to address these issues throughout the mining lifecycle are more likely to gain funding and avoid potential project delays through proactive risk and stakeholder management. This session will analyze what ESG factors investors should take into account, and how they may differ across the spectrum of mining clients (from Juniors to Majors). It will also show how an understanding of your ESG risks can be mapped out to help mitigate risks through a project's lifecycle.

3:05 PM
Grade Control and Mine Planning – Observations from the Front Session: Practical Incorporation of Technology in Operations

D. Cameron; Cameron Resource Consulting, LLC, Harrison, ID

Mine planning at the feasibility stage tends to be a compartmentalized function which often produces an unsatisfactory result for grade control effectiveness. Once the mine plan is complete and operations begin, changes are painful and costly, lessons are hard and tend to repeat. Grade control fits what's already available in the time allotted—blast holes, chip muck sampling, drilling from available platforms. The geologist should insert himself into the planning process at the pre-feasibility level, and it should be the responsibility of management to facilitate this, placing capable, experienced advocates into the feasibility team, whether consultants or employees. The geologist should be prepared to demonstrate the benefits of the program and to provide all necessary statistics for costing, bidding and manning. Mine planning is an iterative process, thus the grade control plan must also be produced in a format that can be modified rapidly to respond to changes in price, production rate, and other assumptions. Real-world examples are presented of successful integration of grade control requirements into early-stage mine planning in both open-pit and underground operations.

3:25 PM
The Value of Independent QA/QC Audits of Sampling and Analysis Procedures

M. Fairhurst; Oreval, South Saint Paul, MN

Accurate and reliable estimates of ore reserves are fundamental to the development of any successful mining venture. Although not mandated by current legislation, independent QA/QC audits are valuable in identifying errors in sample collection, transport and storage; assay preparation and testing, contamination, accuracy and precision of data recording; and recognizing laboratories that maintain a commitment to best practices. Annual Reporting of resources are based on laboratory data. The paper presents examples to demonstrate how errors in sampling and assaying procedures have affected the viability of operations - and the confidence of investors, venture capitalists and shareholders.

MONDAY, FEBRUARY 26

AFTERNOON

2:00 PM | ROOM 101B

Mining & Exploration: Operations: Mine Planning Methods and Resulting Project Outcomes

Chairs: *E. Corsale, BHP, Saskatoon, SK, Canada*
R. Lamont, University of Kentucky, Lexington, KY

2:00 PM
Introduction

2:05 PM
Underground Mine Planning Optimization Process – A Practical Work Flow to Improve Values

H. Wang; Newmont Mining Co., Greenwood Village, CO

The author would like to share a complete and practical work flow that has demonstrated to improve underground mine and project values: 1. Using block model evaluations with conditional simulations for uncertainties analysis; 2. Using Stope Optimizer (MSO), Level Designer (PUNO) for rapid mine designs; 3. Using Strategic Mine Planning Optimization – Hill of Value Model (HoV) to guide cut-off grades, production rate and other decisions; 4. Using Deswik scheduler to create automatic and manual sequences; 5. Using Schedule Optimization Tool (SOT) for schedule optimization; 6. Incorporate metallurgical, geotech and ventilation requirements into mine design and scheduling; 7. Using first principle cost modeling (Xeras) for financial modeling; 8. Incorporate other strategic tools, such as Minemax to improve the project values from regional prospective. Disclaimer: software tools mentioned above are trademarks of various commercial companies; they are referenced here for relevance, without endorsement.

2:25 PM
Analysis of Robust Pit Shells

D. Hulse; Gustavson Associates LLC, Aurora, CO

The science of "optimal economic pit design" has been highly refined in the last decades. Even with the proliferation of optimizing and heuristic algorithms exploiting ever faster computers, the most common input is a single block model and a single set of cost assumptions, each with a distribution of errors. An analysis of price assumptions produces a suite of nested economic shells, each with its own quantities of ore, waste, grade, and profit, but due to irregularities in the mineralized body, the growth of these shells can be erratic. To control the impact of the errors of the model and cost assumptions when choosing the pit shell for design, graphs of pit shells characteristics, such as stripping ratio, cost per unit of product and profit/ton, can be analyzed to consider points with higher stability, or robust pits. Selection of robust shells for a pit limit and for push backs can help to understand the impact to profit and risk. The robust shells also limit the possible solution sets for final pit and cutoff optimization.

2:45 PM
Methodology for a Dump Design Optimization

j. Puell; Mining and Geological Engineering, University of Arizona, Tucson, AZ

Dump design is critical to effective mine planning. Capital and haulage costs are considerable from early stages and through the life-of-mine as these dumps gradually become immense structures. Delivered mining rates, as well as certain spatial and physical constraints, provide a set of parameters of mathematical and economic relationship that creates opportunities for modelling and thus facilitates the measuring and optimization of ultimate dump design by using programming and empirical techniques while achieving economic objectives. This paper presents a methodology to model and optimize the design of a mine dump by minimizing the total haulage costs. This methodology consists on: (i) Formulation of a dump model based on a system of equations relying on multiple relevant parameters; (ii) Solves by minimizing the total cost using linear programming and determines a 'preliminary' dump design; (iii) Through a series of iterations, modifies the 'preliminary' footprint by projecting it to the topography and creates the ultimate dump design. Finally, an example application for a waste rock dump illustrates this methodology.

3:05 PM
Simultaneous Stochastic Optimization of Mining Complexes / Mineral Value Chains: New Digital Technologies, Concepts, Examples and Comparisons

R. Dimitrakopoulos; COSMO Lab, McGill University, Montrea;, QC, Canada

A mining complex or mineral value chain is a system where raw materials are extracted from mineral deposits, transformed into sellable products using different processing streams, and delivered to the spot-market or customers. The supply of materials extracted from available mines represents a major source of uncertainty and technical risk. New digital technologies facilitate the simultaneous stochastic optimization of mining complexes in a single optimization model. This advancement resolves major limitations of past approaches, as demonstrated in this paper with examples from gold and copper value chains. Benefits stemming from jointly optimizing the interrelated aspects of a mining complex, including scheduling of material extraction along with their uncertainty, encompass: technical risk management, blending, stockpiling, capital investments, non-linear transformations occurring in and utilization of processing streams, and transportation of products to customers. Compared to past approaches, the examples show that the reliability of an operation's meeting production forecasts is markedly improved, larger amounts of metal are produced, and higher economic value is generated.

3:25 PM
Integrated Tactical Mine Planning at Chino Narrows Planning-Execution Gap

J. Castaneda[1] and J. Schmidt[2]; [1]Hexagon Mining, Rio Rico, AZ and [2]Long Range Planning, Freeport-McMoRan Chino Operations, Silver City, NM

Chino is an open-pit copper mining complex faced with intricate material routing requirements. Historically, this was challenging at the mine, in part because the shovel dig plan, haul plan, and dump plan were prepared completely separately. The mine now uses an integrated workflow for faster evaluation of schedules, which facilitates preparing balanced cutoff grade-to-equipment requirements, supports better mineral production, and improves schedule viability, while considering operational implications. Located in the state of New Mexico, Chino is one of nine Freeport-McMoRan mining operations in North America. This presentation discusses the benefits of implementing an integrated approach to tactical mine planning. This includes improvements in completion time for preparing a schedule, minimal risk from manipulating Excel macros, data integration required to make short-term planning decisions, and better understanding of the mine plan's effect in relation to the business's key performance indicators. Ultimately, the integrated approach to tactical mine planning at Chino has led to production forecasts which are more achievable and reduced planning and execution variance.

3:45 PM
Forward Thinking, the Importance of Including an Exit Strategy and Project Off-Ramps During Project Permitting

S. Kozicki and A. Haus; Foth I&E, De Pere, WI

Mine permitting efforts tend to be front loaded, with both regulators and permittees focused on passing requisite permit gates to advance the project into development and operations. Plans regarding what will happen after reclamation is complete tend to be less detailed and definite. In the absence of permit or regulatory guidance that defines how closure will be achieved and how long a site must be monitored, mines risk getting caught

in a perpetual monitoring cycle. A proper exit strategy should include defined off-ramps that specify conditions to meet before the regulatory agency can accept a reduction or termination of monitoring. As more polymetallic mining opportunities arise in the Midwest, it is important to think about structuring the mining permit in a way that provides clearly defined off-ramps from monitoring. In the long term, this foresight also potentially eliminates the need for post closure permit modifications. Parallels can be drawn to established EPA site close-out guidance, including examples of end goals tied to regulatory standards, and consequent step down of oversight by shrinking monitoring programs, reducing parameter lists, or reducing site visits.

4:05 PM

Sill Mat Construction for Accelerated Extraction of a High Grade Gold Vein

R. Garcia and M. Gonzalez; Gold Resource Corp, Oaxaca, Mexico

Mine planning is usually associated only to the operations space. This way of thinking could be costly as many projects of a short life span can have a tremendous impact in the actual ore production of the mine. Mine planning should be looked at as the set of every single activity and task that could have a potential impact in the tonnes fed to the mill and beyond. This is the case of a considerable concrete sill mat that was constructed in less than two months and allowed a gold and silver mining operation to correct its course and successfully achieve its yearly budget objectives.

MONDAY, FEBRUARY 26

AFTERNOON

2:00 PM | ROOM 101C

Mining & Exploration: Operations: the Reality of Operations; Working in a Dynamic Environment

Chairs: *M. Scherr, Cliffs Natural Resource*
N. Beukema, Cliffs Natural Resources, Virginia, MN

2:00 PM

Introduction

2:05 PM

What is a Charrette? A Helpful Process to Build Community Support

J. Marinucci; SEH, Virginia, MN

A charrette is a meeting in which all stakeholders in a project attempt to resolve conflicts and map solutions. This talk will take you through the process of a major highway relocation, instigated by the expected extension of a mining operation. It is a great story of building community awareness and support well ahead of the formal notification, permitting and construction phases of the highway. Utilizing a charrette provides a safe environment to visualize the opportunity that comes with change and incorporate these visions into the planning phases of a large scale project.

2:25 PM

Cut-off Grade Optimization and Impact on Daily Material Routing Strategy at Freeport McMoRan Sierrita

A. Ashok Parmar[1], A. Soderman[1], A. Moharana[2] and S. Dutta[2]; [1]Freeport McMoRan Inc, Green Valley, AZ and [2]Hexagon Mining, Tucson, AZ

The Freeport McMoRan, Sierrita mine is an open pit truck and shovel operation which produces copper and molybdenum. The mine is located approximately 20 miles southwest of Tucson, Arizona. This technical presentation discusses the concept of dynamic cut-off grade in the context of the grade control process at Sierrita. Traditionally, a fixed cut-off grade is used to define ore and waste boundaries in short-range mine planning and for grade control (GC) routing process. Since haulage costs are not considered as part of the GC planning process, the chances of misrouting an ore block to a waste dump or a waste block to crusher increases, which leads to lost value. The paper discusses using the dynamics of best possible destination including haulage for grade control in comparison to using only material types as a criterion. This presentation will discuss the methodologies and procedures as well as the optimization techniques used to integrate the dig, haul and dump plan. It will also provide a better understanding on how material routing based on best possible destinations (haulage) impacts selection of cut-off grade and value gained with the new approach.

2:45 PM

Sedimentation Control Strategy to Increase Longevity in Moore Pit Dewatering Wells.

B. Mojica; Technical Services, Barrick, Cotuí, Dominican Republic

Mines dealing with unwanted ground water effects such as decreasing slope stability, decreased mine production rates, equipment lifetime and safety, typically engage in large and costly dewatering well programs to mitigate these effects. Furthermore, in most countries, mine dewatering programs are subjected to strict regulatory controls and long-lasting approval processes which restrict the number of wells planned. Ensuring achievement of projected productions rates and increasing the longevity of each production hole becomes therefore, a key feature on any long term dewatering strategy. An unfavorable effect to the success of this program is the progressive deposition of leached metals around the wells screen and submersible pumps; a common process on many high sulfide ore deposits such as the ones present on Pueblo Viejo mine in the Dominican Republic. Continuous depressurization is crucial in a pit of these characteristics, just as it is to have the proper approach to maintain a pumping network functionality and longevity. This paper defines the used strategy to maintain a network of 32 pumping wells in a developing mining phase while dealing with pipes clogged by sediments.

3:05 PM

Underground Mine Power Reliability

J. Fisher; Stantec, Tempe, AZ

The reliability of underground mine power distribution has many interdependent influences. There are electrical engineering standards, processes, terms and requirements that can be applied to each unique mine application. Theoretical approaches to mine distribution reliability include statistics, software simulation and design. Practical considerations include, safety, cost, environment and suitable application for the location. How the system is operated and maintained has a large underestimated role in its reliability and should strongly influence initial design. This paper services to explain some of the jargon and offers some practical considerations for existing mines and those being designed.

3:25 PM

Practical Application of Schedule Optimization Technologies in Today's Complex Surface Mine Environments

J. Kraft and R. Diaz; Minemax, Highlands Ranch, CO

Mine planners are increasingly charged with evaluating a number of downstream alternatives in order to inform the most appropriate operating strategy. Examples of these alternatives often include assessing dynamic options for pit backfill, leveraging the encapsulation of certain waste material types, accommodating limitations on land access, and fulfilling requirements for

tailings dam material delivery. Each of these common surface mine situations presents a unique opportunity to leverage optimization to uncover value for the operation by incorporating these beyond-the-pit decisions at the same time the mining sequence decision is made.

3:45 PM
Mining Dilution: Variable Versus Fixed Factor
A. Ebrahimi; Mining, SRK Consulting, Vancouver, BC, Canada

Mining dilution affects the economy of mining projects in many ways. For example, dilution increases costs and can cause reconciliation issues that are common in mining operations. A common approach to estimating mining dilution is to apply a fixed factor to the entire block model. The fixed dilution factor is usually driven by assumptions that are made based on experience and general knowledge. Mining dilution occurs in contact area of ore and waste, but not in the centre of the orebody. Because fixed dilution factor ignores the changes of values within an orebody, the designs driven by such studies can become suboptimal. The methodology described in this paper assures dilution factors are calculated on a block-size scale and honor the variability of values within the orebody. Applying a variable dilution factor enhances the accuracy of mining studies and subsequent economic evaluations. This will be demonstrated using a case study.

4:05 PM
Zone Selection in Underground Mining
B. King; Mine Planning, Newmont Mining, Denver, CO

In large underground mines selecting the correct zones or regions to mine is critical to maxmizing value. We use a real world application of a large underground ore body that has three mining zones. Each zone has a drastically different grade tonnage curve, which makes it difficult to rank the zones through simple analysis. Therefore, we construct a series of interger programming models to determine the cutoff grade, production capacity, mining method and zone order which maximizes the NPV.

MONDAY, FEBRUARY 26
AFTERNOON

2:00 PM | ROOM 101D
Mining & Exploration: Technology: Technology Innovations in Mining

Chair: *J. Anderson, Barrick, Elko, NV*

2:00 PM
Introduction

2:05 PM
Stantec's 3D Mining Experience
M. Peden; Mining, Stantec, Tempe, AZ

This presentation is an exhibit of Stantec Mining Divisions experience in 3D mine and mine infrastructure modeling. Project examples are presented and discussed that illustrate unique design features of various systems along with their constructability aspects. Various software's utilized to produce the designs are noted along with future expectations for the mining industry.

2:25 PM
Advanced Mine Planning and Ore Control Data Integration
P. Alvarado Herrada; SME, Aurora, CO

The most important reason for advanced mine planning and ore control data integration is to get most of the deposit by understanding environmental, economic, geological, geotechnical, etc. aspects. To do that mine planning and ore control block model data must be studied and created. Then the block model must be imported or a brand-new block model must be created in suitable mine planning software. Best technology must be used to do technical operations with block models. Naturally, LTP, STP, and OC activities will require sharing back and forth information not only block models; but also, polygon, patterns, and triangulations. Topography, ultimate pit, phases, plans, and mining polygons are polygon objects designed to accomplish LTP, STP, and OC activities. However, it is imperative to manage logically these objects and professionals must generate value while integrate this data by following mine planning sequence of activities. Advance data integration saves time and makes professionals work efficiently. The goal is to integrate mine planning and ore control data using modern algorithms and this organization can create economic value by improving efficiency in more than 20%

2:45 PM
Mining Truck Availability Estimation Model from Standard OEM Telematic Data
N. Priegnitz[1] and J. Yoo[2]; [1]Komatsu America Corp. / Bradley University, Peoria, IL and [2]Industrial & Manufacturing Engineering & Techology, Bradley University, Peoria, IL

Sensitive to commodity prices and general economic trends, mining companies frequently operate close to the margin and demand high availability and efficiency from equipment they purchase. Even in situations where this is not a guaranteed figure, manufactures of heavy mining equipment try to monitor and track availability as a key measure of competitiveness in the market. One potential source of insight into availability is the analysis of sensor data transmitted back to the OEM through factory standard telematics systems. This study explores the correlation between sensor data and availability to develop a indicative model of availability that does not require the sourcing of maintenance data.

3:05 PM
A Multi Objective Multi Stage Mining Fleet Management System Linking Dynamic Operation to Short-Term Plan
A. Moradi Afrapoli, S. Upadhyay and H. Askari-Nasab; Department of Civil and Environmental Engineering, University of Alberta, Edmonton, AB, Canada

Fluctuation in market price of mineral products has enforced mining companies to cut down their operating costs. One useful way of reducing operating costs in mining operations is to implement efficient mining fleet management systems (FMS). Since 50 years ago several types of FMS have been developed in the mining systems. However, there are two major shortcomings in existing systems. Firstly, none of the existing systems consider effects of the short-term plan on dynamic truck assignment. Secondly, most of them make decisions in a way that optimize a specific objective while ignoring others. Herein, we propose a multi stage and multi objective FMS that deals with aforementioned shortcomings of the currently available systems. The developed FMS, in its upper stage, links semi-dynamic operational decision making process to the short-term production plan by implementing its first multi objective decision making model. Then in its second stage, in a real time dynamic decision making process, it assigns trucks to shovels and corresponding destinations by optimizing its second multi objective decision making model. The developed FMS has been verified using an Iron ore case study.

3:25 PM
Tablet Capabilities, Interface Approaches, and Internet of Things (IoT) Applied to Fleet Management Systems and Interactive Digital Safety Forms
S. Dessureault; MISOM Technologies, Tucson, AZ

Smart devices such as iPads and wireless sensors and have transformed modern life and are poised to revolutionize the mining industry. Internet of Things (IoT) and Mobile apps have enabled affordable automated fleet management (FMS) and safety tracking to mines of any size. Several recent innovations in technology and then deployments of innovative IoT nearables for tracking cycles, even sequences automatically, locating personnel, low-cost proximity sensing, as well as collecting digital safety and maintenance forms, has shown that technology cost is no longer a challenge to overcome. For example, surface mining wireless infrastructure can be simplified by using modern-day LTE communications rather than expensive proprietary Wi-Fi and interior or underground location through low-cost sensors rather than older and expensive RFID technology. The challenges and benefits from several deployments of an iPad, and IoT-based FMS at different mines throughout the world will be reviewed. This includes the key challenges facing these technologies such as entrenched existing concepts of the costs of technology, the technology selection process, and the need for focus when using data.

3:45 PM
Efficient, Real-Time, Verifiable Inspections for Mining Equipment Fleets
S. Penmetsa; rapidBizapps, Milpitas, CA

Traditional paper-based methods of conducting inspections of mining equipment have numerous issues, including incompleteness or inaccuracies in information (due to loss or damage of physical inspection cards, or due to illegible handwriting), and an inability to instantly and verifiably place in sequence a series of events that led to an inspection exception. Paper-based solutions also inevitably come up against the "transcription bottleneck" where an individual may be tasked with entering data from physical cards into a legacy computer database.

4:05 PM
Mechanical Vein Miner
A. Alexander[1] and M. Ramström[2]; [1]Lucky Friday Mine, Hecla Mining Company, Mullan, ID and [2]Atlas Copco, Oerebro, Sweden

Hecla's Lucky Friday underground mine has been in operation for 75 years with production from depths over 2.3 kilometers (7,500 feet) below the surface. Challenges at this depth include high rock temperature and seismicity. The use of new and innovative mechanization in hard rock cutting is being evaluated for ore production. Principal advantages of mechanization are the reduction of personnel exposure, reduced seismic triggers, and increased efficiency. Lucky Friday and Atlas Copco have partnered to design, build, test, and deploy a mechanical miner for primary ore production. We will discuss the background, concept, development and deployment strategy for a mechanical miner.

MONDAY, FEBRUARY 26
AFTERNOON

2:00 PM | ROOM L100I

Mining Blasting Technologies
Chairs: *C. Johnson, Rolla, MO*
J. Silva, University of Kentucky, Lexington, KY

2:00 PM
Introduction

2:05 PM
Modeling and Prediction of Underground Blasting Vibration
A. Konya and C. Konya; Explosive Engineering, Precision Blasting Services, Montville, OH

In the past, the U.S. Bureau of Mines and others have established envelope equations that related scaled-distance to peak particle velocity in an attempt to predict the maximum ground vibration that could be expected from surface blasting operations. Over the past twenty years Linear-Regression Modeling has become widely accepted for ensuring that vibration limits are not exceeded at a site, using the Scaled-Distance variable. In today's industry, numerous equations are present for different scenarios, geologic environments, hole sizes, and numerous other factors with an emphasis on site-specific equations developed for all major projects; however, underground blasting applications have not been analyzed to a great degree of detail. Without previous knowledge this puts underground blasting operations into a guessing-game to ensure that vibration levels are not exceeded. This paper will review two recent underground blasting projects that have been completed by the authors and linear-regression models that were used with both burn cuts and stope blasts.

2:25 PM
Fast Rock Segmentation Using Artificial Intelligence
M. Ramezani, S. Nouranian, I. Bell, B. Sameti, D. Cooper and S. Tafazoli; Motion Metrics International Corp., Vancouver, BC, Canada

Image-based rock fragmentation sensing in mines and quarries includes an important rock boundary delineation step, commonly referred to as rock segmentation. This paper presents an artificial intelligence-based solution to this challenge. The proposed technique encodes prior knowledge of previously analyzed images into mathematical/statistical models. Human-labeled images are used as inputs to train neural networks through an optimization process. The networks can then be used in real time for rock delineation. To build the models, special deep artificial neural networks are used as a pixel classifier. The proposed classifier labels each pixel (edge, rock or fine) by analyzing a plurality of pixels within the image. Advances in machine learning allow the network to contain many parameters. The increased number of parameters is a strong factor in the classifier's ability to correctly classify each pixel. Deep learning-based segmentation, combined with 3D imaging followed by post processing, provides a unified fragmentation sensing solution. Results from automatic segmentation are compared to human labeled segmentation using the percentage passing curves for 64 rock images.

2:45 PM
Hot & Reactive Ground Stockpile Blasting at Barrick's Pueblo Viejo Mine.
A. Rosario, S. Aguirre, R. Gonzalez and R. Proulx; Mine Drill & Blast, Barrick Pueblo Viejo, Bonao, Monsenor Nouel, Dominican Republic

Pueblo Viejo is an open pit gold mine in the Dominican Republic which mines hot and reactive sulfide ground. Stockpiles of various ore grades and chemistry are used to send the appropriate blends to the mill to maximize recovery. Re-solidification of the sulfide bearing stockpiles has created a

challenge for heavy equipment such as dozers, rock breakers and front end loaders due to the degree of consolidation at the mining dig face. Blasting the stockpiles with a low powder factors was considered the best solution to solve this problem. After drilling, high temperatures of plus 300°F (150°C) were recorded in some blastholes. A combination of safe procedures, rock reactivity testing and the use of site specific inhibited emulsion along with high temperature resistant initiation systems allowed Barrick's Pueblo Viejo Mine to blast safely and efficiently in the Hot and Reactive Stockpiles.

3:05 PM

Application of Small Unmanned Aerial Systems to Ascertain Emission Quantities and Health Impact of Nitrogen Oxide from Surface Blasting

J. Brinkman and C. Johnson; Missouri University of Science and Technology, Rolla, MO

The most common emissions from detonating explosives are nitrogen oxides (NOx), which are potentially deadly if inhaled. Lab studies estimate emission quantities, though great variation is shown based on site-specific conditions, and lab tests may not fully represent field results. Field values have not been measured due to the vast area affected. OSMRE recently promised to release a ruling regarding surface mine NOx production. Once the ruling is implemented, it may eventually be necessary to monitor site-specific NOx production from blasting. A small unmanned aerial vehicle system (sUAS) is able to carry a NOx gas monitor, rapidly travel to the blast location, and to follow resulting clouds of dust and emission gasses. This project will perform laboratory tests to expand on current estimations, determine an optimal method for collecting data, and evaluate the ability for this unique application of sUAS to assist in health risk assessment for mine employees and nearby communities. Additionally, large initial NOx concentrations do not necessarily correlate to unsafe conditions, and this project will be groundbreaking in observance of surface blasting emission dispersion.

3:25 PM

3D Ore and Waste Movement and Dilution Modeling for Underground Blasting

D. Preece[1], S. Silling[3], S. Boyce[2], R. Yang[1], A. Tawadrous[1] and M. Rothery[2]; [1]Explosives Applications Research, Orica Mining Services, Saratoga Springs, UT; [2]Mining Technology Research, Orica Mining Services, Kurri Kurri, NSW, Australia and [3]Computer Science Research Institute, Sandia National Laboratories, Albuquerque, NM

A three-dimensional blast heave modeling capability, DMC-3D (Distinct Motion Code in 3D) has been modified and applied to underground blasting. Parallelization of DMC-3D-UG allows underground blasting simulations that treat hundreds of blastholes with millions of 3D spherical particles in a reasonable computation time. It is now possible to simulate blasting induced rock movement, with ore and waste constituents, and to forecast final muck location and configuration. From these 3D models it is possible to asses different mining approaches and configurations with different blast designs. Wireless Electronic Boosters (WEB) have also opened up many new possibilities for underground mining methods that seek increased efficiency along with a reduction of ore dilution and waste. These new mining methods are being developed through extrapolation from current approaches and experience aided by DMC-3D simulations. Planning is also underway for field testing of these new techniques in underground mines. This paper will give an overview of DMC-3D with parallel processing and its application to the development of WEB enabled mining methods and the impact on ore waste and dilution.

3:45 PM

Drill and Blast Costs ... to Reduce or Not to Reduce? That is the Question

N. Rouse, T. Worsey and K. Hall; Respec, Lexington, KY

Many mining operations will try to reduce operational costs by reducing drilling and blasting costs. Drill and Blast cost reduction can be achieved by increasing drillhole diameter, burden, and spacing; decreasing powder factor; renegotiating with contractors; etc. Operations that reduce drill and blast costs in this manner may not have the resources to evaluate the downstream effects of reducing drilling and blasting costs. In many cases, the downstream costs can escalate to a point where the operation actually pays more to produce rock even though drill and blast costs are reduced. This presentation provides some case studies and examples of reducing operating costs by improving drill and blast quality control, varying drill and blast practices, and in some cases, actually increasing drill and blast costs.

4:05 PM

Phase Characteristics of Blast Ground Vibrations

L. Li and J. Silva; Department of Mining Engineering, University of Kentucky, Lexington, KY

Ground vibration is a long-standing issue of blasts in mining or civil engineering, which is related to the safety of nearby buildings and structures, geology along the wave propagation path, or the blast process. So, people want to study blast ground vibration, predict it and control it. A very fundamental and useful measure to study ground vibrations is Fourier transform, which can be easily implemented on a computer. Fourier transform can convert a real time-domain signal into a complex frequency-domain signal with magnitude and phase contents. That is, both magnitude and phase are indispensable to determine a waveform. However, most research is only focused on the magnitude spectrum so far, and the phase is usually overlooked. This paper studied the characteristics of phase spectrum of blast ground vibrations as well as its derivatives which is called group delay. Group delay implies the time delay of sinusoidal components of a signal with different frequencies. The studies prove that the phase contents are frequency-dependent and influence the time-domain waveform extremely and should be considered as important as the magnitudes.

MONDAY, FEBRUARY 26

AFTERNOON

2:00 PM | AUDITORIUM ROOM 1

MPD Plenary Session

Antoine M. Gaudin Lecturer: *Keviv Galvin*
Robert H. Richards Lecturer: *Hans Von Michaelis*
Milton E. Wadsworth Lecturer: *Chris Fleming*

MONDAY, FEBRUARY 26

AFTERNOON

2:00 PM | ROOM 101G

Research: Focus on Innovation in Mining Industry – Academies

Chairs: *A. Samal, GeoGlobal LLC, Riverton, UT*
B. Li, Michigan Technological University, Houghton, MI

2:00 PM

Introduction

2:05 PM

Metrics and Methods for Assessing Resilience Impacts from Integrated Above- and Below-ground Urban Infrastructure

P. Nelson; Mining Engineering, Colorado School of Mines, Golden, CO

In order to make better decisions concerning the use of underground space, particularly in urban environments, the functions and operations of the human and physical infrastructure systems must be understood in an integrated framework with common and meaningful metrics and representations. Considering the importance of economics, sustainability and vulnerability to extreme events, decision makers need an understanding of the valuation for underground space as a resource in order to consider life-cycle engineering and trade-offs and pros and cons of above- and below-ground infrastructure investments. This paper discusses an appropriate framework and metrics for infrastructure analysis that can include complex systems representations for all sectors – physical, social and environmental.

2:25 PM

A Monte Carlo Approach to the Phase Boundary Problem in Automated Mineralogy

I. Barton; UA Lowell Institute for Mineral Resources, Tucson, AZ

Automated mineralogy (MLA, QEMSCAN, TIMA) is a group of scanning electron microscope-based techniques used to quantify mineral proportions and grain size in mining, geometallurgy, and process samples. Although they work well in the interiors of grains, these techniques can yield ambiguous results in and near zones where two or more minerals are in contact, since both contribute to backscatter and X-ray readings. Contact zones are therefore usually identified as "boundary phases" distinct from the touching minerals. The compositions of boundary phases are uncertain and thus may contribute significantly to error in estimates of sample mineralogy. In this project, I use Monte Carlo simulations to examine the interaction of an electron beam with a sample at various distances from a boundary between two minerals. This enables a rough assessment of the width of the zone likely to be identified as a boundary phase and the effects of composition on boundary phase characteristics. It is intended as a first step toward a more complete examination of sources and magnitudes of error in automated mineralogy techniques and their potential effects on geometallurgy and mineral processing.

2:45 PM

X-Ray Micro Tomographic Image Analysis to Understand the Relationship Between Pore Structure, Distribution and Failure Surface of a Studied Rock Sample

D. Chakravarty[1], A. Dutta[2] and A. Agrawal[3]; [1]Mining Engineering Department, Associate Professor, Kharagpur, West Bengal, India; [2]Mining Engineering Department, Final Year Dual Degree Student, Kharagpur, WB, India and [3]Mining Engineering Department, BTech Graduate Student, Kharagpur, WB, India

There is growing interest in using advanced modern-day 3D imaging technologies to study the complex pore structures of natural rocks helping scientific investigations in a non-destructive testing. In this study, analysis of rock properties for the effects of pore structures, pore volumes, pore coordinates in 3D space along with the grain materials has been tried. An investigation to represent the complex pore spaces obtained from the analysis of X-ray micro tomographic images (with approximately 15μ size) with subsequent use of 'pore-scale' distribution approach to characterize the region-wise porosity, has also been tried out in this study. Sandstone samples are taken to examine the internal pore structures and their 3D distribution of coordinates through tomography, assuming failure surface propagation is directly influenced by pores volume and inversely by pores distance, with that we have tried to develop an index representing the relation between pore structure, its distribution and failure surface. Also, the pore distributions are classified quadrant wise for the whole of the sample. It was also observed that there exists heterogeneity in pores distribution of the samples.

3:05 PM

Effects of Heat and Water Saturation on Mode I Fracture Toughness (K_{IC}) with Changes of Bedding Plane Orientations

V. Maruvanchery and E. Kim; Mining Engineering, Colorado School of Mines, Golden, CO

Fracture toughness, an intrinsic material property of rocks, can vary with temperature, water content, and bedding plane orientation of the rocks. The objective of this study is to identify the effects of heat and water saturation on mode I fracture toughness (K_{IC}) depending on bedding plane orientations. The specimens of cracked chevron notched Brazilian disks (CCNBD) of a calcite cemented sandstone were categorized into three groups based on the orientation of the chevron notch with respect to the bedding planes (divider (D), arrester (A) and short transverse (ST)) and were subjected to three conditions: oven dried (control), furnace heated and water saturated. In dried samples, the K_{IC} of D was 35.5% and 22.9% higher than A and ST, respectively while in heated specimens, the K_{IC} of D was 10% and 18.7% higher than A and ST. In addition, the K_{IC} of water saturated D samples was 6.1% and 18% higher than A and ST. The results suggest that heat and water saturation can significantly reduce the effects of bedding plane orientations on K_{IC}. Also, our results obtained with environmental scanning electron microscope indicate the degrading effect of heat and water saturation on K_{IC}.

3:25 PM

In-Situ Bioleaching in Crystaline Rock Formations: Comparison of Conditioning Methods for Enhanced Permeability

R. Schlueter and H. Mischo; Institute of Mining and Special Civil Engineering, TU Bergakademie Freiberg, Freiberg, Saxony, Germany

The global mining industry is facing more and more different challenges concerning geological, technological and social aspects. Potential exploitation of deposits show a tendency to increasing depth with complex ores and decreasing grades. A promising approach to deal with these constrains is by applying alternative extraction methods like (bio-)hydrometallurgy as in-situ leaching (ISL) technology. The Freiberg University of Mining and Technology established the "Biohydrometallurgical Center for strategic Elements" (BHMZ) to foster the interdisciplinary research along the whole biohydrometallurgical process chain to extract indium from sulfide ores. The involved Department of Underground Mining Methods deals with the design and implementation of a small-scale underground testing facility for microbial in-situ stope leaching in its "Research and Educational Mine". This paper demonstrates the potential of in-situ bioleaching under technological aspects. In addition, different conditioning approaches based on hydraulic and explosive methods for enhanced permeability in the formation are introduced and the gathered data will be presented.

3:45 PM

Acrete: A Novel Geopolymerization Technique to Apply Coal Fly Ash as a High Strength Construction Material

J. Zhang; University of Arizona, Tucson, AZ

Through the present investigation, Acrete, a novel geopolymerization technique has been developed to apply coal fly ash as a high strength water-resistant construction material. XRD, FTIR and SEM test were performed to study how experiment conditions and the properties of fly ash affect geopolymerization. Test results show that the obtained compressive strength of the geopolymerization product can reach above 100 MPa. The product shows very high water resistance without losing noticeable compressive strength after a one month soaking time. Compared to other geopolymerization methods, Acrete is a simple and convenient process with fewer additives, which makes it an economical process to be applied in industry practice. Key words: Acrete, coal fly ash, geopolymerization, water resistant, compressive strength.

3:45 PM

Use of Fiber Optic Systems for Distributed Monitoring of Rock Mass Strain, Temperature, and Vibrations: an Underground Case Study

M. MacLaughlin[1], C. Kammerer[1], M. Speece[2] and N. Nesladek[2]; [1]Geological Engineering, Montana Tech, Butte, MT and [2]Geophysical Engineering, Montana Tech, Butte, MT

Rock mass strain, mine seismicity, and temperature were measured using fiber optic technology at Montana Tech's Underground Mining Education Center. This research demonstrates the effectiveness of new fiber-optic-based distributed strain and temperature (DST) and distributed acoustic sensing (DAS) technologies under various mining conditions, facilitating their use in the mining industry and contributing to mine safety. The objectives are to demonstrate that these technologies can be employed in an underground mine, to reliably and accurately detect ground deformation of different characters, fluctuating temperature profiles, and vibrations when deployed along rock surfaces, in boreholes, and submerged in water. Sensing cables were installed in two 30m boreholes, around a large pillar, and along the surfaces of the drifts in various orientations. The sensing cables were attached to the rock with either grout or epoxy. Seismic events monitored by the DAS were compared to geophones also installed at the site. Sensing cables were submerged in two flooded shafts (one to a depth of 500m) to monitor changes in water temperature. Additional tests at two active mines will also be reported.

3:45 PM

Improving Tank House Current Efficiency and Sulfuric Acid Leaks Identification Using Drone Mounted Thermographic Camera- Process Safety

F. Dakubo; Hydrometallurgy, Ray Mine, Kearny, AZ

There are several things that affect Tank house current efficiency; includes short circuits, concentration of iron in the electrolyte, specific flow, poor contact from bent anode or cathode contact bars with the triangle bars and leaks. Amp clamps and hand-held infrared camera have been used to identifying shorts in Tank house. However, these methods are tedious and sometimes unsafe. Example, using amp clamps usually exposes one to the current in the buss bars. This study looks at shorts identification using drone mounted thermographic (IR) camera. We will also demonstrate the use of the drone IR camera in identifying sulfuric acid in difficult to reach areas.

3:45 PM

Sharing Learnings Through Social Media

B. Ross; Lowell Institute for Mineral Resources, University of Arizona, Tucson, AZ

The way that many people communicate and the sources they use have changed significantly the past several years. Instead of books, trade magazines, conferences, and courses to share knowledge and ideas many people rely on the internet and particularly social media to be their primary source of information. This paper discusses the use of LinkedIn as an outlet to share information such as critical safety and health controls or leadership to an international audience quickly and effectively. This method has a tremendous advantage in its ability to reach an audience that in many cases would have been out of reach to other communication methods. However social media also has disadvantages in there is less control on the accuracy of the content or the ability to easily retrieve an article when doing a search for research purposes. In addition to the pros and cons, this article will discuss methods to make your LinkedIn article more effective from an author that has written a book and several popular mining related LinkedIn articles on sharing health and safety critical control measures and leadership learned from the massive Manefay landslide at Bingham Canyon.

TUESDAY, FEBRUARY 27

MORNING

9:00 AM | ROOM 200ABC

6th North American Iron Ore Symposium: Agglomeration & Pelletizing

Chairs: *M. Garant, Corem, Québec, QC, Canada*
R. Kiesel, UMD-Natural Resources Research Institute, Hibbing, MN

9:00 AM

Introduction

9:05 AM

New Binders for Iron Ore Pelletization: Step Change for a Sustainable Future

J. Halt and S. Kawatra; Chemical Engineering, Michigan Tech University, Houghton, MI

Iron ore beneficiation needs advances in process control, automation, more efficient burners and furnace designs, new silica-free binders, and even alternative iron-making routes. Some, like new binders, are only step-changes towards a more sustainable future; however, they are important tools for the iron maker's tool box. This presentation will show new binders designed with the hypothesis that thickening and filtration - which precede pelletization and are designed to agglomerate fines and produce flocs for rapid water removal - are bad for pelletization. Under coagulating or flocculating conditions, pellets are rough, weak after drying and organics are combusted (35 N dry, 32 N at 500 °C), and they abrade easily (4.7 g/kg-min at 1100 °C, 0.8 g/kg-min at 1250 °C). However, under dispersive conditions (ie the new binders), pellets are smooth, strong after drying and after organics are combusted (78 N dry, 65 N at 500 °C), and abrasion resistant (2.6 g/kg-min at 1100 °C, 0.43 g/kg-min at 1250 °C). The presentation will show why that is and why the new binders work. It will also compare the new binder to the traditional binder, bentonite.

9:25 AM

BASF Novel Iron Ore Binder Technology: Study of Bentonite Modification

A. Villanueva[1], S. Hoff[2] and A. Michailovski[1]; [1]Mining Solutions, BASF SE, Ludwigshafen, Rhineland Palatinate, Germany and [2]Mining Solutions, BASF Corporation, Silver Bay, MN

In this study, we compare the influence of two water soluble polymer-based organic binders added to bentonite, to form a hybrid-binder system for Iron Ore Pelletization. The kinetics of the agglomeration process and resulting properties of green pellets were analyzed, and examined in detail through Scanning Electron Microscopy (SEM) and Confocal Laser Scanning Microscopy (CLSM) analytical techniques. It was encountered that the differences in the mechanical properties of the pellets produced by each binder system could potentially be explained by the ability of the polymer to interact with bentonite at a macromolecular level.

9:45 AM

Mustang Pellets – From Pot Grate Tests to Production

P. Carlson; Cliffs Technology Group, Cliffs Natural Resources, Ishpeming, MI

Cliffs has been providing high quality iron ore to their steel customers for over 170 years. The Mustang pellet currently being produced at United Taconite is no exception. The Mustang pellet was tailor-made to replace the Viceroy pellet from the Empire Mine in Michigan. Developing a customized

pellet takes time and technical cooperation between the client's engineers and our Cliffs' team. The goal was to optimize the properties of the iron ore pellet to improve blast furnace performance. Laboratory testing and flowsheet development resulted in a $75 million dollar investment at the plant and a pellet with superior metallurgical properties.

10:05 AM
Pellet Process Parameter Analysis
G. Strueber; Agglomeration, Paul Wurth S.A., Luxembourg, Luxembourg

SUMMARY Paul Wurth has performed a pellet plant operational audit utilizing a pallet car equipped with thermocouples in order to record the real process temperature of the main body and grate bars, when subjected to the conditions in the induration furnace during the pellet indurating process. In addition, the process gas temperature exiting the pallet car were recorded and evaluated. Several critical operational areas were also analysed to correct any deficiencies and improve operations. Photos of the instrumented pallet car will be presented. Test trials, before insertion of the instrumented pallet car into the indurating furnace will be shown. Test campaigns will be outlined and the data recorded will be presented in data-logger curves and charts. Observations in several plant areas will be discussed.

10:25 AM
Case Studies in the Use of Agglomeration by Extrusion in the Steel Industry
M. Steele[1], J. Falter[1] and Z. Voss[2]; [1]J.C. Steele & Sons, Statesville, NC and [2]Voss Metallurgical Solutions, Pittsburgh, PA

Recovery and recycling of iron-containing byproducts has long been a topic of interest in the steel industry. In many cases the byproducts are in the form of fines or sludges, making direct use in metallurgical vessels challenging. Various forms of agglomeration have been used to recover these materials for use in blast furnaces, rotary hearth installations, and steelmaking furnaces. This paper will review a number of case studies in the steel industry where extrusion is used to effectively and efficiently agglomerate byproduct materials into a valuable, usable product.

TUESDAY, FEBRUARY 27
MORNING

9:00 AM | AUDITORIUM ROOM 2

Bulk Material Handling: New Technology & Concepts in Bulk Material Handling

Chair: *N. Madison, Cornerstone Conveyor Engineering, Fayette, AL*

9:00 AM
Introduction

9:05 AM
The Vital and Missing "C" in IPCC – the Lost Opportunity of High Angle Conveying in IPCC
A. Duncan; Dos Santos International, Marietta, GA

The high angle conveyor offers the link to optimization of any IPCC system, yet that industry continues to struggle with the use of conventional conveyors and haul trucks to achieve the high angle function. The results are sluggish low angle conveyor systems of limited flexibility requiring excessive maneuvering time, excessive excavation and fill, re-handling and grading in order to accommodate the low angle limitations. The current alternative to conveyors is the fall back position of using ever larger haul trucks at great operating and environmental costs. Recent studies have represented resurgence in interest in high angle conveying. Though the primary purpose is to demonstrate suitability for open pit mining applications, this presentation will first recap the early development of the latest sandwich belt high angle conveyors and their commercialization over the last 30 years. It will highlight the features that make Dos Santos Sandwich Belt high angle conveyors particularly energy efficient and suitable for use in the harsh requirements of the IPCC systems. A brief comparison with pipe conveyor systems will be discussed.

9:35 AM
The Adder Snake: Low to High Angle Conveying with No Transfers
M. dos Santos; SME, Marietta, GA

Sandwich belt high angle conveying is a mature technology with hundreds of commercial installations around the world. It has been an efficient solution for elevating bulk material over a short footprint for more than thirty years. The alternate steep angle systems do not discharge material completely and are limited in capacity. The sandwich belt system is unique, featuring smooth surfaced belts of large width (and high capacity), which are scraped clean at the discharge with ordinary belt scrapers. All traditional systems utilizing high angle conveyors encounter a need that the Adder Snake resolves: a transfer point is needed to transition from a long low angle to a high angle (or vice versa). The Adder Snake eliminates that transfer by directly enveloping the conventional conveyor belt into the sandwich to elevate the material to a clean and complete discharge. This paper will compare the Adder Snake to current conveying technology. It will summarize the benefits of merging long conveyors into the elevating system, uniting these historically distinct systems into a single conveying system without intermediate transfers.

10:05 AM
Maximizing Conveyor System Efficiency with Internal Drives
A. Kanaris; Van der Graaf, Brampton, ON, Canada

For decades, conveyors have primarily been powered by external motors & gearboxes, which all require maintenance while being mechanically inefficient. With rising electrical and labor costs, mines & quarries cannot afford to overlook conveyor system efficiency. New technology is entering the industry, making these older designs outdated & hazardous to operate. An internally driven head pulley, or drum motor, eliminates external components and houses the electric motor & gearbox inside the drum, saving space and increasing system efficiency up to 30%. All the components, including the motor, gearbox, shafts & bearings, are enclosed inside the drum. Regular maintenance intervals are no longer required to guarantee worry-free operation. This reduction in maintenance further increases efficiency & savings. Manufacturing drum motors for the past 30 years in the USA & Canada, Van der Graaf continues to adhere to a simple principle: design a superior product to meet customer needs in a changing marketplace. Van der Graaf started in a 3,500 sq. ft. facility in 1985. Today, we have over 200,000 sq. ft. of manufacturing space in USA and Canada utilizing the latest technology and CNC equipment.

10:35 AM
Intermediate Drive Technology as a Cost-Saving Solution for Belt Conveyor Upgrades
R. Hoet; Voith Turbo Inc, York, PA

The demands on belt conveyors continue to increase. Availability and reliability are key factors for increased productivity. Linear booster drives for mining conveyors were initially used in the US in the 1980-90's with marginal success. The primary issue of this technology was controlling and transferring the power to the belt. Voith has succesfully applied linear booster drives to over 300 installations worldwide. The Voith TurboBelt "TT Linear Booster" Drive, is optimized in a complex engineering process to meet the customers' targets. Linear booster drives can save both Capex and Opex costs as high

as 25% or more. The lecture will highlight the advantages of the TT drive concept, the potential applications that can benefit from this type of conveyor design, and cover several examples of this technology. The TT drive solution significantly reduces the belt tensions, allowing the use of lower rated (and lower cost) belts. This can benefit new installations as well as extend the life and/or upgrade the capacity for existing conveyor installations. Voith Turbo, a Group Division of Voith GmbH, offers intelligent drive solutions, systems and comprehensive drive system services.

11:05 AM
Vertical Conveying in Plant and High-Lift Applications with New Pipe-Conveyor Technologies
M. Lurie; thyssenkrupp Industrial Solutions USA, Greenwood Village, CO

Technologies for vertical or steep transfer of coarse or abrasive materials are currently under development by thyssenkrupp Industrial Solutions. Materials that are very abrasive or sticky are a challenge for traditional equipment, and elegant solutions for high tonnages or great depths remain on primary industry's wish-list. So the target applications are in plants (cement, ports, mineral processing, tunneling), and mining (open pit and deep underground). In these new designs most of the material's weight is supported at the walls of a steep pipe belt, as in a silo. In one design, the material moves upward by a lift/slip mechanism. In a second method, flexible baffles held loosely in the pipe trigger stable blockage or self-bridging in discrete cells. The flexible baffles don't sustain damage or distort the pipe shape even when large rocks are loaded. By controlling the fill of the cells, the tension in the belt can be matched to its width. This design should eventually allow single-flight lifts to be feasible for applications such as deep underground mines, where high availability and small mineshaft diameters produce attractive results in economic comparisons to skip hoisting.

TUESDAY, FEBRUARY 27
MORNING

9:00 AM | ROOM L100E

Coal & Energy: Accessing Capital in the Ever Changing Energy Landscape: What are the Options? What is the Market Outlook?

Chair: *T. Alch, Vice Chair NY Section of SME and Co Chair of SME's Mining Finance Conference, Edgewater, NJ*

9:00 AM
Introduction

9:05 AM
Current Trends and Issues Impacting Coal Mine Operators and Electricity Generators
R. Marston; Golder Associates Inc, Ballwin, MO

Richard will share his views of the current marketplace, including key trends and issues while reflecting on his work that includes coal geology and modeling, project and mine engineering, project feasibility reports, NI 43-101 and JORC reports, due diligence work, and marketing and transportation. Richard also has extensive knowledge of coal supply strategies for electric utilities, steelmakers, and other consumers and specializes in coal mine design, project evaluation, and coal supply contracts.

9:25 AM
The Outlook for the US Coal Industry The Importance of Innovation in the Sector
R. Stall; Ernst & Young, LLP, Atlanta, GA

Bob will discuss the current state and outlook for coal mining and power sectors. Mr. Stall represents the Capital Equipment team on EY's Global Valuation and Business Modeling Steering Committee. He has been active in the appraisal industry since 1987. Mr. Stall specializes in valuing machinery and equipment in numerous industries. These studies have addressed a variety of value premises, including fair market value, fair value, investment value, liquidation value and forced liquidation value. These studies have been conducted for the purpose of financial and tax allocations, residual forecasting, sale-leaseback financing, asset based financing, bankruptcy proceedings, interest expense apportionment, ad valorem tax and litigation.

9:45 AM
A Banker's Perspective of the Coal Mining and Utility Marketplace in North America
R. McCormick; Headwaters MB, Dallas, TX

Ray will discuss the coal and related sectors reflecting on his 40 years of experience in the mining, banking and advisory industries. He is currently with Headwaters. Earlier he founded a private investment banking firm that focused on the mining sector, which he managed for over 20 years, worked in the Global Corporate Banking Department of Mellon Bank and served as Vice President and Manager of the mining section for 10 years and earlier was a consulting mining and geological engineer with the John T. Boyd Company. There he supervised economic property valuations and feasibility studies for mining companies with reserve holdings and operations in the United States and Canada. Ray's background combines financial, marketing and technical skills, with expertise in project financings, gold loans, equipment leasing, private placements, acquisition financings, production payment financings and mergers, acquisitions and divestitures. He is a certified professional geologist, holds a Bachelor's Degree in mineral economics with a geology minor from the Pennsylvania State University and a Master's Degree from the Department of Engineering at the University of Pittsburgh. He has also taken postgraduate courses at the Colorado School of Mines, and has served on the Board of Directors for the Engineers Society of Western Pennsylvania, the Society of Mining Engineers, and the Pittsburgh Coal Conference.

10:05 AM
The Impact of Regulations and Government Policy on Coal Miners, Utilities and Investors
J. Craynon; Engineering & Environment Division Export-Import Bank of the United States, DC, WA

John will talk about the changing landscape of government policy and regulation related to the mining and use of coal in the electrical generating sector creates significant impacts for both financial and technical reasons. Changes in administrations have significantly modified the nature of those impacts.

10:25 AM
Issues and Trends Impacting the North American Coal Market – How Hard is the Road Ahead for Coal?
L. Lupori; CRU, Wexford, PA

As head of Metals Consulting, North America, Lynn will present CRU's views of the latest business and economic trends in the North American coal sector, including discussion of various cost, demand, supply and other issues impacting the industry. CRU relies on robust methodologies to develop market analysis, forecasts, price assessments and costs for the global coal and steel industries along with 30+ additional commodities. Lynn is focused on working with customers to develop and execute projects related to important and strategic issues such as market analysis, strategy development, risk assessment, as well as valuation services and negotiation support. Prior to joining CRU, Lynn worked for nearly 20 years with domestic as well as international manufacturers (primarily in the metals and mining industries) determining strategic growth opportunities as a Managing Consultant with Hatch Consulting. Throughout, her career she has worked with North American as

well as global companies on issues such as market assessment/forecasting, capital investment plans, marketing and competitive strategy. Lynn holds a BSBA and a Certificate in International Business from Duquesne University.

10:45 AM

Successful Evaluation and Siting of Wind and Solar Projects on Landfills and Brownfield Sites

P. Curran; BQ Energy LLC, Wappingers Falls, NY

Paul will discuss his views of his work of leading the development of several renewable energy projects on brownfields and industrial sites, including the Steel Winds facility, the Greenfield Solar Farm and others. He will share his insights and highlight reason for his projects' success, some of which have resulted in BQ Energy receiving awards and being recognized by the US EPA, and several worldwide publications for the sustainable redevelopment of brownfield sites as well as the innovative development practices in the renewable energy industry

TUESDAY, FEBRUARY 27

MORNING

9:00 AM | ROOM L100C

Coal & Energy: Application of CFD in Mine Ventilation

Chairs: *V. Raj, NIOSH, Spokane, WA*
A. Haghighat, Virginia Tech, Blacksburg, VA

9:00 AM

Introduction

9:05 AM

Numerical and Experimental Investigation of the Impact of Gob Location on Methane Flame Front Propagation Velocity and Pressure Rise in Cylindrical Vessels

M. Fig[1], C. Strebinger[1], G. Bogin[1] and J. Brune[2]; [1]Mechanical Engineering, Colorado School Of Mines, Littleton, Co And [2]Mining Engineering, Colorado School Of Mines, Golden, CO

The prevention and mitigation of methane explosions in the gobs of longwall coal mines requires a fundamental understanding of flame acceleration in confined spaces, paired with knowledge of flame propagation behavior through rock rubble. Numerical models of high-speed methane deflagrations in reactors filled with simulated gob material are detailed, along with corresponding experimental results. A transient CFD model was used to calculate combustion chemistry, heat transfer and turbulent fluid dynamics for the range of experiments performed. Modeling and experiments were used to explore three main areas of interest: 1) The impact of ignition location on flame acceleration; 2) The impact that the simulated gob has on explosion pressure produced; and 3) The impact of reactor diameter on flame acceleration and overpressure. Gob material either retards or intensifies initial flame acceleration, depending on ignition location. Flame acceleration is observed within the simulated gob. The CFD model accurately predicts the flame acceleration due to the simulated gob. Further experimental studies will be conducted in a scaled-down model of an actual longwall mining face.

9:25 AM

Mine Explosion Hazards from Gob Breathing: Cause, Effect and Recommended Best Practices

S. Lolon[2] and J. Brune[1]; [1]Mining Engineering, Colorado School of Mines, Golden, CO and [2]Deswik USA Inc., Denver, CO

In underground mining, the gob and other abandoned mined-out areas are generally not monitored, and therefore, gobs frequently contain methane forming explosive methane-air mixtures. These mixtures can migrate out to the longwall face and surrounding gob entries during the phenomenon known as gob breathing, which commonly occurs when mine atmospheric pressure changes. This paper summarizes the modeling research conducted at the Colorado School of Mines to investigate gob breathing and the associated explosion hazards. Researchers present a number of critical findings, including the intensity of explosive mixture outgassing in relation to the magnitude and rate of barometric pressure variations, the tolerable limits of pressure swings, the consequences of gob breathing to the mine, and the critical time span it occurs following the gob breathing. This paper also presents recommended best practices in preventing and mitigating the negative result of gob breathing such as the recommended locations for continuous mine atmospheric monitoring system.

9:45 AM

Numerical Investigation of Radon Control Measures in Block/Panel Cave Mines

K. Ajayi[2], K. Shahbazi[2], P. Tukkaraja[1] and K. Katzenstein[3]; [1]Mining Engineering and Management, South Dakota School of Mines and Technology, Rapid City, SD; [2]Mechanical Engineering, South Dakota School of Mines and Technology, Rapid City, SD and [3]Geology and Geological Engineering, South Dakota School of Mines and Technology, Rapid City, SD

One of the mitigation measures for radon control in an underground working environment such as a block/panel cave is ventilation. However, the dynamics of the caving process complicate the design of effective ventilation systems for block/panel cave mines. Therefore, this study uses a computational fluid dynamics (CFD) simulation approach for investigating different radon control mitigation measures. The results show that the undercut ventilation has an impact on the radon concentrations in the production level; increase in radon concentration levels through the production drift is not linear; and that maintaining negative pressure on top of the cave significantly reduces radon concentrations in the production level.

10:05 AM

Thermal and Humidity Model Elements of the CED Solver for Mine Ventilation Simulations

G. Danko; Mining and Metallurgical Engineering, Univ. of Nevada, Reno, Reno, NV

Time-dependent thermal and humidity model formulations are described as part of a new network solution, based on the Computational Energy Dynamics (CED) method. The model consists of heat and humidity transport solution for the ventilating air in the shafts and drifts with mining activity and transportation; and the heat and moisture flow model of the strata rock. These two model elements are coupled at the airway wall. For analyzing the effects of seasonal, daily or hourly temperature variations, the strata heat flow is modeled using the Numerical Transport Code Functionalization (NTCF) methodology which includes the full temperature history in the strata rock, showing the "thermal flywheel effect." The NTCF matrix of user-defined size is pre-calculated in the model only once for the strata rock type, airway diameter and the desired time divisions. The Gibson's age function (GAF) solution, applied in mine ventilation practices with a step-change temperature solution may be selected for comparing the results with the true solution. Examples are shown for temperature and humidity fields of the ventilating air along a mine transportation airway as a function of distance and time.

10:25 AM

CFD Modeling of Dust Dispersion in Mineral Processing Plant

C. Pritchard; SMRD, NIOSH, Spokane, WA

Workers at mineral processing facilities are often exposed to high levels of dust generated during ore processing. Crushing, grinding, screening and other processes generate large quantities of dust which can exceed threshold values prescribed by the Mine Safety and Health Administration. Many ores contain quartz (silica), which has been known to cause serious health problems in workers over time. Given the structure of mineral processing plants the airflow regime is not coherent inside the building which may lead to multiple recirculation zones. These recirculation zones can trap dust, and concentrations can then rise over time. Therefore, there is a need to understand the airflow phenomena inside the mineral processing facility and how it interacts with the dust generation processes, to identify the zones of high dust concentration. CFD modeling can give a better understanding of the airflow and help recommend designs and methods to mitigate the high dust concentrations in a mineral processing plant. This paper presents the CFD modeling of airflow inside a mill building as well as the generation and subsequent dispersion of dust due to crushing, grinding and other activities.

10:45 AM

A Parametric Study of the Effect of Intake Turbulence in a Full Scale Dust Gallery Using Transient CFD Models

B. Coleman, W. Wedding and T. petrov; Mining Engineering, University of Kentucky, Lexington, KY

The University of Kentucky has recently developed a full scale model of a coal mine face which will include a continuous miner. This model will be used to study the effectiveness of current engineering controls in the face area of coal mines which includes exhausting and blowing ventilation systems, air quantities, a fully functioning scrubber system, dust suppression sprays and a passive wing regulator device. A laboratory setting such as this will allow for safe measurements of gas and dust in multiple mining scenarios in an efficient manner. This gallery can also be used to develop new methods which may cut miner's exposure to respirable dust and explosion hazards. However, the ability of the dust gallery to mimic conditions which have been observed in a coal mine must be confirmed. This research will explore how different levels of turbulence intensity in the intake air affect the flow patterns of the gallery and what value provides the closest approximation to a mine scenario using computational fluid dynamics.

TUESDAY, FEBRUARY 27

MORNING

9:00 AM | ROOM L100F

Coal & Energy: Mine Safety I

Chair: *S.Bealko, GMS Mine Repair, Oakland, MD*

9:00 AM

Introduction

9:05 AM

NIOSH Extramural Research Funding: Fulfilling the Mandate of the MINER Act

G. Luxbacher, J. Burr and D. Snyder; Office of Mine Safety and Health Research, National Institute for Occupational Safety and Health, Pittsburgh, PA

The Mine Improvement and New Emergency Response (MINER) Act of 2006 established the Office of Mine Safety and Health Research (OMSHR) within NIOSH and provided authority for awarding contracts related to the development and implementation of new mine technology and equipment; Congress provided additional funding to NIOSH to initiate and continue the program. OMSHR has fulfilled this Congressional mandate through annual Broad Agency Announcement (BAA) solicitations, directed Requests for Proposals (RFP) and Inter-Agency Agreements (IAA) and has further expanded the program through Capacity Build BAA contracts with US university mining departments in the areas of mine ventilation and ground control. This paper describes the extramural funding program and broadly examines the results of the 150+ contracts issued to date, grouped into key focus areas.

9:25 AM

RISKGATE: A Pilot Study in a Central Appalachian Coal Mine

M. Turner, K. Luxbacher and N. Ripepi; Virginia Tech, Blacksburg, VA

U.S. underground coal mines utilize advanced technologies and safety management systems in order to minimize the risk presented to their workers. Those in the industry largely agree that sharing knowledge related to mine safety is mutually beneficial for everyone. This work pilots an Australian model for risk management called RISKGATE in a US underground coal mine. RISKGATE is a database that uses collective knowledge of major risk events, each of which is then analyzed using bowtie risk analysis. Bowtie analysis determines causes, effects, and the different controls that can be used to either prevent an event or mitigate its consequences. The U.S. model was populated with three topics, with knowledge recorded from multiple workshops with miners, technical personnel and supervisors. Once the database was populated, the information was used in a case study for a medium sized underground coal mine in central Appalachia to determine its efficacy. RISKGATE was used for delivery of daily safety meetings, as well as coordination of tasks which miners did not perform on a regular basis. RISKGATE was evaluated with a survey tool utilized before and after RISKGATE was introduced.

9:45 AM

Influence of a Continuous Mining Machine and Mesh on Magnetic Proximity Detection Systems

J. Li, C. Zhou, J. Ducarme and C. Jobes; The National Institute for Occupational Safety and Health, Pittsburgh, PA

Magnetic proximity detection systems (PDS) are used with continuous mining machines (CMM) to protect miners from striking and pinning accidents. Generators in a PDS create magnetic fields covering the space around a CMM. The PDS determines the nearness of a miner relative to the CMM based on the magnetic flux density detected by a miner-wearable component, and alerts the miner and stops motion of the CMM if the miner is too close. A stable magnetic field is essential to the accuracy of the proximity calculations performed by the PDS. This paper presents the results of a systematic study of the influence of two types of steel structure found near a CMM: the body of the CMM itself and the wire mesh used for roof and rib control. The results show that the steel of the machine body can change the magnetic field distribution, and also alter electrical parameters of a PDS by destabilizing the generator current. The study also shows that depending on the distance between the mesh and a generator, the field can also be altered. These results provide a better understanding of the influence of the steel in the body of a CMM and wire mesh on the magnetic field distributions of PDSs.

10:05 AM

Testing the Performance of a New Silencer Prototype to Reduce Noise From Auxiliary Ventilation Systems

S. Bhattacharyya[1] and F. Calizaya[2]; [1]Energy and Mineral Engineering, Pennsylvania State University, State College, PA and [2]Mining Engineering, University of Utah, Salt Lake City, UT

Mechanized underground mines often suffer from noise overexposure. Noise levels are usually above the Permissible Exposure Limit (PEL) where underground fans are used. Sound levels in active workings can reach 120 dB(A), especially when fans are not equipped with silencers. Use of silencers seldom ensure PEL for various reasons. Overexposure of noise induces permanent hearing loss among mine workers. Recent field studies by a

NIOSH-funded research project at six mines, coal and non-coal, revalidated the findings. The University of Utah has undertaken laboratory studies to reduce fan noise at the source. A new silencer prototype with varying noise dampening material has been designed and tested. The silencer and associated extension can be repacked with different dampening materials. The silencer and the extension were used in various configurations. Attempts were also made to simulate field conditions where installations are quick and not perfect. The test results are presented here.

10:25 AM

Evaluation of Contamination Ingress for Built-in-place Refuge Alternatives

T. Lutz, J. Noll and L. Yan; CDC NIOSH, Pittsburgh, PA

Mine disasters such as fires and explosions can create a hazardous atmosphere due to the generation of carbon monoxide (CO). Most built-in-place (BIP) refuge alternatives (RAs) use an air delivery system to provide breathable air. After a mine disaster, contaminated mine air can enter the RA as miners enter. Testing took place in the Pittsburgh Experimental Mine using 5, 15, and 30 subjects. The experiment used sulfur hexafluoride (SF_6) as a tracer gas and was released into the air outside of the BIP RA to establish a uniform concentration. The human subjects entered the BIP RA and the SF_6 levels inside were measured to quantify how much contaminant entered the BIP. With no air delivery, less than 3% of the contaminant entered the BIP RA and with air delivery, less than 2% entered the BIP RA after all subjects entered, respectively. Considering a mine disaster can result in 10,000 ppm CO in the mine atmosphere, these percentages indicate that unhealthy CO concentrations which may lead to headaches, dizziness, and loss of judgement can occur in a BIP RA. This research will help the industry develop effective mechanisms for purging hazardous concentrations from within a BIP RA.

TUESDAY, FEBRUARY 27

MORNING

9:00 AM | ROOM L100D

Coal & Energy: Young Perspectives: Collegiate Mine Rescue & Young Professionals

Chair: *K. Musick, Virginia Tech, Blacksburg, VA*

9:00 AM

Introduction

9:05 AM

Computer Simulation in Collegiate Mine Rescue Education and Training

J. Brune[1] and H. Mischo[2]; [1]Colorado School of Mines, Golden, CO and [2]Inst. f. Bergbau Und Spezialtiefbau, TU BA Freiberg, Freiberg, Saxony, Germany

A number of mining universities worldwide have made significant progress in the introduction and implementation of mine rescue and disaster control contents within their mining engineering curricula, to the extent that some of the schools are hosting now fully operational and certified student mine rescue teams. Both the Colorado School of Mines in Golden, CO, USA and the Technical University Bergakademie Freiberg in Freiberg, Germany are making use of virtual reality (VR) computer simulation programs for the formation and training of the student mine rescue teams. This paper will present examples of different VR training programs and how they are applied within the mining industry, not only at universities but also, increasingly, in the mining industry. The impact of the application of VR simulation tools for an improved mine rescue training the will also be discussed, with an outlook towards future developments

9:25 AM

Student Mine Rescue at Virginia Tech Presentation

M. Noonan; Minerals and Mining Engineering, Virginia Tech, Blacksburg, VA

This presentation will be given on the Mine Recuse Team at Virginia Tech. It will include a description of the collegiate competitions that are attended throughout the academic year, along with a break down of our training program through our exercise models. The presentation will detail its past experiences and describe how they have influenced our team. It will also describe the newly implemented student leadership model for the team and how it has impacted the overall team function on and off the field. The team would not be what it is today without our founders and devoted trainers, so we will also thank them for their work.

9:45 AM

How to Maintain a Collegiate Mine Rescue Team, on the Example of Colorado School of Mines Student Mine Rescue Team

M. Hetherington, Q. Nguyen and J. Brune; Colorado School of Mines, Golden, CO

The vigilant safety culture that has been established in today's mining industry is an important aspect of the industry and should become a habit of young professionals as soon as possible in their careers. Because of this, mine safety programs are implemented into the mining curricula in many universities around the world. Some universities choose to extend their mine safety programs by hosting and training collegiate mine rescue teams that are fully certified and operational. Establishing and training a collegiate mine rescue team means that the university has to have meticulous planning, organization, and implementation. To maintain and improve the team and to run a consistently well trained team requires dedication, time commitment and financial resources. Researchers will discuss several necessities when establishing a new team, including how to build an equipment inventory, making networking connections for joint trainings, and sustaining financial support. This paper will present planning and strategy options, and how they are applied to the Colorado School of Mines Student Mine Rescue Team in order to maintain the team since the team's creation in 2009.

10:05 AM

A Career In Coal

K. Pan; Murray Energy Corporation, St. Clairsville, OH

Creating a career in mining is not the easiest path in today's world. Through my expereinces I hope to give you insight into how I've been able to develop myself and create a career in today's coal mining industry. I will cover my educations, extra cirricular development, and job skills, that have led to my personal sucess in mining.

10:25 AM

Varying Your Experience

D. Mason; Atkinson Construction, Seattle, WA

Balancing work ambitions with personal life goals can be a difficult line to walk in the mining industry. Regularly re-evaluating these goals is an important part of your personal and professional development and can often lead to difficult decisions. Regardless of how you prioritize these things, remaining flexible in your career path can help you seize the right move. There are an endless number of opportunities available in the mining industry so take advantage of all it has to offer.

TUESDAY, FEBRUARY 27

MORNING

9:00 AM | ROOM L100H

Environmental: Circular Economy and Mining

Chairs: *L. Reemeyer, Resourceful Path*
G. Mudd, RMIT University

9:05 AM

Mining and Metals Industry Structure and Interaction with the Circular Economy

L. Reemeyer; Resourceful Paths, Vancouver, BC, Canada

The circular economy for metals currently centers around recycling/reprocessing smelter, refinery and semi fabricated wastes, and consumer scrap materials recovered from end of life sorting. Some mining companies are connected to the circular economy through integrated mine to refine value chains, while others are disconnected as they only produce mineral concentrates. How does industry structure influence how mining companies engage in or are affected by the circular economy? Will circular economy related government regulations and corporate sustainability targets change the economics, environmental and stewardship aspects of mined metal supply? The topic will be analyzed using the copper and lead/zinc industries as examples.

9:25 AM

Behavior of Tellurium During Current Extraction Processes and Assessment of Future Potential Resources

S. Hayes; Eastern Mineral and Environmental Resources Science Center, US Geological Survey, Reston, VA

Critical elements, including tellurium (Te), underpin alternative energy generation. However, questions exist about future supplies, especially for elements recovered as byproducts. Tellurium is recovered primarily as a byproduct of copper extraction with a recovery rate of ~2%. The majority of the losses (~90%) occur during the initial concentration step, warranting additional investigation of Te behavior. Electron microscopy revealed that about 4% of Te is contained in tellurides in the flotation concentrate. Remaining Te is presumably distributed in the sulfide matrix (chalcopyrite with minor pyrite and sphalerite, and trace galena and tellurides), which has important implications for potential improvements for Te recovery.

9:45 AM

Potential for Nickel Leaching from Waste Heaps at the Bruvann Ni-Olivine Deposit, Northern Norway

M. Tinsley[1], I. Walder[1], F. Stopa[2], R. embile[1] and A. Winton[2]; [1]Earth and Environmental Sciences, New Mexico Tech, Socorro, NM and [2]Mineral Engineering, New Mexico Tech, Socorro, NM

The Bruvann nickel deposit is part of a layered mafic intrusion in Northern Norway. Some peridotite layers have substantial sulfide mineralization, which led to mining and flotation processing from 1989 to 2002 (Lamberg 2005). The area now lies abandoned, with large heaps of waste rock leaching nickel into the environment. It would be ideal if the nickel could be extracted instead. To examine the potential for economic leaching, fourteen samples were selected from waste heaps and are undergoing kinetic testing. Ten columns are rinsed with water weekly, an amplified version of natural leaching. Four columns were rinsed with water for the first eight weeks, then with pH 2.0 H_2SO_4 for nine weeks, and finally with pH 1.5 H_2SO_4 for seven weeks. At the conclusion of this test, two of those columns will be returned to water leaching. This will yield information on how quickly the magnesium silicates neutralize remaining acid, as well as whether additional nickel is released after the acid leaching. The other two acid leach columns will be leached with a pH 12 NaOH solution to determine whether silicate dissolution at the higher pH releases more nickel.

10:05 AM

The Role of Scrap Recycling in the Circular Economy

P. Mackey; P.Eng., Kirkland, QC, Canada

Recycled metals provide a significant source of supply, and the potential for significantly lower environmental impact than primary metals. The effect of geography, trade regulations and economics on domestic recycling and international trade in scrap are examined through case studies in copper, aluminum, steel, cobalt and rare earth elements. GHG emissions are calculated for primary vs. recycled metals from different locations and processing methods. Opportunities to increase recycling through enhanced collection and dismantling are investigated.

10:25 AM

Metals and the Circular Economy in Quebec

L. Beaulieu; EDDEC, Montreal, QC, Canada

In 2015, the EDDEC Institute commenced a collaborative research project to investigate the potential to develop circular economy opportunities for iron, copper and lithium in Quebec. The study used life cycle analysis, material flow analysis and techno-economic analysis to evaluate opportunities. The unique geography of Quebec, including the presence of natural resources, low carbon hydroelectric power, and access to processing and logistics infrastructure was considered in potential for circular economy opportunities.

TUESDAY, FEBRUARY 27

MORNING

9:00 AM | ROOM L100G

Environmental: CSR, FPIC, ILO 169, Sustainability, Social License and Related Concepts? What Mining Companies Need to Understand

Chair: *J. Ventura, Ventura and Associates LLC*

9:00 AM

Introduction

9:05 AM

Tailings Dam Engineer of Record (EoR) – There's Nothing Conventional About It…

K. Morrison; Morrison Solutions, Inc., Lakewood, CO

Engineer of Record (EoR) is a simple and resolute concept that is applied throughout the western world for civil works construction. It is a term used to represent a single person who is solely responsible for engineering design and confirming that construction meets the design intent. But how can the EoR concept be applied to a transient design - one that implements the observational approach with a construction life that covers decades, often exceeding a design engineer's career or lifetime, and one that is directly impacted by changes in the state of practice? This is where the EoR definition becomes unclear. Tailings storage facilities (TSFs) are the necessary result of successful mining, milling and/or power production. However, unlike con-

ventional dams that are viewed as an asset, TSFs and the dams that retain them are an undesirable, yet necessary and ongoing, liability. In the wake of the Mount Polley and Samarco tailings dam failures, the efficacy of the EoR for TSFs has been brought into question globally.

9:25 AM

CSR, FPIC, ILO 169, Sustainability, Social License and Related Concepts – What Mining Companies Need to Understand

J. Ventura; Ventura and Associates LLC, Salt Lake City, UT

CSR has been around for a long time and, although it started out as a voluntary concept, many aspects of CSR are becoming mandatory. Mining companies are now being held responsible for the economic, social and environmental consequences of their activities, and also faced with serious challenges from foreign governments, indigenous peoples, NGOs, and local communities. Pressure from financial institutions and investors, as well as public perception, have caused mining companies to react to and mitigate risk by undertaking the task of developing appropriate CSR strategies. This task can appear daunting. As indicated by the title of this technical session, there exists a complicated hodgepodge of CSR initiatives, all of which can have significant impacts on a company's CSR strategy. Through the participation of speakers representing both mining and non-mining stakeholders, this technical session will attempt to educate mining companies concerning this complicated hodgepodge, so that they can hopefully begin to have an understanding of some of the basic components that are required for them to start developing an effective CSR strategy.

9:45 AM

Artisanal and Small-Scale Gold Mining in Ghana and Sustainability

K. Bansah[1], G. Galecki[1] and N. Dumakor-Dupey[2]; [1]Mining Engineering and Nuclear, Missouri University of Science and Technology, Rolla, MO and [2]Mining Engineering, University of Mines and Technology, Tarkwa, Ghana

For more than a century, artisanal and small-scale gold mining (ASGM) has been a major source of livelihood to many rural Ghanaian people who have few employment alternatives. However, the ASGM has resulted in many social and environmental issues. This study provides a comprehensive overview of ASGM in Ghana and discusses the major challenges affecting the development of the ASGM sector. Both qualitative and quantitative methods were used in the study. Lack of proper legislation, enforcement of existing regulation and training and a series of unsustainable interventions since the late 1980s have been observed as the main factors impacting the growth and development of the ASGM sector. In authors' view the much-talked-about sustainability is yet to be known in the ASGM sector in Ghana. Education, training, and capacity building are required to ensure sustainable ASGM and to promote safety, socio-economic and environmental performance.

10:05 AM

Creating Stakes for the Local Community: What Has Worked and What Has Not – Experience from India

N. Singh; ERM India, New Delhi, Delhi, India

Mining has been one of the most challenged sectors in India, especially with respect to its relations with its local community. From the largely employment and philanthropy focused programmes in the public sector mines, to recent experiments with setting up of District Mineral Funds with mandatory contributions from mining profits, to providing direct benefits to individual households, a range of approaches have been experimented with in the last few decades. However reviews of all such initiatives indicate that these programmes have not been dynamic to reflect the changing and evolving local community interests and expectations, or have not set up adequate frameworks to provide good governance, transparency and a long term sustainable development focus. Community continue feeling marginalized and exploited. These have thus been lost opportunities for the sector. It's time to reflect and refocus benefit sharing arrangements in mining.

10:25 AM

Forging a Shared Vision; Uncovering a Comunity Driven Moral Case to Earn Stakeholder Trust

J. Davies; CEO, Davies Public Affairs, Santa Barbara, CA

Today's operating mines are leading the way in social responsibility and collaborative community partnerships. However, many mining projects remain on the sidelines facing unnecessary delay due to public opposition prior to earning permits. In fact, the U.S. continues to have one of the longest permitting processes in the world, adding to project costs and creating uncertainty regarding financial viability. No review of the mining sector concerning CSR and building community social value would be complete without looking at the deeper problem of why many communities fail to trust or engage with a mine developer in the first place. Only by fostering a shared vision early in the process that is derived from thoughtful community feedback that addresses real concerns can a mine developer begin to earn trust and create sustainable community engagement throughout the life of the project. Attendees will come away with a method to actively listen and uncover a community's hopes, dreams, and fears; learn steps to develop a community-driven moral case; learn how engaging a diverse group of stakeholders throughout the permitting process can help shape a stronger project.

10:45 AM

It's Not if You Engage, But How

A. Coppel; Sustainability & External Relations, Newmont Mining Corporation, Greenwood Village, CO

Building interpersonal relationships based on trust is the fundamental building block to creating long-term shared value, and often the weakest link in social responsibility programs. Before being able to truly understand stakeholder collaboration, and create long-term sustainable outcomes that result in tangible benefits to all parties involved, leaders and practitioners must have the appropriate engagement skills. Many already do, but lack the vocabulary to articulate the frameworks that they use, limiting their ability to coach their colleagues. Others, including site managers and staff who interface frequently with external stakeholders, are often put in the position of having to engage without the formal training needed to do so. Allison Coppel, Director of Social Responsibility for Newmont Mining Corporation, will draw upon her experience at five top mining companies, as well as working or living on six continents. She will share insights taken from inspiring professors and practitioners along the way. She will give the audience a glimpse into engagement strategies that work globally, plus techniques and frameworks that instantly improve stakeholder relationships.

TUESDAY, FEBRUARY 27

MORNING

9:00 AM | ROOM L100I

Environmental: Geochemical Modeling? What is Working? (ADTI-MMS)

Chairs: *C. Bucknam, Au (Analytical Unlimited LLC), Parker, CO*
D. Castendyk, Hatch, Lakewood, CO

9:00 AM

Introduction

9:05 AM

Advances in Geochemical Modeling Applied to the Characterization and Remediation of Acid Mine Drainage

D. Nordstrom; Water Mission Area, U.S. Geological Survey, Boulder, CO

I found a quantitative Nernstian relation between measured and calculated redox potentials for acid mine waters in 1975 using WATEQ. This result was one of the first to show the reliability of our speciation calculations. Today's popular codes include PHREEQC, EQ3/6, TOUGHREACT, and The Geochemist's Workbench®. Currently, we can simulate pyrite oxidation and results match well with field data. We can draw quantitative generalizations about the behavior of iron and aluminum during the oxidation and neutralization of acid mine drainage. These generalizations are a key to understand how other trace elements will behave. Remediations scenarios can be used to estimate downstream water chemistry with modeling. Today's researchers and consultants can model reactive-transport of fluid flow through tailings, waste-rock piles, open pits, and the fate of mine contaminants in receiving streams. Our modeling has become more sophisticated than the actual field data needed to constrain the models. Meaningful predictions require the modeler to know model assumptions, complexities of hydrogeology, and complexities of mineral-water reactions to reveal the limitations from computational modeling.

9:25 AM

Relating Kinetic Test Solute Release Data to Sulfide Oxidation Rate Laws and Implications for Developing Geochemical Models for Water Quality Prediction

Z. Wenz and S. Koski; Minnesota Department of Natural Resources, Saint Paul, MN

A technique that uses the particle lifetime model to calculate the reaction rate of individual sulfide grains has been developed. Chalcopyrite, cubanite, and pyrrhotite reaction rates were calculated from samples extracted from laboratory kinetic tests and pyrite reaction rates were calculated from naturally weathered taconite tailing samples. Pyrite and pyrrhotite reaction rates were comparable to geometric surface area-normalized reaction rate data from batch reactor type experiments. Reaction rates calculated for cubanite and chalcopyrite were about a factor of 6 less than pyrrhotite. The oxidation rates calculated for chalcopyrite and cubanite for a mildly acidic (about pH 5) system were similar to values from a rate law derived for acidic (pH 2.5-3) ferric iron oxidation of chalcopyrite, possibly indicating oxygen is an increasingly important oxidant at circumneutral pH. Reaction rates for chalcopyrite and cubanite decreased with experiment length, possibly indicating inhibition of reaction progress with time. These time dependent reaction rates may allow for determination of inhibiting factors (e.g., oxygen diffusion) for developing transient mine-water prediction models.

9:45 AM

Coupled Groundwater-Geochemical Modeling Using PHAST

M. Velleux[1], P. Nolan[2], J. Hallden[1] and T. Wilson[1]; [1]HDR, Mahwah, NJ and [2]Independent Consultant, Omaha, NE

Simulating mine-influenced waters often requires a suite of models whose results drive geochemical calculations to evaluate regional groundwater quality. PHAST, which combines PHREEQC and HST3D, can perform three-dimensional reactive transport simulations that couple groundwater flow, solute transport, and multi-component geochemical reactions into one framework. By coupling flow and geochemistry, reactive transport simulations can dynamically simulate groundwater quality changes and identify factors that affect contaminant levels to optimize conditions and reduce unacceptable impacts. To illustrate this process, simulations representing the transport and geochemical control of acidic and alkaline solutions mixing with ambient groundwater were simulated using PHAST. These simulations demonstrate how selective modification of the geochemical environment has potential to substantially influence evolution of groundwater quality downgradient of mine-impacted sites. The capability to dynamically simulate reactive transport over the life-cycle and post-closure periods of facilities can improve the ability to cost-effectively plan and manage sites to meet environmental quality objectives.

10:05 AM

Copper Water Quality Criteria: Biotic Ligand Model Applied to Regional Waters

A. Haus, M. Ciardelli, H. Hallett and S. Kozicki; Foth Infrastructure and Environment, Lake Elmo, MN

The United States Environmental Protection Agency (USEPA) is promulgating a new method for determining water quality standards for metals, particularly copper. The Biotic Ligand Model (BLM) is an alternative to the current hardness based determination of water quality criteria for copper, and takes into account several additional aspects of water chemistry that can act to influence copper toxicity. Input data for the BLM includes temperature, pH, dissolved organic carbon (DOC), major cations (Ca, Mg, Na, and K), major anions (SO_4 and Cl), alkalinity, and sulfide. The BLM has not yet been adopted in many states, including most Midwestern states which still define copper water quality criteria based on water hardness. Copper criteria by federal and state methods was determined for representative regional waters and sensitivity analyses identified major dials in model. For some regional waters, especially those where pH and DOC are exerting control on available copper, the BLM-based copper criteria provides an alternative limit to what is generated by the hardness-based approach.

10:25 AM

Regulatory and Data Needs of Environmental Models at Mine Sites Subject to Regulatory Review

A. Nicholson; Integral Corporation, Broomfield, CO

As outlined in the recent ADTI volume on modeling, environmental models are often used to support mine permitting, design, and closure decisions made by both mining companies and governmental regulators. The application and acceptance of models in decision making should flow from a combination of quality science, transparency of presentation, appropriate review, and a detailed uncertainty analysis. Good models need good underlying science as a basis. This data should include adequate characterization of chemical and hydrologic processes relevant to a mine. Often data must be extrapolated from other settings (laboratory conditions or other locations) to the mine. Models should also be well presented to show all underlying asumptions and the underlying assumptions and code. Reviewers of models, they should be skilled enought and provided enough resources to adequately reproduce the results and test the underlying assumptions of the models. Finally, models should have a rigorous uncertainty analysis to test how underlying assumptions affect model results, how data variability propagates through the model, and show the limits of where the model is useful.

TUESDAY, FEBRUARY 27

MORNING

9:00 AM | ROOM L100B

Health & Safety: Learning from the Frontline: What Works to Promote Operational Excellence and a Positive Safety Culture

Chairs: *E. Haas, National Institute for Occupational Safety and Health, Pittsburgh, PA*
A. Lashgari, Pennsylvania State University, University Park, PA

9:00 AM
Introduction

9:05 AM
Sharing Safety Critical Control Measures – Bingham Canyon Case Study
B. Ross; Lowell Institute for Mineral Resources, University of Arizona, Tucson, AZ

All mining operations gain important safety and health learnings during the process of mining, sometimes at a high price in lives lost or significant injury. Applying these learnings is one of the key first steps to identifying the material unwanted events (MUE's) when using ICMM's Critical Control Management (CCM) method to prevent serious events. The CMM method relies on companies being able to identify MUE's as well as ways to control them – even if they have not previously occurred at a site or operation. One method to make the identify MUE's is to use what has happened at other companies and operations. Unfortunately, many companies are hesitant to share their experiences because of risk of legal or financial ramifications. This paper discusses the benefits of sharing health and safety experiences and learnings across the industry to improve the CCM process for all companies. The Bingham Canyon Manefay failure is used as an example of how critical control learnings have been shared and discusses how the industry has benefited. It then proposes a method for companies to share safety information without posing a legal risk to the company sharing the information.

9:25 AM
Attitudes and Beliefs of Hourly Miners and Salaried Managers Regarding Safety and Health in U.S. Metal and Non-Metal Mines
D. Myers[2], M. Wright[1] and N. Lessin[1]; [1]Health, Safety and Environment, United Steelworkers, Pittsburgh, PA and [2]Occupational and Environmental Health, West Virginia University, Morgantown, WV

The United Steelworkers (USW) is the predominant union in North American metal and non-metal mines, representing workers in more such mines than any other union, and more than are operated by any single company. In 2015-16, under a grant from the Alpha Foundation for the Improvement of Mine Safety and Health, researchers from the USW and West Virginia University surveyed local union leadership in 120 mines regarding the prevalence of, and barriers to effective safety and health programs based on finding and fixing hazardous conditions. This was followed by a survey of every hourly miner and salaried manager in four mines – two surface and two underground – mining four different commodities. One conclusion supported by several different survey items is that miners and managers have different beliefs about the nature of hazards in the mine, and about accident causation. If culture is defined as a shared set of attitudes, beliefs, norms and behaviors, then a single "safety culture" may not exist in these workplaces. It may be difficult to implement an effective and widely supported safety program can be built without first addressing these differences.

9:45 AM
Imminent Danger: Characterizing Uncertainty in Critically Hazardous Situations
J. Hrica, B. Eiter and D. Willmer; Pittsburgh, PA, CDC NIOSH, Pittsburgh, PA

Mineworkers are tasked with making critically important decisions of whether or not a hazard is considered imminent danger. NIOSH researchers collected formative data to investigate mine safety professional perspectives on workplace examinations which revealed a potential gap in how mineworkers are assessing risk and determining whether or not a hazard is imminent danger. During interviews, participants indicated having processes in place for what should be done once an imminent danger situation is identified. Critically, however, they report having no systematic methodology for mineworkers to use to determine if a hazard is considered imminent danger. While this is important for all imminent danger situations (e.g., LOTO), it is especially important for those situations that are not immediately recognizable as imminent danger such as ground control issues. In this paper, we discuss potential methodologies that can be used to improve reporting imminent danger situations. Finally, we identify potential leadership practices to incorporate into risk management efforts including effective feedback, communication, and collaborative correction of imminent danger situations.

10:05 AM
Usability Design Guidelines for Training in Mine Safety and Health
L. Brown and M. Poulton; Lowell Institute for Mineral Resources, University of Arizona, Tucson, AZ

For more than a decade, training practitioners have been calling for changes in the way new and experienced miners are trained. In this work, we propose 15 design guidelines to improve mine safety and health training, focusing on the training media and delivery methods. Our guidelines are derived from a multiyear needs assessment using a data-driven process called Contextual Inquiry. Over one thousand individual pieces of evidence were collected through observations, interviews, apprenticeships, and artifacts, covering a variety of required topics in MSHA new miner and annual refresher courses. Derivation and cross-validation of the design guidelines is provided through top-down and bottom-up analysis of inductive models. Our findings illustrate four principal themes of usability problems, which include limited accessibility, lack of context, lack of consequences, and absence of practicum. Example solutions are provided using active learning techniques and serious games.

10:25 AM
What Other Industries Are Doing About Fatigue, and What It Could Mean for Mining
T. Bauerle, Z. Dugdale and G. Poplin; National Institute for Occupational Safety and Health (NIOSH), Spokane Mining Research Division (SMRD), Spokane, WA

Worker fatigue is as complex as it is understudied. A 'psychosomatic' construct, fatigue lies somewhere between psychology and physiology, making the measurement and management of it difficult with no easy solutions for operators or workers. Answers to even basic questions such as what is fatigue, how is it measured, and how can organizational resources reduce fatigue, can remain elusive with no single clear path to action for the health and safety of the worker. This presentation supplements the growing body of interest in the industry by outlining ongoing research efforts at the Spokane Mining Research Division (SMRD) to synthesize lessons learned about fatigue management from other industries (e.g., transportation, aviation, construction) to determine their applicability to fatigue management systems for mining operations. Covered topics include: basic components of sleep and work from a psychological perspective; an overview of fatigue models, findings, and evidence-based solutions from other industries; and future plans to apply such findings to safety culture and leadership through the evaluation and implementation of fatigue risk management systems in the mining industry.

10:45 AM
Do you really Care? Reflections from the Front Line
M. Routledge; H&S Division Board, Park City, UT

How do you show your team that you care more about their personal well-being than you do about any other imperative of the business? Why, when you get that right, does it drive the most spectacular performance you could hope for across all business objectives and targets? Let's talk through several case studies over a 25 year period and draw out the most consistent aspects of each we believe are responsible for performance improvement. Some themes and tools emerge that are clearly the same in each case study providing a basis for building a high performance culture on a solid foundation or risk management, disciplined approaches to critical controls and clear visibility of leadership activity in the field.

11:05 AM
On-site Assessment of Safety and Health Management Effectiveness
A. Rlchins, M. Nelson, A. Hodgson and W. Rogers; Mining Engineering, University of Utah, Salt Lake City, UT

The University of Utah is conducting a study of the implementation effectiveness of safety and health management systems (SHMSs) in the mining industry. Many mining companies have adopted carefully designed SHMSs to improve worker health and safety at their sites. The effectiveness of management systems been thoroughly studied the healthcare field, but no similar studies have not been done in the mining industry. This study is examines mine with different SHMSs, to understand how well those systems and their implementation correlate with improvements in safety performance. Assessing of employee perceptions is relatively easy, through the administration of well-designed surveys, but the assessment of a given company's approach to safety management is more difficult. For example, a company may not believe it has a well-defined safety management system, but may be actually following the principles of good SHMS as part of its overall management approach. This paper describes the approach that has been developed for use in site visits, to gain an understanding of how human behavior is managed at the site. This affects not just safety but every other aspect of a mining operation.

TUESDAY, FEBRUARY 27
MORNING

9:00 AM | ROOM L100A

Health & Safety: Requirements and Enforcement as a System: Exploring the Interplay and Administration of Legislation, Regulation, Standards, and Policies

Chairs: *M. Savit, Husch Blackwell LLP, Denver, CO*
S. Moore, NIOSH, PIttsburgh, PA

9:00 AM
Introduction

9:05 AM
Examining the Relationship between the Strength of a Company's HSMS Policy and Their MSHA Citation Rates
E. Haas, M. Ryan, D. Willmer and N. Ortiz; Office of Mine Safety and Health Research, National Institute for Occupational Safety and Health, Pittsburgh, PA

Prior to understanding health and safety management system [HSMS] processes, research to characterize their accessibility and frequency of practices is needed to make the "business case" for HSMSs. Publicly available HSMS policies and 2015 year-total MSHA citations for 23 companies were analyzed to determine the relationship between the quantity of H&S practices companies encourage and citations received. A thematic content analysis of the policies identified elements and practices within the text. On average, companies hosted information about 7 elements (Range 1 – 14, SD = 3.49) and discussed 15 practices (Range 2 – 34, SD = 9.13). The elements in which companies highlighted the most practices were Risk Management; Emergency Management; Leadership Development; and Occupational Health. A Spearman's rho showed a moderate, negative correlation, rho = -.44, n = 23, p < .03, with more H&S practices associated with fewer citations. The correlation of determination indicates the quantity of H&S practices explains nearly 20% of the citations received on site. A discussion of the trends in H&S practices show areas that could be leveraged to meet health, safety, and business needs.

9:25 AM
OSHA's Crystalline SIlica Rule: Implications for the Mining Industry
A. Abrams; Law Office of Adele L. Abrams PC, Beltsville, MD

In 2016, the Occupational Safety & Health Administration issued a final rule governing respirable crystalline silica exposure in the general industry (including oil, gas and fracking), maritime and construction sectors. The rule reduced the permissible exposure limit to 50 ug/m3, which is half of the current general industry (and MSHA) limit. OSHA's rule is slated to be in effect iby mid-2018. The rule makes significant causation findings for myriad health effects as a result of exposures above the PEL, and also requires employers to conduct exposure monitoring, medical surveillance, worker training and development of written exposure control plans that emphasize engineering and work practice controls over personal protective equipment. As OSHA-regulated employers work to come into compliance and identify controls that will feasibly reduce exposures in a meaningful way, what about MSHA-regulated facilities? Can they justify allowing workers to be exposed to higher levels at mines? This session will address legal issues arising from the OSHA rule, as they relate to mining opertions, and offer proactive solutions to minimize liability while protecting workers.

9:45 AM
The Global Explosion-Protected Equipment Market – Can US Coal Mines Ever Benefit?
D. Snyder, J. Burr and G. Luxbacher; NIOSH, Pittsburgh, PA

The global explosion protection equipment market is expected to cross the $5 billion dollar mark this year and to continue to grow at 9.4 percent per year. Explosion protected equipment refers to that which is designed to safely operate in explosive atmospheres which would include methane and coal dust. U.S. coal mining equipment represents less than a half percent of this market, and regulations dictate that such equipment be designed to requirements that are unique to U.S. coal mining. Increasingly other countries and other industries are moving from country specific standards towards harmonized global standards to create an economies of scale that will increase availability and reduce the cost of such equipment. This paper examines the difficulty of accepting global explosion protected equipment standards in U.S. coal mining, and provides the historical basis as to how and why the U.S. coal mining requirements are different from other industries in the U.S., and in other countries, with similarly hazardous environments. The factors that need to be considered in moving the U.S. coal mining industry towards global standards, and a potential path forward, are also discussed.

10:05 AM
What Do Policy Makers and Mine Operators Need to Know Before Applying Tthe 'Safety Triangle'?
S. Moore and P. Yorio; National Personal Protective Technology Laboratory, NIOSH, PIttsburgh, PA

In the 1930s, Heinrich established an accident prevention theory that included two fundamental tenets: (1) the ratio of lower to higher severity incidents presents in the form of a 'safety-triangle' and (2) similar causes underlie both high and low severity events. Although used extensively to inform public policy and establishment-level health and safety priorities and activities, recent research challenges the validity of the two tenets. This study explored the validity of the first tenet, the existence of the safety triangle, by evaluating more than 25,000 mines over a 13 year time period. This study answers: (1) Are an increased number of lower severity incidents at an establishment significantly associated with the probability of a fatal event over time?; (2) At the mine level, do the effects of occupational health and safety incidents on the probability of a fatality over time decrease as the degree of severity decreases, thereby taking the form of a triangle?; and (3) Do distinct methods for delineating incidents by severity affect the existence of the safety triangle form? These questions are answered and the impact on policymakers and mine operators are discussed.

10:25 AM
Preliminary Analysis of SHMS Intervention Effectiveness with MSHA Data
A. Hodgson, M. Nelson, A. RIchins and W. Rogers; Mining Engineering, University of Utah, Salt Lake City, UT

In recent years, many mining companies have adopted formal systems for the management of health and safety. An example is CORESafety from the National Mining Association. With the support of the Alpha Foundation, the University of Utah is conducting research to analyze the intervention effectiveness of safety health and management systems (SHMS) in the United States mining industry. Intervention effectiveness of management systems is determined by visiting the mine site, interviewing personnel from all occupational areas, and distributing a written survey to all possible company employees. Then the data are analyzed statistically and subjectively to determine the system's effectiveness. More specifically its effectiveness when correlated with corresponding MSHA injury rate and citation data. The authors are visiting a variety of mines in the United States to contribute to this study. Results of the visits and preliminary analysis will be presented and discussed.

10:45 AM
Respirable Silica Exposure in Metal/Nonmtal Mines
A. Lashgari and J. Kohler; Energy and Mineral Engineering, Pennsylvania State University, University Park, PA

The goal of this study was to determine the efficacy of the MSHA compliance-sampling program for respirable silica dust in surface metal and nonmetal mining operations, also to explore evidence that the current sampling strategy could be changed to better identify overexposed occupations. MSHA compliance-sampling database was used as the primary source of data in this study. Moreover, a field study data was planned to assess whether the knowledge gained from the database analysis could be useful to identify gap areas in knowledge, practices, or control technologies that could reduce overexposure. This research has determined that the MSHA compliance-sampling program fails to meet in many cases its intended purpose of improving health of mineworkers. It shows that data-driven methods could be useful tools to suggest improved sampling strategies that more effectively target high-risk occupations and commodities. The results of this study can help make certain inferences about the utility of the MSHA database for the purposes of improving MSHA's sampling resource allocation, identifying gap areas and developing interventions that effectively target the true sources of exposure.

11:05 AM
The Correllation Between Mine Accidents and the New H&S Legislation in Different Countries
Y. Spivak[1] and V. Razuvaykin[2]; [1]Research and Development, DEZEGA, Kiev, Ukraine and [2]Marketing Department, DEZEGA, Kyev, Ukraine

Modern respiratory protective equipment for underground miners evolved in three stages: • none at all, • filtering respirators and finally… • self-contained self-rescuers. There is a global trend of switching from filtering to self-contained self-rescuers. The choice depends on the local peculiarities of occurrence and extraction, and the change is mostly stimulated by fatal incidents. Most vivid examples of fatalities leading to the restriction of the Mining and OSH Laws are the prominent disasters at: • Bulgarian Lyki mine (1976, 5 killed), • South-African Kinross Mine (1986, 177 killed), • Ukrainian Yuzhnodonbasskaya Mine (1991, 32 killed), • Australian Moura No.2 (1994, 11 killed), • US Sago Mine (2006, 21 killed), • Russian Darasunsky (2006, 25 killed) and Raspadskaya Mines (2010, 91 killed), • Turkish Soma Mine (2014, 301 killed). These amendments mostly dealt with PRE improvement, escape and rescue operations management. Some countries, like Poland and Kazakhstan, etc., introduced mandatory SCSRs preventatively. Some, like Columbia are changing their OSH legislation as you are reading these lines.

TUESDAY, FEBRUARY 27
MORNING

9:00 AM | ROOM 101I

Industrial Minerals & Aggregates: Aggregates in Upper Midwest Region

Chairs: *P. Swenson, BARR in Minneapolis Office*
S. Vitton, Michigan Technological University, Houghton, MI

9:05 AM
Assessing Michigan Aggregates for Amtrak's High-Speed Rail Blue Water Rail Line from Chicago to Detroit
S. Vitton; Civil & Environmental Engineering, Michigan Technological University, Houghton, MI

The Michigan Department of Transportation (MDOT) is evaluating upgrading of their portion of Amtrak's Blue Water Rail Line, which runs from Chicago to Pontiac near Detroit, to accommodate High Speed Rail (HSR) traffic. The MDOT portion of the rail line is known as the Michigan Line. Currently, the rail line handles passenger and freight traffic, while the upgrade would allow HSR trains to travel at speeds up to 110 mph. To meet this speed requirement, the current track structure will need to be assessed to determine if it can handle the increased dynamic loads associated with HSR traffic. An important track structure component is the ballast material. The Michigan Line is in the southern portion of the state where the most common aggregate source is carbonate rock, which the Michigan Line currently uses as a ballast material. The key issue on the replacement of ballast is cost with the tradeoff being the quality of the ballast material and the distance to the rail line. The objective of this presentation is to assess the current aggregate sources in Michigan to determine sources that can provide quality aggregate for HSR ballast.

9:25 AM
Reviewing High Speed Rail Specifications in Regard to Midwest Aggregates
S. Vitton; Civil & Environmental Engineering, Michigan Technological University, Houghton, MI

An important upgrade to the nation's transportation network is the adoption of high speed rail (HSR) on some rail lines in the United States. Nearly all US rail lines were constructed, operated and maintained, however, as passenger and freight traffic rail lines and therefore do not meet many HSR requirements. The quality of the rail ballast will be an important component with HSR lines, both in quality and cost. In general, many railroads were constructed with available local aggregates that will not meet HSR specification and will require aggregates from farther locations thus increasing the cost of the ballast material. This presentation will review both international and national specifications for HSR. Further, the presentation will discuss these specifications in regard to Midwest aggregate sources.

9:45 AM
Using Web Map Technology to Market Construction Aggregate Resources on Minnesota's School Trust Lands
C. Floyd; Minnesota Department of Natural Resources, St. Paul, MN

The projected royalty value of construction aggregate resources (sand and gravel) on Minnesota's 2.5 million acres of School Trust Lands may exceed one billion dollars. The Minnesota Department of Natural Resources (MnDNR) has a fiduciary responsibility to generate revenue from School Trust Lands and has two ongoing projects focused on identifying and developing these aggregate resources. The first project is evaluating the aggregate re-

source potential of each parcel so the highest value can be determined for land management purposes. The second, is marketing prospective aggregate lease sites on the School Trust Aggregate Finder Web Map. This is an interactive tool that highlights School Trust parcels which may contain sand and gravel deposits. Sharing aggregate resource information will help public road administrators and private aggregate companies locate School Trust aggregate more efficiently and improve recognition of lease opportunities. Marketing aggregate lease sites is the next step towards converting resource potential to School Trust revenue through lease royalties.

10:05 AM

Limited Aggregate Resource Assessments Along Pipeline Easements in North Dakota and Minnesota

J. Soberaski, J. Aiken, B. Bangsund and A. Krieger; Barr Engineering, Bismarck, Northern Mariana Islands

To develop an appropriate valuation, a Barr Engineering Co. client wanted a better understanding of aggregate resources on properties along a proposed pipeline route in North Dakota and Minnesota. We prepared a limited aggregate assessment for use in negotiations with landowners claiming an aggregate resource within the easement. A mineable resource cannot be assigned a value unless a market for it exists and it can be mined economically. We estimated the value of the aggregate deposits through an initial resource validation, a mine feasibility assessment, a potential resource estimate, and a market-based valuation. Initial resource validation identified the likelihood of aggregate at each property. Determining mine feasibility included assessing regulatory and physical access constraints. If a viable resource existed and had potential to be mined, we develop a resource estimate using the potential volume of marketable material. Volume was determined using inferred lateral limits, property boundaries, and an assumed average depth. We also conducted a market-based valuation using a range of unit costs based on our experience and information from local aggregate users and providers.

10:25 AM

Mine It and Use It: Making the Most of Mining Materials

L. Zanko; Natural Resources Research Institute, University of Minnesota Duluth, Duluth, MN

The following question was posed during a short-course at last year's SME meeting in Denver: "Are we in the mining business or the waste management business?" It is fair to say that the answer is: "both". Some of the by-product ("waste") and coproduct materials generated by Minnesota's iron ore (taconite) mining industry – such as (but not limited to) low grade overburden rock and tailings – can be significant and environmentally sound sources of high-quality construction aggregate for a variety of conventional and unconventional end-uses and value-added applications. For example, when considered within the context of the critical need for repairing, maintaining, and upgrading the nation's transportation infrastructure, these iron ore mining-derived materials can represent an important alternative to more conventional aggregate sources. But experience has shown that we must consider all potential repurposing options, including consideration of the post-mining landscape. This presentation focuses on both obvious (and perhaps not-so-obvious) alternatives.

10:45 AM

The Way We Have Always Done It; But Why?

R. Kafka and J. Wientjes; Komatsu America Corp, Peoria, IL

It is not uncommon for operations to become comfortable with "this is the way we have always done it". The current industry challenges are forcing operations to question historic operating practices. It is this case that brought a customer to ask Komatsu America Corp. (KAC) Application Engineering for our insight regarding current mining methods. During a site visit, it was observed that the current mining method involving dozing in conjunction with a load and carry application could be optimized. Key bulldozer performance variables such as push distance, push angle, and rehandle volume had to be addressed given the irregular geology and production requirements. An integrative tool was developed to analyze a modified methodology involving production dozing in conjunction with load and carry to a crushing system. This presentation describes the methods used to perform this exercise and illustrates key strategies of incorporating different applications into a single mining system. The distinctive evaluation tools are reviewed to convey how variables in certain practices and depositional conditions can be represented in a simplified and understandable manner.

11:05 AM

Technology in the Aggregate Production Process

K. Burkhardsmeier; Sales, Viking Aggregate Equipment, Webster, MN

Today there is technology all around us. A study done by Deloitte said that Americans look at their phone on average 46 times a day. We have become a society that is immersed in technology. It's no wonder technology is moving into the aggregate production. Before only large production companies could afford integrating the latest technology into their day to day process, but now with technology prices decreasing, we are seeing some form of technology in just about every production site today. From drones, to wireless monitoring, to automated controls, all this is keeping our work force smarter, safer, more effective, and more efficient. I am seeing more and more equipment with the capability to link to other pieces of equipment to make a harmonious circuit, increasing the precision of the process it's trying to complete. Technology will never eliminate the human element in the aggregate process, but as natural resources become less available, specifications change and demands increase, technology teamed up with an amazing work force we are seeing an increase in efficient, more effective ways to produce aggregate.

11:25 AM

Regulatory Issues Involved in a Proposed Aggregate Quarry Permit in Minnesota

S. Vitton; Civil & Environmental Engineering, Michigan Technological University, Houghton, MI

In Minnesota counties, townships or municipalities have the primary authority for regulating aggregate mining by requiring a Conditional Land Use Permit from the county planning and zoning office. A township or municipality may also require a permit in addition to a county permit. An Environmental Assessment Worksheet is required when an aggregate mining operation exceeds 40 acres and are mandatory for operations exceeding 160 acres. This presentation will review a large proposed aggregate quarry located southeast of Minneapolis, MN. The site was located in a farming region with relatively flat topography. As with most quarries there was significant opposition that resulted in the township enacting permit regulations placing some significant obstacles on the economics and operation of the quarry. These obstacles included not allowing mining to within ten feet of the groundwater table and reestablishing the site for agricultural production after mining completion. The technical and practical issues of these regulations will be reviewed. After completing an EIS and encountering significant additional obstacles the quarry permit was withdrawn and the quarry project abandoned.

11:45 AM

Aggregate Resources in Minnesota: Trends and Intiatives to Preserve Future Availability

H. Arends; Lands and Minerals, MN DNR, St. Paul, MN

The aggregate industry is the largest non-fuel industry in the nation. Aggregate is produced in all 50 states with Minnesota being the 4th largest producer of natural sand and gravel. Because aggregate is a high-bulk, low-value commodity, transportation accounts for a considerable amount of the delivered price. Therefore, access to local sources of aggregate is important for building and maintaining publically financed infrastructure. Maintaining access to aggregate deposits is an issue periodically assessed by the Minnesota Legislature. In 1984, the Minnesota Legislature directed the Department of Natural Resource to map aggregate resources. In 2000, the Minnesota Legislature conviened an Aggregate Resource Task Force (ARTF), which resulted in a study estimating the Twin City Metropolitan Area available aggregate reserves to be depleted by 2020. More recently, the 2016 legislature commissioned a follow-up ARTF to provide recommendations several topics that focus on preservation of aggregate reserves. This presentation will look at recent trends that impact aggregate availability and the outcomes of the 2016 ARTF.

TUESDAY, FEBRUARY 27

MORNING

9:00 AM | ROOM 101H

Industrial Minerals & Aggregates: Mining and Processing Wastes-secondary Resources (Ministry of Education Key Laboratory of Solid Waste Treatment & Resource Recycle (SWUST)

Chairs: *H. Kim, Chonbuk National University, Jeonju, Korea (the Republic of)*
M. Chen, Southwest University of Science and Technology, China

9:00 AM
Introduction

9:05 AM
Effect of Nitrate on Photocatalytic Activity of Titanium-bearing Blast Furnace Slag

Z. Xiuyan[1], L. chang[2], L. Xuefei[1] and X. Xiangxin[2]; [1]Northeastern University at Qinhuangdao, Qinhuangdao, China and [2]School of Materials and Metallurgy, Northeastern University, Shenyang, China

With the titanium-bearing blast furnace slag in Pangang doping different proportionsnitrates asraw material, nitrates-modified titanium-bearing blast furnace slag (N-TBBFS) photocatalysts were prepared by the high energy ball milling method at300 degrees centigrade for 2 hours. N-TBBFS photocatalysts were characterized by X-ray diffraction(XRD), Fourier transform infrared spectroscopy (FTIR), thermogravimetric (TG), UV-vis absorption spectra and scanning electronic microscopy (SEM) measurements. Theirphotocatalytic activity were checkedthrough the photocatalytic reduction of Cr(Vi) aqueous solution as a model compound under UV-vis light irradiation. The results showedthat the N-TBBFS photocatalysts have a higher photocatalytic activity when the optimum addition proportion of nitratewas 5%;the photocatalytic reduction efficiency of Cr (Vi) was over 99% after 4 hours.

9:25 AM
Mineral Carbonation of Desulfurization Residue for CO2 Sequestration

D. Wenjin and H. Sun; Key Laboratory of Ministry of Education for Solid Waste Treatment and Resource Recycle, Southwest University of Science and Technology, Mianyang, China

The feasibility of mineral carbonation of desulfurization residue for sequestering CO2 was evaluated both through theoretical and experimental approaches. Concentration of ammonia, CO2 flow rate, liquid to solid ratio and temperature impacted on the carbonation ratio of desulfurization residue through their direct and definite influence on the rate constant. Concentration of ammonia and liquid to solid ratio were the most important factors influencing the desulfurization residue carbonation in terms of both the carbonation ratio and reaction rate. Under optimized conditions the carbonation ratio could reach approximately 98% when using industry-grade CO2. The crystalline phase of the carbonated desulfurization residue was calcite and vaterite with spherical and granular morphology. The CO2/O2/N2 mixed gas was also used as the simulated desulfurization fuel gas in the carbonation reaction and it had a relatively minor effect on the carbonation ratio. However, it slowed the carbonation reaction and produced a carbonation product with a smaller average particle size, which included high purity (≥99%) white calcite.

9:45 AM
The Thermodynamics, Kinetics and Process Technology Evaluation of Asbestos Tailings in Resource Utilization

H. Sun, T. Peng, D. Wenjin and Y. Yu; Southwest University of Science and Technology, Mianyang, Sichuan, China

As a industrial solid waste, chrysotile asbestos tailings may have great harmfulness to the ecological environment. However, this tailings is also a potential mineral resources. Roasted with different additives and leached with water, a variety of silicon and magnesium compounds were prepared. Thermodynamics indicated that the reactivity of H_2SO_4-$(NH_4)_2SO_4$ co-roasting method was less than that of NH_4HSO_4. However, it was higher than that of other four additives. Using co-roasting method, about 86% MgO was extracted from the tailings. The roasting process could be divided into three phases with the apparent activation energy of 93.21, 162.34 and 122.21 kJ/mol, respectively. The $Mg(OH)_2$ sheet and MgO were prepared from leachate with 94.8% of the Mg conversion rate. The crystal quality and size of product was exponential increased with the reaction time. The superfine silica was prepared from the leaching residue. This process was a second-order reaction with kinetic constants of 0.0019 dm^3/(mol.min). This process is environmental and economic benefits. The tailings could be reduced, $(NH_4)_2SO_4$ could be recycled, and a variety of valuable products could be obtained from this tailings.

10:05 AM
Optimization of Operational Parameters to Improve Bioleaching of Arsenic from Mine Tailings in Continuous Stirred Tank Reactors

D. Borja[1], K. Nguyen[3], I. Casasbuenas Cabezas[2], R. Silva[4], S. Choi[3], E. Ngoma[5], J. Petersen[5], J. Park[6] and H. Kim[3]; [1]Geography, University of Calgary, Calgary, AB, Canada; [2]School of Mines, Universidad Nacional de Colombia, Medellin, Antioquia, Colombia; [3]Mineral Resources and Energy Engineering, Chonbuk National University, Jeonju, Korea (the Republic of); [4]Process Engineering, Memorial University of Newfoundland, St. John's, NL, Canada; [5]Chemical Engineering, University of Cape Town, Cape Town, South Africa and [6]Geotechnics and Recycling Technology Division, Institute of Mine Reclamation Corporation, Wonju, Korea (the Republic of)

This study aimed to determine the optimum operating parameters of a continuous bioleaching system to leach arsenic (As) from mine tailings using a mesophilic bacterial culture. The microbial consortium, previously adapted for effective growth at high pulp density and metal concentrations, was mainly composed of Leptospirillum Ferriphilum, and Acidithiobacillus Caldus. The mine tailings, collected from Janggun mine (South Korea) contained 11% (w/w) of As. The tests were performed in a laboratory scale unit composed of 3 reactors connected in series following a cascade configuration. Agitation speed, air supply, solid concentration, residence time and temperature were systematically optimized to assess the leaching behavior. Several parameters were monitored on a daily basis, including the As released into solution, iron oxidation rates, pH, cell concentration, dissolved oxygen and redox potential. Overall, the improvement of oxygen transfer, by optimizing the agitation speed and air supply, presented the most tangible impact over the leaching performance. The highest leaching efficiency observed in this study was 82%, which supports the feasibility of the process.

10:25 AM
Solide Waste Management of China: A Case Study of Electronic Waste

M. Chen; Key laboratory of solid treatment and resource recycle, Southwest University of Science and Technology, Mianyang, China

Though China has a histry longer than 5,000 years, whose solid waste managment still has a long way to go. After the foundation of PR China, solid waste management has passed two stages: none, following the model of developed countries, especially the US and the waste countries, and now is undergoing its third stage: on the way of this own stratiegies. Herein, we take the core of "urban mining" - electronic waste - as an example by describing its deveopement, highlighting its weekness, and pinpointing its future directions, hoping this could help to understand the development of solid waste and server as a guidance for the future research and development for the solid waste itself.

10:45 AM

High Grade Rare Earth Oxides Produced by Solvent Extraction from Leachates Produced from Coal Sources

A. Chandra and R. Honaker; Mining Engineering, University of Kentucky, Lexington, KY

Recent studies funded by the National Energy Technology Laboratory (NETL) have shown that coal and coal by-products are an excellent resource for valuable rare earth elements (REEs). For the NETL project that led to the results presented in this publication, the objective was to generate a high grade rare earth oxide concentrate using solvent extraction. A parametric study was conducted to optimize the selectivity of the process using Di-(2-ethylhexyl) phosphoric acid (D2EPHA) as the extractant. After optimizing the process, incorporating redox potential control and adding a scrubbing stage prior to stripping, a rare earth oxide concentrate containing 51% total REEs was produced from a feed leachate containing 120 ppm REEs with recovery values above 85% for most REEs.

11:05 AM

Slag: What is it good for? Steelmaking Slag to Remove Phosphate and Neutralize Acid

N. Piatak, R. Seal, D. Hoppe, C. Green and P. Buszka; U.S. Geological Survey, Reston, VA

Steelmaking slag from near Chicago, USA, may be a viable option for treating phosphate-rich or acidic waters. Batch and flow-through experiments using slag document efficient removal of phosphate from synthetic solutions. Air-cooled fine fractions (< 10 mm) of modern slag were most effective; other types, including modern granulated, modern air-cooled coarse (> 10 mm), and legacy slag removed phosphate, but to a lesser degree. Most slags tested have high net neutralization potentials (NNP). Phosphate removal capacity and NNP correlated positively with total Ca content; dissolution of Ca minerals facilitates secondary Ca phosphate formation and consumes acid during hydrolysis.

11:25 AM

Towards the IOT Mine – from Intelligent Wear Protection to Intelligent Materials

M. Magerstaedt, E. Garcia, T. Raeth, L. Lai, d. plourde, N. Rentmeister, S. Forster and R. Altmeppen; ROSEN Group, Stans, Switzerland

In the past, wear of polymeric internal coatings of a steel pipe could not be measured from the outside. An internal elastomer coating was developed containing wear sensors that transmit data to the outside of the pipe with no need for pipe perforation. Field data from approx three years of field experience in oil sands tailings with such "intelligent" polymeric internal coatings, prove accurate and reproducible wear measurement. Wear mostly occurs around the 6 o'clock position due to gravity. Based on these data, operators can schedule maintenance and rotation intervals more accurately, potentially saving cost in the million $ range. Whilst the sensors used in pipe wear monitoring were "conventional" sensors embedded into an elastomeric wear protection coating, more recently, elastomers have been developed that can function as sensors themselves. Hence, these are truly intelligent materials. These elastomer films can serve e.g., as pressure, strain, or temperature sensors allowing continuous condition monitoring of critical mining equipment. Essentially, an Internet Of Things is created in the mine; another step towards a fully controlled, highly efficient automated mining process.

TUESDAY, FEBRUARY 27

MORNING

9:00 AM | ROOM 101F

International: Tailings Impoundments: Management Practices and Impacts

Chairs: *M. Gavrilovic, GR Engineering Services, Denver, CO*
S. Marcuson, Marcuson Associates, LLC

9:00 AM

Introduction

9:05 AM

What in the World is Happening with Tailings?

M. McCaslin[1], K. Hays[2] and E. Casey[2]; [1]WesTech Engineering, Murray, UT and [2]Bluefield Research, Barcelona, Spain

The paper examines trends in tailings management for some major mining countries. Globally there is speculation about where mining is headed in regard to tailings management. Highly publicized failures brought worldwide attention to the use of earthen dams and changes are expected. Yet there is still a lot of business-as-usual in conventional tailings impoundments, in part due to the market downturn. On the other hand, a number of incremental innovation efforts are afoot. And what are the regulatory drivers now, versus what they are likely to be in the foreseeable future?

9:25 AM

Tailings Impoundment Failures in South America

D. East; Mining, Graña y Montero, Lima, Peru

Recent experiences with tailing facility failures in South America have created understandable public alarm and suggest an underestimation by senior mine industry management of the risk associated with the design, construction and operation of mine waste management facilities. This risk is related to human life, environmental damage, reputational damage and, as we have recently observed, significant financial damage. This paper describes the build up to, and failure of, two significant tailing facilities in South America within recent times and attempts to analyze these failures so that the industry may learn to prevent such events from ever happening again.

9:45 AM

Progressing Towards an Ultimate Solution to the Florida Waste Clay Pond Problem

J. Zhang[1], H. El-Shall[2] and J. Hazen[3]; [1]Florida Industrial and Phosphate Research Institute, Bartow, FL; [2]University of Florida, Gainesville, FL and [3]Met Pro Supply, Mulberry, FL

Phosphate mining in Florida generates over one ton of waste clay per ton of phosphate rock produced. In current practice, phosphate clay slurry with an average solids content of about 3% is pumped through pipelines to clay storage ponds where the clay slowly settles. Clay settling ponds occupy a large portion of mined lands and generally have limited use after reclamation. Since its inception, FIPR has always made it a research priority to develop technologies to reduce or eliminate clay settling ponds. Past achievements in this area include addition of fibrously materials to enhance dewatering of flocculated sand-clay mix, high-solids sand-clay paste using deep cone thickener, and installation of geotechnical drains. However, these approaches could only make incremental improvements. A recently completed project may well have solved the problem once for all. This research is new and novel in three aspects: 1) creating a mixture of sand-clay-overburden for reclamation, 2) producing a high-value land for intensive agriculture, and potentially for construction, and 3) achieving instantaneous reclamation of mined lands without clay settling ponds.

10:05 AM
Mount Polley Investigation and Follow Ups
S. Farhangi; Mine Waste, Golder Associates, Mississauga, ON, Canada

There are 65 permitted mines registered in the Province of British Columbia with 173 TSFs. Since 2014, technical submissions were reviewed for completeness, compliance with the Code, Ministry guidelines, and best engineering practices. The detail review of submission and case-by-case response has resulted an overall improvements in the quality of the submissions. This is reflected by a decrease in the number of high priority recommendations observed for each mine between the 2014 and 2016 submissions. In addition, the mines which did not have a formal dam classification, operation manual or emergency plans, have confirmed that they are in process of addressing these deficiencies. In addition, the Ministry's following up on the deficiencies noted in the previous DSI reports, has expedited the completion of the recommendations, and thus improved the overall safety and stability of the TSFs. In this presentation some of the trends observed in the last 3 years will be reviewed in detail.

10:25 AM
A Review of Current Tailings Disposal Technologies
H. Lammers and L. Figueroa; Mining Engineering, Colorado School of Mines, Denver, CO

Technologies utilized for the disposal of slurry, paste, thickened, and filtered tailings include containment within impoundments, open pit backfill, submarine placement, underground backfill, tailings and waste rock combined disposal, and dry stack placement. Each technology has inherent environmental, social, and economic elements, and characteristics unique to the location of the disposal facility to be considered during the life cycle of the disposal facility. This paper presents environmental, social, and economic elements, and site-specific characteristics unique to each of the six identified tailings disposal technologies. Environmental elements include surrounding land and water disturbance; social elements include human health and safety, the political and regulatory climate, aesthetics of the facility, and post-mine land use; and economic elements include cost associated with processing, construction, operation, and closure. Site-specific characteristics include transport distance, facility capacity, and climate.

10:45 AM
Proof of Principle: Tailings Management Needs Genomics Informed Chemical Understanding
L. Warren; Civil & Mineral Engineering, University of Toronto, Toronto, ON, Canada

The joint application of genomics and geochemistry offers capabilities, not available even ten years ago, to develop new biologically informed tools that offer adaptive, flexible and more sustainable approaches to better monitor, manage and treat mine tailings; such tools are critically needed industry wide. Tailings are blackbox bioreactors; full of largely unexplored bacteria that can generate impacts or offer beneficial biotechnological applications. Here, results assessing microbial communities and geochemistry of an Ni/Cu mine tailings impoundment in northern Ontario, identify distinctive microbial communities (i.e. not predicted by better studied ARD systems), and extensive sulfur metabolic capabilities that are coupled to common and abundant tailings associated compounds not currently linked to sulfur associated impacts; i.e. current models are not biologically comprehensive, underscoring why they can fail. These results, highlighting how genomics will provide a better understanding of microbial contaminant creating processes that are currently a black box for tailings management, as well as how they offer new adaptive tools development, will be presented.

11:05 AM
Social Aspects of Tailings Disposal and Storage
J. Pfahl; SRK Consulting, Denver, CO

Abstract to follow.

TUESDAY, FEBRUARY 27
MORNING

9:00 AM | ROOM 101A

Mining & Exploration: Geology: Open Pit Design Geology

Chair: *R. Kaunda, Colorado School of Mines, Golden, CO*

9:00 AM
Introduction

9:05 AM
Thoughts on the Responsibility of Geotechnical Engineers and Hydrogeologists in Mining
R. Sheets; Hydrology and Geotechnical Engineering – Carlin Operation, Newmont USA Ltd., Carlin, NV

What is the primary responsibility for geo-engineers in mining? Early in my career, I was asked this question by an experienced engineer. After explaining some of the tasks, I was quickly informed that the main responsibility was to monitor, period. Although this proved true for many cases, I came to understand that monitoring is merely one means to achieve the primary responsibility of a geo-engineer in mining – ensure the safety of all personnel. Inherently, we monitor to identify risks; we analyze designs and develop models to mitigate risks; and we are provided opportunities to explain to supervisors the geo-risks to personnel and mine plans that may stem from particular courses of action. I shared experiences from the first several years of my career as a geotechnical engineer within my company's junior geo-engineering staff. The intent was to share my own development, so they could understand our responsibility to the mine operation. Similarly, the purpose of this presentation & paper will be to share these thoughts with geo-professionals new to industry.

9:25 AM
The Use of ImageJ to Investigate Geologic Effects on Open Pit Slopes
F. Wang and R. Kaunda; Mining Department, Colorado School of Mines, Golden, CO

When dealing with densely jointed or fractured rock mass in pit slopes, the traditional rock mass characterization systems have many parameters that are difficult to judge objectively and accurately. In this study, rock slopes were analyzed with ImageJ software and artificial neural networks to obtain parameters to assess the conditions of a slope and to evaluate stability conditions. The adopted method is found to be useful, especially for establishing models in weak or highly fractured rock mass characterization environments.

9:45 AM
A Strategic Rock Mechanics Study for the Kevitsa Open Pit Mine
J. Sjöberg[1], J. Switala[1], R. Ortiz[2], A. Bergman[3] and P. Bergström[4]; [1]Itasca Consultants AB, Luleå, Sweden; [2]Itasca S.A., Santiago de Chile, Chile; [3]Boliden, Boliden, Sweden and [4]Boliden Kevitsa, Petkula, Finland

The Boliden Kevitsa open pit mine in northern Finland is currently revising its strategic plan. A new pit optimization project is undertaken to investigate an increase in production. In conjunction with this, the geotechnical slope design parameters for the final pit depth, including a possibly deeper pit, need to be analyzed. This paper presents the assessment of slope stability for future open pit mining at Kevitsa for all scales — from benches to overall slopes, including: (i) total slope angles for final pit depths, (ii) interramp

slope angles, (iii) maximum interramp height, (iv) bench slope geometries, (v) recommendations on slope depressurization, and (vi) recommendations for slope monitoring and further data collection. The paper demonstrates the current state-of-the-art for both large-scale stability analysis (2D and 3D modeling) and kinematic analysis for benches and interramp slopes, incorporating acquired experiences and knowledge from large open pits worldwide. For the bench and interramp slopes, a combined analysis considering spill length, catchment criteria, and kinematic stability was conducted, and validated against the as-built geometry of the current pit.

10:05 AM

Simulating Coupled Hydromechanical Processes in Open Pit Dewatering Models – Impacts to Predictions on Groundwater Inflow and Pit Wall Pore Pressures

M. Gabora; DHI Water & Environment, Centennial, CO

Hydromechanical coupling, the physical interaction between hydraulic and mechanical processes, is a potentially important component of a groundwater flow system (e.g., mine inflow). However, in transient groundwater models such processes are often ignored. A new plug-in (module) for FEFLOW has been developed to explicitly incorporate these hydromechanically coupled processes within the framework of a three-dimensional groundwater flow and transport model. The module uses methods applicable to flow problems in both porous media and fractured rock. The approach allows for feedback between hydraulic parameters (hydraulic conductivity and storage) and effective stress using an elasto-statistical model function developed from Hooke's law. The module is applied to an open pit mine to evaluate how incorporating the hydromechanically coupled process effects the predicted groundwater inflow to the mine, groundwater level drawdown and pore pressure predictions. The results demonstrate that the inclusion of the processes have strong implications for these results which impact slope stability analyses, mine water management costs and processes and environmental permitting.

10:25 AM

Stope 12 Mining Case Study Jofree Duran, Scott Carlisle, Sarah Milne, William Boyd, Matthew Frohbieter

J. Duran, S. Carlisle, M. Frohbieter, S. Milne and W. Boyd; Newmont Mining Corporation, Victor, CO

Newmont operates the Cripple Creek and Victor Mine (CC&V) located between the cities of Cripple Creek and Victor in Colorado. Historic mining within the CC&V district has been predominantly underground from the early 1890's through the 1980's when open-pit mining first began. Open voids from underground mining are hazardous to open pit operations as there is potential for collapse and falls that may affect personnel and equipment. Underground openings have been modeled using historic maps. As open pit mining progresses an on-going probe drilling program is conducted, targeting the modeled open areas that are planned to be mined. The program is designed to confirm the location and geometry of open voids. Intersected voids area scanned using a cavity scanner. An evaluation of the void stability is then conducted and a remediation and safety plan developed to fill or collapse the void making it safe for pit operations. This paper presents a case study of mining through a large void named Stope 12. The stope dimensions from the scanned geometry shows a big open stope 330 ft of height, 320t ft along the strike and 65 ft wide.

10:45 AM

Machine Learning Approach for Large Open Pit Slope Designs Above Underground Workings

A. Peretiatko and R. Kaunda; Mining Engineering, Colorado School Of Mines, Golden, CO

The design of large open pit mine slopes above underground workings can pose a serious challenge to engineers. Typically geotechnical and geological characterization of site conditions enables a suitable classification of the rock mass to design interamp and overall slope angles. The presence of voids or underground workings in the vicinity of pit slopes alters the stress regime of a system in such a manner that static limit equilibrium-based slope stability analysis methods may fail to capture. In this study, a machine learning design approach based on crown pillar design is adopted and validated using a case example.

TUESDAY, FEBRUARY 27

MORNING

9:00 AM | ROOM 101E

Mining & Exploration: Management: The Future is Now: Opportunities, Challenges, and Success Stories of the Automated Mine

Chair: *P. Stockburger, Stantec, Tempe, AZ*

9:00 AM

Introduction

9:05 AM

How the Industrial Internet will drive an Increasingly Productive Mining Operation

K. Shikoluk; General Electric, San Ramon, CA

Mining companies continue to experience volatile commodity prices and challenging economic fundamentals as global demand slows. Following an extended period of massive capital investment, the mining industry is now firmly focused on improving productivity and sustainable cost management. An emphasis on digital asset and process management has enabled leading industrial companies to achieve breakthrough levels of efficiency through increased asset availability and optimized processes. Combining the technologies of machine sensors, connectivity, data capture, visualization and big data analytics, the industrial internet supports asset lifecycle management, remote monitoring and operations, condition-based and predictive maintenance and real-time operator intelligence. While significant efficiency gains have already been realized in other industries the power of the industrial internet is beginning to emerge in mining. This presentation will provide illustrations of these productivity improvements including examples in mining and explore how the digital transformation journey and vision will lead to sustainable step changes for the Mining industry.

9:25 AM

Integrated Mine Operations

J. Nyqvist[2] and D. Andreo[1]; [1]Process Industries, Mining, ABB Inc., Denver, CO and [2]Process Industries, Mining, ABB Sweden AB, Vaesteras, Sweden

Digitalization is ongoing in many industries and so also in mining. The digital landscape is transforming from isolated operations through integrated operations to final autonomous operations. The "islands of automation" can have its own data, data format and interfaces, and operators and control room staff must scrutinize a multitude of conceptually disconnected screens in order to coordinate different parts of the process. The key to the future of mining, then, lies in total integration of data and work processes meaning convergence of more information from real-time systems into software systems, which will enhance efficiency, responsiveness and profitability across the mining value chain. The operational focus shifts from machine operations to process flow operations for efficiency and optimization. An installed use case, one of the first integrated mines - underground to mill – will be dis-

cussed, and we will also look into the future with some examples of the next generation of mine automation. Performance analytics of press filters and grinding and flotation optimization will be presented.

9:45 AM

Implementation Strategies for Advanced Digital Technologies

D. Richardson[1] and B. Sharpe[2]; [1]Global Mining, Stantec, Tempe, AZ and [2]Mining, Metals & Cement, North America, Rockwell Automation, Brampton, ON, Canada

As the mining industry continues its shift towards leveraging advanced digital technologies to achieve safer and more productive mines, barriers to implementation continue to persist. While the industry has slowly become saturated with the concept of 'the mine of the future', reaching this goal is impeded by a number of implementation risks, including a lack of commitment & collaboration, or rushed implementation. Many of these risks can be mitigated by the development of an overall technology roadmap, followed by deliberate and staggered implementation to add new applications and devices over time. This staged investment of capital spreads implementation risk over time into more manageable pieces, while maintaining flexibility to implement 'tried and true' technologies now while reserving the capability to upgrade in the future. Some of the strategies to quick and efficient enhancements will be discussed, including modular, plug-and-play components and equipment, flexible network topologies, hardware and software standardization, and open protocols.

10:05 AM

Development of a Roof Hazard Rating System for the Waste Isolation Pilot Plant, Carlsbad, New Mexico, USA

E. Keffeler[1], J. Nopola[1] and R. Supka[2]; [1]RESPEC, Rapid City, SD and [2]Nuclear Waste Partnership, LLC, Carlsbad, NM

The Waste Isolation Pilot Plant (WIPP) in New Mexico is the only operational permanent geologic repository for nuclear waste in the United States. The underground repository consists of a single mining level excavated 2150 feet below ground in the bedded salt of the Permian Salado Formation. Roof conditions in parts of the repository are challenging because of constantly changing conditions, including the formation of separations and low angle roof shears. A semi-quantitative roof hazard rating system (RHRS) was developed as a tool to increase safety and prioritize geotechnical resources. The RHRS quantifies how mining-induced fractures, condition of ground support elements, and trends in deformation rates contribute to roof stability and assesses the relative likelihood of a ground fall occurring. Action thresholds were developed based on both the overall hazard score and the input parameters for the RHRS. The action thresholds include the installation of ground support, increased monitoring, and restricting access. The RHRS has been implemented in the repository and is used as a tool for prioritizing ground control activities, performing inspections, and assessing risk.

10:25 AM

Mobile Mapping in the Mining Industry

T. Thomas; Engineering, H2H Associates, Troy, NY

Advancements in survey and mapping technologies have made the collection and quality of topographic information more accessible and practical for use in everyday mining applications. Mobile mapping techniques are now routinely applied to not only above ground applications, but underground and marine environments as well. Advancements in software allow users to easily transform data into useable surfaces and models that are directly importable into industry standard mine planning software packages allowing integration of existing geologic and geochemical information. H2H has been at the forefront of providing integrated mobile mapping and mine planning services for multiple mining clients throughout North America.

10:45 AM

New Approaches for Mine Control Stations for SME Mining Companies via OPC UA

T. Krichler; Institute for Mining and Civil Engineering, TU Bergakademie Freiberg, Freiberg, Germany

Current mine control stations are either single-position systems with high engineering effort or all-in-a-box solutions with low integration possibilities of third-party devices. Above all both approaches are cost-intensive and not feasible for small companies. This paper shall be an inspiration of how to enhance the productivity and monitoring of an existing mining system in a modular way by introducing a proven technique of the ongoing digital revolution: A Wi-Fi network based on the communication protocol OPC UA. The starter kit consists of a single-board computer, a WLAN access point and any electronic sensor.

TUESDAY, FEBRUARY 27

MORNING

9:00 AM | ROOM 101C

Mining & Exploration: Operations: Opportunities, Metrics, and Tools to Drive Performance and Profitability

Chairs: *R. LaDouceur, Montana Tech, Butte, MT*
J. Werner, University of Utah, Layton, UT

9:00 AM

Introduction

9:05 AM

Plant Optimization Using Low-Cost Ore Characterization and Benchmarking Methods

P. Amelunxen; Aminpro, Colebay, Sint Maarten (Dutch part)

In recent years the authors have developed and applied a series of low-cost ore characterization tests for predicting and optimizing the performance of mineral concentration plants. The tools are applied in two steps. The first step consists of a detailed ore characterization campaign in which the key process index parameters of future ores are measured, spatially modeled, and distributed to the block model. The second step consists of a series of targeted plant surveys or audits designed to calibrate and/or validate the process models that are used to convert the index parameters into estimates of mill throughput, recovery, grade, or efficiency, depending on the context of the study. The calibrated models are then used to predict and optimize mill performance when processing the future ores that were characterized in step 1. In this paper we review the methods, costs, and sources of error for the new characterization tests, describe the procedures for calibrating the process models, and present some case studies illustrating the methodology.

9:25 AM

Back to the Basics to Maximize Opportunities in Milling Operations

K. Kim; KK Mineral Advisor, Biggs, CA

All milling operations want the best recovery and high throughput. Unfortunately, many operations have problems with low recovery, low throughput or both. In majority of these cases, the solutions to improve recovery and throughput were simple. The solutions did not include implementation of

new technology or major capital, but rather a return to fundamentals. In a majority of cases problems have occurred because the operation was not following their own operating procedures, because the design of the circuit was changed, or because the basic metallurgical measurement was not taken or ignored. In this presentation, examples these problems and their solutions derived from long and varied experience will be discussed. The objective of this presentation is to provide the milling operator practical and readily implementable solutions to common milling issues to improve throughput and recovery.

9:45 AM

Sharing Best Practices from Other Industries and Identifying the Gap Using the MaintenanceScoreTest©

N. Blechschmidt and C. Frenzel; ConMoto Consulting Group, München, Germany

In pursuit of better availability and reliability for mining equipment and reduced cost for maintenance, it might be worthwhile to look outside of the mining world. Since there are some significant differences in the operating environment of mining equipment compared to other industries one of the challenges is to identify lessons learned that can be applied. The MaintenanceScoreTest© is a one-week, 360°-review that includes best practices from a whole range of industries which provides a comprehensive and in-depth evaluation of any maintenance system. By analyzing 67 individual criteria that make up Maintenance Excellence, benchmarking KPI, identifying weaknesses of the existing maintenance system possible improvements are identified and prioritized. For high-priority value creation areas roadmaps are developed that can be implemented efficiently.

10:05 AM

From Block to Blasting, Blending and Onward – How to Control the Impact of Variability in Your Mining Operations

K. Scholey; GE Mining, Mississauga, ON, Canada

The complexity and uncertainties that accompany the mining process, from the block model, through blasting, blending, and processing, leave most mines vulnerable to dramatic profitability swings. Much of the excess cost incurred at a mine results from variability occurring in one or more of these steps and the downstream impact on processes. The most profitable mines going forward will be looking to manage that variability, as well as at the interrelationships between the steps, to achieve a competitive advantage. Tools available to mines today, paired with developmental solutions that require a customized co-creation approach to tailor them to the specific, unique operational needs of a mine, will help to ensure the efficiencies needed to optimize the flow of material through the operational silos of the value chain. This session is designed to present new ways of looking at the mining value chain from block model through finished ore and discuss opportunities for reducing the variabilities that negatively impact a mine's recovery, productivity, and costs.

10:25 AM

The Balanced Scorecard of Mining Drives Operational Excellence

M. Routledge; H&S Division Board, Park City, UT

What does a simple balanced scorecard look like for mining and how can it be used to drive significant improvements in performance across the operations. How do you build a scorecard and align it with best practice principles of operational excellence? Using case studies we will discuss an approach any miner can apply to create a framework all levels of an organization can use to communciate effectively and set expectations for the team to deliver the plan.

10:45 AM

Metallurgy Analytics: Transforming Plant Data into Actionable Insights

J. Steyn[3], O. Bascur[1] and B. Gorain[2]; [1]OSIsoft, LLC., Houston, TX; [2]Barrick, Toronto, ON, Canada and [3]Flankeng, Toronto, ON, Canada

The advent of digital revolution has now enabled us with numerous tools that could be leveraged to transform our operational data into actionable insights. Key opportunities with digitization include better visualization, transparency, integrated planning and execution for value-chain optimization, that results in smarter production, intelligent response to changes in ore, process and equipment conditions, reduce energy and waste along with prevention of asset breakdown, safety and environmental issues. It is important to realize that these digital tools have limited value, from a metallurgical operational context, if we cannot bring-in the appropriate domain expertise along with getting the basics right. The focus within Barrick is to ensure that there is adequate depth of different disciplines built into our platforms along with breadth to integrate other disciplines such as geology and mining for an effective Mine-to-Mill integration. This paper discusses the methodology, findings, and challenges in the ongoing journey of implementing a Metallurgy Analytics platform that evolves from being retrospectively descriptive to anticipatively prescriptive.

11:05 AM

Operational Data to Operational Improvements in a Mineral Processing Plant

O. Bascur; OSIsoft, LLC., Houston, TX

Applying the latest technologies has become a serious challenge to both management and technical teams due to their rapid change. The digital revolution has created a new focus for continuous process improvement and innovations —one that spans operations, service organization and customer interaction. With this expanded focus comes the need to improve processes more openly, more iteratively and more collaboratively. A novel strategy to cleanse operational data based on business targets provide a new way to transform data into insights. This paper presents an integrated approach for grinding and flotation management. The objective is to maximize recovery while reducing operating costs. The current grinding sensors and flotation analysis provide large amounts of data, Adding the right context and time events enables to augment to operational knowledge for proactive actions for improving the performance of the grinding and flotation circuits. Grinding is improved by using the line Gaudin distribution module index and flotation by estimating the optimal air hold up profile.

11:25 AM

Leveraging Terrestrial LiDAR to Optimize Performance, Profitability and Efficiency for Design Conformance and Slope Optimization.

N. Goncalves[1] and D. Ball[2]; [1]I-Site Technical Services, Maptek, Lakewood, CO and [2]Corporate Geomechanics, FreePort-McMoRan Inc., Oro Valley, AZ

Evaluating design conformance in real-time is becoming important as margins and profitability in the mining industry become tighter. 3D laser scanning provides the ideal solution for survey, geology, geotechnical and operations teams to safely, accurately and rapidly evaluate design conformance. It allows all stakeholders to quickly compare as-builts to designs in the field and to foster real-time decision making. Failure to achieve design provided by engineering can have significant consequence. Digging out of tolerance to the design can lead to dangerous high-wall safety concerns and an inability to recover the planned material, leading to reduced profits. Empower operations with the most accurate, real-time design conformance tools to make corrective adjustments. In this presentation, we'll discuss how 3D laser scanning and software solutions are helping Freeport-McMoRan optimize performance, profitability and efficiency in their slope optimization program. Specifically, how design conformance visualization in 3D helps survey, geotechnical and operations increase safety by meeting proper catch bench widths, reducing personnel exposure and increases ore recovery.

TUESDAY, FEBRUARY 27

MORNING

9:00 AM | ROOM 101B

Mining & Exploration: Operations: Practical Incorporation of Technology in Operations

Chairs: *B. Syers, Twin Metals Minnesota, Saint Paul, MN*
J. Dufek, Freeport-McMoRan, Tucson, AZ

9:00 AM
Introduction

9:05 AM
Supporting Smart IOT in the Mine
D. Fisk; 3D-P Inc., Calgary, AB, Canada

With the demand for data growing exponentially, the questions are also growing exponentially. How much data is enough data? How do I get it from our equipment in a timely manner? How can I efficiently transport it to where it is needed, whether locally or in the Cloud? We discuss approaches to near real time data collection on mobile equipment, hosting of applications on board to speed access to data, reduce traffic and ensue that priority data gets through and less important but needed data is delivered in a timely manner.

9:25 AM
Data Transport Over Leaky Feeder Utilizing Internet Protocol Enabled Land Mobile Radio
R. Jacksha[2] and C. Sunderman[1]; [1]Spokane, WA, CDC NIOSH, Spokane, WA and [2]Spokane, WA, CDC NIOSH, Spokane, WA

Mine monitoring is a vital component of successful miner safety and health programs. Data from environmental, geotechnical, infrastructure, and other types of sensors are increasingly being used to discover and mitigate health and safety concerns in underground mines. In many smaller underground mines, as well as in new development headings of larger underground mines, leaky feeder communication systems may be the only available means to transport crucial monitoring data. In addition, data transport is increasingly being delivered using Internet Protocol while older forms of serial communication are being retired. This paper presents the selection, configuration, and testing methodologies employed to integrate commercially available land mobile data radios into an existing leaky feeder communication system to provide Internet Protocol data transport.

9:45 AM
Underground Data is Getting Bigger… How to Make the Best of It
J. Del Rosario; Micromine, Englewood, CO

With a growing underground mine industry, there is an ever-increasing amount of data that needs to be managed in a more efficient manner in order for mining companies to make better decisions. Traditionally, underground mining operations are known for having large and unorganized sets of data. The mines were not used to having as many points of data as they do today as technology has changed. In today's typical underground mine, the amount of data that comes from their operation is gigantic. Data sets from haulage information, assets location, equipment health and location status are some of them. Capturing this information and having the knowledge and tools to use it properly are key factors to be successful in this growing side of the industry. The concept behind this technical paper, is to show how this increasing amount of underground data can be captured and used with a Fleet Management System (FMS) solution to improve the day to day operation. Along the way, some actions and process that industry leading companies are following, are going to be presented as examples of good practices.

10:05 AM
Maximize Your Shovel Loading Operations for the Lowest Cost per Ton – Pass Match or Payload Strategy?
R. Riggle; Surface Mining & Technology, Cat Global Mining, Tucson, AZ

Numerous papers, presentations have been written on Mining Haul Truck Payload management and effects of payload on haul truck availability. Mining operations around the world understand the value and concept of haul truck payload optimization. This article will discuss loading from the electric rope shovel perspective. Electric rope shovels dippers are engineered for optimal pass match loading with 3-4 passes as the ideal loading system to produce the lowest cost per ton. With real time data systems, equipment performance monitoring technology on both haul trucks and shovels, field studies at large mining operations reveal that haul truck payload optimization may be hindering shovel performance. The haul truck payload optimization, the 10-10-20 payload rule and technology at some operations have led to some questionable operationally practices of trucks waiting for the payload to register while waiting under the shovel, taking very valuable production time away from the shovel loading time. This article will explore the advantages and disadvantages of shovels loading to a pass match verses loading to a payload.

10:25 AM
How Do We Measure the Effect of Consistency or Variability in the Mining Operations?
M. Yildirim, R. Hall and J. Skerik; Global Mining, Caterpillar Inc, Chandler, AZ

The significant improvements in computer technology in mining industry brings the opportunity to optimize the operations, increase the throughput, and reduce the overall operating cost in mines. The operational consistency is very important to achieve the optimal productivity. With the availability of vast amount of data thorugh the fleet management systems, the consistency and the variability of many operational KPIs can be analysed in detail. The term called variability-mining is used in other industries for years. However, it is not fully utilized in mining industry yet. A data-driven, systematic approach can be used to measure the effect of variability on overall mine optimization. It is easier to plan and execute more effectively when the operational KPIs are more consistant rather than variable. How do we measure the optimum variability? This paper shows the technique of reverse engineering to measure the effect of consistency vs variability on productivity.

10:45 AM
Installation of a Thin Spray-on Liner Ground Support System at the Cote Blanche Mine Production Shaft
G. Sutton; Mining Operations, Cementation USA, Bunker, MO

The Cote Blanche Mine is a major producer of salt located on the Gulf of Mexico in south Louisiana, and is owned by Compass Minerals. Following a rigorous internal review of safety systems throughout the company, in this case a remedy was sought to mitigate risks associated with unlined portions of the shaft. Compass Minerals made a decision in 2015 to install a thin spray-on liner ground support system in the unlined portion of the shaft. Compass Minerals entered into agreement with Cementation USA to complete the work, which included engineering and fabrication of work decks to fit the existing configuration, cleaning the walls, spraying the liner material and installing the rock bolts. This presentation will discuss the challenges and successes that went along with this innovative new shaft liner system installation including scheduling, coordination, methodology, and includes the final results of the project which was completed in April 2017. Other potential applications for this support system in the mining industry will be discussed as well.

11:05 AM

Grade Control Technological Innovations at Goldcorp Peñasquito Mine

C. Calderon-Arteaga[1], J. Barrios[2], M. Almond[3], R. Ruiz[6] and S. Gering[4]; [1]Mine Planning Technical Services, Hexagon Mining, Tucson, AZ; [2]Ore Control, Penasquito Mine, Mazapil, Zacatecas, Mexico; [3]Mine Geology Manager, Penasquito Mine, Mazapil, Zacatecas, Mexico; [4]Product Manager - Software Development, Hexagon Mining, Tucson, AZ and [5]Long Term Planning and Modeling Engineer, Penasquito Mine, Mazapil, Zacatecas, Mexico

Peñasquito is Mexico's largest gold producer, consisting of two open pits - Peñasco and Chile Colorado - containing gold, silver, lead and zinc. Looking for a better control of the mine grades, specially because an expected lower grade production during the incoming years, a new Grade Control system was adopted in August of 2016. This case study will discuss a Grade Control solution that was implemented at Peñasquito mine. This project required managing blasthole data, model interpolation, model calculations among other modeling related tasks. It was also required the creation of new ore control databases to manage material routing, daily mining, model reconciliation and the communication with third party systems at the mine. The implemented solution uses the blasthole database as a primary input while also serves as material routing input for the fleet management system, and as a source to generate various reports. The ore control system data is turned into information that supports the decisions and evaluation making processes at the mine. This presentation will review the current solution, challenges encountered and some lessons learned from the project.

11:25 AM

Next Generational Fleet Management Scaled to Small Operations Delivering Large Scale Returns

R. Howell and J. Nolke; Global Mining Sales and Support, Caterpillar, South Milwaukee, WI

Many large mining operations currently use a combination of fleet management, terrain guidance, and health monitoring technologies to measure their performance, manage their equipment, and maximize their production. The desire to minimize waste, reduce cost, and increase efficiency are the same goals shared by hundreds of smaller mines and quarries around the world, but implementing powerful technology solutions historically requires a significant investment to achieve maximum results. In order to lower the cost of entry for these customers Caterpillar is leveraging cloud computing and machine learning to create an automated, accurate, and scalable Next Generational Fleet Management System.

11:45 AM

Optimization of Cable Bolting Strategies at an Underground Mine

E. Karampinos[1], P. Morissette[2] and J. Hadjigeorgiou[1]; [1]Lassonde Institute of Mining, University of Toronto, Toronto, ON, Canada and [2]LaRonde Mine, Agnico Eagle Mines Limited, Rouyn-Noranda, QC, Canada

In response to challenging ground conditions, mines continually update their ground support standards. This paper reports on the integration of a 3D distinct element model in the design process. The model used pull test data of reinforcement elements and was calibrated to the observed deformation in mine drives and performance of ground support. The numerical model has been extended to explicitly model the behavior of several cable bolt installation configurations. Furthermore, it investigated the impact of the time of installation at different deformation stages of the drives. Analysis of the results of these numerical investigations, and field observations, provide further confidence in proceeding to field trials and the optimization of cable bolting strategies.

TUESDAY, FEBRUARY 27

MORNING

9:00 AM | ROOM 101D

Mining & Exploration: Technology: Technology Innovations in Underground Mining

Chair: *B. Kamran, Colorado School of Mlnes*

9:00 AM

Introduction

9:05 AM

Robust, Scalable SIC/OMS for Underground Mines

A. Sawant; RapidBizapps, Milpitas, CA

Short interval control (SIC) systems, also known as operational management systems (OMS), have long held great potential in terms of helping mine managers understand and rapidly respond to operational changes underground. Until recently, such systems were primarily demonstrated in a one-off and/or proof-of-concept manner. However, advances in hardware and networking technology coupled with high-quality agile software development have greatly contributed to the creation of a short interval control system. In this presentation, we describe "groundHog", a multi-screen, app-driven, centralized SIC/OMS platform that empowers underground mine managers to monitor, assess, and reoptimize activities across headings, operators, and equipment on a minute-by-minute level. We discuss features, such as offline/online connectivity and a highly intuitive user interface, that make this platform ideal for deployment at most underground mines worldwide. We continue with promising results from a recent deployment at a major underground gold mining facility in Nevada, and we conclude with observations on how SIC/OMS platforms with interact with other advanced mining technologies in the years to come.

9:25 AM

Improving Overall Equipment Effectiveness: Mobile Equipment Telemetry in Underground Mining

J. Bouchard; Newtrax Technologies, Montreal, QC, Canada

Today's underground mining operations must optimize every step of the mineral extraction process in order to remain profitable in all market conditions. Monitoring haulage truck fleet productivity allows for proactive measures to be taken to ensure production proceeds as planned, quotas are met, and equipment life is maximized. Applicable to all haulage truck brands and models, the Newtrax Mobile Equipment Telemetry (MET) solution monitors truck payloads, either by providing a complete custom-fit Payload Monitoring System, or by interfacing directly with the OEM's existing sensor network. The interfaced alternative involves retrofitting the Newtrax Payload display to the OEM's load cells. This paper will show how the Newtrax Mobile Equipment Telemetry (MET) solution enabled an underground mine to quickly identify that their trucks were hauling average payloads which were significantly below the nominal capacity of their trucks.

9:45 AM

Low Cost LIDAR Ground Control Hazard Detection Network

N. Maerz, K. Boyko, I. Ahner, K. Robertson and A. Alzahrani; Rock Mechanics and Explosives Research Center, Missouri University of Science and Technology, Montreal, MO

Roof falls can largely be predicted by measuring the minute movements that act as precursors to catastrophic failure. Conventional instruments like extensometers are costly to purchase, install, and monitor, and typically mea-

sure only a single point. This paper demonstrates the feasibility of using low cost solid state LIDAR scanners for measuring these minute movements, and the use of inexpensive ZigBee radio networks to transmit the measurements in real time. Experiments with these LIDAR scanners reveal that sub-mm measuring precision can be achieved using sophisticated algorithms. Costing as little as $100, these scanners can measure at multiple points of interest. ZigBee radio nodes, costing as little as $50 per node can be used to both control the scanner and transmit data to the surface. Radio waves are line of sight, but have a range of up to several km, so intermediate nodes are only required where there tunnels change direction. ZigBee networks can "sleep" and have a duty cycle of less than 0.02% thus a battery life of many months. A functioning system is installed in the Missouri S&T experimental mine, and systems will be installed this fall in two Missouri mines.

10:05 AM

Getting Reliable Access to Data from the Working Area

S. Harrison; Engineering, Innovative Wireless Technologies, Lynchburg, VA

Getting reliable access to data from the working areas – the so-called "last mile" – remains a problem in underground mining. The capability is key to capturing the real-time data needed from the working areas to enable effective management and continuous improvement of production operations. A review of technology implementations that have been tried and/or are in use today - including fiber, leaky feeder, and WiFi - with the benefits and weaknesses of each, are reviewed. Performance, reliability, survivability, communication range, ease of maintenance, and initial and life cycle costs will be considered. A new technology solution has been developed specifically to address the challenges of the working area environment and promises reliable, real-time, high bandwidth data transmission. It will be assessed using the same criteria previously discussed.

10:25 AM

Limits to Underground Mining at Depth.

C. Fairhurst; Itasca Consulting Group, Minneapolis, MN

Hostile environmental and ground control conditions are key factors limiting the depth of underground mines. Development of autonomous mining systems increases worker safety, and places greater focus on ground control. Recent innovations in numerical modeling of (i) mining in fractured rock under high stress conditions; (ii) rock fragmentation; and ongoing developments in high speed computing provide new practical tools for better assessment of ground control, and innovation in rock excavation systems. The paper will provide practical examples of these innovations. Greater commitment to Research and Development in Mining by industry is essential to achieve maximum practical benefit to be realized.

10:45 AM

uGPS Rapid Mapper: the Genesis of a Mobile 3D Scanning Technology for Short Interval Control Applications in the Underground Mining Industry

A. Chapman and C. Watson; Peck Tech Consulting Ltd., Montreal, QC, Canada

Three-dimensional scanning technology has been used in surface mining operations for decades, and over the years has also permeated the underground mining market. However, until only recently, these scanners have been stationary in nature. Mobile 3D scanning has been increasing in performance and popularity in the mining market, due to its faster and more flexible data acquiring workflow. This presentation covers the authors' experience in developing a mobile 3D scanning product for the underground mining industry. Based on a positioning technology for GPS-deprived areas, the uGPS Rapid Mapper has evolved and adapted since its release in 2015 to achieve adequate accuracy for a variety of common underground survey applications. The journey from commercialization to deployment is reviewed, including technical challenges, input from industrial partners, and results from real-world Customer use cases such as: mobile convergence monitoring, dynamic shotcrete thickness monitoring, overbreak analyses, deletion/dilution reconciliation, and "will-it-fit?" analyses.

11:05 AM

Battery Electric Vehicles

D. Sanguinetti; GMSG, Ormstown, QC, Canada

The application of battery electric vehicles (BEVs) in hard-rock underground mining has generated a lot of interest in recent years, due to its significant operating cost savings and its health and environmental benefits. An impediment to its adoption, however, has been the lack of any industry standards or guidelines. In answer to this, the Canada Mining Innovation Council (CMIC) partnered with the Global Mining Standards and Guidelines Group (GMSG) to create a best practices guideline for BEVs in the underground. Published in April of 2017, the guideline includes information on mine design, vehicle design, charging philosophy and design, and performance testing. This presentation will review the contents of the guideline and give use cases of how it is being applied. It will also give a preview of what is going into the 2nd edition of the guideline, the work for which has just recently begun.

TUESDAY, FEBRUARY 27

MORNING

9:00 AM | AUDITORIUM ROOM 1

MPD: Comminution

Chairs: *M. Larson, Consultant, Ewen, MI*
M. Dennis, FLSmidth USA Inc., Midvale, UT

9:00 AM

Introduction

9:05 AM

Studies in Grinding Media Sizing

W. Conger[2], R. McIvor[1], T. Weldum[3] and J. Dupont[4]; [1]Metcom Technologies, Marquette, MI; [2]ME Elecmetal, Cook, MN; [3]Cliffs NR, Ishpeming, MI and [4]Detour Gold Corporation, Toronto, ON, Canada

These studies analyzed the relationship between the size of grinding media in the mill and grinding performance, specifically energy efficiency. Starting with a review of the literature, the issues of initial media sizing for a new ball milling circuit, and then optimal media sizing for an existing milling operation, were examined. The Functional Performance parameters "Mill Grinding Efficiency" and cumulative "Mill Grinding Rates" from both plant and test-scale equipment were used to provide new insights into this long debated topic. A plant media sizing diagnostic tool is presented, as are testing and follow-up plant evaluation methods and case studies.

9:25 AM

Novel Technology Provides On-line Measurement of Particle Size in Individual Cyclones: Barrick Cortez Case Study

D. Cirulis[1], T. Rana[2], J. Bosch[2], D. Winkowski[1] and J. Mercuri[1]; [1]CiDRA Minerals Processing, Salt Lake City, UT and [2]Barrick Gold Corporation, Toronto, ON, Canada

In minerals processing plants, the particle size distribution of the cyclone overflow is an important parameter and can be viewed as the product of the comminution process. Too coarse of a product will likely have poorly liberated valuable minerals and make downstream recovery difficult. Too fine of a product may represent a missed opportunity to increase plant throughput. A novel and robust technology utilizing acoustic signal processing enables on-line measurement of the particle size in the overflow of individual cyclones. The system is based around a wetted sensor design with no moving parts

and provides a real-time trend of the desired target grind size parameter. The system does not require sampling and associated sample transfer piping that is prone to plugging, thus avoiding high maintenance requirements. The CYCLONEtrac Particle Size Tracking (PST) system offers significant advantages over what is considered standard equipment in the industry and is successfully deployed at multiple large concentrators. This paper describes the installation and results of the latest CYCLONEtrac PST design installed at the Barrick Cortez operation in Elko, Nevada.

9:45 AM

Performance Prediction of a Vertical Stirred Grinding Mill

D. Rocha[2], P. Taylor[1], E. Spiller[1] and H. Miller[2]; [1]Metallurgical, Colorado School of Mines, Golden, CO and [2]Mining, Colorado School of Mines, Golden, CO

Over the last decade, the performance and energy efficiency of stirred milling technology has become a preferred alternative to ball mills for fine and regrinding operations. The difficulty encountered in fine grinding is the increased resistance to comminute small particles when compared to coarse particles. Therefore, increased energy inputs are then necessary to raise the number of stress events in a mill to contribute to the comminution of fine particles. This work presents a hypothesis of a methodology to predict the product size distribution of a vertical stirred mill using a Bond ball mill. The Population Balance Model (PBM) was used to empirically analyze the performance of a vertical mill and a Bond ball mill. The breakage parameters obtained for both grinding mills are compared to determine the possibility of predicting the product size distribution of a vertical mill based on the results obtained from a Bond ball mill. The biggest advantage of this methodology is that most of the minerals processing laboratories already have a Bond ball mill to perform the tests suggested in this study.

10:05 AM

HPGR in a Heap Leach: Two Case Studies

G. Sauermann and H. Plath; Minerals, ThyssenKrupp Industrial Solutions, Atlanta, GA

Golden Queen Mining Co., LLC ("Golden Queen") successfully commissioned its gold / silver heap-leach operation during the first quarter of 2016. This project is significant for being the first commercial heap-leach operation in North America to feature an HPGR at the heart of the crushing plant. This followed on the successful operation of an HPGR at the Goldfields Ghana Tarkwa Gold Mine. The installation at Tarkwa mine established the industrial benefits of the HPGR in heap leach operations. Both Tarkwa and Golden Queen opted to install High Pressure Grinding Roll (HPGR) technology in order to take advantage of the higher initial extraction rates and ultimate gold and silver recoveries. The HPGR's breakage mechanism is promotes mineral liberation from gangue material. In addition, the HPGR provides various operational benefits to the modern comminution plant. This paper provides a case study of plant design, with emphasis on the tertiary (HPGR) section. In addition to a general discussion on the HPGR design and operating principles, the paper compares and highlights various plant design features and discusses the most important best practices.

10:25 AM

20 Years of HPGR in Iron Ore Processing

T. Lundquist and F. Van Der Meer; Weir Minerals, Frederic, WI

More than 20 years have passed since the first HPGR iron ore installations at the Empire pebble crushing circuit and VALE, LKAB, and Kudremukh pellet feed grinding circuits. Experiences in these plants have contributed to a better understanding of the process, operation, and maintenance required for a successful application. Subsequent improvements in design have led to lighter, larger and more versatile HPGR with significant improvements in durability of wear and replacement parts along with improved control systems. Additionally, by optimizing the position of HPGR in the circuit, adapting the acceptable feed distribution to preceding stages, and maximizing the production of fines to match downstream grinding facilities the HPGR has been able to expand into copper, gold and diamond processing. It is also covering new ground in industrial minerals and circuit concepts with dry air classification. This publication summarizes some of the features of HPGR circuits and maintenance concepts for selected applications against the background of 20 years of experience in high pressure grinding technology in iron ore processing.

10:45 AM

Next Generation Comminution – an Update of Prominate Gold Application

G. Sauermann and H. Plath; Minerals, ThyssenKrupp Industrial Solutions, Atlanta, GA

thyssenkrupp recently supplied innovative comminution equipment to a variety of gold mines in North and Central America. Three examples are the Polycom HPGR at Golden Queen Mining in California, a SAG and Ball mill for the Haile Gold mine in South Carolina and 5 Mills to the Pueblo Viejo mine in the Dominican Republic. The common denominator in these diverse applications is the fact that they all benefit from using next generation comminution equipment. The Pueblo Viejo operation features 5 shell supported mills with a variety of drive arrangements, including a GMD on the 26ft ore ball mill, and twin Combliflex gear reducers on the 32ft ore SAG mill. The Haile gold mine features shell supported SAG and Ball mills with Combiflex gear reducers. The Golden Queen mine features the Polycom® HPGR. This paper provides an update on the operational experience at these mines with specific emphasis of the benefits derived from next generation comminutions equipment employed.

11:05 AM

Reimagining the Mining Comminution Process

M. Powell[1] and L. Nordell[2]; [1]Liner Design Services, Btisbane, QLD, Australia and [2]Conveyor Dynamics, Bellingham, WA

The mining industry has a surprisingly low uptake of redesigning processes based on the advanced computational techniques that are now available to us. The majority of comminution equipment and process development is either through incremental changes or lone inventor ideas utilising theory and models developed over 30 years ago. When computational techniques, such as DEM or CFD are used they tend to be applied to an idea to prove it rather than to design it. The use of outdated and highly simplified breakage models severely limits the predictive capability of these design simulations, in fact they can be misleading by ignoring the major contributors to the comminution process. We present the opportunity awaiting the industry through adopting a process design strategy built form the ground up based on the latest computational capabilities, such as massive parallel GPU processors, and understanding of particle fracture, such as force to fracture and particle strength distribution. This can be applied to redesigning mill internals, rock transport and new equipment to dramatically reduce the energy needs and thus capital and operating costs of comminution for mineral recovery.

TUESDAY, FEBRUARY 27

MORNING

9:00 AM | ROOM 200IJ

MPD: Flotation I: Fundamental Aspects of Flotation

Chairs: *T. Bhambhani, Cytec Industries Inc., Stamford, CT*
C. Young, MT Tech, Butte, MT

9:00 AM

Introduction

9:05 AM

Utilizing the Multi-Site Complexation Model to Explain Hydroxamate Adsorption on Mineral Surfaces

W. Zhang and R. Honaker; Mining Engineering, University of Kentucky, Lexington, KY

Hydroxamate collectors play an important role in achieving an efficient flotation performance for a number of minerals due to their specific chelation effects. A systematic literature review of hydroxamate adsorption mechanisms on several mineral surfaces found that a number of mechanisms have been proposed including chemisorption, surface reaction, surface and bulk precipitation, physical adsorption, and ion-exchange. Different explanations have been suggested regarding the fact that maximum adsorption densities of octano, benzo and salicyl hydroxamate collectors normally occur at pH 9.0. However, none of the explanations can explain the fact that maximum adsorption on cassiterite and rutile surfaces occurs at pH values lower than 9.0. A multi-site complexation model was utilized to predict the surface active sites of cassiterite and rutile, which yielded a fundamentally sound explanation and provided more insight into the role of hydroxamate in flotation surface chemistry.

9:25 AM

MDS Analysis of Bubble and Drop Attachment at the Molybdenite Face Surface

J. Jin[1], L. Dang[2] and J. Miller[3]; [1]Freeport-McMoRan, Salt Lake City, UT; [2]Pacific Northwest National Laboratory, Richland, WA and [3]Metallurgical Engineering, University of Utah, Salt Lake City, UT

Nanoscale nitrogen bubble and hexane drop attachment at the hydrophobic molybdenite face surface are studied by molecular dynamics simulation (MDS). The water film is unstable, and, as expected, simulated attachment results in a nitrogen bubble contact angle of about 90°, whereas the hexane drop spreads and wets the molybdenite face surface. Simulated nano contact angles are compared to experimental measurements with good agreement. In contrast, the water film is stable at the hydrophilic quartz (001) surface and the bubble/drop does not attach. Details of water film thinning, rupture, and displacement are reported. Film stability and bubble/drop attachment are described with respect to interfacial water structure for molybdenite and quartz surfaces of different polarity. Interfacial water molecules at the hydrophobic molybdenite face surface have relatively weak interactions with the surface when compared to the hydrophilic quartz (001) surface, as revealed by the presence of a 3 Å "water exclusion zone" at the molybdenite/water interface. In this way, attachment can be described by an attractive van der Waals force.

9:45 AM

Surface Forces Affecting Two-Liquid Flotation

R. Yoon and K. Huang; Virginia Tech, Blacksburg, VA

Recognizing the limitations of flotation with fine particles recovery, many investigators explored the possibility of using oil droplets rather than air bubbles for the recovery of hydrophobic particles. The process, known as two-liquid flotation, showed that it can readily recover submicronic particles (Lai and Fuerstenau, 1968). In general, oil drops form substantially larger contact angles than air bubbles do, providing an explanation for the benefit of using organic liquids for flotation (Stratton-Crawley and Shergold, 1981). In the present investigation, the surface forces present in the thin liquid films (TLFs) of water formed between oil drops and hydrophobic surfaces have been measured. The results show that oil drops give stronger hydrophobic forces, larger rupture thicknesses, and more negative free energies of interaction than air bubbles can. Reasons for these advantages associated with the two-liquid flotation process will be discussed.

10:05 AM

Effect of Nano Particles on Froth Characteristics in Complex Sulfide Ore Flotation

M. Hayat, L. Alagha, Z. Xiao and K. Monyake; Mining Engineering, Missouri University of Science & Technology, Rolla, MO

Froth flotation is known to be one of the key technologies in the field of Mineral processing. In any flotation cell, there are two major zones; the two-phase pulp zone and the three-phase froth zone. The overall performance of any flotation process is dependent on both zones. Froth stability in froth zone is a key factor to achieve an optimum flotation performance. The aim of this study was to investigate the possibility of using nano materials to manipulate the froth stability in sulfide mineral flotation. Optimum dosages of collector (sodium isopropyl xanthate), frother (MIBC), air rate, impeller speed & depressants (ZnSO4 & NaCN) were determined using a three-level Box–Behnken design combined with a response surface methodology (RSM). Froth stability at these optimum conditions was measured after the addition of nano materials in a modified flotation cell. Three different nanomaterials, namely SiO2, TiO2, and Al2O3, were used in the experiments. Froth stability was assessed based on froth height, froth growth rate, dynamic froth stability factor & air recovery. These froth stability factors were compared to have a whole picture of the effect of nano materials on froth stability.

10:25 AM

Measurement and Applications of Zeta Potential in Water-based Separation Processes: Implications on Process Optimization

M. Khodakarami and L. Alagha; University of Missouri, S&T, Rolla, MO

Water–based separation processes such as flotation, filtration, flocculation, precipitation, crystallization, etc. are substantially dependent on the molecular interactions at the solid/liquid interface. The adsorption of chemicals on the surface particle is strongly influenced by the particle size, charge, and orientation of molecules as well as other microstructural characteristics. The nature of the interfacial reactions can be predicted by studying the so-called electric double layer. Zeta potential is a fundamental factor which describes the electrical characteristics at the solid/liquid interface by measuring the electrophoretic mobility of charged particles moving under the influence of an applied electric field. The focus of this work is to examine the role of reagents in modifying the electrical characteristics at the solid/liquid interface. Selected examples of zeta potential application in different water–based separation systems are presented. Result obtained from this study will help to advance the understanding of the role of surfactants and additives in controlling stability of mineral suspensions which is critical from the application point of view.

TUESDAY, FEBRUARY 27

MORNING

9:00 AM | ROOM 200EDE

MPD: Plant Design

Chairs: *A. House, Samuel Engineering, Greenwood Village, CO*
O. Bascur, OSIsoft, LLC., Houston, TX
D. Rose, Midvale, UT

9:00 AM

Introduction

9:05 AM

FRP Loose Linings for Hydromet Process Vessels

J. Eisenman[1] and B. Hebb[2]; [1]Engineering, Maverick Applied Science, Inc., Palmetto, FL and [2]Engineering, RPS Composites, Inc., Mahone Bay, NS, Canada

Fiberglass Reinforced Plastic (FRP) provides a reliable solution for many corrosion concerns in hydromet processes. This is particularly true with

chemical services, like sulfuric acid and hydrochloric acid. In these corrosive applications FRP is a prominent material of construction for process piping, tanks, pressure vessels and stacks, to name a few, in processes such as solvent extraction and electrowinning. FRP is beginning to replace rubber lining in thickeners and similar solvent extraction equipment. Initially, FRP was bonded directly to the steel shell. In recent years, loose lining systems have been developed for corrosion resistant linings in thickeners for mineral separation and solvent extraction. This presentation will discuss the benefits of loose FRP linings in steel and concrete process equipment, such as thickeners. The details of construction and material selection of FRP materials will be discussed. This paper will present a discussion of design aspects, requirements and design validation to ensure reliable performance in hydromet processes.

9:25 AM

Slurry Pump Selection Based on Particle Size

M. Paschke and C. Walker; Weir Minerals, Madison, WI

Understanding the influence of slurry particle size on wear is essential to maximizing the life of centrifugal pumps operating in mineral processing plants and for hydrotransport duties. Particle size influences not only the wear rate but also the wear pattern in pumps. Complicating the situation is the different relative wear rate for different pump parts depending on particle size. A simple Slurry Wear Type (SWT) number based on particle size and size distribution is proposed as a means for categorizing slurry pump wear patterns and optimizing pump application and material selection.

9:45 AM

Shahuindo Project Update

P. Dalke; SME, Miami, FL

The social precedent of past-failed projects, the intrusion of informal miners, and the various engineering and technical challenges of building a heap leach operation, define Shahuindo. After 70-years and 6-previous owners, Tahoe Perú has become the operator of Shahuindo, which has a reserve base of almost 2-million ounces, located in Cajamarca, Perú. Undertaking the non-technical challenges of informal miners operating on Company property and a palpable anti-foreign mining sentiment requires proactive and sustainable social responsibility. Undertaking the technical challenges of a valley-fill 3:1 slope leach pad, an ore with a high-fines portion requiring agglomeration, limited water resources, and no national grid power connection requires diligent engineering, flexible execution, and tight controls of costs. Currently at the peak of construction, Shahuindo has over 400 Shahuindo employees and 1,500 contractors operating a ROM leach pad and constructing the "Shahuindo Projects". This paper will provide an update and insight into the projects required and lessons learned in bringing a new mine into commercial production in a challenging technical and non-technical environment.

10:05 AM

Process Vessel Hydrodynamic Performance Evaluation and Improvement through the Use of Computational Fluid Dynamics (CFD)

T. Plikas and U. Shah; Hatch Limited, Mississauga, ON, Canada

Insufficient residence time, excessive flow short circuiting, poor mixing, and other hydrodynamic inefficiencies are some of the operational issues associated with any process vessel design. Being able to accurately assess a process unit operation for the above is very valuable, and can lead to ensuring reliable performance. This paper provides an overview of recent applications of Computational Fluid Dynamics (CFD) to the hydrodynamic aspects of process vessel design, and showcases four different examples. It is demonstrated through the case studies that CFD is an extremely effective tool for: reducing technical risk in the design phase, identifying the root-cause of operational problems, and evaluating various solution options to arrive at the most practical and cost effective solution. Rapid advancements in hardware architecture, code algorithm development, lower solution execution time, physical model accuracy, high performance cloud computing and lower software costs have made CFD the preferred engineering method of choice in addressing these types of hydrodynamic problems.

10:25 AM

Towards Safer NaHS Storage and Delivery: Using Risk Assessments to Reduce H2S Hazards

D. Steiner[1], C. Kominski[3] and C. Stoiber[2]; [1]Metallurgy, KGHM Robinson Mine, Ruth, NV; [2]Technical Services, KGHM, Miami, AZ and [3]Technical Services, Tessenderlo Kerley, Phoenix, AZ

Sodium Hydrosulfide (NaHS) is widely employed as a copper suppressant in Molybdenum flotation circuits. The use of NaHS carries with it the hazard of hydrogen sulfide (H_2S) exposure and has been linked to several tragic accidents in mining. Indications are that the regulatory health standards are moving towards more restrictive time weighted average (TWA) and short term exposure limit values (STEL TLV) to improve worker safety. Controlling H_2S emissions in Cu/Mo flotation separation circuits and in the storage and delivery systems to meet those new standards will become a significant challenge. At the Robinson Mine, Risk Assessment tools such as HAZOP and Job Hazard Assessments were used to identify instrumentation and component modifications to the NaHS storage and delivery system. The result was greatly reduced H_2S exposure for maintenance and operations personnel that meet the anticipated regulatory requirements.

10:45 AM

New Life for the Humboldt Mill: Design, Construction, and Commissioning as a Modern Ni/Cu Concentrator at Eagle Mine

D. Stacey, H. Staton and N. Michaelson; Mill, Eagle Mine, Champion, MI

Eagle Mine is an underground, high-grade nickel and copper mine located in western Marquette County of Michigan's Upper Peninsula. Ore is mined and transported by truck to the Humboldt Mill for processing into separate copper and nickel concentrates. Mill commissioning began in mid-2014, and design throughput, recoveries, and concentrate quality were all achieved within a few months of start-up. The mill now operates at an efficient steady-state throughput of 2,000 tonnes per day. Originally built to process iron ore in the 1950's, the Humboldt Mill was converted to a gold processing plant in the 1980's before being repurposed once again by Eagle Mine to treat nickel and copper. The processing flowsheet contains three-stage crushing followed by single stage grinding, bulk flotation, and a separation flotation circuit prior to dewatering and load-out into rail cars for customer delivery. Considered a resounding success, commissioning and ramp up of the mill was not completed without challenges. This paper will detail some high level design considerations that were taken, and cover some of the important lessons learned during the project, construction, and commissioning phases.

11:05 AM

Optimization of Copper Mountain Mine's Comminution Circuit

J. Weber[2] and D. Rose[1]; [1]Process Technology, FLSmidth USA Inc., Midvale, UT and [2]Copper Mountain Mine (BC) LTD., Princeton, BC, Canada

Copper Mountain Mine was commissioned with a plant design based on a 35,000 tpd comminution circuit. In 2016, the average processing rate for the year was 38,900 tpd with a fourth quarter average of 41,200 tpd. The circuit is a conventional SABC with a 34' x 20' EGL SAG mill, two 24' x 39'6" ball mills and a Raptor XL900 pebble crusher. The commissioning of a Pre-Crushing circuit in 2014, a Raptor XL2000 cone crusher, allowed the comminution circuit to adequately process the highly competent ore from the various operating mining faces. An optimization program in the comminution circuit to handle the pre-crushed feed has provided the opportunity for the process rate to increase year over year. This paper reviews the reasoning and implementation of various optimization changes that were applied following the installation of the pre-crushing circuit to achieve the record throughput numbers of today.

TUESDAY, FEBRUARY 27

MORNING

9:00 AM I ROOM 200GH

MPD: Pyrometallurgy I

Chair: *J.Grogan, Gopher Resource, Eagan, MN*

9:00 AM
Introduction

9:05 AM
Computational Fluid Dynamic Modeling of a Secondary Lead Reverberatory Furnace

A. Anderson[1], J. Grogan[1], G. Bogin[3] and P. Taylor[2]; [1]R&D, Gopher Resource, Tampa, FL; [2]Metallurgical and Materials Engineer, Colorado School of Mines, Golden, CO and [3]Mechanical Engineering, Colorado School of Mines, Golden, CO

A computational fluid dynamic (CFD) model has been developed to idenfity mechanical and thermal stresses that occur within the refractory lining of a secondary lead reverberatory furnace. Once a base case simulation was validated using data from an operational lead reverberatory furnace, predicted areas of high refractory wear were determined through the calculation of the temperature and velocity distributions within the furnace. The average burden surface temperature was also evaluated as this parameter was used as a measure of smelting rate. The CFD model was used to assess whether the predicted areas of high refractory wear could be minimized by various operational changes to the burden geometry and burner alignment. The results showed that the amount and location of the burner flame impingement was sensitive to changes in both burden geometry and burner alignment and greatly affected the overall flow patterns and heat transfer within the furnace. The results also indicated that there could be a tradeoff between smelting rate and refractory lifetime.

9:25 AM
A Survey of Pyrometallurgical Arsenic VolatilzationTechniques

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

This presentation will delineate the pyrometallurgical volatilization of arsenic from Anaconda copper smelter flue dust. In part, this smelter was built in 1919 and then subsequently operated by some of the ancestors of Dr. Anderson. Background information as to origin of these materials along with other noted technologies will be outlined. Updated statistical analysis will be utlized and presented to determine key parameters for successful selective Arsenic separations.

9:45 AM
Recent Developments in Ecomaister-Hatch Dry Slag Atomization for the Non-Ferrous and Ferroalloy Industries

J. Bolen; Hatch, Mississauga, ON, Canada

The dry atomization process uses a jet of high volume, low pressure air to atomize metal, matte and slag and create particles from 0.5 to 12 mm in size. The rocess advantages include reduction of fire and explosion risks, reduction in crushing and other material handlings costs and elimination of water use and water treatment costs. The process is industrially established in the iron and steel, zinc and manganese industries. Hatch's labatory and pilot scale facilities have been used recently at a number of industrial sites for new metal, matte and slag applications. Recent development work in the stainless steel, copper, nickle and platinum industries will be reviewed.

10:05 AM
Settling of Copper and Copper Sulphide Particles in Slags

B. Davis[1], T. Lebel[1] and R. Parra[2]; [1]Kingston Process Metallurgy, Kingston, ON, Canada and [2]University of Concepcion, Concepcion, Chile

Settling of copper and copper sulphide particles in slag is important in both primary and secondary copper production. The settling rate is a function of the slag chemistry, temperature, and drop size. Some copper is left in the slag as soluble copper and some remains in particles too fine to settle. This presentation will discuss the combination of experimental work and modelling to generate a recovery vs. time output as a function of depth for particle settling in slags. Using this, settling time can be optimized for throughput and recovery. Partial addition and tapping as opposed to complete batch processing will also be discussed.

10:25 AM
Lead Blast Furnace Operations in North America

J. Grogan; Gopher Resource, Eagan, MN

Lead is one of the last non-ferrous refuges for the blast furnace. Blast furnaces are used for lead recycling at numerous sites in North America. Its mode of operation can vary. It can be used for recycling direct charged lead scrap, as a slag cleaning furnace, treating lead ores, or a combination of all three. This paper aims to give and overview of these operations and the differences between them. Also the differences in design and operation versus their iron making counterparts will be discussed.

10:45 AM
Rare Earth Metals Separation and Recycling Processes

R. Chiou, P. Velu and R. Reddy; Met. Matls. Eng., The University of Alabama, Tuscaloosa, AL

Rare earth elements are one of the fascinating group of materials used in diverse industrial applications. The elements in the periodic table with atomic numbers 57-71 are known as rare earth elements. In this presentation, rare earth metals and alloys separation and recycling by metallothermic reduction and electrolytic extraction and refining processes are discussed. Metallothermic processes are prominent for light rare earth metals. Very high purity metals and alloys are produced using fluorides as feed materials. Electrochemical processes are small scale production processes and rare earth metals and alloys produced using chloride or oxide feed materials. Metallothermic reduction is the most widely used commercial process for Ce, Pr, Nd and Sm metals and their alloys.

11:05 AM
Onsite Carbon Ashing for Recovering Gold from Waste Carbon

W. Clary, D. Albin, D. Kappes and T. Rauch; Kappes, Cassiday & Associates, Reno, NV

Nearly all gold recovery plants – whether they use CIL, CIP, or CIC processes – have the problem of activated carbon size reduction due to abrasion. The result is carbon fines that contain a percentage of the gold value, which may be recovered by smelting, or additional stripping of the carbon in specialized equipment. Often, the fine carbon is high in mercury, mixed with a large amount of sand and clay particles, or impregnated with chemical scale all of which make it hard to handle. An alternate route to recovery is to burn the carbon and send the ash to an on-site doré furnace, or back to the cyanide leach circuit. Ashing, however, is a challenging method of fines processing for gold recovery; mineral impurities cause the burning rate to be slow, and dilute mercury vapors are difficult to capture. KCA has spent over six years perfecting an ashing furnace, mercury scrubber and related materials handling equipment, called the "Carbon Converter," to make this process efficient, operable, and an effective means of gold recovery.

TUESDAY, FEBRUARY 27

MORNING

9:00 AM | ROOM 101G

UCA of SME: Shafts

Chair: *G.Sturgis, Registered Member, Coeur d'Alene, ID*

9:00 AM
Introduction

9:05 AM
Shaft Boring Roadheader: from Prototype to proven Technology
S. Dube; Herrenknecht, Etobicoke, ON, Canada

In 2012 Herrenknecht's first Shaft Boring Roadheader for deep blind shafts went into operation. This paper will outline the improved design of the Shaft Boring Roadheader transforming the concept from a Prototype to a reliable Technology for the safe and rapid sinking of shafts in the future.

9:25 AM
Innovations in Raise Boring Technology
S. Dube; Herrenknecht, Etobicoke, ON, Canada

Over the past 8 years Herrenknecht designed and manufactured innovative Raise Boring Rigs for the demanding global mining industry. This paper will outline several innovations applied on existing rigs or currently being designed and tested. One example is Herrenknecht's RBR900, using 15" pipes and capable of raising shafts of to 2000m in depth or 8m in diameter.

9:45 AM
Maintaining Worker Health and Safety During Deep Shaft Development in High Temperature Conditions
T. Vincent, M. Swanson and E. Smith; US Contracting, Cementation, Sandy, UT

As the depth of underground mines continues to increase, so do the temperatures at which these mines must be developed. Cementation has recently completed two shaft projects in high temperature environments, encountering rock temperatures in excess of 65 degrees C at both projects. Special attention to worker safety was required, and resulted in the development of effective heat management strategies and procedures. This paper will discuss some of the methods and policies used to ensure worker safety and overcome the unique thermal hazards that are encountered in deep mine development. Topics include: Setting Standards – work restrictions based upon ambient temperature measurements in the workplace; Sampling Methods – core-body ingestible sensor application and environmental heat monitoring; Controls – Ventilation; PPE - from eye protection to actively cooled clothing, using the proper equipment for the conditions; and Fit for Duty Preparations – monitoring hydration. The continued integration of these methods into current and future projects will allow Cementation to maximize productivity in these challenging environments while maintaining worker safety as top priority.

10:05 AM
Ground Freezing at Newmont's Leeville Turf #3 Shaft Project
G. Witwicki, S. Pearson and E. Winsor; Thyssen Mining, Regina, SK, Canada

Thyssen Mining completed the sinking of the Newmont Leeville Turf #3 Shaft in early 2016. The 26ft (7.9m) diameter, concrete lined ventilation shaft extends from surface to a depth of 2050 ft. Ground conditions varied and included a number of water bearing zones and a major fault. Sinking conventionally through ground such as this is challenging and risky. As proven in many other areas of the world, ground freezing is a predictable, low risk method of sinking through moisture laden ground. Ground freezing at this project was not only unique as it is the first deep shaft to be frozen in the Western United States, but freezing while pouring relatively thick shaft walls of high strength concrete added additional challenge. The shaft was equipped with sophisticated ground temperature monitoring probes that provided useful insight to the conditions beyond the shaft liner. Upon project completion, the Leeville mine was able to reverse it's ventilation, allowing the mine to extend production well into the future. The project was completed on time and budget making the Newmont Leeville Turf #3 Shaft project a successful example of the implementation of ground freezing technology.

10:25 AM
A Study of Shaft Stability and Anisotropic Deformation in a Deep Shaft in Idaho, United States
G. Walton[2], E. Kim[1], S. sinha[2], G. Sturgis[3] and D. Berberick[3]; [1]Mining Engineering, Colorado School of Mines, Golden, CO; [2]Geology & Geological Engineering, Colorado School of Mines, Golden, CO and [3]Hecla Mining Company, Coeur d'Alene, ID

The shaft liner was significantly damaged by excessive anisotropic ground deformation during construction of #4 shaft 4 at Hecla 's Lucky Friday Mine. This necessitated a substantial design change during construction, with the excavated shape of the shaft being modified from a circular to an elliptical geometry. This study uses extensometer data obtained during construction as well as a 3D finite discrete model (FDM) of stress redistribution around the shaft and a calibrated 2D FDM to understand the factors that affect the relative stability of both shaft geometries. Although the main focus of the work is the ground deformation behavior, the role of liner installation in suppressing ground displacements is also analyzed. As a result, the change in shaft geometry appears to be very effective in improving the stability of the shaft, with the maximum time-dependent displacement around the shaft decreasing by approximately an order of magnitude. In addition, the results of FDM support the conclusion that increased stress concentrations around the shaft caused by adjacent level developments play a significant role in exacerbating ground deformation in the circular portion of the shaft.

10:45 AM
Newmont – Northwest Exodus Ventilation Shaft
G. Friesen and C. Gammill; Undergroundn Operations, Newmont Mining Corp., Spring Creek, NV

The Northwest Exodus gold deposit is located in Newmont's Carlin North Area, Eureka County, Nevada. Northwest Exodus is an extension of the Exodus underground mine adding eight years of mine life to the operation and 2.6 million tons of mineable resource. The selected mining option for the new Northwest Exodus area quickly proved that the existing "intake" and "exhaust" declines would not be adequate due to the increase in mining depth and haulage distances. As a result of the ventilation engineering work, a surface-to-underground shaft was designed to supply adequate ventilation to support the mining methods as well as increase the airflow quantity to comply with a 160 μg/m3 DPM limit. This paper discusses the shaft design and sinking methodology for the Northwest Exodus ventilation shaft that managed both safety and geotechnical risks. The outcome was a safe means of excavation and a final product that met the mine's requirement for safety, ventilation as well as longevity to support a long mine life with the potential for expansion.

11:05 AM
Shaft Construction
A. Jain; Mining Engineering, Undergraduation, Dhanbad, Jharkhand, India

Shafts are the doorways to the tunnels and underground structures, serving as the location at which all material enters and exits. Also shafts are vital access for construction, operation, and maintenance of tunnels and underground structures. The choice of a shaft's temporary ground support method can have a significant impact on a tunneling project's cost and program. They vary in size and depth, and their design and construction are key to the successful completion of any tunneling project.

TUESDAY, FEBRUARY 27

MORNING

9:00 AM | ROOM L100J

Valuation I: Case Studies and Methodologies

Chairs: *Z. Smith, Hafner Valuation Group*
T. Knobloch, AIMA, Marietta, OH

9:00 AM
Introduction

9:05 AM
Comparable Transactions Analysis Methodology
W. Roscoe; RPA, Inc., Toronto, ON, Canada

In the minerals valuation/appraisal world, exactly comparable properties are rare or non-existent. This can be compensated for identifying somewhat comparable transacted properties and making adjustments to bring each into line with the subject property. An alternative method, described here, is to analyze a number of similar or somewhat comparable properties to derive a range of values to apply to the subject property. Comparability factors such as commodity, geological setting and deposit type, stage of exploration or development, access and infrastructure, political jurisdiction, and transaction date can be used to compile a data set of transacted properties. The property values can be expressed as dollars per unit metal or dollars per unit of property area. Typically a large range of values characterizes the data set, and the range selected to apply to the subject property should reflect this variability. The method is illustrated with examples.

9:25 AM
Managing an Uncertain Future: Monte Carlo Simulation of a Real Options Valuation Model to Improve Investment Decision Making
B. Teschner[1], D. Berberick[2], J. Grubb[1] and E. Holley[1]; [1]Mining Engineering, Colorado School of Mines, Golden, CO and [2]Hecla Mining, Coeur d'Alene, ID

Mining companies have historically used deterministic discounted cash flow models to determine the net present value (NPV) and internal rate of return (IRR) of a proposed project. Typically, these values are used as the primary metrics to determine whether to advance a project. Unfortunately, these models do not tell the whole story: they inherently assume that the development decision must be made now and that revenues and costs will remain unchanged over the life of the project. This presentation shows a more robust model that addresses these shortcomings. We employ a real options approach to model management flexibility to delay construction into the future, and Monte Carlo simulation of commodity prices, capital, and operating expenses to determine a suite of project outcomes. The method increases the NPV of a project by incorporating the value of management flexibility. In addition, the method can be combined with a company's risk tolerance to optimize the project hurdle rate, and the likelihood that the project will get built in the future. This presentation will demonstrate the method using a generic project where capital costs and future metal prices are uncertain.

9:45 AM
Cash Flow Models - Evaluations Versus Valuations
A. Jacobsen and R. Cameron; Behre Dolbear Group Inc., Edgefield, SC

Cash flow modeling is a widely accepted tool for evaluating and valuing mineral projects. But the appropriate application of this tool is often misunderstood. The use and results of a cash flow model can be quite different when applied to evaluations versus valuations. The net present value determined in the process of evaluating a project may not necessarily indicate the value of the project in terms of standard valuation methodologies. This paper provides a comparison of the use, application, methods, inputs and results for cash flow models that are used in valuations as opposed to evaluations.

10:05 AM
The Use of Appraisal Standards and Techniques Outside the Mineral Appraisal Process
A. Stagg; Stagg Resource Consultants, Inc., Cross Lanes, WV

It is not uncommon as a mineral appraiser to be retained in matters involving valuation issues that do not involve the formal appraisal of an interest in real property. Such matters frequently arise in litigation and arbitration and, in many such instances, it is the appraiser's experience in conducting formal appraisals that is desired. In the author's experience, an understanding of and the application of accepted formal appraisal standards and techniques in these instances adds considerably to the relevance and credibiity of the appraiser's testimony. In this presentation, several examples of the application of these standards and techniques from matters in which the author has been retained are provided, with an emphasis on how they enhance credibility.

10:25 AM
Opening Balance Sheet Valuation Method
J. Morgan; Respec, Lexington, KY

The challenge of determining the value of the mineral reserves and resources for multiple sites in numerous countries is complicated and is further exacerbated by the variation in the mineral ownership status, which varies from mineral ownership, surface ownership, mineral leases and surface leases and any combination of the above. This paper will use a case study to define the approach to the determination of the balance sheet value of the mineral reserves for a multi-national company with 200 sites in 11 countries and totaling over 3 billion tons. The asset register of a company is not a suitable source of the reserve / resource value. The value of a farm with planning approval purchased a year could have a book value a thousand times higher than a farmer's field purchased decades ago with the same reserves. Similarly, a 10 million ton reserve on a leased property could have a totally different accounting treatment to a 10 million ton reserve on a property owned in fee. The paper will detail the approach to reserve calculation, development of a synthetic royalty methodology and then the value calculation based on agreed discount factors, production rates and licence / permit terms.

TUESDAY, FEBRUARY 27

AFTERNOON

2:00 PM | ROOM 200ABC

6th North American Iron Ore Symposium: Alternate Iron Products

Chairs: *M. Couillard, BBA Inc.*
D. Fosnacht, University of Minnesota

2:00 PM
Introduction

2:05 PM
Iron Ore for Alternate Iron Processes
J. Poveromo; Raw Materials & Iron Global Consulting, Bethlehem, PA

Iron ore for alternate iron processes concerns alternate iron products designed for use in EAF (electric arc furnace) steelmaking processes. These alternate iron products include both DRI (direct reduced iron), HBI (hot briquetted iron) and merchant pig iron. Merchant pig iron can be produced in conventional blast furnaces, mini blast furnaces (including charcoal BF's) or novel processes such as RHF/SAF (rotary hearth furnace/submerged arc furnace) such as Iron Dynamics or RHF such as Mesabi Nugget. These novel processes are coal based and can use iron ore concentrates or recycled steel plant oxides. The blast furnace processes can use conventional feed materials: pellets, sinter, lump ore and coke. However, DRI and HBI processes are predominantly pellet based but require DR grade pellets that are low enough in acidic guangue (SiO2 and AI203) to avoid additional expense in the EAF process This paper will focus on the quality and availability of DR grade pellets for NAFTA DRI/HBI plants but also concentrates for fines based processes and feed materials for merchant pig iron production.

2:25 PM
A Novel DR Process for Iron Ore Concentrates
K. Reid; University of Minnesota, Eden Prairie, MN

In the fifteen year period 1995 to 2010 US BOF steel production decreased from 60% to 40% while EAF production rose from 40% to 60%. This is not good news for Minnesota since taconite pellets are only suitable for blast furnaces. There is consequently a great interest in the potential application of DR technology to produce higher added value products suitable for EAFs. The recent reduction in natural gas prices makes currently available gas fired DRI plants attractive, but CO2 emmisions remain an environmental concern. After reviewing current technology and trends a new pat pending In-Flight Direct Reduction Process (IFDR) is described that has an optional mode that produces only iron and oxygen.

2:45 PM
Production of DRI for Iron Ore Mining Companies: the Opportunities and the Challenges
A. Manenti; TENOVA, Coraopolis, PA

Iron ore mining companies, big or small, if located nearby to an economical source of natural gas, have a key advantage and incentive to produce and sell DRI vs. just iron ore pellets. DRI production adds significant value to iron ore mining products. In this paper will be analyzed the fundamental reasons for this fact, identified which is the best DRI to produce for given market, the challenges of the DRI production and the best plant size for different market location.

3:05 PM
NRRI Fixed Bed Dynamic DRI Process Simulator
K. Kangas and R. Kiesel; Coleraine Labs, Natural Resources Research Institute, Coleraine, MN

EAF steel producers have shown that supplementing scrap steel with direct reduced iron (DRI) increases productivity, energy efficiency and product quality. Through Minnesota's Mining Innovation Initiative, in 2017 NRRI received a grant to develop a fixed-bed dynamic DRI process simulator that more closely simulates process conditions found in commercial DRI shaft furnaces. This paper presents NRRI design process and the final design selected for project execution. NRRI's DRI Simulator will allow the industry to understand how different iron oxides perform in terms of reducibility, metallization, compression strength, fines generations, and clustering without having to do costly commercial scale trials.

3:25 PM
Importance of Understanding Raw Material Value-In-Use for Steelmaking
J. Jones; CIX Inc, Lantana, TX

As EAF steelmakers have started to use a greater variety of raw materials in the furnace, it has become more important for them to be able to distinguish the value that a particular commodity brings to the operation. There are a number of parameters than can be considered and the ultimate value of any material will vary from one facility to another. The International Iron Metallics Association (IIMA) tries to provide information for ore based materials (OBM) to the steel industry. As part of its' activities, IIMA has worked with Continuous Improvement Experts (CIX) to provide a value-in-use tool to the steel industry. This tool can assist steelmakers in better understanding of OBMs and how they can best be used in the EAF. This paper will discuss the key concepts and components of a value-in-use model and will demonstrate how the model can be used in real life situations. 1. Introduction to IIMA 2. What is "Value-In-Use" 3. Historical perspective of VIU 4. What parameters are Important? 5. Development of a VIU model 6. Application of VIU to real-life steelmaking operations 7. Understanding the dynamic nature of VIU

3:45 PM
Overview of DR Production Processes and Implications for Iron Ore Pellet Quality
J. Bolen; Hatch, Mississauga, ON, Canada

There are a number of direct reduction processes that are being considered for North American projects - shaft based natural gas (Midrex and Energiron), HIsmelt and coal based rotary hearth with and without smelting furnace. A technical overview of the various processes will be provided. The suitability and advantages and disadvantages of the processes for North American DR projects will be discussed. Iron ore chemistry and physical requirements for the processes are slightly different and will be reviewed.

TUESDAY, FEBRUARY 27
AFTERNOON

2:00 PM | AUDITORIUM ROOM 2

Bulk Material Handling: Reliability and Safety Improvements in Conveyor Systems and Components

Chair: *S. Shadow, Baldor/ABB Inc, Parker, CO*

2:00 PM
Introduction

2:05 PM
Best Practices and Innovative Monitoring Technologies for Conveyors: Increasing System Reliability Using Systematic Failure Modes Monitoring Approach
E. Botelho and O. da Rocha; Industrial Automation Service, ABB Brazil, São Paulo, São Paulo, Brazil

Presently the healthiness of the conveyor belt is largely determined through physical inspections at regular intervals and time based maintenance. However, in many cases the conveyor belt damage happens between the actions causing huge production and time losses to the mining plants. A right knowledge about its main failure modes avoids unexpected and catastrophic events in the conveying systems, providing enough time for maintenance team to act in order to take control of the equipment wear and maintenance planning. The application of modern control and logging systems in mining provides great amount of precious data that normally is underused. If treated properly, can provide to the maintenance engineering and reliability groups an important information source about the conveyor system health. The purpose of this presentation is to explain how some traditional maintenance

gaps on the conveyor condition based monitoring can be filled through the application of systematic failure modes continuous monitoring. The existing information on the traditional condition based systems can be integrated providing a full-view for the maintenance teams embracing mechanic, electric and automation.

2:35 PM

Monitored Rollers. A Yet Real and Available Solution

J. Eguiluz and J. Perlacia; Mining Division, Ulma Conveyor Components, Otxandio, Bizkaia, Spain

The rollers are consumables in the conveyor belts and have to be changed periodically. If the rollers get broken before replacement the consequences could be very important, generating additional costs and operational losses. Needless to say that, for critical applications, this possibility is a nightmare for Maintenance Departments The R&D Department of ULMA Conveyor Components, has been working since early 2012 on the development of Monitored Rollers along with a Management Software to provide the capacity of Managing and Monitoring rollers from desk, getting continuous online information on the internal temperature of the bearings, on the working status of the rollers as well as identifying rollers close to their end of life so that they could be changed during the next maintenance stop of the conveyor belt. In short, a system of Preventive Maintenance for Conveyor Belt Rollers Ulma Conveyor Components is proud to introduce their Monitored Rollers Technology, the Maintenance Management Software as well as live online access to some installations already working all over the world. The presentation will show the features of the systems, the applications and their main advantages

3:05 PM

Using the Latest in Engineering Technology for the Aggregates Industry

A. Gibbs; ASGSO, Allentown, PA

Asset optimization has never been more critical in the everyday things we do at home and at work. Conveyors are the lifeline to any aggregate plant's productivity. Proper consistent training, periodic inspections of the conveying systems and reliable turn-key installation and on-going maintenance will ensure an incident and injury free workplace while maintaining a productive reliable workforce. All of which are essential to any material handling system and the employees who maintain and are responsible for them. This presentation will review ASGCO's "Conveyor Training 101" program and the most common mistakes and problems that affect conveyor efficiency and how to identify and correct them to improve the productivity, safety and reliability of your conveyor systems. What safety guidelines should you be aware of when working on or around conveyors? What are the causes and more importantly the corrections of conveyor belt tracking? What are the reasons and corrections that you should know regarding belt cleaners and how they affect your conveyor performance? And finally, how do you implement a conveyor inspection and maintenance service program that works for your plant?

3:35 PM

DEM Modeling: Changing Bulk Material Handling Analysis In the Mining Industry

C. Hartford and T. Holmes; Jenike & Johanson, San Luis Obispo, CA

Discrete Element Method (DEM) modeling has been expanding bulk solids flow analysis beyond the traditional quasi-static analytical methods developed by Dr. Jenike. The three case studies shared illustrate how DEM is changing the way flow problems are analyzed. The first study reviews a 50t bottom-dump skip design for an underground potash mine. Calibrated DEM modeling aided with ensuring reliable handling and correctly predicted that discharge and cycle durations would meet project requirements. The second study involves the redesign of three existing transfer chutes to allow handling of magnetite concentrate at 10,000tph, from the first day of service. Plug-gages in the existing chutes had previously limited throughput to ~3,000tph. In the third study, DEM allowed efficient evaluation of alternative truck-bed shapes and liner materials to solve carry-back issues with sticky ore in mining trucks. In all cases, the calibrated DEM model predictions closely match field observations. Such recent successes show that properly-calibrated DEM modeling is a powerful tool used in combination with good design practices add to the body of evidence required to gain acceptance in mining.

4:05 PM

Cost Effective Reliability and Productivity Improvements for Conveyors and Conveyor Drive Systems

P. Spels; ABB Inc, New Berlin, WI

Overland and in-plant conveyor systems are critical assets and often form a production bottleneck. Getting maximum return from existing conveyors and minimizing downtime is the main target for maintenance teams. Limitations on downtime and capital often prevent minesites to improve return of conveyor infrastructure. A number of modern as well as time proven and cost effective paths of conveyor system productivity improvements, including digital solutions, will be presented. Diagnostics using unified approach for the whole system (bearing and gearbox health monitoring, belt and idler monitoring, diagnostics and prognostics for motors and electrical infrastructure) can provide substantial benefits for existing conveyor systems. Aging drivetrains with limited upgrade options pose a challenge as well. Upgrades utilizing existing motors (SCIM and WRIM) is a cost effective method of productivity and reliability improvements. State-of-the-art gearless drivetrains provide long-term benefits for existing conveyors. Recent project examples will be provided.

TUESDAY, FEBRUARY 27

AFTERNOON

2:00 PM | ROOM L100F

Coal & Energy: Carbon Sequestration

Chairs: *N. Ripepi, Virginia PolyTech Inst State U, Blacksburg, VA*
R. Pandey, Southern Illinois University Carbondale, Carbondale, IL

2:00 PM

Introduction

2:05 PM

Subsurface Stress Modifications Resulting from CO_2 Injection in Unconventional Reservoirs

S. Saurabh and S. Harpalani; Mining and Mineral Resources Engineering, Southern Illinois University, Carbondale, IL

Carbon capture and sequestration is integral to the success and future of the fossil fuel industry. Deep unconventional gas reservoirs, along with providing a critical energy source, can also serve as repositories for long-term storage of carbon dioxide (CO_2). However, the sorption behavior of these reservoirs, although critical in their ability to retain CO_2, also results in rock deformation under pressure, leading to in situ stress modifications which, in turn, can affect the technical and economic viability of geologic sequestration in these reservoirs. Furthermore, large changes in stresses can activate faults in the reservoirs susceptible to seismic activities. This paper analyzes the stress-strain relationships of coal and shale for increasing CO_2 pressure. Using poro-elastic equations and initial in situ stress conditions, a model is presented to predict the changes in stress with continued injection. Experimental data for coal and shale show excellent agreement with the modeled results. In its current form, the model is somewhat preliminary. Further experimental and modeling effort can significantly improve its application when selecting potential sites for sequestration.

2:25 PM

Demonstration of Flue Cas CO_2 Capture and Utilization with Microalgae

J. Groppo[1], M. Wilson[2], D. Mohler[3] and M. Crocker[2]; [1]Mining Engineering, University of Kentucky, Lexington, KY; [2]Center for Applied Energy Research, University of Kentucky, Lexington, KY and [3]Center for Applied Energy Research, University of Kentucky, Lexington, KY

Fossil fuels, including coal, will remain the principle fuel source for global electricity generation for at least several more decades. With this in mind, there is a continuing need for the development of technologies to reduce CO_2 emissions from these sources. While significant effort is being expended to develop CO_2 capture technologies, one approach adopted by the University of Kentucky has been to develop a technology that will not only capture CO_2, but also utilize it in revenue and energy neutral manner. The technology utilizes microalgae grown in a novel photobioreactor to capture CO_2 via photosynthesis. Microalgae is then harvested using fine particle dewatering technology, followed by utilization as a feedstock for biofuels and/or bioplastics production. A description of the process will be provided along with results from pilot-scale demonstrations conducted at a utility site using flue gas from coal combustion as a CO_2 source. A brief description of biofuel and bioplastics production evaluations will also be included, along with an update on commercial development activities with project partners in China.

2:45 PM

Optimization of Carbon Dioxide Storage and Enhanced Gas Recovery from an Enhanced Coalbed Methane Pilot Test in Central Appalachia

C. Keles, A. Louk, C. Schlosser and N. Ripepi; Virginia Tech, Blacksburg, VA

Geological storage of carbon dioxide (CO_2) can mitigate greenhouse gas emissions while enhancing natural gas production from coalbed methane wells. The capacity and success of CO_2 storage are based on both reservoir conditions as well as the effect of production of gas and water from off-set wells. In this study, a sensitivity analysis is done by shutting-in production wells surrounding three injection wells. The surrounding production wells were set open and shut-in prior to injection and/or in flowback period to investigate the CO_2 plume extent, CO_2 storage efficiency and the enhanced methane production for different scenarios. The reservoir models were created based on real data collected from an ongoing US Department of Energy funded pilot project. As a part of the ongoing pilot project, fourteen thousand tons of CO_2 were injected into three vertical wells over a one-year period in Buchanan County, VA.

3:05 PM

Co-extraction of Coal and Methane – an Upstream Example of the Circular Economy

F. Ruiz[2], R. Pilcher[1], J. Marshall[1] and C. Long[1]; [1]Raven Ridge Resources, Incorporated, Grand Junction, CO and [2]Climate Change Division, United States Environmental Protection Agency, Washington, DC

Methane deposits co-located with coal could be an economic boon to mines that extract coal if the gas is used. Methane in coal mines is not considered an asset, but a hazard and a potential liability. The strength of a circular economy is measured by process efficiency. Reconsidering the design of coal mines and the extractive process to cost-effectively produce both coal and CMM resources leads to higher efficiencies, safer and more sustainable mining. The Global Methane Initiative (GMI), is an international organization comprising 43 partner countries that provides technical and policy support for developing projects that reduce CMM emissions while creating value for project developers, investors and other stakeholders. Co-extraction of CMM and coal are not hindered by lack of technology, only a lack of awareness and the know-how to turn a wasted byproduct into an asset. GMI brings awareness to the mining sector by partnering with government and industry to promote the use of methane, by disseminating information, convening meetings for the exchange of ideas and promotion of internationally recognized best practices for the extraction and use of CMM.

TUESDAY, FEBRUARY 27

AFTERNOON

2:00 PM | ROOM L100D

Coal & Energy: Coal Mine Reclamation I

Chair: *P. Conrad, Montana Tech, Butte, MT*

2:00 PM

Introduction

2:05 PM

Regulatory Requirements for Operating in Sage-Grouse Habitat and Mitigation Plans Designed to Enhance Sage-Grouse Populations

D. Maunder; Technical Services, Cloud Peak Energy, Gillette, WY

Despite a recent decision of the USFWS to not "list" the sage-grouse, it remains a species of high focus for regulators. Agencies with mining oversight have developed requirements to increase protections. These impose restrictions such as avoidance, distance, or noise limitations near leks or even place large tracts of land off-limits to mining. These policies and regulations result in a complex array of requirements that must be navigated to successfully permit a mine in sage-grouse habitat. There are a number of strategies that may be used to increase population numbers and mitigate mining impacts on the bird. An effective means to assure protection of the bird is through conservation agreements. Other measures are focused on improving or developing habitat including reclamation plans that emphasize sagebrush establishment or actions that reduce threats to the bird, such as control of West Nile virus, conifer control, grazing management, and reduction of habitat fragmentation. Proper planning and execution of well-developed mitigation plans provides a means to promote mining while also assuring protection of sage-grouse and the ability to increase populations of the species.

2:25 PM

Huling Branch, Abandoned Mine Reclamation in Clinton, PA

D. Baker; BAMR, Ebensburg, PA

The Huling Branch project eliminated 4 dangerous highwalls that were in excess of 70 ft high and 6,000 lf. An ATV recreational trail system was enhanced. FRA method was utilized for the rough grading backfill and tree planting. This grading method also promoted storm water infiltration. The end result of the FRA method provided a final irregular rough grade of hummocky mounds and deep tilled depressions that will provide for an excellent tree growth condition for years to come. The ACFdonated 100 American Chestnut were planted by DCNR. Highly acidic spoil area and acidic draining groundwater within the site have been negatively impacting fish and other aquatic life within the Kettle Creek Watershed for decades. In an effort to improve the acidic draining groundwater by neutralizing the highly acidic spoil, over 310,000 tons of alkaline addition materials were blended within the spoil backfill areas against the dangerous highwall. 36,000 Tons of coal was incidently removed for the installtion of the rock underdrains to convey and treat acidic groundwater. Water sampling and monitoring have illustrated improved water chemistry within the watershed.

2:45 PM

Developing Trees Tolerant to Degraded Mine Soils in an Underground Greenhouse

C. Opoku-Ware, P. Conrad and M. Kukay; Montana Tech, Butte, MT

Montana Tech is currently exploring the potential for developing trees that are tolerant to degraded un-reclaimed mine site soils and tailings as a solution for re-establishing long-term tree growth on those sites. The project incorporates growing tree seedlings in an underground greenhouse grown from

seeds planted in the degraded mine soils in which they will be planted. It is believed that the project will lead to a successful solution for re-establishing tree growth in soils containing high metal concentrations in arid environments with minimal human intervention. The research is being conducted in an underground greenhouse/tree farm located 100 feet below the surface in the Underground Mine Education Center (old Orphan Boy Mine) located on Montana Tech's campus.

3:05 PM

A Protocol for Reclaiming In-Pit Tailings Ponds to Exceed Federal and State Regulations

J. Seifert[1], P. Conrad[1], C. Smith[2], S. Rosenthal[1] and L. Hunter[1]; [1]Montana Tech, Butte, MT and [2]Premier Silica, Brady, TX

The goal of the protocol for reclaiming in-pit tailings ponds to exceed federal and state regulations was to develop a series of steps that can be followed to design, operate, and reclaim a tailings disposal pond that will develop into grazing land with a wetland for open pit sand mines in warm dry climates. By incorporating a wetland into the reclamation design, the post mining land use gives back to both the wildlife as a source of water as well as providing for a diverse range of post mining land use including but not limited to livestock grazing and ranch land use. An example design was completed using this protocol to demonstrate how the protocol can result in in a well-designed, reclaimed tailings disposal pond.

3:25 PM

The Deer Creek Mine Pool of Alleghany County, PA: History, Monitoring, and Treatment.

A. Iannacchione and J. Van Ness; Civil and Environmental Engineering, University of Pittsburgh, Pittsburgh, PA

The Indianola and Russellton Mines contain the Deer Creek Mine Pool in Allegheny County, Pennsylvania. Both mines are connected by two underground entries. The Indianola Mine is lower in elevation than the Russellton, so water flows from Russellton into Indianola. In 1985, pumping from the Indianola Mine ceased. Months later, unplanned discharges occurred at the overlying Redland Brick plant and from the Indianola Shafts. A second treatment plant (Berry) within the Russellton Mine has been in operation since the 1960s. The Berry facility contains tanks, aerator, water and sludge pumps, a pond and an injection borehole. In 2013-14, the PA DEP initiated a new treatment strategy for the mine pool, consisting of sealing boreholes penetrating the mine pool, drilling two 8-inch relief boreholes and constructing a 2-acre water settlement pond. This presentation reviews the complex treatment history and determines the factors influencing the mine pool elevation and water quality.

3:45 PM

Successful Restoration after Traditional Reclamation?

R. Pal, M. Mariano and J. Trilling; Biological Sciences, Montana Tech of the University of Montana, Butte, MT

One hundred years after the intensive operations of mining and smelting, Butte still has serious environmental problems. Reclamation efforts, guided by the EPA's Superfund Program, includes cleanup of contaminated sites. The approach has been to cap these areas with clean topsoil and to re-vegetate using commercial seed mixes which mostly comprised Eurasian grass species. However, reclamation is not the final goal of these sites as the Superfund Program adopted the Administrative Rules of Montana (ARM 17.24.711) as applicable or relevant and appropriate requirements for the caps in Butte. That basically suggests the restoration of these sites. Based on the Annotated Rules native plant diversity is required in restoration but is nonexistent on the reclaimed sites. The Native Plant Program at Montana Tech has tried several approaches to increase native plant diversity. In this presentation both the successes and the failures of our restoration efforts will be demonstrated from the past six years.

TUESDAY, FEBRUARY 27

AFTERNOON

2:00 PM | ROOM L100E

Coal & Energy: Research and Development-I

Chairs: *M. Trevits, Xtraction Science and Technology, Inc, Pittsburgh, PA*
T. Klemetti, NIOSH, Pittsburgh, PA

2:00 PM

Introduction

2:05 PM

SCSR Technology in US Coal Mines: the Long Road Travelled

G. Luxbacher, R. Matetic and D. Willmer; National Institute for Occupational Safety and Health, Pittsburgh, PA

In 1969 a National Academy of Engineering study on Mine Rescue and Survival recommended the development of an emergency life support device for underground workers that would provide a respirable atmosphere regardless of the environment and outlined a number of key device specifications. While significant progress has been made toward this goal with the adoption of Self Contained Self Rescuers (SCSRs) in underground coal beginning in 1981, the original specifications from 1969 remain somewhat elusive. This paper describes the initial work done under USBM contracts to develop SCSRs, the subsequent regulatory requirements, the collaborative efforts between government, industry and manufacturers that resulted in the current generation of SCSRs, current industry practice and the impact of recent regulatory changes (42 CFR Part 84, Subpart O). The impact of significant changes in mining practices and the implementation of health and safety technologies within underground coal mining that have occurred since 1969 are also considered.

2:25 PM

Technologies for the Next Generation Closed-Circuit Escape Respirator

R. Fernando; Research Branch, NIOSH-NPPTL, Pittsburgh, PA

The NIOSH National Personal Protective Technical Laboratories (NPPTL) is currently leading an effort in developing the next generation of self-escape breathing apparatus for use to egress from confined spaces in the case of an emergency. As part of the research imperative directed by the MINER Act of 2006, a backpack style closed-circuit mine escape respirator was developed. Feedback from stakeholders indicated that it would be desirable to make the unit smaller without sacrificing performance. This presentation outlines some of the technologies that may be investigated toward developing such a small sized respirator. Some of the technologies being considered are novel chemicals for improved CO_2 absorption and producing O_2, eliminating a dedicated CO_2 scrubber by incorporating its function in the spaces of the respirator's breathing loop and storing oxygen in a liquid form with long standby capabilities. When these technologies are applied in a future design, there is the possibility of having an escape respirator that can be belt worn and capable of being certified to 42CFR84 standards including sub-part O for escape purposes including mine escape.

2:45 PM

Self-Contained Self-Rescuer Breathing Apparatus Improvement

B. Toole; NAVSEA, NAVY, Panama City, FL

The Office of Mine Safety and Health Research with the Naval Surface Warfare Center Panama City Division are identifying and adopting technologies

for improvement of a self-contained self-rescuer (SCSR) breathing apparatus for underground mine emergencies. This work will highlight the various developments used in the design to increase user safety. Specific areas of improvement were in wear-ability, emergency deployment, thermal load on the user, oral and optical interfacing, docking and switchover capability, miner's belt and harness integration, and high pressure oxygen storage and delivery. Evaluation of the breathing performance will be compared to the standards set forth in 42 CFR 84 Part O. The ergonomic features of the harness and miner's belt integration, emergency deployment and wear-ability for both the deployed and pre-deployed state will be discussed. In addition, the evaluation of the Valve Integrated Pressure Reducer including hydro and burst testing for structural integrity, temperature vs. time experimentation for restricted valve opening, and oxygen pressure shock testing for ignition sensitivity in a high pressure oxygen system.

3:05 PM

Robotics Technology in U.S. Mine Disaster Reconnaissance, Rescue and Recovery

M. Trevits, L. Patts and G. Luxbacher; Office of Mine Safety and Health Research, National Institute for Occupational Safety and Health, Pittsburgh, PA

It is almost a given that post-disaster mine conditions will have compromised ventilation, resulting in a hazardous atmosphere in portions of the mine, and left extensive debris fields and roof falls. Robotic technologies provide the opportunity to gather valuable information to assist decision making while lessening exposure to dangerous conditions. MSHA has utilized a fully permissible mine robot for a number of years. NIOSH examined the need for additional robotic units and has funded three different technologies: the Snake Robot, the Gemini Scout, and the Mule, a robotic assist vehicle. The Snake is designed to be lowered through a borehole and to conduct surveillance (gas monitoring, video and audio) in the immediate vicinity, while the Gemini Scout, designed to be deployed in the mine opening, serves as a more mobile and agile exploratory tool. The Mule was developed in response to needs expressed by mine rescue teams for a versatile remotely operated support vehicle. This paper describes the development of the robot prototypes and discusses their limitations in the prototype stage, possible enhancements and potential applications, as well as the utilization of the Mule.

3:25 PM

Increasing Effectiveness of Mine Safety Training Using Inexpensive Camera and Rendering Technology

S. Schafrik[1], M. Trevits[2] and G. Frampton[3]; [1]Mining Engineering, University of Kentucky, Lexington, KY; [2]Xtraction Science and Technology, Inc., Pittsburgh, PA and [3]Running Right Leadership Academy, Contoura Energy, Charleston, WV

Mine safety training materials have long included pictures of mine conditions, equipment, hazards, etc. These images are invaluable to both the trainee and the trainer to convey many important concepts. The human eye takes in a tremendous amount of information, while the field-of-view from a consumer grade camera is, generally, 40 degrees to 90-degrees. This difference in field-of-view is a primary reason that pictures, especially of dark and dusty areas, don't adequately describe the scene. For conveying information to a trainee, these images lack context. Today, 360-degree cameras are available with consumer-grade cameras costing a few hundred dollars. Also, the display technology is already owned by most trainees and trainers and is widely available. The resulting 360-degree videos and pictures can be readily viewed on smart phones and inserted into Microsoft PowerPoint slideshows. These images and videos can easily be included in existing training modules, disseminated using the internet, and used by trainees easily. We propose a methodology for utilization of 360-degree video and images with simple display technology for the miner training.

3:45 PM

Advances in Battery Technology Leads to Future of Mining

J. Haughey[1] and R. Herndon[2]; [1]Underground Mining, Komatsu Mining Corporation, Warrendale, PA and [2]Voltabox of Texas, Cedar Park, TX

As all types of mines continue to work to protect workers and the environment, while continuing to be profitable, advances in battery technologies will allow mining companies to accomplish all. 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 first look at the different available battery technologies and the advantages of each. Second, the paper will look at the current issues with Lead Acid batteries in the underground coal market and provide the benefits of Li-Ion. Finally, a business case will be presented, with actual field data, that will show the financial benefits of operating Li-Ion over Lead Acid in Battery Haulers.

TUESDAY, FEBRUARY 27

AFTERNOON

2:00 PM | ROOM L100C

Coal & Energy: Ventilation Innovations

Chairs: *P. Tukkaraja, South Dakota School of Mines and Technology, Rapid City, SD*
M.Gray

2:00 PM

Introduction

2:05 PM

Scaled-Model Testing for the Effect of Turbulent Intensity on Continuous Miner Face Ventilation

K. Mayfield, W. Wedding and T. Novak; Mining Engineering, University of Kentucky, Lexington, KY

Mine ventilation provides fresh air to workers, dilutes methane and dust, and removes other contaminates from the working areas of a coal mine. Researchers use a variety of modeling techniques, including full-scale, reduced-scale, and computer modeling, to understand active-face flow phenomena. A one-twelfth scaled model of an active continuous-miner face was constructed to examine airflow patterns under multiple conditions in a controlled environment. Preliminary testing shows that the splitting of air at the end of a line curtain is affected by the amount of turbulence of the intake air, which is measured as turbulent intensity. This value and other boundary conditions have often been assumed in Computational Fluid Dynamics (CFD) models. Using particle-image-velocimetry (PIV), the flow patterns under various conditions can be evaluated and the turbulent intensity measured in the reduced-scale model. The results of these experiments, which are presented in the paper, are instrumental for building more accurate computer-based and physical models in the future.

2:25 PM

An Experimental Investigation of the Airflow Requirements for Underground Mines in Case of a Duct Fire

A. Jha[1], Y. Pan[1], R. Bhargava[1], P. Tukkaraja[1] and K. Katzenstein[2]; [1]Mining Engineering and Management, South Dakota School of Mines and Technology, Rapid City, SD and [2]Geology and Geological Engineering, South Dakota School of Mines and Technology, Rapid City, SD

From a safety point of view, the design of an emergency ventilation system is critical for underground operations. However, there is not sufficient information available to design an emergency ventilation system in case of a duct fire in underground mines. This study investigates the burning behavior, gas emissions, and heat release rates of commonly used duct materials for estimating airflow requirements. this study uses a lab-scale model for collecting experimental data on gas emissions, and heat release rates of commonly

used duct materials. The main objective of this study is to provide a starting point for estimating the airflow needed to dilute gas emissions from a duct fire to current permissible limits in underground mines. This knowledge will help ventilation engineers in designing an emergency ventilation system for underground mines. It should be noted that the airflow requirements reported in this study are yet to be validated.

2:45 PM

Effect of Air Gap on the Ventilation System of a Block/Panel Cave Mine: An Experimental Study

Y. Pan[1], R. Bhargava[1], S. Sreekumar Ajitha[1], P. Tukkaraja[1], K. Katzenstein[2], K. Shahbazi[3] and D. Loring[4]; [1]Mining Engineering and Management, South Dakota School of Mines and Technology, Rapid City, SD; [2]Geology and Geological Engineering, South Dakota School of Mines and Technology, Rapid City, SD; [3]Mechanical Engineering, South Dakota School of Mines and Technology, Rapid City, SD and [4]Climax Molybdenum – Henderson Operations, Empire, CO

Due to lower production costs and higher production rates, block caving is a preferred underground mining method for the exploitation of large, low-grade, deeply-seated orebodies. As part of the caving process, an air gap is intentionally created to induce stress magnitudes that are necessary to break intact rock in the cave. However, from the point of view of effective mine ventilation, the air gap provides room for airflow recirculation zones within the cave. These zones (eddies) reduce the total air pressure energy in the system that affects ventilation system particularly in the production level. This study investigates the effect of differing air gap geometries on the airflow resistance of a cave. In this study, a lab scale (approximately 1:100 scale) physical model of a panel cave mine is created, and it is utilized for validating Computational Fluid Dynamics (CFD) simulation models.

3:05 PM

A Scale Model Investigation of Airflow Resistance of a Block/Panel Cave under Changing Cave Porosity Conditions

R. Bhargava[1], Y. Pan[1], S. Sreekumar Ajitha[1], P. Tukkaraja[1], K. Shahbazi[2], K. Katzenstein[3] and D. Loring[4]; [1]Mining Engineering and Management, South Dakota School of Mines and Technology, Rapid City, SD; [2]Mechanical Engineering, South Dakota School of Mines and Technology, Rapid City, SD; [3]Geology and Geological Engineering, South Dakota School of Mines and Technology, Rapid City, SD and [4]Climax Molybdenum - Henderson Operations, Empire, CO

Block caving/panel caving, unlike most other traditional mining methods, relies mainly on the natural stresses (in-situ and gravity-induced) within the rock mass to fragment and transport the ore. In the caving process, rock first gets broken in the cave and when the ore is extracted from the draw bells, broken material starts to migrate in the cave. During the material migration (vertical and horizontal movement) inside the cave, due to comminution and grinding processes, the shape and size of rock particles changes. These changes will affect the porosity of the cave. This study investigates the effect of cave porosity on the airflow resistance of a cave by utilizing a small scale (approximately 1:100 scale) experimental model of a panel cave mine.

3:25 PM

Molecular Dynamics Modeling for Development of Mechanically Robust Low Thermal Conductivity Material for Heat Insulation in Hot Underground Mines

G. Gupta, K. Muralidharan and M. Momayez; Mining & Geological Engineering, University of Arizona, Tucson, AZ

As critical minerals are becoming scarce near the surface, mines around the world are getting deeper. One of the greatest issues with deep mines is strata heat. The high ambient temperatures make it impossible for humans to work without special ventilation methods which is highly expensive. This is a great setback considering the higher cost of operation due to the increased depth. One of the solutions would be the use of a thermally insulated material to reduce the heat entering the mines, thereby greatly increasing the efficiency of the ventilation system and thus, reducing costs. Properties of aluminosilicate geopolymer materials are investigated as a primary ingredient for this material. They can be found in the tailings dump of a mine and thus, will not only be inexpensive but also will help reduce surface impact of tailings facility making it environmental friendly. Molecular dynamics simulations are used to understand how various molecular structural features and compositions will help achieve the desired thermal properties and mechanical strength.

3:45 PM

Challenges for Ventilation in Deep Geological Repositories

S. Poetzsch, J. Weyer and H. Mischo; Chair of Underground Mining Methods, TU Bergakademie Freiberg, Freiberg, Germany

A large number of research projects are dealing with postclosure safety assessments for deep geological repositories. An underrated safety challenge is the ventilation in the operational phase. The ventilation of a normal mining operation is determined by exhaust gases of diesel equipment and blast fumes. The tasks for ventilation in a deep geological repository are wider. In case of an incident it has to be ensured additionally that no airborne radiation is distributed underground and the contaminated air is filtered before leaving the facility. Furthermore waste bins can corrode, which causes a formation of the explosive gas hydrogen. This paper describes ventilation concepts in existing and planned deep geological repositories in North America and Europe. Main issues like the positioning of fans or the decision for push- or pull-type ventilation are discussed. Similar and different approaches for separating the air flow for excavation area and emplacement area are presented. Furthermore strategies in case of a radionuclide release are described. Objects of study are WIPP Site (New Mexico), Konrad (Germany), Ciégo (France) and Olkiluoto (Finland).

4:05 PM

Investigating High-Speed Deflagrations Through Rock Rubble Resulting from Methane Gas Explosions in Confined Spaces

C. Strebinger[1], M. Fig[1], D. Pardonner[2], B. Treffner[3], G. Bogin[1] and J. Brune[4]; [1]Mechanical Engineering, Colorado School of Mines, Golden, CO; [2]Engineering Physics, University of South Florida, Tampa, FL; [3]Mechanical Engineering, Red Rocks Community College, Lakewood, CO and [4]Mining Engineering, Colorado School of Mines, Golden, CO

Methane gas explosions in a longwall coal mine can originate from in or around the gob which can have a disastrous impact to workers and equipment. To understand the resulting flame and pressure wave propagation in the mine, it is important to investigate methane flame interaction with rock rubble and other mine structures that can lead to enhanced turbulence and heat transfer causing high-speed deflagrations. Researchers performed high-speed deflagrations by igniting methane-air mixtures in horizontal cylindrical reactors containing obstacles used to simulate various gob characteristics; rock material/geometry/porosity and ignition location/energy were investigated. Surface roughness from rock obstacles increased fluid motion, flame front velocity, and pressure rise. Certain ignition locations and geometries increased peak overpressure and average pressure rise. Experiments were used to validate a combustion model to be incorporated into a mine-scale CFD model used to simulate large scale explosions. This research shows that a complete understanding of fluid dynamics, heat transfer, and thermodynamics is necessary to provide insight into methane gas explosions in a longwall mine.

TUESDAY, FEBRUARY 27
AFTERNOON

2:00 PM | ROOM L100H

Environmental: Climate Change and Reclamation Modeling

Chairs: *D. Williams, Bureau of Land Management*
L. Figueroa, Colorado School of Mines, Golden, CO

2:00 PM
Peat Mine Restoration at the Lake Superior Wetland Bank
D. Deuschle; Natural Resources, Short Elliott Hendrickson Inc, St. Paul, MN

Construction of the Lake Superior Wetland Bank was initiated in 2015, and is striving to restore more than 23,000 acres of partially drained bog and fen habitat through permanent removal of a 65-mile ditch network. Within the wetland bank is a 160-acre peat mine, which was also drained through a series of parallel drainage ditches, and altered through excavation of material. Restoration of the peat mine was achieved through filling of the drainage ditches with vegetation and soil, in conjunction with the overall watershed-scale hydrology restoration of the larger surrounding bog. A trajectory towards successful restoration appears to have been acheived based on preliminary observations. The pre-restoration conditions, regulatory process, construction methods, and results observed following restoration will be discussed. Focus will be on the approach, success criteria, measurements for assessing success, and lessons learned.

2:00 PM
Planning for Climatic Uncertainty: Implications for Mine Closure and Long Term Stewardship
S. Warner; Ramboll Environ, Emeryville, CA

Climatic uncertainty creates challenges for mines and the long-term obligations to protect environmental conditions and to maintain important structures for perhaps thousands of years. Such challenges are unique to the mining industry and create hurdles that few other major industries must solve. Management strategies and infrastructure/containment systems that were designed with reference to the current or historical climate must be developed to perform under future scenarios of extreme weather events or radical climatic shifts and thus must rely on still developing models and analysis. Our work in North America and Australia, for example has shown that quantification of the duration, occurrence interval, and intensity of future events is relevant to the risk analyses of critical components with the most common way of adapting to climate change being the alteration of design standards for key structures. This approach is hampered by uncertainty regarding the timing and magnitude of impacts; yet examples of proactive management strategies that accommodate this uncertainty do exist. Our presentation discusses our research on the state of the practice to illustrate key developments.

2:00 PM
Planning for Climatic Uncertainty: What are the Costs for an Extreme Precipitation Event at a Minesite?
D. Williams[1], P. Bierbach[1] and S. Reinecke[2]; [1]USDI Bureau of Land Management, Butte, MT and [2]Stratos Incorporated, Ottawa, ON, Canada

One element of Climate Change that poses particular challenges for minesites is the increasing likelihood of extreme precipitation events. Increases in the percentage of precipitation falling as intense precipitation has increased throughout the United States and is projected to increase globally as the climate continues to change. An extreme precipitation event at the Zortman-Landusky Mine, a bankrupt minesite in North Central Montana, jointly managed by the U.S. Bureau of Land Management and the Montana Department of Environmental Quality can give us some perspectives on the costs that a minesite could potentially incur if storm water management relies on outdated or inadequate estimates of potential storm events. Our presentation discusses the repairs performed, the relevant costs and possible mitigations that might be used to develop more resilient and robust water management and closure options

TUESDAY, FEBRUARY 27
AFTERNOON

2:00 PM | ROOM L100G

Environmental: the Benefits of Stakeholder Dialogue: Creating Shared Value in the Mining Sector

Chairs: *J. Render, Community Contexts, Binghamton, NY*
E. Muteb, Freeport McMoRan, Morenci, AZ

2:00 PM
Introduction

2:05 PM
Finding Mutual Ground: Changing the Narrative Around Conservation and Mining
E. Muteb[1], A. George[1] and D. Davis[2]; [1]Freeport McMoRan, Morenci, AZ and [2]Wildlife Habitat Council, Silver Spring, MD

Across the industry, there is growing awareness of the importance of building strategic partnerships as part of a company's ability to maintain its social license to operate. Within the conservation arena, collaborations with agencies, non-governmental organizations and community groups not only build reputational capital, but also shifts the prevailing narrative around biodiversity and the industry. One of Freeport-McMoRan's key partners is the Wildlife Habitat Council (WHC), a conservation-focused non-profit that promotes habitat management initiatives through community outreach and education projects. This partnership supports Freeport-McMoRan's key business objectives, while sharing a story of biodiversity on a broader stage to demonstrate that that conservation and industry can, and do, co-exist.

2:25 PM
Learning from the Past to Chart the Future: Early Innovations in Corporate Social Responsibility at AMAX
J. Smith; Colorado School of Mines, Golden, CO

Many accounts of the rise of CSR in mining paint a progression of the industry first responding to issues of workplace safety in the 1960s and environmental sustainability in the 1970s, before moving CSR to the center of corporate values in the 1990s as companies managed community conflicts in the Global South. This presentation adds a missing dimension to that history by tracing how AMAX pioneered a commitment to best-in-class stakeholder engagement in the 1970s in their domestic operations, particularly in Minnesota and Colorado. The rise of AMAX's environmental services division and its proponents established a core set of principles and best practices for new mine assessment and development that anticipated what would later come to be called CSR, including staying on ahead of potential policy changes and crafting strong relationships with local and state government officials and community leaders to manage those; proactive, early and strategic engagement of stakeholders; inclusion of key stakeholders into a more transparent open planning process; and the integration of CSR into the company throughout its top management and its onsite operations personnel and activities.

2:45 PM

The Impact of Native American Tribal Concerns on Mine Development and Operation

A. Martin; Mining, Foth Infrastructure & Environment, LLC, De Pere, WI

Over 500 Native American Tribes are accorded partial or full sovereignty across these United States. Tribal culture prioritizes respect for the environment, history, and future generations. The tribes wield significant influence over the mining industry, particularly to proposed mines. This influence can touch all permits and underlying studies including air, water discharge, and environmental impact studies. In light of the industry's social license, the tribes are an important participant. There are sadly numerous mining projects that have been shelved with the contribution and implementation of tribal concerns. The Environmental Review (ER) process for new and modified mine projects focusses on the preparation and communication of the technical aspects of the proposed project, hence ER documentation and permit applications are typically lead and fulfilled by technical professionals. What are the obligations of the US government to represent and advocate tribal interests? The project team and stakeholder configuration will be examined and strategies identified to improve project proposals and public relations in the arena of managing and responding to tribal concerns.

3:05 PM

A Holistic Approach to More Sustainable Artisanal and Small-Scale Gold Mining Systems in Peru

N. Smith; Mining Engineering, Colorado School of Mines, Golden, CO

Artisanal and small-scale gold mining (ASGM) is a critical livelihood strategy for millions of people, but it is notoriously known for its environmental and human health risks. Because of these risks, ASGM activities are a concern for governments, development agencies, industry, and academics; however, projects promoting cleaner and safer technologies have had limited success. This paper proposes that some of the challenges to project implementation may be attributed to a lack of integrated technical and social data on ASGM systems. For example, social science analyses provide insights into the social and political context of ASGM, but pay too little attention to the technical processes involved with ore processing. Similarly, technical analyses involve close examinations of mercury use and its alternatives yet fail to explain why people continue to use mercury when they are aware of the risks. By reporting on a project involving engineering and social science faculty and students at US and Peruvian Universities, governments and NGOs, businesses, and communities, this paper demonstrates a holistic approach to promoting cleaner, safer, and more sustainable ASGM livelihoods in Peru.

3:25 PM

Impact Benefit Agreement – Comparative Experience in Canada and Latin America

A. Recalde; Mining Committee, Peruvian Canadian Chamber of Commerce, Oakville, ON, Canada

Mining projects have always found an area not so easy to handle in social issues. Therefore, social risk has become one of the main factors of success or failure in a mining project. While technical and financial variables can be controlled with some objectivity, the social factor is not. Even an environmental risk can be managed according to an adequate impact mitigation plan. Local stakeholders must be part of a careful process of relationships and agreement. These agreements should be mutually beneficial. The impact benefit model is a methodology practiced in Canada since the 1980s. In Latin America, there is no one model. It is based on achieving a consensus between the mining company and socially and economically impacted communities for a new project. Environmental impacts can be identified based on scientific methods. In parallel, the social and economic impacts on populations are highly subjective. Such subjectivity can be reduced by a consensual contract that lists the impacts and benefits in consideration. Thus Impact Benefit Agreement is planned and agreed upon with a methodological approach.

3:45 PM

Own Your Story Proactive Engagement to Improve Your Reputation

T. Champo and P. Rhodes; Strategic Communications, Salt Lake City, UT

The mining industry has long suffered from negative community perceptions on issues of environmental stewardship, safety performance and long-term economic stability. These perceptions frequently act as a drag on a project's progress towards permitting and, for existing operations, can impede a business' growth and its ability to attract new talent. This presentation will provide a case study example of how one of the world's most prolific open pit mining operations consistently receives high public approval ratings, despite its proximity to a heavily populated metropolitan area. Rio Tinto Kennecott achieves 80 percent approval from stakeholders located in the adjacent communities, according to annual public opinion polling, with 70 percent saying they prefer the mine remain in operation for several more decades. Using Kennecott as an example of success, this presentation will illustrate how a community engagement plan must be in place before a public crisis, and how a robust, multi-faceted approach is increasingly necessary in the modern age. Managing corporate or project reputation must be a companywide initiative that includes the employee empowerment as company ambassadors.

4:05 PM

What to Do After the Bull Has Left the China Shop – Picking Up the Community Relation Pieces

P. Eger; Global Minerals Engineering, Hibbing, MN

Today successful mining projects must meet the "triple bottom line"; economic, environmental and social. In 2010 Gogebic Taconite (GTac) acquired a lease option to develop an open pit taconite mine in northwestern Wisconsin. Although the company had mining experience, it was limited to coal near existing mines with minimal opposition. GTac's proposed development was seen as either an economic boon or an environmental disaster. GTac's decision to focus on lobbying at the state level mobilized opposition from the local, environmental and tribal communities. After spending millions of dollars in additional resource evaluation and environmental studies, GTac decided to abandon the project in 2015. When the option to lease was terminated in 2015, LaPointe decided it was important to rebuild local partnerships and begin to develop sound data so that future decisions could be based on science and not fear. These efforts include support for scientific studies, baseline regional water quality monitoring and periodic meetings with community leaders.

TUESDAY, FEBRUARY 27

AFTERNOON

2:00 PM | ROOM L100B

Health& Safety: Got Safety? See How Tech Savvy Companies are Managing the Safety and Health of Their Workers I

2:00 PM

Introduction

2:05 PM

Proving It! Using Technology to Track Leading Indicators and Balance the Safety Performance Scale

J. Wickizer; HSE, Safety and Health, Kaysville, UT

How do you measure risk management success? Reduction in failures and cost attributed to loss? Increase in employee engagement, management

support, or individual development? Rely on lagging statistical data to solely evaluate our efforts in achieving better safe work performances? Or, do we establish measurable leading statistics to utilize in the evaluation of a balanced program? Technology utilizes real time data gathering to prove the efforts. Historically a company's success as related to safety performance has relied on the lagging measurement approach causing a more "reactive to failure" response instead of a more "proactive to positive efforts" produced by leading indication tracking. Looking at technology and risk management effort tracking by individuals, groups, and entire organizations to establish an equally weighted measurement system. This data can be utilized in contrast and direct comparison with an equally weighted lagging results system. Analysis of both sets of data gives critical insight on new program implementation. Flexibility is allowed when the data is measured in real time with technology allowing nimbleness in change for continual improvement.

2:25 PM

Behavioral Differences with Technology to Inovate, by Gathering Data on Individuals Concerning Risk Tolerance

J. Wickizer; HSE, Safety and Health, Kaysville, UT

On the front line, data for organizations becomes more visible by utilizing technology and real time information gathering. Why not take this same data and establish risk tolerance levels for individuals? What data is utilized to create this risk profile and what do we do with that information? It is beneficial to both the organization and the employee to know what their risk level is. With this information we can make job placement and work assignments, set future goals and training, pair and match work groups, all to the associated tolerance of the individuals. This creates an increase in safety culture. Does it make sense to have an entire group of individuals with the same level of risk tolerance work with one another or would a more balance approach with frontline involvement be more beneficial? Is it possible to adjust the level or risk tolerance in an individual if we have an idea of where they are currently located on the spectrum of risk? We can utilize data collection tools, training, awareness, evaluation and technology to help monitor efforts in addressing risk level improvement. Let us look at the initial findings of some basic risk identification methods.

2:45 PM

Demonstrating the Financial Impact of Mining Injuries – Safety Pays In Mining

J. Heberger; CDC NIOSH, Pittsburgh, PA

The Safety Pays in Mining web application, developed by the NIOSH Mining Program, helps mines determine the potential costs associated with mining injuries and the distribution of these costs. This web application groups injuries by type, either by the cause of the injury or by the nature of the injury. When the user selects one of over 30 common mining injuries, the application provides information on the distribution of costs of workers' compensation claims for that type of injury. Based on other user inputs, the program will estimate the total costs of the selected injuries, including an estimate of additional indirect costs, the impact of total injury costs on mining company profits, and examples of ways that companies could spend the savings that result from the prevention of injuries. This conference proceeding reviews the Safety Pays in Mining web application by discussing the development of the application, how it is used to show the true costs of mining injuries, and how mines can benefit from using this application.

3:05 PM

Avoiding EHS Culture Killers

T. Laser; Global, CH2M, Katy, TX

EHS culture often reflects the attitudes, beliefs, perceptions, and values that employees share in relation to safety in a workplace, so can be stated simply as 'the way we do EHS around here'. Unfortunately, over time, these terms have been overused, becoming a crutch-term to fix problems that are not truly understood. The result of the abuse of the term "Culture", along with many other faux pas are continuing to weaken organizational culture in epic proportions. In this presentation, we discuss many 'culture killers', including those that are seen as 'taboo', and review some best practices, resources, and solutions that can be implemented. It's imperative that we start acknowledging the true "Culture Killers" among us, and start doing something about it! Only then, will we be able to make tremendous strides towards improving problems that constantly challenge our ability to maintain positive sustainable organizational cultures that promote safe workplaces.

3:25 PM

Balancing Productivity and Safety: a Case Study

D. Bongers; SmartCap Technologies, Milton, QLD, Australia

Mining operations are continually looking for opportunities to improve operational safety and for productivity gains, both of which ensure a sustainable business. However, productivity initiatives are often associated with increases in the total time that operators spend in an active, operational environment, which can cause perceptions that the business values productivity over safety. Finding the right balance is not easy, and requires careful consideration, comprehensive risk assessment, and often a delicate and considered approach to change management. This paper will present a case study where a productivity initiative was evaluated and justified through the use of a fatigue monitoring system. The methodology for risk evaluation will be presented, however the focus will be on the change management approach used to ensure the initiative received the support and endorsement of the workforce and its representatives.

3:45 PM

Has Your Team 'Got Safety'? How to Achieve a 'Visible Safety Culture'

M. Routledge; H&S Division Board, Park City, UT

There are lots of safety systems and technology available today to support a safety improvement program. The biggest challenge is how you can tell that your team and the supporting teams from your contractors got the messages and are understanding the critical reasons to follow your safety protocols and systems. How can you really tell if they 'Got Safety'? In the form of a couple of case studies we will discuss some ways you might measure how your teams got safety and how that visibility can drive significant results in fatal risk reduction and injury rates using new technology or simple manual system.

4:05 PM

Validation of the PHS Model in Hot Underground Mines

P. LAZARO and M. Momayez; Mining and Geological Engineer, University of Arizona, Tucson, AZ

Heat Related Illnesses (HRI) are relatively common in hot underground mining operations. When workers are exposed to extreme environmental heat stress in addition to the heat created by the body because of internal metabolic rate, the overall heat load on the body will increase. Heat strain is the result of the body responding to external and internal heat stress. Therefore, the conditions leading to heat strain must be detected and treated. HRI is manifested by exhaustion and heat stroke. The Predicted Heat Strain (PHS) [ISO 7933 (2004)] model has been developed to predict body's response in terms of core body temperature and water loss. The PHS Model tested in this study is based on eight physical parameters that are measured at different intervals during a work shit. These parameters are air temperature, humidity, radiation, air velocity, metabolic rate, clothing insulation, posture and acclimatization. The model predictions are then compared with a direct physiological measurement such as core body temperature. We present the results of an extensive study that monitored and predicted body's response to heat stress under different environmental and working conditions.

TUESDAY, FEBRUARY 27

AFTERNOON

2:00 PM | ROOM L100A

Health & Safety: Panel Discussion: Professional Certification in Mining Safety and Health: Past & Future

(by invitation only)

Chair: *T. Hethmon, University of Utah, Salt Lake City, UT*

2:00 PM

Professional Certification in Mining Safety and Health: Past & Future

T. Hethmon; University of Utah, Salt Lake City, UT

The mining industry is locked in a perpetual debate regarding the best way to manage safety. Ask 100 industry decision-makers and you are likely to get 90+ different answers. The debate continues unabated. Fortunately, one aspect of the debate that is becoming clearer is the role and importance of the mining safety and health professional. For the past 25 years, the 'CMSP' credential sponsored by the International Society of Mine Safety Professionals (ISMSP) served to define the competencies associated with these important roles through professional certification. In 2016, the ISMSP discontinued operations and the certification program was acquired by SME. A new board of directors was formed within the Health & Safety Division to manage these certification programs. This change has resulted in significant new developments that will affect current and prospective mining safety and health professionals and their organizations in the US and abroad. This roundtable will address the status of international mine safety and health certification, its challenges and benefits, the broadening of the mine safety and health body of knowledge, and review of the new International Academy of Mine Health and Safety of SME (IAMHS-SME), and its certification programs."

TUESDAY, FEBRUARY 27

AFTERNOON

2:00 PM | ROOM 101H

Industrial Minerals & Aggregates: Industrial Minerals in Advanced Materials Engineering

Chairs: *B. Li, Michigan Technological University, Houghton, MI*
T. Hilderbrand, Thiele Kaolin Co

2:00 PM

Introduction

2:05 PM

Antimicrobial Mineral and Nano ZnO Composite Materials

B. Wang; Imerys, San Jose, CA

Antimicrobial composite materials were prepared by in-situ formation of nano ZnO particles on mineral surface. These composite materials can be used for various applications such as antimicrobial toothpaste abrasive and antimicrobial filter aid. Test results show that oral bacteria (such as Streptococcus mutans) growth can be significantly reduced by the perlite and nano ZnO composite antimicrobial toothpaste abrasive. Diatomite and nano ZnO composite antimicrobial filter aid can also reduce bacteria level in the beverages (such as lactic acid bacteria).

2:25 PM

Current Applications and Prospectives Sepiolite

H. Wang and B. Li; Department of Materials Science and Engineering, Michigan Technological University, Houghton, MI

Sepiolite is a magnesium-rich, porous and fibrous clay mineral with broad applications. These applications take advantage of sepiolite's high specific surface area and special nano-sized channel structure. This article reviewed the recent achievements in developments and applications of sepiolite in environmental protection, catalysts, construction, biotechnology, and nanomaterials. The prospectives of sepiolite applications is also analyzed.

2:45 PM

Minerals with Copper for Antimicrobial Applications

B. Li; Michigan Technological University, Houghton, MI

Copper is one of the major elements with antibacterial and antifungal activities. However, copper could be contained in various chemical compounds, minerals, solutions, or even copper alloys with alternative existing states and concentration. For antimicrobial utilizations, the state of copper atoms existing in a material is the most critical factor for bacterial and fungal inhibitions. Many minerals containing copper could be a potential antibacterial and antifungal agent. This article overviews the recent research achievements of copper-based materials for antimicrobial applications.

3:05 PM

Innovative Applications of Bentonite in the USA

W. Miles; Miles Industrial Mineral Research, Denver, CO

The major applications and markets of bentonite and annual trends for the last 15 years are related to the USA economy and other factors. Swelling Na bentonite dominates non-swelling bentonite with more than 97% of the total market. Interestingly, the major application is not related to economic trends, but to migration from farms to cities of our population. Another trend is due to the new and very successful fracking technology for oil and gas recovery from shales. USA gas production from these shales exceeded USA demand and developed export gas markets. Wyoming was the leading producer of swelling bentonite, followed by Utah, Montana, Texas, California, Oregon, Nevada and Colorado. Recovery from the 2008 recession has not been successful for housing production and related uses.

3:25 PM

Wear resistance of Different Hard Facing Materials in Mining Applications

W. Hu, J. Rostami and O. Frough; Colorado School of Mines, Golden, CO

Characterizing the abrasiveness of soil/rock and the wear life of hard facing products is vital for performance assessment of mining tools in various conditions. The Soil Abrasion Test Machine at Colorado School of Mines is one of the recently developed methods capable of testing soil/crushed rock abrasion under various conditions. It is also capable of testing the performance of various types of hard facing materials. This paper will present a recent study on regular steel as well as 6 different hard facing materials in a standard sand, as well as rock samples from a Michigan mine to observe the wear properties of different materials in different rock/soil types. The study included nine abrasion tests where the weight loss of each cover was measured over time spans up to 1hr of testing. The results show the distinct

performance differences between steel with 17HRC hardness and the hard facing produced for the mining operation. The results can be used to evaluate the abrasivity of different materials and performance of various hard facings in each working condition, which can be used in selection of cutting tool and comparison of relative wear life between different materials.

3:45 PM

Surface Engineered Industrial Minerals for Industrial Applications

B. Moudgil; Materials Science and Engineering, University of Florida, Gainesville, FL

Conventional processing techniques have contributed significantly to industrial mineral/material production, and researchers and practioners continue to make progress in achieving new functionalities, properties and applications. Efforts are being also devoted toward sustainable develoment including greener reagent schemes for processing purposes. At the same time, it is being realized that adapting/hybridizing with emerging technologies can result in a major leap in the types, quality, and economics of the industrial mineral products and processes. Researchers at the Center for Particiulate and Surfactant Systems, CPaSS - a NSF Industry/University Cooperative Research Center have been attempting to cross hybradize technologies across industry sectors. In this presentation, surface engineering of existing industrial minerals to develop new new value addded products, by adapting nanotechnology based concepts, will be highlighted.

TUESDAY, FEBRUARY 27

AFTERNOON

2:00 PM | ROOM 101I

Industrial Minerals & Aggregates: Safety and Health of Industrial Minerals and Aggregates

Chair: *J.Garska, Imerys, Milledgeville, GA*

2:00 PM

Introduction

2:05 PM

Impact of Aging on Performance of Impactor and Sharp-Cut Cyclone Size Selectors for DPM Sampling

S. Gaillard[1], E. Sarver[1] and E. Cauda[2]; [1]Mining and Minerals Engineering, Virgina Tech, Blacksburg, VA and [2]NIOSH, Pittsburgh, PA

Diesel particulate matter (DPM) is an occupational health hazard in underground mines. It generally occurs in the submicron range, and is often present in the mine atmosphere with significant concentrations of dust particles that tend to occur in the supramicron range. Since dust can interfere with DPM analytical methods, it is often removed using an impactor-type size selector (DPMI). Because the DPMI physically removes oversized particles from the stream, its performance may be reduced with aging. Sharp cut cyclones (SCCs) represent an alternative size selector for DPM sampling, with a major advantage being that, by design, they should not be susceptible to rapid aging. This paper presents results of a field study designed to compare the performance of aged versus new/clean DPMIs and SCCs in an underground mine. DPMI aging resulted in clogging of the device, and eventually a reduction of its effective particle cut size – though, when sample flow rate was maintained, DPM sample mass collection was not affected until significant aging had occurred. Under the conditions present for this study, effects of SCC aging were observed to be minimal by the end of the study period.

2:25 PM

Development of a Comprehensive Pillar and Roof Monitoring System at a Steeply Dipping Underground Limestone Mine

M. Murphy[1], B. Slaker[1], M. Van Dyke[1], A. Iannacchione[3], G. Buchan[1], G. Rashed[1], T. Minoski[1], D. McElhinney[1] and J. Winfield[2]; [1]Pittsburgh Mining Research Division, National Institute for Occupational Safety and Health, Pittsburgh, PA; [2]Graymont, Plesant Gap, PA and [3]University of Pittsburgh & Global Energy Services, Pittsburgh, PA

NIOSH has previously established pillar design guidelines for the underground stone industry. These guidelines were created from an empirical database of pillar observations and is largely drawn from shallow, flat-lying mining operations. Current trends forecast a great amount of underground stone mines developing in deep cover and with seam dips. The complex loading conditions and limited experience in these environments present a substantial increased risk of ground failure. To investigate these loading conditions, NIOSH has installed a pillar and roof monitoring system at an underground limestone mine in central Pennsylvania. The mine is operating in a seam that dips 15-degrees and at depths exceeding 1300 ft. Uniaxial accelerometers and biaxial stressmeters installed in an undeveloped pillar are currently measuring pillar behavior in response to stress redistribution during excavation. Uniaxial accelerometers installed in an adjacent pillar and surrounding area are monitoring roof behavior in response to mining. Laser scans are being used to measure ground displacement and changes in conditions associated with local geological features.

2:45 PM

Integration of Laser Scanning with Numerical Modeling Using 3DEC in Structurally Controlled Underground Limestone Mines

J. Monsalve, J. Baggett, R. Bishop and N. Ripepi; Mining and Minerals, Virginia Tech, Blacksburg, VA

Structurally controlled instability is one of the largest risks in underground stone mines. This mode of failure poses a high risk not only to miners, but also to machinery and the mine design since this could affect the geometry and strength of the pillars. The discrete element code 3DEC is a powerful tool that represents the rock mass structure by considering all structural features that may generate potential instability. However, it is important to perform an adequate rock mass characterization in order to provide valuable inputs to the software that allows for a close representation of the rock mass. Laser scanning technologies can provide a three dimensional detailed image of the rock mass that allows one to quickly map, with more precision and less bias, the structural features presented in the rock mass. This paper presents the application of a methodology that integrates laser scanning and discrete element modeling, in order to identify and prevent potential rock falls during the mining process in an underground limestone mine operation.

3:05 PM

Ground Penetrating Radar (GPR) for Karst Detection in Underground Limestone Mines

J. Baggett[1], J. Monsalve[2], R. Bishop[1] and N. Ripepi[3]; [1]Mining & Minerals Engineering, Graduate Student, Blacksburg, VA; [2]Mining & Minerals Engineering, Research Assistant, Blacksburg, VA and [3]Mining & Minerals Engineering, Principal Investigator, Blacksburg, VA

In underground tunneling and mining environments operating in carbonate rock masses, anomalous karstic features pose risks of water inrush, structural instability, difficult rock mass characterization, and engineering uncertainty. Coupled with the fracturing prevalent in folded sedimentary rocks, karsts are complex and challenging ground control risks. Traditional methods of predicting karst locations, such as probe drilling, probability studies, and borehole data analysis are impeded by the inconsistent spatial distribution and variable sizes of the features. Ground penetrating radar (GPR) is a geophysical technique that transmits radio waves into a medium and subsequently detects the transmitted waves via a receiver. The travel time and energy of received signals are then filtered, processed, and interpreted manually to map out the structures within the medium. The difference in material properties between limestone and water causes radio waves to reflect most of their energy, producing a strong signal. This paper studies the viability of GPR as a means of karst detection in underground limestone mines, and compares the GPR technique to traditional and similar alternatives.

3:25 PM

Photogrammetry for Rock Characterization in Underground Limestone Mines

R. Bishop, J. Monsalve, J. Baggett and N. Ripepi; Mining Engineering, Virginia PolyTech Inst State U, Blacksburg, VA

Photogrammetry is a proven technique for capturing composite images for 3D spatial analysis. While the technology has been applied to the mining industry in numerous ways, there are unique risks to underground limestone mining including water inflow and geologic features such as faults and weaknesses. Over the past ten years 40% of underground mining fatalities were caused by ground control issues related to ground collapses and over the same period the underground stone mining industry has had the highest fatality rate in four of those ten years. This research is testing photogrammetry to improve the safety of underground limestone mining as a useful tool for site characterization and ground control monitoring in large opening underground mines. Recommendations will be made for hazard recognition, risk assessment and ground control best practices to implement in training and operations management.

3:45 PM

A Reality Check – Oil Mining/Shale/Sands Projects with MSHA IDs

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

The NIOSH mining and oil & gas programs have been interfacing to identify and address common concerns. While the interaction between these two extractive industries programs is multifaceted, one aspect considered was mining associated with hydrocarbons. A review was conducted of the fifty (50) mine identification numbers issued by MSHA since 1970 as broken down by SIC Code related to oil shale, oil sands and oil mining, with a focus on the six (6) operations that are currently either classified as active or intermittent operations (the remaining 44 are "abandoned"). These six operations are broken down into one oil shale, three oil sands and two oil mining. Since an MSHA identification number is required to conduct an actual mining operation, this analysis provided a baseline (or reality check) as to the current activity level. This paper describes the results of that review and includes a description of the six operations as well as several operations that entered abandonment since 2000.

TUESDAY, FEBRUARY 27

AFTERNOON

2:00 PM | ROOM 101F

International: Updates on Mining in Mexico

Chairs: *P. Williamson, INTERA, Boulder, CO*
S. Flores Castro

2:00 PM

Introduction

2:05 PM

Recovery of Gold and Silver by Pressure Cyanidation Leaching and Electrocoagulation

J. Valenzuela; Chemical Engineering & Metallurgy, University of Sonora, Hermosillo, Sonora, Mexico

This paper describes a new technology of pressure oxidation/cyanidation leaching for the dissolution of gold and silver and the recovery of the precious metals by using the electrochemical process of Electrocoagulation (EC). The novel method demonstrates that the oxidation and dissolution of gold and silver in alkaline cyanide solution can be conducted simultaneously in the same reactor in less than 90 minutes with a recovery that exceeds 96%. Then, the pregnant cyanide solution with gold and silver is sent for recovery of precious metals by using a very promising electrochemical technique (EC) that does not require high concentrations of silver and gold in cyanide solutions. Gold is classed as a noble metal because of its inertness to most chemical reactions under ordinary conditions. At the present time, cyanidation has superseded all previous leaching processes, particularly chlorination, because of its ability to effectively and economically treat ores containing as little as 1-3 g/ton gold. Cyanidation processes are especially suitable for treatment of gold/silver-bearing sulphidic materials.

2:25 PM

Gold Adsorption in Thiosulfate Solution Using Anionic Exchange Resin

J. Valenzuela; Chemical Engineering & Metallurgy, University of Sonora, Hermosillo, Sonora, Mexico

This paper involve a new ion exchange resin for extraction of gold, AuRIX®100, also this investigation involve the ammonium thiosulfate as a lixiviant for gold recovery. Gold adsorption was studied with $(NH_4)_2S_2O_3$, using NH_4OH as pH regulator, in an ion exchange resin AuRIX®100, evaluating the adsorption stage, the experiments were carried out in batch tests and on an ion exchange column. It was found NH_4OH, maximizes the adsorption of gold at pH 10.5 and the presence of thiosulfate, it is favorable for the adsorption of the gold to 99%. In column tests the adsorption is achieved to a 75% of gold. In the model of adsorption the experimental data were adjusted to the Freundlich isotherm. The AuRIX®100 resin is efficient; it has a higher capacity and fast kinetic and the results of experiments at room temperature favor the kinetic adsorption process.

2:45 PM

Recovery of Gold and Silver from Pregnant solutions of the Merrill Crowe Process by Electrocoagulation Process

J. Parga Torres; Materials Sciences, TEC Nacional De Mexico - ITS, Saltillo, Coahuila, Mexico

In Mining operations, cyanidations is the predominant process by which gold and silver are recovered from their ores and it is recognized that the Merrill-Crowe process, Carbon in Pulp or the Ion Exchange Resins are used for the concentrations and purification of gold and silver from cyanide solutions. Electrocoagulation (EC) is a very promising electrochemical treatment technique that does not require high concentrations of gold and silver in cyanide solutions. First, this study will provide an introduction to the fundamental concepts of the EC method for recovery metals from cyanide solutions. In this research, Powder X-ray Diffraction, S E M and Transmission Mossbauer Spectroscopy were used to characterize the solid products formed at iron electrodes during the EC process. The results suggest that magnetite particles and amorphous iron oxyhydroxides present in the EC products remove gold and silver in 5 minutes with an efficiency of more than 99 % from cyanide pregnant solutions. The application of this results to the Mexican mining companies of Grupo Minero Bacis, Minera Williams and Minera Avino gived in this three Companys, recoveries of gold and silver more than 99%.

3:05 PM

Copper and Sodium Cyanide Recovery from Barren Solutions of the Merrill Crowe Process

J. Parga Torres; Materials Sciences, TEC NACIONAL DE MEXICO - ITS, Saltillo, Coahuila, Mexico

This study is a brief application of the role of inducing the nucleated precipitation of copper and zinc in a flashtube serpentine reactor, using sodium sulfide as the precipitate and sulfuric acid as pH control this was 99% effective. The results showed that pH had a great effect on zinc cyanide removal efficiency and the optimum pH was about 6 to 4. Also at this pH value copper cyanide removal efficiency could be achieved above 20% and the best results for the copper were in the range of pH 2-3. In this process the cyanide associated with the copper, zinc, iron cyanide complexes are released as

HCN gas under strong acidic conditions, allowing it to be recycled back to the cyanidation process as free cyanide. Industrial application of this process were in Mining Williams and Group Bacis in Mexico and the results give more than 97% of the recovery.

3:25 PM

Arsenic, Lead and Cadmium Removal from Groundwater without Chemicals Reagents

J. Parga Torres; Materials Sciences, TEC Nacional De Mexico – ITS, Saltillo, Coahuila, Mexico

Arsenic contamination of drinking water has been reported from many parts of world and at this time the groundwater pollution caused by arsenic, lead and cadmium in Torreón in Mexico has led to a major environmental crisis. Due to its high toxicity, especially arsenic and lead drinking water regulations only permit the presence of extremely low concentrations of As, Pb and Cd. Present, investigation was found that when arsenic, lead and cadmium water was treated with Electrocoagulation (EC) method and then with an adsorbent of cow bone powder, it produced arsenic, lead and cadmium-free water. In this treatment method, more than 99 percent removal of arsenic, lead and cadmium was achieved in one minute without added any chemical reagents. Experiments were conducted to determine the optimum operating conditions such as current density, conductivity, pH and retention time. Analysis of the solid adsorption product by XRD, FTIR, and Mössbauer Spectroscopy revealed the expected crystalline iron oxides (magnetite, lepidocrocite). Results from the thermodynamic studies showed that the thermodynamic data fit the primer order langmuir isotherm model well for arsenic, lead and cadmium.

3:45 PM

Pitfalls of Geochemical Mine Waste Characterization in Mexico

P. Williamson; Mining, INTERA, Boulder, CO

Inadequate characterization of mine waste resulting in metal leaching and acid rock drainage (ML/ARD) can create significant environmental, reputational and financial risks for mine operators. Guidance documents on best practices for mine waste characterization and management (e.g.INAP or MEND) stress the importance of a site-specific approach based on a conceptual geochemical model, quantification of the geochemical variability of waste materials and use of appropriate analytical methods. The exclusive use of the Mexican mine waste regulations can lead to vulnerabilities for operators and investors, as the regulations are inadequate for characterizing ML/ARD potential based on best practices. Such a scenario is likely because several of the proscribed sampling and analytical methods are inappropriate and can result in underestimation of the ML/ARD potential at a mine. To address these issues, mine operators and consultants working in Mexico should develop parallel programs that address the Mexican regulations, supplemented with more comprehensive and site-specific analyses that address best practices for mine waste characterization.

4:05 PM

Challenges and Opportunities for Women in the Commercial Areas of the Mining Industry in Peru

M. Bbarrios; Metal Trading, MCC NFT Latin America – Metallica Commodities Group, EnginZone SAC, Surco, Peru

Mining is the top contributor to the economy in Peru. It represents 12% of the country's GDP and 50% of all the revenue from exports. For every person working directly in mining, there are seven others who indirectly live from the industry. Due to traditional cultural beliefs, women have faced great challenges to become part of the Peruvian mining industry. Yet during the last decade women have found many new opportunities to participate actively in the commercial side of mining including areas like trading, administering metal contracts, working in brokerages and managing logistics. This presentation will show how women in Peru are now part of mining's commercial supply chain and will look at the types of jobs to which they have access. The path has been rough, yet both the industry and the country have benefited as women continue to take on increasingly important positions.

TUESDAY, FEBRUARY 27

AFTERNOON

2:00 PM | ROOM 101A

Mining & Exploration: Geology: Resource Estimation

Chair: *A. Samal, GeoGlobal LLC, Riverton, UT*

2:00 PM

Introduction

2:05 PM

Rules of Thumb for Geological Modeling

E. Ronald; SRK Consulting, Denver, CO

Geological and Resource models constitute the underlying foundation of the mining and mineral exploration business. These models form the basis of Mineral Resource reporting, mine planning, economic evaluations, business plans, and company strategic planning. A robust and useful model can be the difference between a marginal exploration prospect and a profitable mine. Therefore, their construction and overall quality to represent the ore body are critical to success. The creation of geological and Resource models is a combination of art, science, engineering, statistics, and well-informed hypotheses. A series of considerations are presented to ensure models are both useful and provide a robust representation of the deposit. These considerations include: 1) clear objectives of model use; 2) understanding local and regional geology; 3) the incorporation of all trusted data sources; 4) fundamental statistical understanding of data; 5) a regional perspective; 6) a sound geologic structural framework; 7) determine significant attributes dependent upon scale of model; 8) modelling of waste units; and 9) all modeled wireframes modeled in three-dimensions.

2:25 PM

Complex Domain interaction: Resource Estimation for a Bimodal Population Gold Deposit with Distinct Primary Continuities

T. Matthews; Geology, Gustavson Associates, Lakewood, CO

In many deposits, there is a clear spatial anisotropy which controls mineralization, and is well supported by both geostatistics and geological interpretation. Other deposits have more complex interactions, with multiple intersecting structural anisotropies, but with consistent grade distribution within the structural sets. This paper describes a bimodal mineralized system where there are two clear, overlapping mineralized geometries, each of which has a distinct grade population. An estimation technique is proposed to honor both mineralization geometries, and to control for the distinct grade populations encountered in the overlapping zones.

2:45 PM

Getting More from Your Resource Estimation Routine: Boundary Analysis in Micromine

A. Amoroso; SME, Denver, CO

Grade distribution and relationships among different domains can be difficult to investigate and fully understand, especially in multi-domain projects. Knowing how grade changes across a domain contact is critical in the resource estimation process. A Boundary Analysis conducted entirely within Micromine can help yield a better understanding of soft and hard domain boundaries. This analysis provides the geologist with potentially crucial and accurate information on how to best characterize grade intervals in certain domains during resource estimation. By calculating the distance, trend, and plunge of grade intervals relative to a domain boundary, one is able to calcu-

late the change in grade across the domain contact and determine whether the boundary is hard, soft, or somewhere in between. This can be critical in the resource estimation process.

3:05 PM
Maturi Deposit – Updated Mineral Resource Estimate
D. Reid; APEGBC, Reno, NV

The Maturi Deposit is located near Ely, Mn. Various drill programs were conducted in the area since the 1960s, multiple resource estimates have been completed over the years. The updated mineral resource estimate was completed in 2014. The geological model was generated based on logged intervals. Gridded surfaces for the various geologic units were constructed using Vulcan™ Gridcalc modeling functions. A stratigraphic model of the principal S3 and S2 units was developed by dividing the calculated S3 unit thickness into five equal units and the S2 unit thickness into three equal parts. In addition, four structural domains were defined to aid in orientation of search ellipses and to refine variography. The 2014 resource model was completed using Vulcan™ software and ordinary kriging (OK) interpolation. Multiple elements were estimated within six geological units. The Maturi Mineral Resource is tabulated using a 0.30% Cu cutoff grade. The Mineral Resource is tabulated by Measured, Indicated and Inferred classifications.

3:25 PM
Plurigaussian Simulation of Geological Domains in the Presence of Spatial Trends
N. Madani[1] and X. Emery[2]; [1]Mining Engineering Department, School of Mining and Geosciences, Nazarbayev University, Astana, Kazakhstan, Astana, Kazakhstan and [2]Department of Mining Engineering / Advanced Mining Technology Centre, University of Chile, Santiago, Chile, Santiago, Chile

Plurigaussian simulation is used in subsurface modelling to quantify the uncertainty in the boundaries of geological domains. The conventional model relies on strong stationarity assumption and is restricted in the number of domains and their spatial behaviour over the region of interest. This paper proposes model improvements to account for the cases when the number of geological domains is large and when spatial trends or zonations arise from geological formations. The proposed plurigaussian approach consists in truncating intrinsic random fields of order k (IRF-k), instead of stationary fields, and is illustrated through the probabilistic modelling of seven rock domains in the Rio-Blanco copper deposit located in the Chilean Central Andes. Despite the scarcity of conditioning drill hole data, the results show a remarkable agreement between the simulated domains and the rock type model interpreted by mining geologists, while the conventional stationary plurigaussian model fails at reproducing the expected zonation.

3:45 PM
A Commentary on the International Reporting of Coal Resources and Reserves
S. Rupprecht; MiningEngineering, University of Johanesburg, Doornfontein, South Africa

The public reporting of Coal Resources and Reserves is a key component of national codes, which falls under the guidance of the Committee for Mineral Reserves International Reporting Standards (CRIRSCO). CRIRSCO has worked towards the creation of a set of standard international definitions for the public reporting. Although CRIRSCO has created an international template that is intended to make public reporting compatible with international reporting codes there remains differences in the reporting guideline between national codes e.g. Australian, South Africa, Canada, and the USA. This paper discusses the implications of the difference between the four international reporting codes (JORC, SAMREC, CIM and SME) in terms of coal reporting and how this may influence public confidence in coal reporting. In addition to the differences between the individual reporting codes, public reporting remains far from ideal. Public reporting practices are also discussed in this paper and examples provided of poor reporting practices, as well as examples provided of best practice in public coal reporting.

TUESDAY, FEBRUARY 27
AFTERNOON

2:00 PM | ROOM 101E

Mining & Exploration: Management: to Change or Not to Change: What New Technology or Mining Method Prompts an Operation to Change from 'Traditional' Methods to 21st Century Technology

Chair: *D. Vatterrodt, Jackleg Consulting LLC*

2:00 PM
Introduction

2:05 PM
Ore Control in the Modern Mining Era – Are We Doing Enough?
J. Baar; Technical Services, Barrick Gold Cortez, Elko, NV

With the mining industry rapidly changing around us, it would appear Ore Control is being left in the dust. Mining has automation. Mills have fancy detectors. Training has cool simulations. But Ore Control, one of the most important jobs on the mine site, is easily overlooked when production is up and mines are fat. However, this does not mean we need to sit idly by while the rest of the industry is modernizing. Recently, Barrick Cortez Hills Open Pit has been in discussions with Maptek on ways to bring Ore Control into the 21st century. Through this partnership, ideas are being generated which can be used across the entire mining industry.

2:25 PM
Visual Awareness of Minesite Conditions, Production and Equipment
C. Nelms; Mining Division, RDOIC, San Antonio, TX

Green is good and red is bad. Imagine the mine as a living organism as a whole and then as a colony of smaller independent systems that make up the whole. As with any living organism one doesn't stop to read a report on how you are doing. You react to how you feel and where you are. In this instance a site is now able to "sense" through communication with the onboard sensors of each piece of equipment. The "where they are, if they are full or empty of material, fuel, oil, or air pressure" are now graphically displayed on a monitor. Active equipment visible location and color state. Prodution on individual equipment, entire dump sites, pits, all with a visual color state without any lengthy review from on-site engineers or operations managers to determine up to the moment status. The same with inactive equipment. The presentation will review actual examples of how this kind of a system visually reports on equipment, material porduction, and trouble sites on the mine. Also how equipment sensors react to site conditions such as grade, poor road conditions, or areas of frequent mechanical failure.

2:45 PM
Mining in the Future: Academic 2050
M. Javier; EnviroMINE, Denver, CO

Mining makes civilization possible. It also creates socio-economic problems surrounded by sustainability controversies and continues extraction without considering the balance and finitude of nature. Nature requires restoration of equilibrium if mining and life on earth are to continue. Mining is still practiced according to Agricola's view and the consequences it has wrought on our planet demand we critically reexamine it from its very core, to its metrics, to

its design, to its technology, to how it is taught, and to reconsider its raison de être in 2017. This paper proposes tools to new mining engineers that are required to transform and solve new challenges. The task before us is to formulate an updated core curriculum that meets the demands and realities of the 21st Century. Mining professionals must rethink and reteach how to redesign mines before shovel hits dirt, how to mine with restoration of nature figured in to the mining design. Mining needs a new extractive technology in order to transform the results of its well-known liabilities. Mining has evolved and its future must be different than its past. Our industry is capable of doing this but it needs to be shown the way.

3:05 PM

Applying Operational Excellence to Mining Operations – Turning Problems into Opportunites

M. Powell[1], S. Kanchibotla[1], G. Chitombo[2], N. Plint[3] and D. Way[4]; [1]JKMRC, Sustainable Minerals Institute, University of Queensland, Brisbane, QLD, Australia; [2]BRC, University of Queensland, Brisbane, QLD, Australia; [3]Sustainable Minerals Institute, University of Queensland, Brisbane, QLD, Australia and [4]JKTech, Brisbane, QLD, Australia

The Sustainable Minerals Institute is linking the success of JKMRC/ JKTech in mine-to-mill optimisation and the BRC in mass underground metalliferous mining, into the wider processing chain of environmental impact, water, health and social risk. This brings cutting-edge capability to the industry in an integrated manner enabled by the SMI unique process-wide capability. A constraints-based valuation system is used to identify nodes of maximum value generation, then our world experts work with site personnel to convert opportunities into considerable added value. Our key differentiators are: Expertise without borders, across the University and established global research partners Identify value opportunity along the process chain through assessing integrated opportunities at the interface between inter-dependent but decoupled sub-processes - bridging business silos. Quantify and provide paths to reduce RISK arising from ore, equipment and operating variability Deliver future tools now Our approach built on good science, identifies short-term and builds long-term value, forming the basis of sustainable implementation of Operational Excellence across the mining value chain.

TUESDAY, FEBRUARY 27

AFTERNOON

2:00 PM I ROOM 101B

Mining & Exploration: Operations: Bridging the Chasm: Successful Implementation of Applied Research in Mining

Chairs: *A. Brickey, South Dakota School of Mines and Technology, Rapid City, SD*
C. Roos, Montana Tech, Butte, MT

2:00 PM

Introduction

2:05 PM

Stope Optimisation – from Research to Industry Standard

C. Alford; Alford Mining Systems, Kew, VIC, Australia

Design of stope shapes for underground mining is tedious and repetitive when done interactively on a computer screen, and is often done by junior engineers when the result can have a dramatic impact on mine profitability. There had been limited success in translating the design requirements, and shape representation techniques to computer software because of the variety of stoping methods and orebody geometries. A new generation of stope optimization software has evolved from industry funded research projects in the past decade. The research projects were a global consortium drawn from researchers in the university sector, experienced mining consultants, major mining companies and mining software vendors that supply generalized mining packages to those companies. A key goal was implement a software architecture to facilitate a multi-vendor solution and minimize the lead time to commercialization. Six software vendors have adopted what is now an industry standard design tool for stope optimization. This paper will review the approaches taken in research and commercial software over the past three decades, and highlight areas where further advances can be made.

2:25 PM

Clustering Blocks to Form Aggregated Mining Units in presence of Uncertainty

M. Tabesh and H. Askari-Nasab; Mining Engineering, University of Alberta, Edmonton, AB, Canada

Open pit mine planning is a multistep procedure with different planning horizons and different levels of details from strategic planning to operational planning. There is a need to form aggregated mining units in every step in order to create practical mining schedules. The aggregation process has different requirements based on the level of details available and the way aggregates are going to be used. Hence, clustering algorithms can be implemented to use the available information and group blocks together. However, the block information used in aggregation is uncertain in nature. In this paper, we propose a hierarchical clustering algorithm based on Possible Worlds approach where multiple realizations of the block model with estimated rock type and grade are used to form the aggregated units. We implement the clustering algorithm on every realization created using Sequential Gaussian Simulation and use two different techniques to summarize the clustering schemes. We apply the technique on a real deposit and compare the resulting clusters before and after considering uncertainty.

2:45 PM

Paradigm Shift in Our Understanding of Rock Mass Behaviour at the Kiirunavaara Mine, Sweden

J. Vatcher[1], S. McKinnon[2], J. Sjöberg[1] and J. Töyrä[3]; [1]Itasca Consultants AB, Luleå, Select One, Sweden; [2]Queen's University, Kingston, ON, Canada and [3]LKAB, Kiruna, Sweden

A fundamental change in assumptions about mine-scale rock mass behaviour at Luossavaara-Kiirunavaara AB's (LKAB) Kiirunavaara Mine has occurred as a result of recent research. This new understanding is important to future production at the mine, through enabling increased safety via informed engineering design. Initially, mine-scale faults were hypothesised to be the root cause of seismicity near production, so called "fault slip" events. Historic analyses, in particular of the mine's seismic data, supported this hypothesis. As research progressed, however, this plausible and relatively common hypothesis was overthrown in the light from methodologies and techniques developed to evaluate conventional and unconventional data related to the rock mass. Results showed the mine-scale importance of a geomechanical characteristic that was previously overlooked, clay alteration. This paradigm shift in the understanding of the rock mass provides an obligatory foundation for future rock mechanics analyses related to planned production at the Kiirunavaara Mine.

3:05 PM

Development of Algorithm for Optimization of 3-Dimensional Ultimate Pit Design and Its Application to Open Pit Mine Scheduling

N. Niibu[2] and H. Kim[1]; [1]Department of Mining Engineering, University of Alaska-Fairbanks, Fairbanks, AK and [2]Global Resource Engineering, Ltd., Denver, CO

In an ultimate pit design, maximizing the net value of blocks within the ultimate pit limit under pit-slope and mine-sequence constraints has been con-

sidered as one of the most important tasks. Although there have been many studies using 2-dimensional based algorithms, as the geology of the orebody becomes complicated and the financial scale of the project gets larger, a more quantitative pit design model is required. Developing a 3-dimensional algorithm for the pit design is useful for quantitative simulations of mining projects. A mixed-integer linear programming for a 3-D ultimate pit design is developed and implemented in this study. The newly developed algorithm is first verified with data from Fort Knox gold deposit in Alaska, including optimization of the milling and heap-leaching cut-off grades with respect to the maximum net value. Then, the developed algorithm is directly applied for the ultimate pit design and applied for the mine scheduling model for optimizing the net values. The results show that the newly developed 3-dimensional algorithm is very effective for practical open pit design with respect to model accuracy and quantification for optimizing the net values.

3:25 PM

Underground Muck Pass Development: Minimizing Haulage Costs Through Development Location and Scheduling

W. Heasley; Mining, Student, Absarokee, MT

The location, length and scheduling of underground muck passes, i.e, vertical developments used to move broken rock via gravity, can impact direct haulage costs, production rates, and equipment fleet size of the mine they are employed at. We present a mathematical model that satisfies complex real world constraints that achieve production goals while minimizing costs. The resulting solution is being applied at a large scale underground PGM operation with the potential to reduce direct haulage costs by 10%.

3:45 PM

Beyond Pit Shells: Moving from Pit Optimization to Strategic

P. Cawley; GEOVIA, Montreal, QC, Canada

As the capital investment for open pit projects becomes more difficult to obtain, more focus is placed improving the strategic plan to maximize the project's value and return on investment. Applying this focus during the early stages of evaluation often yields dramatic changes to the overall project scope. Currently, many mines use software such as GEOVIA's Whittle to produce economic pit shells based upon the Lerchs-Grossman algorithm and then manually craft a mining sequence from those potential pushbacks. This presentation will outline new technologies to produce a better strategic schedule and extract greater value from the project. The key to this added value is to simultaneously optimize the most critical components of the schedule: mining sequence, stockpiling strategy, and processing cut-off grade. In addition, we will also examine the benefits of rapid, multi-scenario analysis of a wide variety of potential options or future economic conditions on the project's viability. Representative results from actual case studies will be shown to illustrate the gains that can be derived from the implementation of these new methodologies.

4:05 PM

Economic Evaluation of Diesel and Electric Equipment Fleet Using Optimized Underground Mine Production Schedules

R. Akinnuoye and A. Brickey; Mining Engineering and Management, South Dakota School of Mines and Technology, Rapid city, SD

Reductions in Diesel Particulate Matter (DPM) regulation limits are encouraging many mine operators to evaluate replace existing diesel equipment with electric equipment fleets. The common analysis method is to conduct a cash flow analysis using the current long-range plan, created using the parameters associated with the current diesel fleet. We evaluate the use of an integer programming model to produce different production schedules utilizing production rates and ventilation needs associated with diesel and electric fleets, to maximize value. A cash flow analysis is then conducted on the resulting schedules to compare the costs and/or potential cost savings for each fleet.

4:25 PM

Impact of Shear Stresses on Pillar Strength

T. Garza-Cruz[1] and M. Pierce[2]; [1]Itasca Consulting Group, Inc., Minneapolis, MN and [2]Pierce Engineering, Minneapolis, MN

Empirical pillar design methods assume that pillar capacity and demand are directly a function of its width-to-height ratio, rock mass strength, overburden thickness and the pillar's tributary area. While this assumption is generally valid for pillars in flat seams underneath a flat topography, it is not for cases in which the pillars are to be subjected to shear stresses arising from dipping seams or in-situ stress rotations (i.e. due to mountainous terrain). This paper describes the detrimental effect shear stresses arising from non-vertical pillar loading have on reducing pillar confinement and, as a consequence, pillar load carrying capacity. A series of pillars with different width-to-height ratios were modeled using the bonded block model approach in 3DEC and loaded under varying normal and shear stress conditions to gain insight into the pillar damage condition (i.e. spalling) and ultimate strength as a function of such stress demand. The results are presented as a series of normalized charts.

TUESDAY, FEBRUARY 27

AFTERNOON

2:00 PM | ROOM 101C

Mining & Exploration: Recovering from Project Setbacks – Advice from Managers Who Have Been There

Chair: *M. Tilley, Cementation USA Inc, Sandy, UT*

2:00 PM

Introduction

2:05 PM

Ore Pass Design Improvement at Grasberg Block Cave (Gbc) Mine PT Freeport Indonesia

R. Vince and H. Rahadian; Underground, PT Freeport Indonesia, Tembagapura, Papua, Indonesia

Grasberg Block Cave (GBC) is underground mine managed by PT Freeport Indonesia (PTFI) that currently on development stage since 2008. GBC plan its first production in 2019 using block cave method. Learning from existing mine in PTFI, Deep Ore Zone (DOZ) that already start their production since 2000, GBC has improve the design of the ore pass. The main difference between ore handling in these two mines is DOZ using trucks on their haulage level while GBC is going to use automatic train. In DOZ mine the ore pass is vertically connected from extraction to haulage level. Wet muck compacting problem often occurred and difficult to be solved because the limitation of the access with this kind of design. Therefore GBC split the raise for ore handling into two by utilizing service level. Ore pass is the raise that will be passed by the ore from extraction to service level. Chute pass is the raise that will be passed by the ore from service to haulage level. This paper will discuss any factors which affect the design and all the advantages that will be earned. Safety factors, material characteristic, and equipment capabilities will be the main focus on this study.

2:25 PM

Application of Backfilling in the Design of Open-Pit Mining Phases

V. Tenorio and J. MAGUINA; SME, Tucson, AZ

The load-haul-dump cycle in Open Pit mining represents one of the most critical sources of cost. Trying to reduce this cost becomes an opportunity for adding value to the operation. Occupying haulage routes with fully loaded trucks may have a significant impact in the overall cost, especially when the material hauled is waste. Planning the mining phases always considers locating the stocks / pads considerably away from the Open Pit, similarly with what occurs with the dumping sites. In the former, it cannot be easy to relocate the ore discharge points, whereas in the latter, the location of the waste areas is determined at the beginning of the phase design, considering that the pioneering phases are typically for removing and dumping overburden. The cycles for waste and ore haulage, when defining a backfill area close to the pit, can decrease significantly, thus increasing the overall cycle throughput by up to 50%. In addition, because of the lower slopes (by the nature of the design), this value (50%) is susceptible to be increased by adjusting the speeds for fully loaded trucks. This reduction in cost would have a positive impact in the NPV of the project.

2:45 PM

An Approach to Evaluate Mining Projects

S. Kanchibotla; Julius Kruttschnitt Mineral Research Centre, The University Of Queensland, Indooroopilly, QLD, Australia

The strategic valuation of mining assets requires the consideration of a range of interrelated technical and financial considerations. Omitting any of these, or considering any in isolation, can result in less favourable strategic decisions being made. This paper considers a subset of pertinent inputs to the strategic planning process in a sequential framework which considers value, risk and uncertainty. The objective is to ultimately deliver valuation outcomes which are more robust and can therefore be used to more effectively optimise the strategic decisions available to the investors and stakeholders of an asset. In this paper an alternative approach to evaluate the mining project has been presented. This approach will consider the ore body and process uncertainties and price and cost fluctuations to evaluate the value and risk of a mining project.

3:05 PM

Effect of Sample Size on the Unconfined Compressive Strength (UCS) of Cemented Rockfill (CRF)

S. Warren[2], M. Raffaldi[1], J. Seymour[1], k. Dehn[1], L. Sandbak[3] and J. Armstrong[4]; [1]Spokane Mining Research Division, NIOSH, Spokane, WA; [2]Spokane Mining Research Division, NIOSH, Spokane, WA; [3]Turquoise Ridge Joint Venture, Barrick Gold Corp, Golconda, NV and [4]Cortez Mine, Barrick Gold Corp, Elko, NV

Cemented rockfill (CRF) is often used in underhand cut-and-fill operations to develop undercuts for production mining and ground control. This paper hopes to increase the safety of designed man-entry openings under CRF through a better understanding of CRF material properties. The unconfined compressive strength (UCS) of 6×12-inch cast CRF cylinders is the predominant metric used to estimate CRF strength for QC/QA. However, aggregate gradation designs at mines typically allow for maximum aggregate size to reach upwards of 4 inches, which is greater than 50% of the sample diameter and is known to induce scale effects on UCS testing. Estimates of in-situ CRF strength for analysis and design of CRF span stability must account for this and any other scale related effects. This paper presents results of CRF UCS testing of 6×12, 12×24 and 18×36-inch cylinders, cast on-site, at the batch plants of two underhand cut and fill mines in Nevada. The results show that the UCS of CRF reduces as sample size increases. The implication of these findings on estimating in-situ backfill properties and span design are also discussed.

TUESDAY, FEBRUARY 27

AFTERNOON

2:00 PM | ROOM 101D

Mining & Exploration: Technology: Automation in Mining

Chair: *T. Courtney, Atlas Copco*

2:00 PM

Introduction

2:05 PM

Blast Hole Drills: Enabling Automation or Optimization?

T. Berens; Atlas Copco, Garland, TX

Excitement and many questions are common reactions when discussing automated drilling operations that have predominantly always required full time human interaction. What are the reasons large, medium, and small mining operations are enabling drill automation? Where is the value found throughout the mining processes? These questions will be addressed using global real world examples for the audience to visualize the impact automation is making in mine's value chains. These mines are walking through structured models to properly develop and deploy automated drills into their operations with great success. The change management blueprints continue to mature into repeatable processes for each mine to capitalize on previous learnings. This presentation will explore not just the automation portion, but how Automation implementation teams view the mine as a manufacturing process to gain its advantages. We will conclude with where this journey may go in the near future given the tremendous opportunities automation offers.

2:25 PM

Autonomous Haulage – Value Delivered from the Field

C. Smith and J. Deselem; Global Mining, Caterpillar, Perth, WA, Australia

Command for Hauling brings together many leading edge technologies to deliver improved safety, higher throughput, and lower costs. The authors draw on their combined experiences of implementation, growth and sustained operation of autonomous haulage fleets in the Pilbara region of Western Australia to discuss the value potential for miners.

2:45 PM

Automation and Innovation in Surface Mining Equipment Driving Efficiency, Precision and Production

T. Sikora; Mining and Specialty Excavation, Vermeer Corporation, Pella, IA

Vast experience using surface mining equipment globally in various conditions and applications has confirmed and proven the need for automation. Automation is more than just control of general machine functions but also the interaction and communication with grade control systems and automatic steering of the machine. This paper highlights the importance of automation to achieve higher precision and higher production to positively impact every step in the process, resulting in a more efficient operation. The machines log performance metrics that are both available on the machine for the operator or supervisor to see as well as in the office through telemetric communication. Building on these technologies, an innovative new surface mining attachment that combines benefits from the current designs in a way that is new to the industry. An in-house rock lab was developed to test rock samples from all over the world. Correlating results that are witnessed in the rock lab with real-world production values has allowed further understanding of the machines and the entire process. In this paper we will explain a real-world example from collecting the samples to cutting product in the field.

3:05 PM

Increasing Productivity and Conserving Person-Hours Through Automated Fuel Dispatching at Sierra Gorda

M. Caceres[2] and D. Wells[1]; [1]Wenco International Mining Systems, Seattle, WA and [2]Sierra Gorda Mine, Antofagasta, Chile

The fueling process at mines takes working equipment away from production, reducing productivity by hundreds of hours each year. KGHM's Sierra Gorda mine uses an automated dispatching service – Wenco Fuel Dispatch – to handle fueling of its fleet of 58 Komatsu 930E haul trucks. Through automating its fueling, the mine has increased its average fill volumes from 3,400 litres to 3,900 litres per fuel session, with projections to reach 4,200 litres in the near future. At a burn rate of 260 litres per hour, each truck now stays in production an average of 1.92 hours longer before fueling. Use of automated dispatching has also allowed Sierra Gorda to reduce wait times at fuel stations by 10%, further shrinking unproductive time. Moreover, automated dispatching has enabled the mine to redirect its full-time fueling dispatcher to other tasks, thereby conserving one full-time crew member. This paper discusses how implementation of Wenco Fuel Dispatch contributed to increased production time and more robust productivity at Sierra Gorda mine.

3:25 PM

Integrating Process and Power Automation: Safety, Productivity and Efficiency Gains

L. Monaco; Control Technologies, ABB Sweden AB, Vasteras, Sweden

The evolutional process is always about solving existent problems in order to provide further achievements. But the more something evolves, the more challenges it faces towards greater evolution. Industrial automation systems in Mining have also evolved a lot in the past decades, but they now face new challenges about integration: how to integrate different locations and systems, in a way to reduce costs and increase overall mine efficiency and safety for the operation. This paper compares conventional Mining process automation architectures vs. a state-of-the-art, completely integrated system using Electrical Integration based on IEC 61850 standard for Substation Automation Systems. Emphasis is placed on the benefits to manage the entire Mining plant as a whole, not only looking at the production rates, but also at the energy consumption for each part of process. In addition, it is discussed how an integrated system approach unlocks safety and productivity gains such as overall process optimizations, improved operator effectiveness, increased plant availability, and reduced maintenance costs.

3:45 PM

Lab Automation – the Critical Tool for Geo-Metallurgy & Plant Operation

W. Baum[1] and M. Lischka[2]; [1]Process Mineralogy Consultant, San Diego, CA and [2]Geoscience automation, Herzog Maschinenfabrik, Osnabrueck, Germany

This presentation illustrates the advances in lab automation through the use of robotics technology in mining labs and provides a Path-Forward to improving manual facilities. Although automation is advanced from drilling to process control, the effort to automate many of the vintage laboratories is slow. Details for upgrading with automation in existing facilities, expansions, mobile labs, modular automation and/or new highly automated laboratory centers will be illustrated. Even after years of supporting big data and engineering "the-plant-of-the-future", many operations and new startups continue to show inefficiencies linked to poor ore characterization. Better safety and hygiene, higher throughput, analytical quality and turnaround, 24/7 operation, and lower operating cost have been proven in numerous automated labs. Failure to modernize last generation labs imperils mining from pit to plant and contributes to under-performing flow sheets. Lab automation connected to geo-metallurgy will enable high-volume and fast-turnaround profiling of existing ore bodies or new deposits on a continuous basis. Big Data alone will not suffice. Mining requires Big Ore Characterization Data.

4:05 PM

A Leap Towards Automation of Shotcreting

S. Schade[1], T. Hartmann[1], C. Niestroj[1], G. Saelhoff[2] and E. Clausen[1]; [1]Advanced Mining Technologies, AMT RWTH Aachen University, Aachen, Germany and [2]GTA Maschinensysteme GmbH, Hamminkeln, Germany

The digitalization of manually operated mining processes with robust commercial off-the-shelf (COTS) technologies can provide a competitive advantage. For example, shotcreting is a crucial step in hard rock mining which is still controlled manually. Costs, speed and process quality heavily depend on operator's experience and can vary vastly. Challenging operating condition (shotcrete mist, safety requirements) may lead to a non-optimal layer thickness and waste of time and material. This whole process can be enhanced if the operator is provided with better information. Combining the initial face profile with the shotcrete flow rate will reveal information about the current state of the spraying process. Displaying this information via augmented view will support the operator and greatly improve the overall process quality. The used technologies include an inertial measurement unit (IMU), laser scanner (LIDAR), ultra-wideband radio systems (UWB) and Robot Operating System (ROS). This presentation discusses the potential of digitalization of mining processes and gives an example of a successful project with GTA Maschinensysteme as industrial partner.

TUESDAY, FEBRUARY 27

AFTERNOON

2:00 PM | AUDITORIUM ROOM

MPD: Classification: a Panel Discussion

Chair: *D. Meadows, Bechtel, Phoenix, AZ*

2:00 PM

Panel of Industry Experts Discussing the Current State of Secondary Classification

M. Larson; Moly-Cop USA, Kansas City, MO

Join us for a discussion on the current state of secondary classification, focused on cyclones and fine screens. Panel members will come from Derrick Corp, FLS, Metcom Technologies, Metso, Multotec and Weir; with Dave Meadows of Bechtel moderating.

TUESDAY, FEBRUARY 27

AFTERNOON

2:00 PM | ROOM 200IJ

MPD: Flotation II: Physical Aspects of Flotation

Chairs: *A. Noble, West Virginia University, Blacksburg, VA*
D. Laney, Newmont Mining Corp, Elko, NV

2:00 PM
Introduction

2:05 PM
Reducing the Loss of <11µm Copper to Tailings

D. Zoetbrood[1], A. Ang-Ug[1], L. Gurieff[1] and B. Lumsden[2]; [1]Phu Bia Mining Limited, Vientane, Lao People's Democratic Republic and [2]Ausmetec Pty Ltd, Cromer, NSW, Australia

The Phu Kham copper-gold operation is owned and operated by Phu Bia Mining Limited.in Laos. The deposit is a complex and low grade copper-gold porphyry ore. The rougher feed has a particle size distribution of 80% passing 110µm, and the rougher concentrate is reground for cleaning to 80% passing 25µm. The copper losses in the cleaning circuit are primarily in the <C5 (11 µm) fraction. A randomised paired ON - OFF test of magnetic conditioning in one of the two parallel first cleaning circuits was undertaken. The results showed that with magnetic conditioning there was approximately a 10% reduction in the <C5 distribution in the cleaner tail to a 98% level of confidence. The copper distribution in the <C5 fraction was found to give a less variable measure of changes in the <C5 copper recovery than tail assay, and so this was used to monitor the test and evaluate the results. Subsequently, magnetic conditioning was installed in both lines of the cleaning circuit and the survey results monitored after this installation. Comparing the results for the period immediately before and after this installation showed that there was a 20% reduction in <C5 copper losses to the cleaner tail.

2:25 PM
What is an Optimum Power Consumption in a Flotation Cell?

R. Dube, B. Murphy and A. Meharg; Outotec, Centennial, CO

With the increase in maximum available conventional flotation cell size to around 630m^3 in recent years from 160m^3 twenty years ago, the capital cost and foot print for same required flotation volume has decreased significantly. Power consumption per unit ton of ore processed has also reduced as fewer number of flotation cells are needed. Despite these benefits, with decreasing ore quality and challenging mining economics, industry has been pushed to further lower the operating cost which in turn has encouraged to further reduce the power consumption by these flotation cells. Reducing rotor speed and reduced mixing in the flotation cells can help in mitigating some operational cost but it should be noted that the reduced metallurgical performance can further lead to loss of valuable floatable material. This paper discusses the statistical designs along with plant surveys which could be used to determine the optimum rotor speed for a desired metallurgical performance. Rotor speed plays a critical role in performance and slower speed might not always be the best answer to obtain optimum flotation performance.

2:45 PM
Analysis of Venturi Tube Cavitation Pico and Nano Bubble Size Distribution for Column Flotation Using Computational Fluid Dynamics

F. Peng and W. Wang-Geissler; Mining Engineering, West Virginia Universitiy, Morgantown, WV

Using cavitation bubbles has recently been used to improve flotation recovery by generating pico and nano sized bubbles for widening the flotation particle size range, increasing the probability of bubble particle attachment, and reducing the probability of bubble particle detachment. Beyond volume fraction, bubble size distribution is another important factor for cavitation devices to simulate and design. The geometry of a venturi tube was created with computational fluid dynamics. Population Balance Module (PBM) was developed to analyze the bubble size distribution for the water-vapor phase. A mathematical model was created and written as User Defined Functions (UDF) code and complied with ANSYS-FLUENT for to calculate bubble number density, in order to calculate the nucleation rate for the PBM model. To understand the interactions of bubble size distribution with particle size distribution, a 200 µm and a 400 µm diameter ball were added to the venturi grid, separately. These were used to simulate the flow field affected by the particles within. The results indicated that particles could enhance cavitation and reduce the bubble size. These results were validated by experiments.

3:05 PM
Studying the Effect of Non-Sulfide Gangue Minerals with Froth Sampling Techniques

T. Bhambhani[1], R. Farinato[1], D. Nagaraj[1] and P. Somasundaran[2]; [1]Cytec Industries Inc., Stamford, CT and [2]Columbia University, New York, NY, NY

Differential transport of asymmetrically-shaped gangue particles to the froth phase is highly relevant to froth flotation. At several operating plants, problems in concentrate grade can be attributed to problematic gangue transport to the froth phase. The particle transport mechanisms into and through the froth phase as a function of aspect ratio is poorly understood. Experiments carried out by preparing particle mixtures with varying aspect ratio distributions revealed that aspect ratio significantly affects transport. Studying the aspect ratio effects as a function of particle size revealed non-linear interactions between the two variables. The paper discusses differential transport in consideration of the onset of critical aggregation phenomena in the froth phase.

3:25 PM
A Robust Strategy for the Optimal Design of Cell-Based Flotation Circuits Under Uncertainty

S. Amini[1] and A. Noble[2]; [1]Mining Engineering, West Virginia University, Morgantown, WV and [2]Mining & Minerals Engineering, Virginia Tech, Blacksburg, VA

Many circuit design and optimization strategies rely on deterministic modeling approaches that use static values for the technical and economic input parameters. Unfortunately, for mineral processing operations, these input parameters (e.g. feed grade, kinetic coefficients, and mineral price) and scale-up models may be subject to various levels of uncertainty with unspecified statistical distributions. This uncertainty often leads to ambiguity in the design and optimization process, as certain solutions may only be optimal under specific input scenarios. One promising strategy to address this shortcoming is through robust optimization (RO), a unique approach to handling uncertainty that has been widely applied in other disciplines such as supply chain management. In the current work, RO is applied to the design and techno-economic optimization of a mineral flotation circuit. This application example uses ambiguous distributions for several input factors, and RO is used to determine the optimal size, number, and configuration of flotation cells, under different degrees of risk tolerance. These final robust solutions are computed and compared with the original deterministic solution.

TUESDAY, FEBRUARY 27

AFTERNOON

2:00 PM | ROOM 200DE

MPD: Hydrometallurgy I

Chairs: *R. Gow, FLSmidth USA Inc. – Salt Lake City Operations, Midvale, UT*
J. Lee, University of Arizona, Tucson, AZ

2:00 PM
Introduction

2:05 PM
Trona-Lime Buffering, a Possible Solution to Direct Heap Leaching of Sulfide Gold Ores

R. Buffington[2] and R. Bowell[1]; [1]SRK Consulting, Cardiff, UK and [2]Hycroft Mining, Reno, NV

Heap leaching of Au-bearing sulfide ore has many challenges. Maintaining Au in solution requires a pH of 9.9-10.4. If too high, Ca-and Fe-minerals form; too low then Au-CN will not form. Sulfides oxidize and produce acid. More lime is required to compensate. Caustic soda is a short term method, but this can precipitate mineral solids that choke irrigation lines and flowpaths. In a trona-lime neutralizing system, the barren cyanide solution sent to the heap will contain cyanide species and essentially a CO_3^{2-} - HCO_3^- solution where the CO_3^{2-} to HCO_3^- ratio is 1. This ratio will ensure a pH of 10.3 due to the bicarbonate-carbonate buffer formed naturally by Na_2CO_3-$NaHCO_3$. As the trona in solution neutralizes acid in the heap, a portion of the CO_3^{2-} will be converted to HCO_3^- that changes the ratio. The pH change will be controlled by the CO_3^{2-} - HCO_3^- buffer, assuming excess trona. Prior to barren solution return to the heap, the ratio of CO_3^{2-} to HCO_3^- can be restored to 1 by adding hydrated lime. Hydroxide reacts with HCO_3^- to convert it to CO_3^{2}, and Ca removes SO_4^{2-} and CO_3^{2-}.

2:25 PM
Investigating the Effects of Temperature, Power Outages, Cobalt and Manganese Concentrations on the Current Efficiencies in Copper Electrowinning Using Long Term Benchscale Systems

C. Abbey and M. Moats; Material Science and Engineering, Missouri University of Science and Technology, Rolla, MO

A benchscale anode corrosion testing facility was used to run 16 L of electrolytes at 150 mL/min for 28 days to measure current efficiency and anode corrosion rates. The cells were run at 380 A/m^2 and made up of two Pb-Ca-Sn anodes and three copper starter sheet cathodes per cell. The base electrolytes contained 40 g/L Cu, 20 mg/L Cl, 1.2 g/L Fe and 180 g/L sulfuric acid and 0.6 g/day of DXGF 7 was added twice daily to help produce smooth cathodes and reduce the risk of short circuits. The effect of 150 mg/L and 600 mg/L Co, 50 mg/L and 600 mg/L Mn and 35 and 45 ^{0}C temperatures were investigated. The effect of 6 hours per day, three days per week power outages were also investigated. Solution samples were analysed daily and controlled at the set points. The measurements made showed that 28 days was not sufficient to generate reliable corrosion data, current efficiency (CE) was observed to decrease with increasing temperature, increase with increasing Mn concentration and decrease with increasing Co concentration. The power outages decreased CE.

2:45 PM
Improvements in Mass Transfer by Sparge System Design Optimization for Minerals Processing

R. Kehn[1], A. Iniguez[1] and R. Kehn[2]; [1]Application Engineering, SPX FLOW, Inc., Rochester, NY and [2]Director of Engineering for Mixers, SPX FLOW, Inc., Rochester, NY

As the commodity and precious metals markets continue to struggle worldwide, process improvements become a necessity in order to keep operations profitable. Fluid mixing equipment is no exception to this trend. Mixers used in minerals processing often require the suspension of solids in combination with gas dispersion and mass transfer. Some examples of these types of gas-liquid applications include cyanide destruction, leach tanks, biological leaching, neutralization, and pre-aeration, among others. Gas is typically injected in a tank through a sparge system. Improvements in mass transfer can translate into potential operational savings, making the optimization of the sparge system crucial to maximize yield. The purpose of this study is to analyze the differences in mass transfer coefficient versus the sparge system design. Experimental testing was performed at atmospheric pressure in an open tank with a water-air system and single axial flow impeller at a scale large enough to reliably measure mass transfer differences.

3:05 PM
Cu SX Best Practices for Processing of Concentrate Leach Liquors

T. Ratnaweera[2], B. Wellbrook[2] and T. McCallum[1]; [1]Solvay, Tempe, AZ and [2]Freeport-McMoRan Inc., Morenci, AZ

Pressure oxidation (POX) leaching of Cu concentrates continues to be explored as the next generation of leaching processes to sustain existing Cu SX/EW operations as easily leachable ores become scarcer. The leach liquors produced, particularly from total pressure oxidation, contain high concentrations of Cu and acid making solvent extraction processing more challenging. This will require innovative processing techniques and continuous improvement to be successful in achieving satisfactory physical and metallurgical performance in the SX plant. The ability to efficiently process these feeds via SX has an important role in the continued success of POX technology. Dilution within existing heap leach inventories, SX configuration optimization, and auxiliary equipment usage allows efficient processing with current commercial SX extractants. Characteristics of a concentrate leach PLS are discussed along with best practices that should be considered for processing by solvent extraction. The findings are expected to reduce process risk and bring additional improvement to the industry with minimal change to the solvent extraction plant.

3:25 PM
Low Temperature Ionic liquids Process for Production of Zn from ZnO

A. Liu, H. Yang and R. Reddy; Met. Matls. Eng., The University of Alabama, Tuscaloosa, AL

A novel pathway for the high energy efficiency electrodeposition of metals from metal oxides and metal compounds by means of electrolysis in ionic liquids at low temperature was investigated. Experimental results for electrochemical deposition of Zn from ZnO using Urea ($(NH_2)_2CO$) and Choline chloride ($HOC_2H_4N(CH_3)_3^+Cl^-$) or (ChCl) are discussed. The results showed that pure Znmetal was deposited on the cathode. Successful deposition of metal from metal oxide dissolved in Urea/ChCl (2:1) was accomplished with efficiency greater than 87%. The advantages of the electrodeposition of metals using ionic liquids compared to industrial aqueous metals processes are low temperature, low energy consumption, and low pollutant emissions.

3:45 PM
Selective Precipitation of Rare Earth Elements from Leachates Generated from Coarse Coal Refuse

W. Zhang and R. Honaker; Mining Engineering, University of Kentucky, Lexington, KY

To evaluate the feasibility of using heap leaching processes for recovering rare earth elements (REEs) from coarse coal refuse, a preliminary study

was conducted involving the selective precipitation of REEs from leachates emanating from six different refuse sources having a relatively high pyrite content. The pH values and REE concentrations of the leachates were in the range of 2.47-3.55 and 0.67 – 6.71 ppm, respectively. In addition, the critical REEs (Y, Nd, Eu, Tb and Dy) represented approximately 50% of the total REEs, which was much higher than contents of the original coarse refuse solids material. Selective precipitation test results indicated that REEs were preferentially precipitated from the leachates in the pH range of about 5.5 to 6.5. Precipitates containing 1.1% total REEs were obtained with a heavy-to-light REE ratio of 1.54 compared to a value of 0.20 in the original reject solid material.

4:05 PM

Total Recycling of Spent Auto-Catalyst Using Akaline Roasting and Sulfuric Acid Dissolution

H. Trinh[2], J. Lee[1], R. Srivastava[3] and S. Kim[1]; [1]Mineral Resources Research Div.,, Korea Institute of Geoscience and Mineral Resources (KIGAM), Daejeon, Korea (the Republic of); [2]Resources Recycling Engineering, Korea University of Science and Technology (UST), Daejeon, Korea (the Republic of) and [3]TAE-HYUNG Recycling, Gyeongsangbuk-do, Korea (the Republic of)

Spent auto-catalyst is a potential secondary resource because of the higher concentration of valuable platinum group metals (PGMs) as compared to the primary ores. It is critical to recycle not only the PGMs but also other metals contained in the cordierite substrate of spent auto-catalyst such as aluminum, magnesium and cerium oxide (CeO_2). This is particularly important as no recycling process has stressed upon the recovery of cordierite substrate and CeO_2 since the main target metals are mostly the PGMs. In this study, a new hydrometallurgical approach has been proposed in order to recover the PGMs as well as cerium oxide and materials from the cordierite substrate by using sodium hydroxide roasting followed by hot sulfuric acid dissloution and cementation. Under the optimal conditions for roasting at above 600°C, and weight ratio of sample to NaOH of 1:1 for 60 min, the cordierite was converted to the soluble phases. Dissolution of the roasting products under a suitable conditions using hot H_2SO_4 enriched the PGMs and Ce contents in the residue, which can be subsequently recovered by leaching-cementation method.

TUESDAY, FEBRUARY 27

AFTERNOON

2:00 PM | ROOM L100I

Tools and Technologies that Can Support Your Cyber Journey

Chair: *J. Faxon, Newmont C.Dooley*

2:00 PM

Introduction

2:05 PM

Lessons Learned: Building a Cyber Security Program Across a Converged Technical Environment

J. Faxon; Newmont, Greenwood Village, CO

Businesses with industrial automation needs are discovering significant value in adoption of information technology (IT) solutions to improve their operations. However, those benefits create challenges and risk(s) for both IT and Operating Technology (OT) environments. The most visible challenge is convergence. Where is the line of separation between IT and OT systems, networks, standards and governance? A key requirement for protecting OT environments from cyber-attacks is protecting the automated systems used to monitor and control critical processes. In the modern OT realm, automation should provide a consistent way of executing tasks and processes similar to information technology environments AND these systems need to be secure – this is no straight forward task This session will provide insights from security leaders working in mining companies that are working to answer these questions. They will share challenges and lessons learned gained during their journey and provide you insights about things to consider when your company asks the question; what is our plan to address cyber security risk across our operating technology platforms?

TUESDAY, FEBRUARY 27

AFTERNOON

2:00 PM | ROOM 101G

UCA of SME: Tunnels

Chair: *J. Rostami, Colorado School of Mines, Golden, CO*

2:00 PM

Introduction

2:05 PM

Three-dimensional Numerical Modeling of Tunnel Stability in an Underground Mine in the USA

Y. XING[1], P. Kulatilake[1] and L. Sandbak[2]; [1]Mining and Geological Engineering, The University of Arizona, Tucson, AZ and [2]Barrick Gold Corporation, Winnemucca, NV

Tunnel stability in an underground mine in the USA was investigated using the distinct element code 3DEC. The three-dimensional model incorporated the large-scale persistent and non-persistent faults, a non-planar dike layer, and a complex tunnel system which included both the open and backfilled tunnels. The sequential excavation, backfilling and supporting were simulated as they were implemented in the field. Additionally, a novel routine based on the stress relaxation method was invoked to simulate the delayed installation of supports. The properties of rock masses were estimated using empirical equations based on the intact rock properties and the RMR values, and the strain softening behavior was prescribed for the rock masses. For faults, the linear relations between the joint stiffnesses and normal stress obtained from laboratory tests were numerically simulated using the continuously yielding joint model. Numerical results are presented through the rock mass stresses, displacements, failure zones, the shear displacement of the major fault, and the support failure condition. Good agreements were obtained between the numerical modeling results and the field measurements.

2:25 PM

Roadheader Performance Monitoring at Barrick Cortez – Range Front Declines

R. Thareja[1], M. Belderrain[1] and D. Schumacher[2]; [1]Mining and Tunneling Division, Drill Tech Drilling and Shoring, Antioch, CA and [2]Cortez Hills Underground Mine, Barrick Gold, Crescent Valley, NV

East decline – 8100' long and West decline – 7200' long are being excavated mechanically by a Sandvik MH620 Roadheader at Barrick Cortez Underground mine to connect to level 3950 and expand to deeper ore zones in the near future. Drill Tech Drilling and Shoring was awarded the contract

in June 2016 for the excavation of twin declines. The excavation of the declines started September 2016 and this study summarizes roadheader performance in varying ground types over the last 6500' of excavation with the roadheader. Performance parameters discussed include RMR, pick consumption, cutting rates, cutting times and cubic yards excavated. This study summarizes lessons learned over the last year of mining with the roadheader in hard rock discussing key advantages and disadvantages of mechanical cutting with a roadheader vs conventional drill and blast in Nevada ground. Picks per foot and picks per cubic yards have been discussed with varying ground types to help evaluate use of roadheader for future mining activities. Lastly, and most importantly this project maintains a triple-zero safety standing to date – going home safe and healthy every day is our goal.

2:45 PM

Tunnelling Methodology Selection Based on Independent Risk Assessment

S. Saki; Tunneling, Aldea Services LLC, Frederick, MD

There are greater risks involved in tunneling when compared to other infrastructure projects since there is limited knowledge about the ground conditions and behavior ahead of the tunnel face. Risk assessment and management is essential for successful completion of any tunnelling project. Risk analysis approach can be used to compare the risks of a single large diameter tunnel versus two smaller twin tunnels and all the resultant impacts stemming from each option. The quantification of both alternatives' risks impacts with respect to time and cost can help to determine the optimum option. The risks are identified and characterized for tunneling project using a level of detail and precision sufficient to meet the decision-making objectives. This paper describes the process used to come-up with a comprehensive decision-making basis using comparative risk profiles of two tunneling alternatives.

3:05 PM

Innovative Full-face Approach in the Conventional Tunnel Excavation: Methodology and Advantages

M. Invernizzi[1] and P. Asadollahi[2]; [1]Technical, ALPI Engineering LLC, Austin, TX and [2]Technical, Principal, Washington, DC

The paper describes the innovative full-face conventional tunnel excavation technology, for primary and secondary access tunnels, with its advantages in terms of savings and safety. The full-face approach has been developed throughout the experiences gained in tunnel construction. The innovative design approach is focused primarily on the deformation response of the ground acting first and foremost ahead of the face, which is analyzed, predicted and controlled by pre-confinement of the core. The advantage of this method is particularly evident in difficult grounds. This paper will present the outstanding benefits given by the adoption of the full-face approach.

3:25 PM

Assessment of Rock Strength from Scratch Testing

E. Detournay; University of Minnesota, Minneapolis, MN

The uniaxial compressive strength (UCS) is the most common measure of strength used in civil, mining, and petroleum engineering, with applications ranging from the design of underground structures in rocks to the selection of tools for mechanical excavation. The procedure to determine the UCS has been standardized by the ASTM and the ISRM. The scope of this paper stems from an effort initiated at the University of Minnesota (UMN) in the mid-nineties to build a scientific apparatus to study the cutting action of a single cutter in order to assess the dependence of the cutting force on the rock mechanical properties and on the UCS, in particular. In this paper, we first review basic aspects of the mechanics of rock cutting, with considerations given to the ductile and the brittle regimes, and to the influence of a wear flat on the magnitude of the cutting force. We then describe the rock strength device, as well as the test methodology. Finally, we produce compelling evidence that under conditions referred to as the ductile regime, the specific energy of cutting is well correlated with the UCS.

TUESDAY, FEBRUARY 27

AFTERNOON

2:00 PM | ROOM L100J

Valuation Session II: Lessons Learned and Fundamental Issues

Chairs: *B. Groff, Groff Engineering & Consulting LLC*
T. Knobloch, AIMA, Marietta, OH

2:00 PM

Introduction

2:05 PM

Get Help with Your Secret Valuation Fears! A Panel Discussion

J. Gustavson; Mineral Appraiser LLC, Boulder, CO

We are trying a NEW CONCEPT: We have gathered a Panel to answer all your secret mineral valuation fears! And it will be CONFIDENTIAL! Your questions, that is! As the Moderator I have sworn total secrecy and have invited a large group of mineral appraisers to submit their most worrisome questions and fears under which they labor when appraising mineral assets! The subjects will not be traced back to anyone (just in case the appraiser, who popped the question, wrote a forensic testimony on that particular problem!) The questions have been sorted and a Panel of our peers has been assembled to discuss and answer, if not all, then most of the questions. We thus have 4 Panelists plus me, John Gustavson as the Moderator. Each Panelist will kick off with an introductory commentary (4-5 minutes) based on his/her understanding and view on each nagging subject. Many are troublesome, so the discussion promises to be lively. The difficult questions span the realms of REGULATIONS, STANDARDS, REPORT REQUIREMENTS, HIGHEST & BEST USE, SALES COMPARISON, DISCOUNT RATES, ETHICS AND MORE.

2:25 PM

Desktop Data Evaluation and Qualifications for Coal Reserve Estimation and Valuation

D. Lumm; ECSI, Lexington, KY

Desktop studies and summary reports of coal reserve tonnage estimates prepared by geologists and mining engineers are typically used by mineral appraisers to prepare a subsequent, independent appraisal report for a subject property. Although the mineral appraiser may himself be an established professional geologist or mining engineer, there is often a disconnect in the use and application of the reserve report for producing a mineral valuation. For example, the "reserve report" may not completely conform to SEC or CIRIRSCO guidelines and instead be purposed for obtaining a lease or mine permit on a property, for extending the life of a mine property, or for reasons other than banking or investment. Moreover, the tonnage estimates may be based upon thickness modeling and mapping sourced from incomplete, inaccurate, or unverifiable borehole or coal quality data. The mineral appraiser should thus have a firm understanding of the data and methodology used in the tonnage estimates, and should question or reject the tonnage estimates from these reports. This presentation will review the qualifications of desktop data for use in coal reseve reports and some of the guidelines in reporting.

2:45 PM

Pricing Strategies for Mine Property Valuation: Example for Potash Property

D. Hambley; Agapito Associates, Inc., Lakewood, CO

When valuing a producing property on the basis of the value of the mineral reserves or a property under development by means of an economic study,

the choice of selling price can significantly alter the value of the property. Spot prices for metals and minerals can fluctuate, sometimes quite significantly, over relatively short periods so that the selection of a realistic price or price trend for a property with an expected long life is thus open to some uncertainty. The US Securities and Exchange Commission (SEC) recommends the use of a three-year, or more recently, two-year trailing average. In a market where the price has been consistently falling over several years, such a practice will tend to overvalue a property. Conversely, if a level or declining trend has been followed by a recent surge in the price, use of a trailing average may seriously undervalue a property. Use of a current price has similar drawbacks since the price can either rise or fall in the future. This paper will examine the effect of various pricing strategies on the value of a hypothetical potash mine selling fob Vancouver.

3:05 PM

Impact of Adverse Environmental Conditions on Mineral Property Appraisals

E. Mudd; Independent, Overland Park, KS

Adverse environmental conditions such as soil and water contamination can significantly impair a mineral property. In some cases, the cost of cleanup is proportionally insignificant to overall project value, and no adjustment by the appraiser is necessary. In other cases, once the full nature and extent of cleanup has been determined, the possibility of developing the mineral may simply evaporate, leaving only a liability behind. This paper examines several environmental impairments common to the mining industry and summarizes the extent to which those conditions impact property value. Investment risks and incentives, assumptions of liability, and character of transactions are discussed to provide a framework for analyzing environmental impairments as they relate specifically to mineral properties.

3:25 PM

Effective Use of Geographic Information Systems to Aid the Minerals Appraiser

B. Groff; Groff Engineering & Consulting LLC, Mt. Sterling, KY

Valuation of a surface mineable solid mineral deposit is often a straight forward task, but a significant amount of research must be performed to fully understand the past history of each one. In the U.S. today, the availability of a vast library of public data for use in geographic information systems (GIS) makes the historical research easier, but this data is often difficult to access by those with little or no GIS experience. This presentation will look at two sand & gravel deposits as case studies for how GIS data may be used to aid the appraisal process and avoid errors.

WEDNESDAY, FEBRUARY 28

MORNING

9:00 AM I ROOM 200ABC

6th North American Iron Ore Symposium: Beneficiation

Chair: *B. Eisenbraun, Barr Engineering*

9:00 AM

Introduction

9:05 AM

Assesment of the Avantages and Limitations of the Reflux Classifier for Iron Ore Beneficiation

D. Amariei[1], N. Hamzeh[2] and G. Gagnon[3]; [1]Physical Separation, COREM, Quebec, QC, Canada; [2]Iron Ore Company of Canada, Labrador City, NL, Canada and [3]ArcelorMittal Exploitation Minière, Mont-Wright, QC, Canada

The Reflux Classifier (RC) is a relatively new technology mainly used in the coal and industrial minerals industries. It uses three separation mechanisms: hindered settling, autogenous dense medium and lamella settling. Given the good results obtained at pilot (RC™300) and laboratory scale (RC™100) for iron ore fine particles recovery, the advantages and limitations of this technology were assessed for iron ore beneficiation. The paper summarizes the performances of the Reflux Classifier for two streams: spiral rougher concentrate and tail. The test work metallurgical results are supported by mineralogical characterization using a Mineral Liberation Analyzer (MLA) and benchmarked against sink-float tests.

9:25 AM

Reagents and Flotation Circuits Used in Iron Ore Beneficiation

R. Silva and F. Fernandes Pinto; Mining, Clariant, Tucson, AZ

This paper reviews the flotation circuits and reagents that have been used to treat hematite and magnetite iron ores. US iron ore mining is dominated by the Taconite Precambrian Banded Iron Formation deposits around Lake Superiorin Minnesota and Michigan. High grade hematite iron ore bodies are found in large deposits in Brazil, South Africa, India and Australia. The criteria to select the most suitable equipment, reagents and configuration for a flotation circuit include a series of parameters, such as size distribution, throughput, flotation kinetics, mineralogy, degree of liberation, etc. Examples involving conventional mechanical cells, flotation cells (high volume round tanks) and column flotation, as well as hybrid circuits, are discussed. Reagents are an important piece of the puzzle when defining a flotation circuit. This paper discusses the different types of flotation circuits classified by the type of reagent package. The most common alternatives are summarized below: Reverse cationic flotation of quartz Reverse anionic flotation of activated quartz Direct anionic flotation of iron oxides Additionally, optimization of the reagents scheme is also discussed.

9:45 AM

New Tools for Process Monitoring of Iron Ore Sinter and Dri Production Using X-ray Diffraction (XRD)

U. König and N. Norberg; Product Marketing, PANalytical B.V., Almelo, Netherlands

The use of high speed detectors made X-ray diffraction (XRD) become an important tool for process control in mining and metal industries. Decreasing ore qualities and increasing prices for raw materials require a better control of processed ore and a more efficient use of energy. Traditionally quality control of iron ore sinter and DRI has relied on time consuming wet chemistry. The mineralogical composition that defines the physical properties such as hardness or reducibility is not monitored. XRD analysis in combination with Rietveld quantification and statistical data evaluation using Partial Least-Square Regression (PLSR) has been successfully established to determine the mineralogical composition and the Fe^{2+} content of iron ore sinter within an analysis time of less than 10 minutes per sample. Both methods take the full XRD pattern into account and can be simultaneously applied on the same measurement. PLSR was found to be the more robust method if only Fe^{2+} results are required. The Rietveld method helps to predict other parameters such as the compressional strength of the sinter by monitoring all existing phases (e.g. larnite C_2S or SFCA-phases).

10:05 AM

Leveraging Upgraded Technology to Accelerate Throughput, Extract Value from Waste and Reduce Solid Waste Generation During Iron Ore Beneficiation in Tata Steel Mines

V. Banty; Tata Steel Limited, Joda, Odisha, India

In Tata Steel mines, Iron ore is processed through wet and dry processing plants. In wet processing, existing circuit produces product mix of siz-

es lumps(+10/-40mm) and fines(-10mm). During processing, significant amount of ores were being lost as slime(~45-53% Fe content and ~25% of ROM). Conventional hydrocyclone(HC) was being used in the circuit for processing of 100% slime before discharging it into slime dam but due to system inefficiency, only 60% of slime generated was being routing through HC.Also, the existing HC circuit was generating 26% slime annually. Decreasing hard ore reserves in mines were resulting in higher fines % in feed mix and increased fines% in feed resulting in higher slime losses for same level of production. Increased slime loss was resulting in higher solid particle discharge into the dam affecting Enviornment and creating future dam space constraint. Basis flow circuit study and analyses, Old HC re-arranged with HC cluster and distributor and screw classifier replaced with advanced and technologically efficient HC screen with new conveyor. The change in circuit and new screen improved solid recovery from HC circuit and slime loss recovery by 9% and as low as by13%

10:25 AM

Application of Database and Process Simulations in Plant Design and Process Optimisation of Comminution Circuits

J. Tian; CITIC SMCC Process Technology, Brisbane, QLD, Australia

Modelling and simulations of comminution circuits have become more essential tools in all stages of project development and operations in greenfield or brownfield mining projects. CITIC SMCC Process Technology has developed a comprehensive system called CM-DOCC® for the design and optimization of comminution circuits, which is primarily based on the Morrell Method, one of the best practice methodology well applied by the mining industry over the past two decades. Through some work examples or case studies, the paper will describe some key steps in the optimization study for brownfield projects or new plant design, which include the design data analysis, determination of SAG or AG mill feed size, selection of mill geometry influenced by various parameters or plant design criteria such as mill aspect ratio, stockpile design as well as energy efficiency of different circuits, and the role of other factors such as capital cost and operating cost during a trade-off study. Benchmarking and validation of CM-DOCC® simulations using the CITIC SMCC's database during the study steps will be discussed.

10:45 AM

Process for Increasing Iron Recovery with Oxidized Iron Ores – an Update

T. Petersen; UMD- Natural Resource Research Institute, Duluth, MN

The Natural Resources Research Institute (NRRI) is evaluating a means to reduce iron mining costs by maximizing iron recovery from current taconite operations and other potential oxidized iron resources. A new innovative process flowsheet has shown significant potential to increase weight recovery and/or concentrate grade on numerous iron ore samples containing oxidized iron minerals. The ongoing work is focused on demonstrating the new processing techniques on the various oxidized and semi-oxidized taconites in the western end of Minnesota's Mesabi Iron Range with pilot plant test work.

WEDNESDAY, FEBRUARY 28

MORNING

9:00 AM | ROOM L100E

Coal & Energy: Coal Mine Reclamation II

Chairs: *T. Gray, Tetra Tech, Pittsburgh, PA*
M. Korb, Tetra Tech, Inc, Wapwallopen, PA

9:00 AM

Introduction

9:05 AM

Natural Zeolite-Based Water Treatment Process for Uranium Removal

D. Shay[2] and D. Eyde[1]; [1]St Cloud Mining, Tucson, AZ and [2]Rimcon, LLC, Rapid City, SD

The Rimcon treatment process utilizing natural zeolites was developed for the removal of uranium from contaminated water sources. The process was field tested for several years at a New Mexico uranium mill super fund site. Water treated at the site is pumped from contaminated aguifer under and near a large uranium tailings pile. The zeolite was the St Cloud Clinoptilolite in 14x40 (1x.5mm) granules. This material has calcium and potassium in the exchange sites, as wll as a high surface charge density. The media is NSF 61 certified for water treatment applications. The process uses sulfuric, or other acids, to alter the pH of the contaminated feed water prior to treatment with the zeolite. And, the process has been field tested at flow rates from 5 to 1200 gpm treating groundwater contaminated with uranium concentrations of up to 10 mg/L, reducing the contanation to non-detect levels. A successful 300 gpm pilot zeolite treatment system led to the construction of a full scale1200 gpm capacity bringing the total treatment capacity to 1500 gpm. The Rimcon system utilized 6000 tons of SCM clinoptilolite. Operational costs range from $1.25 to $2.00 per 1000 gallons of treated water.

9:25 AM

New Application of Direction Drilling and Gas Enhanced Foam for Suppression of Abandoned Underground Coal Mine Fires

M. Trevits[1] and A. Ozment[2]; [1]Xtraction Science and Technology, Inc, Pittsburgh, PA and [2]Fire Solutions, Inc., Longview, TX

According to the Office of Surface Mining Reclamation and Enforcement, in 2013 there were 98 underground mine fires burning in 9 states. This is considered by experts to be an underestimate of the actual number of nationwide fires. Fire Solutions, Inc. has been investigating the use of gas-enhanced foam with directional drilling technology for use on mine fires. Gas-enhanced foam has the advantage of using less water and uses inert nitrogen gas to displace oxygen and it is designed to blanket, infiltrate and suppress a fire. Directional drilling can steer a borehole to a specific place underground. Directional drilling has many advantages over conventional drilling technology because it causes the least disruption to the ground surface (minimizing preparation costs), multiple underground sites can be accessed from a single site and be treated simultaneously and it offers increased efficiency because it is not constrained by difficult terrain. This paper discusses the use of these technologies and provides three demonstration case studies. It is hoped that the combined use of gas-enhanced foam and directional drilling will significantly improve our ability to address mine fires.

9:45 AM

Integrating 3D/2D Shallow High-resolution Seismic and 3D Borehole Imaging, InSAR, and Historic Geologic and Map Data: Advancements in Subsurface Void Detection, Site Characterization, and Remedial Design, Wyoming USA

J. Turner, J. Nuttall and D. O'Connell; MMI, Tetra Tech, Golden, CO

Active-source swept frequency vibratory 3D seismic data and 2D seismic data were aquired across Wyoming at sites where shallow abandoned mine workings pose ongoing risks to roads, buildings, and critical infrastructure. 2D seismic data can improve the design site investigations and inform design of remediation efforts. However, abandoned coal mines are often complex 3D architectures with multiple mine levels within a single footprint. In more complex cases, 3D seismic is much preferred and can potentially image open mine voids on multiple levels. Integration of finite-frequency first-arrival Vp tomography, reflection, group velocity analysis, and relative amplitude processing helped to delineate voids and collapse zones up to ~180 feet. A custom, modular, integrated acquisition design combined with multiple processing approaches is able to adapt to a range of subsurface conditions. Seismic survey targets are based on historic mine maps, borehole data, LiDAR and satellite imagery, and geomorphic features. This integrated void characterization approach is applicable to all shallow voids, e.g. karst, hard rock mines, and to locate open subsurface infrastructure.

10:05 AM

Mather a Coal Mining Town, Greene Co. PA

D. Baker; BAMR, Ebensburg, PA

Mather is located in Greene County Pa which is in the heart of bituminous coal mining in the state. Mather Colliery Mine opened in 1917 and was abandoned in 1964. One of the deadliest U. S. mine disasters of all time occurred at the mine in 1928. It claimed the lives of 195 miners. 47 years of underground mining was a coal refuse pile that spanned approximately 70 acres, contained an estimated 6.2 million cy of refuse, 170 ft thick. The pile is located in Mather, with fifteen inhabitable structures located within 500 feet of it. Over the years since the abandonment, several reclamation projects were completed. Some removed of a portion of the pile and the re-grading and re-vegetation of approximately 27 acres of the site. To eliminate the hazards associated with the pile, the DEP partnered with the DCNR to dredge and transport approximately 252,000 cy of material to cap the pile so permanent vegetation could be established. The cooperative effort between the two state agencies resulted in a successful refuse pile re-vegetation project and eliminated the hazards posed by the instability of the pile.

WEDNESDAY, FEBRUARY 28

MORNING

9:00 AM | ROOM L100D

Coal & Energy: Dust Control II

Chair: *R. Reed, NIOSH, Pittsburgh, PA*

9:00 AM

Introduction

9:05 AM

CFD Modeling and Experimental Analysis of a Non-Clogging Screen for Flooded-Bed Dust Scrubbers for Continuous Miners

O. Velasquez, A. Kumar and W. Wedding; Department of Mining Engineering, University of Kentucky, Lexington, KY

Continuous miners deployed underground usually have an integrated flooded-bed dust scrubber that arrests the generated dust from close to the face and cleanses the air around it. However, the impingement screen gets clogged as particles aggregate on the fibers in the screen. This reduces the airflow quantity through the scrubber thereby influencing the effectiveness of the face ventilation arrangement. A novel non-clogging screen has been developed at the Department of Mining Engineering, University of Kentucky. The proposed impingement screen is built up of three individual sheet metal panels measuring 1.5 mm thick and separated by 6 mm. The screens have regularly spaced arrangement of long vertical slits measuring 6 mm. The combination of panels forces the dust laden air to make sharp turns. The heavier dust particles cannot change directions rapidly and are separated out based on their momentum. Water sprays continuously on the screen keeping it wetted and provides for the filter element to arrest the dust particles. Preliminary results indicated by CFD models and supported by laboratory experiments have been discussed in this paper.

9:25 AM

Simulation of Particle-Droplet Interaction to Predict Dust Control Efficiency of Spray Systems

J. Swanson[1] and C. Negoita[2]; [1]Magdeburg-Stendal University of Applied Sciences, Magdeburg, Germany and [2]Oregon Institute of Technology, Klamath Falls, OR

Water spray systems used for dust control in mining are typically selected without regard to the specific application and environmental conditions. Incorporating a detailed understanding of the relative sizes of the water droplets and dust particles, as well as their relative speeds, concentrations and properties combined with the interaction environment, the quality of a dust control spray system can be simulated. This is done primarily through the development of a mathematical model based on the momentum equations and the Navier-Stokes equations for flow around a water droplet in a two-phase flow. Implementing a numerical solution to this system, different path-lines of dust particles and collision with water droplets can be simulated for different spray systems. The outcome of the simulation can then be validated with experimental spray efficiency data from a wind tunnel. Finally, the model is used to simulate the capture efficiency of a specific nozzle and application and provide the engineer with simple spray nozzle selection criteria based upon known information would provide for a better use of resources and best possible dust control for a specific mining operation.

9:45 AM

Computational Fluid Dynamics (CFD) Modeling of an Appropriately Sized Vortecone Scrubber System for Installation on Continuous Miners

A. Kumar, W. Wedding and O. Velasquez; Department of Mining Engineering, University of Kentucky, Lexington, KY

To cleanse the air from close to an active underground coal mining face, continuous miners are often equipped with a flooded-bed dust scrubbers. However, the screen is prone to clogging due to an accumulation of dust, thereby lowering the flow through the scrubber and, potentially exposing the mine workers to higher levels of dust. Although fans are able to compensate by varying their operating parameters to some extent, the scrubber screen needs significant maintenance which leads to downtime. The ventilation research team at the University of Kentucky has proposed a Vortecone as an alternative for the flooded-bed dust scrubber system. Water is used as the filter medium, which is replaced and recycled continuously. Frequent idling of machine is ruled out and a steady airflow could be realized. Preliminary CFD investigations of Vortecone scrubbers have indicated higher cleaning efficacies, especially in the respirable range. This paper presents results including the flow characteristics and capture efficacies of a full-scale Vortecone. Multi-phase flows, including free-surface modeling methods, have been adopted.

10:05 AM

Effects of Air-blocking Shelf on Dust Dispersion for Drill Shroud Using Computational Fluid Dynamics

Y. Zheng[1], R. Reed[1], J. Potts[1], M. Li[2] and J. Rider[1]; [1]Dust, Ventilation and Toxic Substances Branch, National Institute for Occupational Safety and Health, Pittsburgh, PA and [2]NIOSH, Fires and Explosions Branch, Pittsburgh, PA

The National Institute for Occupational Safety and Health (NIOSH) Pittsburgh Mining Research Division (PMRD) has recently developed a series of validated models utilizing computational fluid dynamics (CFD) to study the effects of air-blocking shelf on airflows and respirable dust distribution associated with a medium-sized surface blasthole drill shroud with a dry dust collector system. Using these previously validated CFD models, three different air-blocking shelves were included in this study: 15.2 cm (6 in.) wide at one level; 7.6 cm (3 in.) wide at one level; and 7.6 cm (3 in.) wide at four levels. In addition, 1.75:1, 1.5:1, 1.25:1 and 1:1 dust collector-to-bailing airflow ratios were evaluated for the 15.2 cm (6 in.) wide at one level air-blocking shelf. This paper describes the methodology used to develop the CFD models. Effects of air-blocking shelf and dust collector-to-bailing airflow ratios were identified by the study and problem regions were revealed under certain conditions. The simulation results could be used for future development of dust control methods for a surface mine blasthole drill shroud.

10:25 AM

Guidelines for Selecting the Right Dust Suppression

J. Brown; Management, Quaker Chemical, Louisville, KY

In today's business environment it is critical to operate safer, more efficiently, and with a greater focus on the environment around us. The generation of dust is an unavoidable consequence of our operational activities and one that can impact onsite safety, health, and production among many other concerns. There are several ways to treat fugitive dust emissions but they do not come in a "one size fits all" solution. As regulations increasingly become more stringent it is imperative that operators know the options available and how to properly select for their specific site. What are the various dust suppression options available and how should an operation choose what means to employ? Ways to Suppress Dust: Preventative Measures Mechanical Water Spray/Dry Fog Systems Chemical Suppressants Re-vegetation/Reclamation I will briefly touch on the various ways to prevent and/or control dust emissions, along with the pros and cons for the various methodologies.

10:45 AM

A Ranking of Dust Suppressants Under Different Atmospheric Temperatures to Control Fugitive Dust Generated from Mine Haul Roads

D. Omane, W. Liu and Y. Pourrahimian; School of Mining and Petroleum Engineering, University of Alberta, Edmonton, AB, Canada

Fugitive dust generated from mine haul roads poses a severe threat to workers, traffic, and equipment on mine sites. To effectively control fugitive dust, dust suppressants are often recommended to reduce these emissions, but the influence of atmospheric temperatures on dust suppressants over time have not been systematically studied yet. The aim of this research is to investigate the role of different atmosphere temperatures on the effectiveness of various dust suppressants. In this study, water and four typical dust surfactants—salt, chloride free agents, polymers, and molasses—were tested experimentally for their dust retention efficiency under atmosphere temperatures of 35°C (hot), 15°C (normal), and -19°C (cold), respectively, within a time frame of 72 hours. It is found that atmospheric temperatures have significant impacts on the dust retention efficiency of suppressants. In summary, a preliminary ranking chart of the suppressants has been provided regarding the atmospheric temperatures, dust retention efficiency, application frequency, costs, and potential environmental impacts.

11:05 AM

Comparison of Sub- and Supra-micron Dust Particle Characteristics in Eight Appalachian Coal Mines

C. Keles, V. Johann and E. Sarver; Virginia Tech, Blacksburg, VA

In the US and elsewhere, respirable dust in coal mines is primarily regulated on the basis of total mass concentration and mass fraction of crystalline silica – and, accordingly, much of what is known about coal mine dust has been learned from tracking these metrics. However, recent upticks in the apparent incidence of occupational lung diseases, including the most severe and rapidly progressing forms of disease, suggest that a more comprehensive understanding of dust exposures is needed. In particular, an understanding of dust particle characteristics such as size, shape and mineralogy may provide important insights to health outcomes, as well as targeted dust control strategies in the mine environment. Previous work has focused characterizing dust in the supramicron range, but an increasing body of evidence suggests that submicron particles may yield even more detrimental effects on lung tissue. Here, we present and compare respirable dust particle characteristics across the sub- to supra-micron range (i.e., about 0.1-10 um), on a set of samples collected in eight Appalachian coal mines. Analysis was done using scanning electron microscopy with energy dispersive x-ray (SEM-EDX).

WEDNESDAY, FEBRUARY 28

MORNING

9:00 AM | ROOM L100C

Coal & Energy: Research and Development-II

Chairs: *M. Trevits, Xtraction Science and Technology, Inc, Pittsburgh, PA*
A. Dutil, Jennmar

9:00 AM

Introduction

9:05 AM

Large-Scale Screen Testing: More Realistic but What Changes?

T. Klemetti and T. Batchler; Ground Control Branch, NIOSH, Pittsburgh, PA

How representative are small-scale screen tests of the in situ response of screen to roof and rib deterioration and displacements? Can a more representative test procedure improve the utilization and effectiveness of screen as a roof and rib support? This paper details a new large-scale screen test procedure and initial results. The test frame was designed to test an 8 by 16 feet screened area with bolt spacing as small as 1 foot increments. The initial design was planned for testing up to 6 pull points, but additional locations can be added to produce a more uniform loading. The test frame was developed to capitalize on the capabilities of the Mine Roof Simulator at the Pittsburgh Mining Research Division of the NIOSH. The initial tests included a baseline test using the original 4 by 4 feet test frame, a 4 by 4 feet test in the large-scale test frame, and two multiple pull point tests. The large-scale 4 by 4 tests produced a peak load 6% higher and a yield load 30% lower than the original test frame. The multiple pull points of the large frame produced variable yield, peak, and intermediate loads, but on average were lower than the single pull point tests.

9:25 AM
Calibration of Coal-mass Model Using In-Situ Coal Pillar Strength Study
K. Mohamed, G. Rashed, J. Rusnak, M. Sears and M. Van Dyke; PMRD/GCB, NIOSH, Pittsburgh, PA

Recently NIOSH developed a coal-mass model to simulate the rib behaviors in underground coal mines. In this model, the effect of coal-mass scale on the strength, peak and residual, and deformability is considered. The effect of the orientation of face cleat with respect to entry driving direction on the induced stresses and rib deformability is simulated implicitly. Coal-mass scale and critical plastic strains are the controlling material parameters. The coal-mass scale parameter defines the strength and dilation of coal material. The critical shear and tensile plastic strain parameters define the initiation of fracture in coal material. In this paper the coal-mass model is calibrated by using a study case conducted by the U. S. Bureau of Mines in 1976 at the Keystone No. 1 mine. In this case the induced stresses and rib deformations of coal pillar were monitored while the pillar was reduced from 80 ft. x 80 ft. to 26 ft. x 26 ft. FLAC3D models were conducted to simulate the pillar reduction process. The coal-mass model parameters; coal-mass scale and critical plastic strains, were calibrated by comparing the FLAC3D models with the in-situ measured stresses and deformation.

9:45 AM
Sacrificial Anode Technology for Corrosion Protection of Mine Roof Bolts
A. Bhagwat and S. Tadolini; Minova, Lakewood, CO

Steel members of the ground support systems in underground mines are routinely exposed to corrosive environment that may range from acidic to alkaline. Corrosion of steel bolts leads to metal loss and thereby, reduction in strength and useful life. Protective coatings are commonly applied to the steel bolts to combat corrosion. However, coatings are expensive and often cumbersome in practical applications. Instead, Minova has developed an innovative technology based on sacrificial anodes. The anodes were designed from non-ferritic alloys that are inferior to steel on the Galvanic Series. The present paper will present data from long-term field testing to show significant benefit of the technology. Potential applications in current products will be discussed.

10:05 AM
Evaluation of Different Shielding Materials for Reducing Electromagnetic Interference of the Personal Dust Monitor
J. Noll, J. Li, C. DeGennaro, C. Zhou and J. Srednicki; NIOSH, Pittsburgh, Pa, United States Minor Outlying Islands

The personal dust monitor (PDM) as well as other electronic devices can cause electromagnetic interference (EMI) which can disrupt the operation of some proximity detection systems (PDS). A 6 inch separation distance between the mine wearable component (MWC) of the PDS and the electronic device usually avoids these disruptions but cannot be reliably maintained in all situations. Another method of reducing EMI effects is utilizing shielding. The shielding capability of several different materials was investigated by surrounding the PDM with the material and quantifying the EMI. Copper mesh and MU-Metal reduced measured EMI to below interference levels at separation distances of 4 inches and 2 inches, respectively. However, in the presence of steel mesh, the shielding material itself can affect the PDS's magnetic field, subsequently the system's performance. Results show that when in the presence of steel mesh, the copper material disrupted the PDS operation when within 7 inches of the MWC while the MU-metal disrupted when within 3.5 inches. Shielding reduced EMI of the PDM with MU-Metal providing better results than the copper mesh for the circumstances tested.

WEDNESDAY, FEBRUARY 28
MORNING

9:00 AM | ROOM L100I

Environmental: Effective Wastewater Management

ChairS: *V. Vilela, Matech America*
B. Waterman, Freeport Mcmoran, Oro Valley, AZ

9:00 AM
Introduction

9:05 AM
High Pressure Filters for Iron Ore Tailings
V. Vilela; Matec America, High Point, NC

This study aims to analyze the use of high pressure filters in the treatment of pulps resulting from mineral processing, especially iron ore mining tailings and slimes. The current practice problems of deposition of fines in tailing dams were analyzed, as well as the new challenges faced by the sector in relation to water scarcity and energy efficiency. Are listed technological differentials implemented in Matec filter presses and analyzed the benefits in application of this technology, such as higher water recovery, reduce of environmental impacts and reduce of operating costs for handling and disposal of waste. Lastly, we analyze the filtration tests performed on iron ore tailings and slimes.

9:25 AM
Modeling Mine Water Treatment Processes and Recycle Loops Using GoldPHREEQC
A. Ling and A. Janzen; Barr Engineering, Minneapolis, MN

Design of effective mine water treatment plants depends on the ability to reliably predict treatment outcomes, but systems with multiple chemical and physical treatment processes and recycle loops can be difficult to model. GoldPHREEQC is a modeling framework that integrates mass and flow routing capabilities of GoldSim software and water quality calculations provided by PHREEQC, and is well-suited to modeling parameters of interest in the mining industry, especially metals and sulfate. Physical processes such as membrane separation and greensand filtration are modeled by defining mass rejections for each parameter and flow routing based on vendor projections and bench- or pilot-scale equipment testing. GoldPHREEQC models chemical precipitation processes such as HDS metals removal and gypsum precipitation by (1) performing surface-aging and solubility calculations in PHREEQC and (2) using the GoldSim framework to direct supernatant and precipitate to subsequent process steps. Users can apply this modeling framework to predict effluent water quality, chemical requirements, sludge production, and required equipment capacity to support design, troubleshooting, and cost estimating.

9:45 AM
Considerations for Selenium Treatment of Mine-Impacted Waters
J. Tamburini; Tetra Tech, Denver, CO

Mine-impacted water occurs as surface run-off and ground water seepage contacts waste rock from previous mining operations. The characteristics of the mine-impacted water reflect the weathering characteristics of the waste rock, which may tend to favor weathering of selenate from its waste rock. Combined with the nitrate residues from blasting operations, these dissolved constituents are difficult to remove from mine-impacted water via conventional chemical treatment approaches. At high level, there are three selenium

removal processes: biological, physical, and chemical. Certainly the most widely used approach to selenium removal utilizes a biological approach; however, very little is known about the true microbiology at work, and this approach may lead to unintended consequences. This paper will evaluate several configurations of all three high-level selenium removal processes, and present bench-scale and pilot scale data where possible, as well as SWOT (strengths, weaknesses, opportunities, and threats) tables for many different alternatives.

10:05 AM

Implementing SART at a Complex Gold Project in Mexico

D. Kratochvil[1], B. Baker[1], O. Lopez[2] and D. Salari[3]; [1]BQE Water, Vancouver, BC, Canada; [2]BioteQ (Water) SpA, Santiago, Chile and [3]DENM Engineering, Burlington, ON, Canada

Developing gold reserves veined with cyanide-leachable base metals can be economically challenged by high cyanide consumption and increased operating costs. SART process technology can address the challenge by liberating the cyanide consumed by the base metals and recycling the newly freed cyanide back to the gold leaching circuit. During this process, the base metal is recovered as a high-grade concentrate with commercial value. Despite these attributes, SART – a public domain technology developed in the late 1990s by Lakefield Research and Teck Corporation – adoption has been slow due to concerns about costs and metallurgical performance. With extensive experience in sulphide precipitation, an essential component in the SART process, and involvement in the integration of SART into various metallurgical flowsheets, BQE Water presents a case study overview of the costs and performance considerations to integrate a full-scale 132,000 gal/hr SART plant at a heap leach operation for a gold project in Mexico with high copper levels in the ore.

10:25 AM

Reducing the Toxicity of Gold-Mine Effluents Using Biological Reactors and Precipitation – What Have We Learned So Far?

M. Laliberte; Veolia Water Solutions & Technologies, Saint-Laurent, QC, Canada

In a paper presented at SME 2013 we presented a process to reduce the toxicity of gold-mine effluent by using a combination of biological reactors and precipitation. Since then, we have installed and operated two full-scale plants at two different sites. This presentation will cover what we have learned so far: what went well, what didn't go so well, what remains to be learned. In particular, this paper will cover: The importance of the cyanate and thiocyanate concentration in determining how many biological reactors to use Alkalinity and the use of lime vs sodium hydroxide to maintain the pH The impact of chlorides on the reactors design Metals toxicity, biological activity and redox changes Practical considerations on starting or restarting the biological reactors Algae blooms and other unintended consequences, and how to mitigate them

10:45 AM

Electrochemical Water Treatment for Minerals and Metal Industries

P. Suvio; Outoted Canada Ltd, Burlington, ON, Canada

Advanced tertiary treatment technologies, including electrochemical water treatment can help with the recovery of water during the operations. It can also help with reaching lower residual concentration of impurities within the treated water, therefore reducing the risks related to the environment and the operations. In electrochemical water treatment both chemical and physical mechanisms take place simultaneously to remove dissolved constituents from the wastewater. The mechanisms taking place can be described using the following three steps: 1) electrolytic oxidation of the acrificial anode (dissolving metal electrode, e.g. iron or aluminium), 2) chemical reaction, where dissolved iron and impurities form solid precipitate and 3) aggregation of the particles to form flocs, which can be removed by known solid/liquid separation method. Electrochemical water treatment is very efficient at low residual concentrations of constituents, like oxyanions. Next to oxyanions, EC can target trace metals, low concentrations of organics and improve the settling and removal of solids. Use of modular water treatment systems can have positive impact on the CAPEX, execution and delivery time.

11:05 AM

Best Practices for Reusing Recycled Waste Streams

R. Terrazas[1] and S. Veerapaneni[2]; [1]Mining, Black & Veatch, Walnut Creek, CA and [2]Water, Black & Veatch, Kansas City, MO

The Orange County Water District's Advanced Water Purification Facility (AWPF) located in California is part of the Groundwater Recharge (GWR) System that has been operating since January 2008, recycling treated wastewater secondary effluent (SE). The GWR System supplements existing water supplies by providing reliable, high-quality source of water to recharge the Orange County Groundwater Basin (Basin) and protects the Basin from further degradation due to seawater intrusion. The AWPF will be significantly expanded and upgraded. As part of the upgrade, improvements were considered which focus on the incorporation of energy recovery devices as a way to optimize energy consumption. Various means of balancing fluxes were evaluated, including throttling of permeate flow, inter-stage booster pump, and incorporation of energy recovery. Reuse of waste streams can be advantageous not only for municipalities but also to the mining industry by providing an additional source of water at lower capital and energy premiums. This discussion will provide information related to the Project and will highlight innovative improvements to further reduce energy usage and operating costs.

WEDNESDAY, FEBRUARY 28

MORNING

9:00 AM | ROOM L100H

Environmental: Mother Nature to the Rescue; How Natural Methods Can Lead to An Inherently Stable Site.

Chairs: *J. Forbort, Minneapolis, MN*
R. Reisinger, Arcadis, Highlands Ranch, CO

9:00 AM

Introduction

9:05 AM

Advancements in Iron Terrace Design for Metal Mine Sites

J. Gusek, L. Josselyn and E. Wolaver; Sovereign Consulting Inc., Lakewood, CO

Volunteer iron terrace formations associated with coal mine sites are well-documented in the literature but relatively little has been published regarding iron terraces in metal mining terrain. Iron terraces might be considered a subset of aerobic wetlands that appear to remove iron without macrophytes/plants and open water surfaces. Microbial mechanisms appear to be important. The influence of organic carbon such as leaf litter and other natural cellulolytic material on first-order iron removal kinetics is somewhat uncertain. Early work at understanding the mechanisms in iron terraces (aka terraced iron formations -TIFs) in Eastern US coal mine ARD originated in West Virginia and at Penn State but iron terraces have been studied by the USGS at metal mining sites in the western US in the Rocky Mountains and by others in the Iberian pyrite belt in Spain. This paper examines iron terraces/TIFs from a process engineering perspective as applied to passively treating iron-bearing metal mine drainage as a first step in a multi-unit treatment system that may include biochemical reactors, aerobic polishing wetlands, and manganese removal beds.

9:25 AM

Automated Sluice Gate to Reduce Acid Rock Drainage and Sediment Loading of a Lake Near the Chevron Mining Inc., Questa Mine, New Mexico

J. Gallegos, R. Faber and T. Cox; Arcadis, Highlands Ranch, CO

An innovative method to reduce acid rock drainage (ARD) and sediment loading of a recreational lake was used in the Red River watershed in northern New Mexico. The Red River drains a mining district that contains multiple naturally occurring hydrothermal scars that release ARD and sediment to the river during episodic summer rain storms. A lake is near the mouth of the watershed and is filled with water from the river through a sluice gate and diversion. An automated actuator was installed on the sluice gate to close when the river is impacted by high suspended sediment. Water quality probes were installed at the sluice gate to monitor the river water for turbidity, specific conductivity, and water depth. If high turbidity is measured the sluice gate closes automatically. Remote access is setup with a computer view screen to review the real-time system status. Once the turbidity drops below a threshold, the sluice gate is reopened remotely. The automated sluice gate has successfully reduced the amount of ARD and suspended sediment entering the lake. This reduction has resulted in an improved aquatic habitat for the fishery and benthic macroinvertebrate community.

9:45 AM

Reclamation of Iron Ore Scram Mining Tailings: Year 3 Results of Innovative Research in Establishing Native Vegetation

A. Kramer; Natural Resources, Short Elliott Hendrickson Inc., Duluth, MN

Minnesota has robust reclamation standards and have proven results in the taconite mining industry. Reclamation of overburden spoils, lean ore spoils and fine tailings from taconite production has generally been successful on the Iron Range, using a low input standard reclamation practice. However, new breakthroughs in iron ore scram mining technologies are producing fine and coarse tailings that have not been encountered nor reclaimed in northern Minnesota. This presentation is the culmination of three years of innovative research to investigate potential successful reclamation strategies for scram mining tailings in Minnesota. The research program is divided into three phases, in which Phase I (Year 1) and Phase II (Year 2) will be briefly summarized, with the presentation focusing on Phase II (Year 3) results and recommendations: Phase I (2015-2016): Bench scale/greenhouse study to test nutrient and organic matter amendments with native seed Phase II (2016): Field scale pilot trial testing nutrient/organic matter amendments with native seed in-situ. Phase III (2017): Final in-situ monitoring and technical report with reclamation recommendations.

10:05 AM

Selenium Attenuation via Reductive Precipitation in Diverse Saturated and Unsaturated Subsurface Conditions: Implications for Fate and Transport of Selenium in the Southeast Idaho Phosphate Patch

D. Silverman[1], M. Hay[1], G. Leone[1] and B. Wilking[2]; [1]Arcadis U.S., Inc., Portland, OR and [2]Agrium Inc., Soda Springs, ID

Phosphate mining in the Southeastern Idaho Phosphate Patch (Phosphate Patch) has resulted in groundwater impacts due to the oxidative release of selenium and other metals and metalloids from waste rock. Selenium is of particular concern given its mobility in the environment and its toxicity to livestock receptors. Previous studies have documented selenium attenuation in reducing conditions in stream sediments, wetland environments, unsaturated sub-oxic conditions, and saturated sub-oxic conditions. This process represents an important natural attenuation mechanism for selenium, with implications for both mine planning/permitting and design of reclamation strategies. In this study, groundwater geochemical data collected at several former mines within the Phosphate Patch are evaluated to better understand the diversity of subsurface conditions in which selenium reductive precipitation has been observed. Field results indicate that selenium attenuation via reductive precipitation is observed in both unsaturated and saturated sub-oxic environments beneath or adjacent to waste rock piles. Implications for fate and transport of selenium in the Phosphate Patch will be discussed.

10:25 AM

Feasibility and Performance of Uranium Passive Treatment in a Mine Reclamation Setting

M. Hay, J. Gillow and P. Moran; Arcadis U.S., Inc., Broomfield, CO

Uranium, which is highly soluble in alkaline, oxygen-rich waters, is frequently observed in groundwater and surface water above regulatory limits where ore is mined or milled. The complex aqueous chemistry and stability of the uranyl ion in solution complicates the use of traditional metal-specific water treatment strategies, compounded by the added difficulty of treatment in the remote and extreme environments characterizing many mine sites. At these sites, low-maintenance, semi-passive methods offer many advantages over active water treatment. Treatment strategies may include reduction to less-soluble U(IV), adsorption/ion exchange, or U(VI) precipitation with phosphate, but few field-scale demonstrations exist. In this study, we present bench- and field-scale results on the use of solid phase reagents for dissolved uranium removal. Zerovalent iron, fish bone apatite, and solid-phase organic matter substrates used in flow-through reactive barriers are compared. The results highlight successes and challenges as they relate to site-specific water quality and physical/hydrogeological environment. The implications of these results for full-scale implementation will be discussed.

10:45 AM

Passive Treatment of Mine Drainage Using Peat Sorption Media

P. Eger; Global Minerals Engineering, Hibbing, MN

Mine drainage has been treated passively with biochemical reactors (BCRs) and wetlands for decades, but each approach has shortcomings. In addition to long contact times, BCRs release elevated nutrients and organics during the start up phase; wetland performance decreases in the winter due to channelization and slower reaction rates. Peat sorption media is a granular engineered product made from reed sedge peat. It is lightweight, permeable and can load up to 1 -15% metal by weight. The media can effectively treat 1 gpm/ft2 with minimal head and is easy to install and replace. Other than a small amount of color in the initial pore volumes, there is no release of nutrients or organics. Three gravity flow biocells were constructed at a base metal mine and operated at hydraulic residence times of 15, 30 and 60 minutes. The input mine water was circumneutral with average total concentrations of 2100 ug/l Pb, 115 ug/l Zn and 0.8 ug/l Cd. Lead removal varied from greater than 99% initially to over 80% after 9 months. Estimated lead loading of the peat sorption media exceeded 0.5%.

WEDNESDAY, FEBRUARY 28

MORNING

9:00 AM | ROOM L100G

Environmental: Quantitative Methods for Community Engagement

Chairs: *K. Awuah-Offei, Missouri University of Science & Technology, Rolla, MO*
S. Que, Missouri University of Science and Technology, Rolla, MO

9:00 AM

Introduction

9:05 AM

Using Discrete Choice Theory in Mining Stakeholder Analysis: a Case Study in the United States

S. Que[2] and K. Awuah-Offei[1]; [1]Missouri University of Science and Technology, Rolla, MO and [2]Chongqing Jiaotong University, Chongqing, China

Local community acceptance is a key indicator of the socio-political risk associated with a mining project. This research sought to facilitate improved community (stakeholder) analysis using discrete choice theory. The work considered sixteen project attributes and four demographic factors, which have been identified as important for individual preferences for mining projects in the United States of America (USA). A mixed style, blocking scheme, fractional factorial without interaction discrete choice experiment was proposed to overcome the challenge posed by the large number of relevant factors. The design was validated, revised, and implemented in Salt Lake City, Utah, USA to illustrate the usefulness of discrete choice theory in mining stakeholder analysis. The data was used in discrete choice modeling of individual preferences. The proposed approach answers the important questions for enhanced stakeholder analysis: (1) What are the factors that affect stakeholders' decisions and how do these affect their preferences? (2) What is the effect of demographics on individual preferences? (3) What is the value of environmental and social impacts to individuals in the community?

9:25 AM

Eliciting Drivers of Community Perceptions of Mining Projects through Effective Community Engagement

L. Wang; Chongqing University, Chongqing, China

Sustainable mining has received much attention in recent years as a consequence of the negative impacts of mining and public awareness. The aim of this paper is to provide mining companies guidance on improving the sustainability of their sites through effective community engagement based on recent advances in the literature. It begins with a review of the literature on sustainable development and its relationship to stakeholder engagement. It then uses the literature to determine the dominant factors that affect community perceptions of mining projects. These factors are classified into five categories: environmental, economic, social, governance and demographic factors. Then, we propose a new two-stage method based on discrete choice theory and the classification that can improve stakeholder engagement and be cost-effective. Further work is required to validate the proposed method, although it shows potential to overcome some of the challenges plaguing current approaches.

9:45 AM

Information Diffusion as a Mechanism for Evolution of Social Networks

M. Nakagawa[1] and K. Bahr[2]; [1]Mining Engineering, Colorado School of Mines, Golden, CO and [2]Environmental, Tohoku University, Sendai, Miyagi, Japan

The social acceptance is an emergent convergence of opinion, the production and durability of which is highly interdependent with the structure of the stakeholder network. This structure evolves over time as new links are formed and old links decay. In this paper, we propose a social license model in which agent interactions lead to the evolution of network structures, which are then classified according to observed stakeholder networks.

10:05 AM

Investigating Information Diffusion Potential of Social Media Networks for Effective Community Engagement

A. Ur Rehman and K. Awuah-Offei; Mining Engineering, Missouri University of Science and Technology, Rolla, MO

Information diffusion potential of a social media user affects how quickly information about a mineral project can diffuse through that user. If management can use social media and network analysis, in community engagement program, to understand how fast and how far information will diffuse to communities and followers of particular social media, it can selectively focus on the most influential users. This paper proposes a method to examine the information diffusion potential of social media accounts. The work uses Gephi, an open source software, to extract and analyze data from different Twitter handles to predict their information diffusion potential. The work uses case studies of real Twitter users (e.g. mining news organizations and bloggers) associated with mining to illustrate the approach. The case study results show that there are significant disparities in information diffusion potential that will demand selective attention. This research will help mines develop effective social media engagement strategies.

10:25 AM

Investigating the Key Parameters of an Agent-Based Model of Mining Community Preferences for Managing Social Risks

K. Awuah-Offei and M. BOATENG; Mining & Nuclear Engineering, Missouri University of Science & Technology, Rolla, MO

Mining companies have started using quantitative tools, including computer models of community interaction, to gain intelligence on social risks surrounding their projects. Models of changes in community preferences regarding mining projects over time are useful for evaluating changes in project risk due to changes in the social license to operate. For example, agent-based models that use information diffusion models and social networks are useful for studying those changes due to information diffusion. However, such agent-based models are sensitive to many input parameters including the parameters of the diffusion model and the average degree of the social network. This work evaluates the sensitivity of such a model to diffusion and network model parameters (probability of imitation, probability of innovation, and average degree) using the first order and total sensitivity indices. The results show that the model is much more sensitive to the probability of imitation than the other two parameters. Thus, to reduce uncertainty surrounding the model's predictions of community acceptance of mining, mines need to obtain accurate estimates of the probability of imitation.

WEDNESDAY, FEBRUARY 28

MORNING

9:00 AM | ROOM L100A

Health & Safety: Panel: Would Leadership Focused on a Healthier Workforce Result in Improved Safety Culture, Safety Performance, and Increased Operational Productivity?

Chairs: *E. Lutz, NIOSH, Spokane, WA*
M. Poulton, University of Arizona, Tucson, AZ

9:00 AM

Would Leadership Focused on a Healthier Workforce Result in Improved Safety Culture, Safety Performance, and Increased Operational Productivity?

E. Lutz; NIOSH, Pittsburgh, PA

The global mining industry has developed one of the strongest safety cultures of any heavy industry. Virtually all companies promote a safety-first culture and boards of directors carefully monitor safety performance. Protecting worker health on the jobsite is similarly a priority. But a holistic view of workers' health, and the associated behaviors and choices, are not in the domain of the company to monitor. However, recent 'Total Worker Health' findings in other industries have shown impacts on the safety at work and the path of improved safety driving profits is established. Should we work toward implementing total worker health cultures that link healthy habits on/off the job with safety at work? This session will solicit a discussion of these questions and best practices for encouraging workers to prioritize their health as part of a safety culture across the mine operation.

WEDNESDAY, FEBRUARY 28

MORNING

9:00 AM I ROOM L100B

Health & Safety: Got Safety? See What Tech Savvy Companies Are Doing to Improve the Safety and Health of Their Workers II

Chair: *J. Sattarvand, University of Nevada Reno, Reno, NV*

9:00 AM
Introduction

9:05 AM
A Framework to Evaluate Safety Competencies Through Serious Games

L. Brown[1] and B. Granillo[2]; [1]Lowell Institute for Mineral Resources, University of Arizona, Tucson, AZ and [2]Mel and Enid Zuckerman College of Public Health, University of Arizona, Tucson, AZ

Well-designed computer games can be effective tools for stealth evaluation and assessment of training outcomes. In this work, we illustrate a process for mapping workers' gaming behaviors to safety competencies. A computer-based framework was developed consisting of three parts: 1) A serious game with instrumentation to record worker choices and activities; 2) A client-side dashboard for inspection and debriefing; and 3) A relational database to aggregate game logs and interpret results. Data mining algorithms allow trainers to assess and track competencies for individual users and across cohorts over time. Furthermore, a modular approach allows serious games to be re-mapped into arbitrary competency models, thereby enabling customization for each company's standard operating procedures. We discuss the design of our evaluation framework and data mining algorithms, and provide examples of competency-based assessment through serious games, with initial results on field deployment and training efficacy.

9:25 AM
Safety in Hand: Challenges and Opportunities of Mobile Enabling Safety Programs

R. McLain; Health & Safety, Freeport-McMoRan, Phoenix, AZ

As we attempt to place more mobile technology in the hands of employees to foster safer and more productive workplaces; we are faced with myriad implementation challenges. There are generational challenges with the adoption and rollout of new technology. Policy decisions and usage guidelines to consider when deciding when the use of a mobile technology outweighs the potential for on the job distraction. Mobile enablement also brings with it cross departmental issues such as device selection, network access, security, and cost considerations when planning for mobility. However, the opportunity for creative solutions to long term safety problems often lies with bringing simple solutions to where they are needed the most, in the hands of our workforce. In this discussion we will address these challenges and opportunities against the backdrop of several recent projects at Freeport-McMoRan.

9:45 AM
Safety 4.0 – Engineered Solution for a Safer Underground Excavation. The Bzerotondo Tunnel Support System

R. Perlo; Tunnelling, Officine Maccaferri, Zola Predosa, Italy

Safety in construction is tightly linked to the engineering choices, as much as to the necessity of reducing time and costs of realization. Therefore, it is of paramount importance to address it properly from the earliest stage of the design, identifying the risks connected to the work and the variability of such during the different stages of the project. Regarding to occupational safety and health, the risk is the likelihood that a person may be harmed of suffers adverse health effects if exposed to a hazard, e.g. the risk is often measured as the expected value of an undesirable outcome. However, a real case scenario is often more complex than a single binary possibility case. The automatic tunnel support system proved to be a solution able to reduce the time and yet to deliver an enhanced, quality-aware and safer working environment for the operators. The implementation of the system was shortlisted in 2015 for the ITA Award for the Safety Innovation of the Year. In a market industry driven by safety and time constrains the efficiency shall be the ultimate goal, in order to provide solutions able to negotiate with the most challenging ground conditions.

10:05 AM
Emerging Machine Learning-Based Technologies for Ground Control Hazards Identification Through Aerial Photography

J. Sattarvand and R. Battulwar; Mining and Metallurgical Engineering, University of Nevada Reno, Reno, NV

The paper discusses an ongoing NIOSH supported project for automatic identification/monitoring of the signs of ground control hazards, in particular, the tension cracks, through aerial photography and machine learning to enhance the conventional visual inspection of the site, finding of the cracks and installation of the appropriate monitoring instruments that is a hard, time consuming, unsafe, and sometimes an impossible practice. Automatic photography from the open pit terrains with consistent resolution is challenging due to a considerable altitude difference in the mine. The other challenge is to build a mosaic map based on the taken pictures to be suitable for image processing. Moreover, processing of a large size mosaic image, training of the tension crack definition in a fitting artificial neural network as well as handling of all cloud-based computations are other challenging areas of the technology. Training of this neural network involves intensive data acquisition from different types, shapes, and extents of the cracks from several mine sites, which is a quite practical challenge. Simplicity and plug-and-play features that are also designed to be provided in the system.

10:25 AM
Comparison of Multiple Continuous DPM Monitors to the NIOSH 5040 Standard Method

C. Barrett[1], E. Sarver[1], J. Volkwein[2], J. Noll[3], E. Cauda[3], J. Dixon[2], B. Cary[2] and S. Vanderslice[3]; [1]Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA; [2]Consultant, Pittsburgh, PA and [3]NIOSH, Pittsburgh, PA

For monitoring personal diesel particulate matter (DPM) exposures, the NIOSH 5040 Standard Method is well established for analysis of filter samples, and the FLIR Airtec handheld monitor is used for real time personal elemental carbon analysis. However, there is a gap in capabilities for real-time, continuous monitoring in mines, which would support a range of other practical needs. Currently, few instruments may offer such capability. The continuous Magee AE33 Aethalometer is designed to measure atmospheric black carbon. The Airwatch monitor is currently prototyped and is a continuous version of the Airtec. Both instruments have seen only brief field testing and would benefit from calibration to the 5040 Method. Sunset Laboratory Semi-Continuous OCEC field monitor is an automated and deployable version of its full-scale counterpart used for the 5040 method, but has never been tested in a mine setting. In this study, these instruments were tested head-to-head in a controlled laboratory setting to generate calibration curves against the 5040 Method. Additionally, the instruments were tested briefly in an underground stone mine, and results were compared to the 5040 Method results.

10:45 AM
When a Safety Product is Not a Safety Product: Examples of Safety Benefits and Categories from Applied Automation

B. McBain; IMP Automation Canada Ltd., Oakville, ON, Canada

There are several primary drivers for the implementation of automation, including production efficiency, quality management and "big data" devel-

opment. Safety has been a notable factor of late, even though automation is generally not classified as a safety product because it has a primary functional purpose...usually an output in a process stream. Based on experience with a range of laboratory and sample-handling systems, IMP Automation has been able to identify different classes of safety benefits realized from mechanization, semi-automation and automation applications. Several examples will be provided, and a review of the predictive value of each class will be presented.

11:05 AM

Investigating Spatial Perception in Mine Worker Safety Training Utilising Virtual Reality

M. Hitch[1], J. Tibbett[1], N. Holmes[2], P. Hagan[1] and S. Saydam[1]; [1]Mining Engineering, UNSW Sydney, Sydney, NSW, Australia and [2]Psychology, UNSW Sydney, Sydney, NSW, Australia

Spatial awareness in mine environments is crucial for employee safety. Avoiding hazards in the environment, making your way to a refuge chamber or to locations of safety equipment during periods of emergency, require persons underground to have good spatial awareness. The School of Mining Engineering and the School of Psychology at UNSW Sydney are collaborating and utilising virtual reality (VR) mining simulations to uncover the fundamentals of how people new to the underground mining environment learn the spatial layout the mine and navigate the 'maze' to reach a goal. Users wearing VR headsets are tasked with getting from various locations within a virtual mine to an underground muster point and phone for help. After the user has familiarised themselves with 'preferred routes' the simulations then change to inject un-passable hazards into particular routes and force the user to consult their 'mental map' of the mine and navigate alternate routes. Data is recorded on the position of the user in the virtual mine through time and the duration of navigation. This paper presents a summary of the early findings of these experiments and proposes the direction of future work.

WEDNESDAY, FEBRUARY 28

MORNING

9:00 AM I ROOM 101H

Industrial Minerals & Aggregates: Applications of Natural and Manmade Pozzolans

Chairs: *C. Braaten, American Engineering Testing, Inc.*
S. Stokowski, TEC Services, Lawrenceville, GA

9:00 AM

Introduction

9:05 AM

A Brief History of Pozzolan Cements

W. Miles; Miles Industrial Mineral Research, Denver, CO

Historically, Pozzolans consisted of siliceous and aluminous volcanic ash and volcanid tuffs. More than 2500 years ago, the Greeks pioneered the use of pozzolans to blend with lime and make cements. However, the Romans eventually developed the potential of lime-pozzolan pastes as the binder phase in cements and concrete used for underwater construction and buildings. The Romans used these lime-pozzolan mixtures for over a thousand years in the Mediterranean, Europe, the Middle East and Africa. For example, in Rome, the Pantheon, the Colosseum, and other structures have existed for two thousand years or more. About 100 A.D., Vitruvius wrote of pozzolan-lime cements using four types of pozzolana: black, white, grey, and red, all of which can be found in volcanic areas of Italy, When the Roman Empire collapsed, the pozzolan technology was lost until it was "re-invented" in the 1800s. Shortly thereafter, Portland cement was invented and became the dominant technology for mass production. Modern pozzolan cements utilize other minerals, amorphous silica, and alumina hydrates for todays's technology for control of cement settings and hardness.

9:25 AM

Pozzolans in Concrete – Coming Full Circle

J. Clendenen; Pioneer Testing & Engineering, LLC, Ellsworth, WI

Experimented with by the Greeks, and perfected by the Romans, the use of pozzolans in concrete is older than the use of portland cement itself. Building on the knowledge of the past, this presentation will provide a high level view of our modern understanding of the pozzolanic reaction and how they are used in concrete today, with sources such as fly ash, slag cement, silica fume, natural pozzolans, and others. Lastly, I will provide the audience with a few industry references for how to allow pozzolan use in their specifications to provide quality concrete.

9:45 AM

Characterization and Determination on the Degree of Reactivity (the Pozzolan Reaction) for Natural and Artificial Pozzolans on the Microscale Using Laboratory Instrumentation

G. Tomaino; Minerals Technologies Inc, Easton, PA

This talk will discuss laboratory experiments on the characterization of natural and artificial pozzolans with respect to reactivity through the pozzolanic reaction [AS + CH + H à C-S-H and C-A-H] and the level of and crystallinity of C-S-H type and tobermorite type phases using XRD, TGA-DSC and TGA-DSC with specialized pressure-DSC crucibles that are capable of achieving low pressure (100 bar) and intermediate temperature (≤ 600C) processing states.

10:05 AM

Zeolites – New (Old) Sources of Specialty Pozzolans

D. Eyde; St Cloud Mining, Tucson, AZ

St Cloud Mining Company (SCM) is the largest producer of natural zeolites in the Western Hemisphere. SCM has four natural zeolite deposits and one volcanic ash deposit. They are located at Winston, NM, Bowie, AZ, Ash Meadows, CA and NV, and Rome, OR. These deposits constitute the largest drilled out and characterized reserve of natural zeolites in the US. Beginning in 2002, testing and evaluation of the reserves as specialty down hole cements were initiated on the Bowie deposit by Zeox Corporation. Both the Bowie and Ash Meadows deposits were qualified for specialty pozzolanic down hole cements. In 2017, additional test work confirmed that the Ash Meadows zeolite and volcanic ash met ASTM standards. The change in the availability of fly ash as a result of the closure of coal fired power plants is creating a demand for alternative pozzolanic products. Natural zeolites and associated volcanic ash deposits are proven subsitutes having been used since the time of the Romans. A better understanding of the Roman pozzolanic cements using zeolitic materals and their strength and resistance to harsh chemical environments, has created an opportunity for new sources of these unique materials.

10:25 AM

High Volume Pozzolanic Replacement Concrete for Infrastructure

K. MacDonald and M. Lukkarila; Beton Consulting Engineers LLC, Mendota Heights, MN

The use of high levels of pozzolan as a replacement of cement in infrastructure concrete has allowed the construction of high-durability structures where the curing has taken advantage of the heat of hydration to accelerate reactions. The presentation will address real world examples of concrete with high perfromance, including the I 35W and St. Croix Bridges in Minnesota, The Brattleboro Bridge in Vermont and the Harbor Bridge in Corpus Christi.

The projects will be presented in terms of the macroscopic performance requirements, including strength, diffusion, freeze-thaw and scaling resistance as well as at the microscopic features to show the effects of the high pozzolan content on the fabric and composition of the binder. Quarternary and Ternary mixtures were used throughout, and the impact of varying aggregate geology will be discussed. Exposure conditions included cold and wet environments and tropical coastal exposures, and the impact of these on design and construction will be emphasized. The cost and servicability aspects of the concretes will also be addressed.

10:45 AM
Metakaolin Based Pozzolonic Material for High Performance Concrete
P. Malla and Z. Zhang; Research & Development, Thiele Kaolin Company, Sandersville, GA

Production of clinker is a high energy process emitting a large amount of CO_2. The clinker production is responsible for about 5-7% of worldwide CO_2 emission per annum. One of the effective solutions to reducing the environmental impacts of clinker production is a partial replacement of cement by the natural and/or man-made supplementary cementitious materials such as fly ash, slag, silica fume, metakaolin, volcanic and sedimentary materials, etc. Metakaolin is one of the important supplementary cementitious (SCM) materials used in conjunction with Portland cement. The metakaolin SCM is produced by thermally treating kaolin, a naturally occurring 1:1 layer aluminosilicate mineral in the range of 700-900°C. Although metakaolin is typically used in a minor quantity by weight of cement (<10%), it contributes to a large increase in various performance attributes of concrete such as permeability, strength and durability. In this presentation, the effect of metakaolin on various performance attributes will be presented and discussed in view of its physical and chemical properties and reactivity.

WEDNESDAY, FEBRUARY 28
MORNING

9:00 AM | ROOM 101I

Industrial Minerals & Aggregates: Flotation of Industrial Minerals

Chairs: *R. Raitani, Solvay, Stamford, CT*
L. Moore, ArrMaz, Mulberry, FL

9:00 AM
Introduction

9:05 AM
Application of Tailor-made Collectors to Address the Quartz Challenge in Industrial Minerals Processing
L. Moore, G. Wang, R. Xiong and Z. Gu; Mining, ArrMaz, Mulberry, FL

Quartz is the second most abundant mineral in the earth's crust. Not only does quartz have many valuable industrial applications, it is also one of the most concentrated gangue minerals encountered in the processing of other minerals. Minerals such as hematite, apatite, calcite, feldspar, barite, and many more. Numerous applications of industrial minerals are sensitive to the hardness and abrasiveness encountered with quartz minerals, while other applications may lead to processing challenges for the end user. Therefore, process and chemistry optimization must be applied to ensure optimal grade is obtained for these valued industrial minerals. Extensive studies have been conducted in processing various industrial minerals, thus achieving a range of quality specifications, which entailed the application of ArrMaz's CustoFloat and CustAmine collectors towards the separation of quartz from other minerals.

9:25 AM
Anionic-Cationic Process for Silica Sand Flotation
Y. Xiong, Z. Gu and G. Wang; ArrMaz Custom Chemicals, Morgantown, WV

Thousands of years of natural wind sorting has resulted in uniform deposits consisting of 95% pure sub-angular grain silica with the remaining 5% divided between oxides of aluminum, titanium, iron, calcium and magnesium. In many sand deposits, the iron is present as free or loosely bound iron oxide which is easily removed by a simple washing procedure. As these sand deposits become depleted and less accessible, it becomes imperative to provide methods for beneficiation of lower grades of sand. In order to chieve that, an anionic-cationic flotation process has been developed for beneficiating industrial sands with heavy mineral and carbonate impurities by two stage anionic-cationic flotation. Several examples of its application in the refinement of glass sand deposits and foundry sand deposits will be discuss.

9:45 AM
Industrial Experience with Talc Floatation
E. McCarthy; Performance Minerals LLC, Morgan Hill, CA

The mineral talc is hydrophobic and a natural 'floater' that should be very amenable to the traditional froth floatation process. Yet only about 10% of worldwide talc production is beneficiated by this technology. It has had its greatest success in Finland, where all 400,000 tons is floated but in China, the world's biggest talc producer, almost none of the over 2 million tons produced uses this process. There are two talc floatation facilites presently operating in North America, but five float plants have been shut down in the last twenty years. This presentation will review floatation and alternate technologies for beneficiation of talc and examine why success has been elusive and spotty. It will also touch on the issues that talc can impact in metal floatation and its potential use as a carrier in polymer and paper recycling.

10:05 AM
Flotation Circuit Modernization and Cell Retrofit at the Nui Phao Concentrator
K. Aberkrom, B. Murphy and S. Morgan; Metallurgy, Espoo, Finland

Asset management of plant equipment strives to maximize availability and utilization of throughout the life-cycle of the machine. This includes predictive maintenance methods but also modernizations to resolve re-occurring failures. For flotation equipment one aims to maximize the metallurgical performance. These both aspects were put under a magnifying glass when Nui Phao Mining Company Limited (NPMC) and Outotec started cooperation to improve the BSF circuitproducing tungsten, fluorspar, bismuth and copper, with tungsten being the primary product. The objectives of this cooperation work were equipment related safety issues, reliability, wear part life extension and structural integrity. A mineralogical study showed pyrrhotite and pyrite were well liberated at a coarse grain size, these particles were predicted to be recoverable at the right flotation conditions. Prior to the start of the results were validated in pilot scale. The solution to resolve both equipment issues and improve the metallurgical performance was to install Outotec FloatForce® mixing mechanisms in the BSF cells and create a flash flotation circuit with an Outotec SkimAir® prior to the tungsten gravity circuit.

10:25 AM
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K. Aberkrom and B. Murphy; Metallurgy, Espoo, Finland

Asset management of plant equipment strives to maximize availability and utilization of throughout the life-cycle of the machine. This includes predictive maintenance actions but also modernizations to resolve re-occurring failures. These both aspects were reviewed when NPMC and Outotec started cooperation to improve the BSF circuit. The objective of this cooperation

was to work on equipment related safety issues, reliability, wear part life extension, metallurgical performance and structural integrity. A mineralogical study showed pyrrhotite and pyrite were well liberated at a coarse grain size. The solution to resolve both equipment issues and improve the metallurgical performance was to install Outotec FloatForce® mixing mechanisms in the BSF cells and create a flash flotation circuit with an Outotec SkimAir® prior to the tungsten gravity circuit. Since October 2016, the desired results have been achieved after a lack of performance after the first upgrade in March 2016. An increase of 4.7% in sulfur and 2.7% in tungsten was reached, whilst the equipment performance was improved by reducing vibration levels to below 4 mm/s and increase component wear life with 150%.

WEDNESDAY, FEBRUARY 28

MORNING

9:00 AM I ROOM 2101F

International

Chairs: *M. Gavrilovic, GR Engineering Services, Denver, CO*
D. Malhotra, Resource Dev Inc

9:00 AM
Introduction

9:05 AM
Mining and Processing Gold Ores in Ecuador. Historical Review, Current Technology and Potential Development Opportunities

G. Munoz[1], L. Tapia[2] and S. Morales[3]; [1]USFQ, Professor, Quito, Pichincha, Ecuador; [2]INIGEMM, Chemical Specialist, Quito, Pichincha, Ecuador and [3]BCE, Gold trading specialist, Quito, Pichincha, Ecuador

Historical evidence and technical studies have established that Ecuador has rich polymetallic deposits containing gold. Technical exploitation of these deposits is currently taking place, where plants with a processing capacity of 100-300 metric tons per day have shown great success. However, most of the exploitation is done by artisanal miners using crushing and grinding operations followed by gravity concentration and amalgamation. Tailings of gravity concentration are subsequently subjected to cyanide leaching for ultimate gold recovery. Currently, mercury has been prohibited in all mining operations for gold recovery in Ecuador and artisanal miners are looking for new processing technologies to replace amalgamation. This paper presents relevant results of research done by the National Institute for Metallurgical, Mining and Geological Research, through the project "Improvement of the Working Conditions of Small-Scale and Artisanal Mining". Research efforts are directed to eliminate the use of mercury for gold recovery and to develop alternative methods to recover precious metals and base-metal concentrates without the use of the amalgamation process.

9:25 AM
Development of a blastability index for Karst Limestone

R. Bhatawdekar[2], T. Edy[2], S. Annavarapu[1], T. Singh[3] and D. Armaghani[4]; [1]Mining Engineering, IIT Kharagpur, Kharagpur, India; [2]Geotropik, Centre of Tropical Geoengineering, Universiti Teknologi Malaysia, Johor Baru, Johor, Malaysia; [3]IIT Mumbai, Mumbai, India and [4]Civil and Environmental Engineering, Amirkabir University Teheran, Teheran, Iran (the Islamic Republic of)

During the initial stage of a mining project, detailed information on karst limestone deposits may not be available and only preliminary rock mass assessment can be undertaken using RQD, degree of weathering, degree of hardness and percentage cavities based on exploration data. A methodology is proposed to develop a Blastability Index (BI) for Karst limestone based on this rock mass assessment to help design of blasts in karst limestone to reduce flyrock and excessive ground vibrations, and achieve the desired fragmentation. The Blastability index will be compared with recent approaches and these parameters will be considered for rock mass assessment. The proposed methodology of rock mass assessment is based on review and will be useful for blast design and prediction of blast performance at a Cambodian limestone deposit. Further exploration data is classified based on block model based on structures identified, hardness of rock and will be useful for co-relating with the blastability index.

9:45 AM
Adapting Responsible Care Program to the Colombian Mining Industry

O. Restrepo Baena and D. Lezcano; Materials and Minerals, Universidad Nacional de Colombia, Medellin, Antioquia, Colombia

Nowadays, Colombia has a generalized increase in the mining sector where the levels of informality and illegality are evident, in addition not all companies that are legally constituted have clear models of sustainability, demands to build, adapt and improve a sustainability model to specific realities such as the small Colombian mining. This work presents the Responsible Care Mining Model based on the initiative of the Responsible Care® from chemical industry, which builds trust and credibility around the world, it is a management model of voluntary membership, based on self-regulation and continuous improvement. Thus, an adaptation of this model is presented to the Colombian mining industry, with the aim of including tools that really contribute to the sustainability, responsibility and business ethics of the sector. In this sense, through the methodology of the management evaluation, activities and tasks were created, oriented to excellent relations with the community, environmental protection, safety work, best practices in production and safe location.

10:05 AM
Industrial Analysis of Mill Feed Economic Value Flux

K. Heiskanen[1], M. Talikka[2], J. Rohleder[2], V. Takalo[2], J. Raatikainen[3] and i. Auranen[3]; [1]Tech. Mgmt., Outotec, Espoo, Finland; [2]MP, Outotec (Finland) Oy, Espoo, Finland and [3]IMA Engineering, Espoo, Finland

Bulk sorting promises substantial benefits. Such benefits can be calculated froblock models. This paper draws conclusions from months of XRF assaying AG mill feed with about 80% -300 mm at a capacity of 1100-1200 tph. Measurements correspond to a resolution of 20 ton blocks. An economic value was calculated to each block. The frequencies of block values varied depending on the ore type and the location of the block. From a simple transient frequency response analysis of a milling circuit, vale variations with frequencies of 5-8 minutes or less will be averaged out. There were also value flux variations that passed to flotation. The overall phase lag for such variations tend to be close to 180 degrees, causing control restrictions. As a result, the data resolution from the geomodel blocks (at the site typically from 10000 to 100000 tons) is not sufficient to optimize the plant operation. The level of resolution cannot capture details, which has effects on plant performance. The results clearly point towards the benefits of measuring the coarse mill feed for longer periods of time at high sampling frequency before the final technical and economic assessment can be made at any mine

10:25 AM
Socioeconomic Impact of Mining on the Sustainable Development of the Dominican Republic

D. Rodriguez; Mine Engineering, Barrick, Monsenor Nouel, Dominican Republic

Pueblo Viejo, the largest mine in the Dominican Republic, is working towards the goal of sustainability through developing a strong mining culture. Three main pillars; Social, Economic, and Environmental, establish fundamental areas on which the culture can be transmitted. Exposure to safety and technical training has led to a transference of knowledge, leading towards behavioral changes. These behaviors in turn lead to an ability to create social changes in the community. The mine is currently the largest contributor to

GDP growth in the Dominican Republic. Local communities benefit from high paying employment as well as business development opportunities. Nationally, the economic influence of the mine, can assist in stabilization of the economy as well as adding a source of capital for the development. Pueblo Viejo incorporates progressive reclamation of all waste dumps, including the neutralization of all potential acid generating material to demonstrate that mining can occur in symbiosis with the operating environment. Through developing a mining culture Pueblo Viejo will be able to sustainably operate into the future using the synergistic relationship with the Dominican Republic.

10:45 AM

Colombia's Challenges Derived from Its Natural Resources Development

O. Restrepo Baena, G. Aristizabal and A. Delgado; Materials and Minerals, Universidad Nacional de Colombia, Medellin, Antioquia, Colombia

The risk prevision and control is a core factor in determining the path of the transformation produced for the mining development. To achieve a transformation in a positive path, the company should guarantee the use of the technologies and resources for controlling the environmental impacts and the restoration of its quality. The state should provide the goods and services for the healthy growing of the population and the economy under the influence of the project; and the communities, should be engaged for the company and the state in order to provide goods and services to the economy, strength their relations, stablish agreements and obtain benefits from the mining development. The above means that the transformations in the positive trends are conditioned to the performance of the company, the state and the communities in the whole life cycle of the mining project. However, the transformations can also be done in the negative trend, under a non-planned intervention and without enough capacities to take advantage of the opportunities and impact management from the mining project.

11:05 AM

Meerschaum Mining and Processing Activities in Eskisehir, Turkey

M. Yavuz; Mining Engineering Department, Eskisehir Osmangazi University, Eskisehir, Turkey

Sepiolite [Mg4Si6O15(OH)2.6H2O] is widely used in industry because of its adsorptive, rheological and catalytic properties. There are two genetic types of sepiolite around the Eskisehir, Turkey. The most common type is the so-called "Meerschaum" which occurs as nodules and concretions in Miocene-Pliocene conglomerate surrounding the magnesite deposits around Eskisehir. Meerschaum mining has been doing for centuries by local farmers two different regions of Eskisehir. Traditional tunneling methods are used in production activities by local farmers. The produced raw meerschaum is processed by many artists in Eskisehir. The best nodules are carved into objects such as pipe bowls, bracelets, and necklaces. In recent years, various problems have encountered both processing and mining in sepiolite. Primarily, meerschaum production dramatically decreased. For this reason, artists cannot find quality meerschaum. So, domestic and external demand for processed meerschaum cannot provide by artists. In this paper, the studies for solving the problems are described. The solutions for meerschaum sector both production and processing processes have been developed.

WEDNESDAY, FEBRUARY 28

MORNING

9:00 AM | ROOM 101A

Mining & Exploration: Geology: Mining Geotechnical I

Chair: *C.Rehn, Barr Engineering, Kamas, UT*

9:00 AM

Introduction

9:05 AM

Creating a Geotechnical Center of Excellence at the University of Arizona

B. Ross; Lowell Institute for Mineral Resources, University of Arizona, Tucson, AZ

Large geotechnical events have had a tremendous cost in terms of the loss of lives, billions of dollars in damage as well as significant legal and reputational impacts. In addition to these large events, every day operations are further impacted and geotechnical failures damage equipment, impact production and continue to injure or kill people all too frequently. But as expensive as geotechnical events are, we still hear that geotechnical analysis are more of an art than a science. We also know that our operations are getting larger, deeper and more complex but we still rely on many empirical solutions developed decades ago. This paper discusses the creation of a Geotechnical Center of Excellence (GCE) at the University of Arizona. This center will be stakeholder driven and utilize the strength and capabilities of multiple departments across the university to solve critical and difficult geotechnical problems through applied and basic research. The GCE will also help increase geotechnical knowledge and understanding through the development of training modules that can be used for university and continuing education classes.

9:25 AM

Enhancing Failure Criteria for Rock

J. Labuz and F. Zeng; Civil, Environmental, & Geo- Engineering, University of Minnesota, Minneapolis, MN

Mohr-Coulomb (MC) failure criterion is popular due to identifiable material parameters such as cohesion S_o (shear-stress intercept) and friction angle φ, and it can be written as $a\sigma_I + b\sigma_{III} = V_o$, where σ_I and σ_{III} are major and minor principal stresses, a and b are constants related to φ, and V_o is the (theoretical – it is not measured) triaxial tensile strength, with $V_o \sin\varphi = S_o \cos\varphi$. MC can be greatly enhanced by considering all three principal stresses: $A\sigma_I + B\sigma_{II} + C\sigma_{III} = V_o$ where σ_{II} is the intermediate principal stress ($\sigma_I \geq \sigma_{II} \geq \sigma_{III}$) and A, B, C are constants: $A = (1 - \sin\varphi_c)/(2\sin\varphi_c)$, $B = (\sin\varphi_c - \sin\varphi_e)/(2\sin\varphi_c \sin\varphi_e)$, $C = -(1 + \sin\varphi_e)/2\sin\varphi_e$. This failure criterion is called Paul-Mohr-Coulomb (PMC) after Paul (1968). Note that φ_c is the friction angle for conventional triaxial compression, $\sigma\sigma_{II} = \sigma_{III}$, and φ_e is the friction angle for extension, $\sigma_{II} = \sigma_I$. Thus, PMC captures the intermediate stress effect by including two frictions angles. PMC can be extended if true triaxial test data are available, and two different planes can be fit to create a twelve-sided failure surface from the two intersecting six-sided pyramidal surfaces. Paul B.1968.Int J Soilds Struct.175-96.

9:45 AM

Determination of Properties of a Geological Fault Through Back Analysis Using 3D Numerical Modeling

L. Lorig; Itasca, Minneapolis, MN

Numerical modeling has become a powerful tool for stability assessment of planned mining situations, etc. However, reliability of the outcome lies on appropriate input, including properties of the rock mass and those of major geological weak planes. In recent years, many tools have been introduced to convert laboratory scale rock properties to rock mass scale. However, obtaining properties of the geological faults has been a challenge. For making robust pit slope designs, the role of geological structures cannot be ignored as it may lead to not only serious interruption in business plans but severe safety threats also. One way of acquiring properties of geological faults is through three-dimension back- analysis of some instability events through numerical modeling. In this line, a fault triggered instability at Rampura Agucha Mine has been back-analyzed to acquire its properties using 3DEC software. For model calibration, two benchmark events- (a) crack generation at the slope crest and recording of the movement by a set of 15 prisms and, (b) extent of failure predicted by radar and that observed in field are matched with those predicted by the model.

10:05 AM

Determination of RQD by Digital Image Analysis

T. Saricam and H. Ozturk; Mining Engineering, METU, Ankara, Turkey

In this paper, a method is proposed for determination of RQD from digital images of rows of core in core boxes in order to compute RQD in an automatic way using newly written MATLAB routines. First, three digital true color images of a core box, with the same camera position but different light source positions, are taken using a high resolution camera. After detection of the core box with color thresholding, the sections of the box are detected by using Hough transform and boundary tracing algorithms. The cores are extracted from each section using color thresholding. After cleaning shadows created by different light sources using various techniques, the segmentation part is completed. Later, non-cylindrical parts of the cores are detected by looking at the changes caused by two different light sources. Finally, RQD is calculated by measuring the valid centerline lengths of each core. It is shown that the method is capable of separating even tightly fit joint surface cores. The algorithm is cross checked against a manual RQD logging and it is determined that the method is able to calculate RQD within an error margin of 5% in less than 60 seconds per 4 rows of core in a core box.

10:25 AM

Stabilization of Soft Soil Waste Dumps with Geosynthetics

D. Gilbert; Colorado Civil and Mining, Denver, CO

The area of Northwest Ontario is characterized by deep soft till horizons overlaying orebodies. New pit development requires removal of twenty-five to sixty meters of till overburden, and relocation to waste dumps. A recent project startup and rock requirement for starter dam facility, made rock resource scarce. Initially soft soil stabilization considered use of rock to build network of access across the waste dump, to allow for shorter pushes. Material requirements for rock forced operations team to test sample panels of geosynthetics reinforcement as a stabilizing means for weight redistribution of haulage equipment. Successful use of this dropped rockfill usage at dumps by at least 75%, and allowed for successful rockfill resource allocation to dam requirements, ensuring cost and schedule completion.

10:45 AM

Stability Assessment for Stope-and-Fill Mining Operations

C. Newman and Z. Agioutantis; University of Kentucky, Lexington, KY

Over the past decade, as conventional underground deposits have been depleted, mining operations have been forced to produce at deeper depths and in more geologically challenging conditions. As such, there has been a global increase in the application of cemented paste backfill (CPB) in tabular narrow vein deposits utilizing open stope mining method with a delayed backfill placement. Despite the extensive use of CPB, many fundamental factors affecting the design of safe and economical fill structures are still not well understood. A critical issue in the design of backfilled stopes is the determination of stress states within the fill material itself as well as the surrounding rock mass. Analytical equations provide a means of quickly evaluating the effectiveness of a given design. However, in developing these equations large assumptions are implemented to simplify the design problem. It is important that one understands these simplifications as well as their effect on the overall design. This paper investigates common analytical equations utilized in the evaluation of single vertical backfilled stopes and their assumptions through comparisons to numerical modeling results.

WEDNESDAY, FEBRUARY 28

MORNING

9:00 AM | ROOM 101E

Mining & Exploration: Management: Underground Mining, Planning the Future

Chair: *D. McLane, Stantec*

9:00 AM

Introduction

9:05 AM

Evaluation of Fragmentation by Blasting to Evaluate the Flow Conditions of the Ore Throughout a Given Ore Pass Dimension

G. Borquez; Mining Consultant, Lafayette, CA

This paper represents a case study of an Underground Mininin operation using Open Stope and long hole blasting given considerations to the rock mass quality. From the mining operation point of view, the objective is to optimize the ore extraction from the bottom of the stope and the subsequent flow of the ore through the Ore Pass. A procedure is presented to obtain the drilling an blasting desing that will provide a good rock fragmentacion. The fragmentation obtained is used to estimate the productivity of the LHD loaders and the possible flow conditions of the ore through an Ore Pass of a given dimension The set of geotechnical data that caracterized the rock mass, are based on actual study. This data was used to make simulation of the fragmentacion by blasting to obtainthe rock size distribution, which will provide the factors for estimating the transportation of the ore to the Ore Pass and its flow conditions. In this manner adjustment can be made to obtain the drilling and blasting design to obtain the desirable rock fragmentation. The size of the an Ore Passis determined by the ration of the maximun rock size and the minimun opening requiredto assure a continue flow condtions

9:25 AM

Wet Muck Panel Prediction for Remote Control LHD Implementation At Deep Ore Zone (Doz) Mine PT Freeport Indonesia

R. Vince and M. Hutahaean; Underground, PT Freeport Indonesia, Tembagapura, Papua, Indonesia

Deep Ore Zone (DOZ) is underground mine managed by PT Freeport Indonesia that currently producing for 40,000 tons ore per day with ultimate ramping up plan up to 60,000 tons per day. DOZ Mine is an operating cave mine located between 3076 and 3146 AMSL where the ore taken at 3126m level. Since 2008, the mine start using remote control LHD to reduce personnel exposure to unsafe mining environment including wet muck or mudrush and dusty condition. As the wet muck spreading throughout the footprint, an extensive close monitoring for safety reason, planning and preparation

of autonomous infrastructure needed to avoid delay in material delivery and unexpected interruption in production operational. To have a better planning on material order for the infrastructure and machine conversion-kit, a wet muck panel prediction has been built by considering drawpoint height of draw (HOD), rock type, and forecasted draw distribution. In this paper, we will estimate and predict the remaining manual LHD at Panel 1F, 1G, 1H, 1I and 1J in the south part of the footprint to become wet remote area. This study can also be implemented for Deep Mill Level Zone (DMLZ) mine, the successor of DOZ mine.

9:45 AM

Underground Localisation: Which is the Right Technology?

C. Niestroj, S. Schade, T. Hartmann and E. Clausen; RWTH Aachen University, Aachen, Germany

These days different indoor positioning systems (IPS) are available on the market. However, only a few of them are in fact suitable for employ in underground environments in order to establish a working underground localisation system (ULS). Especially with regard to the capability to automate mining equipment, the question remains which system is the best in terms of accuracy, precision, and other factors. What is more, the requirements of the mining industry need to be considered when evaluating the suitability of the systems. In order to determine the suitability, an analytical hierarchy process (AHP) analysis was undertaken to establish a ranking of IPS. For this study, not only experts from the mining industry but also researchers gave input on the requirements towards a ULS. In this presentation, the results of the ranking of on-the-market-available indoor positioning systems for an underground localisation system will be presented.

10:05 AM

Instrumentation to Help Improve Drill and Blast Results in Underground Up-Hole Stopping

T. Worsey[2], N. Rouse[1], B. Lusk[1] and K. Hall[1]; [1]RESPEC, Lexington, KY and [2]UK, Lexington, KY

Loading explosives up hole has challenges that is typically not seen in down hole explosive loading. Lack of experience and technology can cause significant problems when loading explosives up hole. When results aren't achieved the blame is commonly put on the design when the true problems are unknown. Not knowing the cause of the problem causes drill and blast designs to be over engineered and very costly with little success. Being able to know and record key data is crucial to actually solving the problem. This paper goes over blast instrumentation that can be used to trouble shoot drill and blast problems in up hole explosives loading in underground mines. The tools and procedures used to trouble shoot include velocity of detonation recorder, photo fragmentation, borehole tracking, seismographs, borehole camera and auditing procedures. Each item will be discussed in detail with a case study to show the usefulness of the instrumentation. The operation discussed in the case study had issues pulling raises and had hang ups in the stope shots. These problems caused production slowdowns and costly remediation blasting that was not very successful.

10:25 AM

The Mine of the Future is Here, Now – Going from Theoretical to Actual with the Borden Gold Project's Battery Powered Fleet

S. Lister; Marketing, CIM, Collingwood, ON, Canada

Goldcorp's Borden Gold project in northern Ontario is slated to be the world's first all-electric underground hard rock mine by the time it reaches production stage in 2018. With construction currently underway, the mine of the future – low carbon, diesel fine particulate removed, and reduced ventilation and fleet maintenance costs – is here, now. This presentation by MacLean Engineering, a Canadian-based equipment manufacturer sourced with providing battery powered units to the project, will focus on mobile fleet operating and total-cost-of-ownership (TCO) data accumulated to date. MacLean delivered five battery powered units to the Borden project in early 2017, and currently has two other battery electric rock bolters working underground in hard rock mines in Ontario, as well as one battery electric boom truck being trialed. The sharing of MacLean's fleet electrification program learnings at the annual SME conference is an opportunity to help advance industry awareness and start to fill in the gaps of knowledge upon which battery power commercialization will be accelerated.

10:45 AM

Changes in Design Philosophy for Underground Heading Cuts Utilizing Modern Explosives and Equipment

A. Konya[1] and P. Worsey[2]; [1]Explosive Engineering, Precision Blasting Services, Montville, OH and [2]Explosive Engineering, Missouri University of Science and Technology, Rolla, MO

With the advent of Ammonium Nitrate explosives, the explosive industry introduced new problems for blasting in underground mining applications such as deadpressing and precompression of explosives. These problems have led to poor fragmentation, an increase in vibration levels up to four to five times that of normal, and in extreme cases freezing of the entire round. These problems have become prevalent in today's underground heading blasting due to close spacing of charges in heading design that relys on an outdated design philosophy that dates to the use of dynamite and other explosives that would not deadpress, but sympathetically detonate instead. This paper describes the mechanisms behind these problems and introduces key design changes to the burn cut and V cut that reduce the risk of deadpressing and precompression of modern explosives from both a theoretical and practical standpoint. Case studies and examples are included.

WEDNESDAY, FEBRUARY 28

MORNING

9:00 AM | ROOM 101B

Mining & Exploration: Operations: Lake Superior-type Iron Ore: Applied and Evolving Mine to Mill Characterization and Reconciliation, Part 1 of 2

Chairs: *H. Taylor, Cleveland-Cliffs Inc.*
D. Gebhart, Cleveland-Cliffs Inc.

9:00 AM

Introduction

To produce a high quality pellet from low-grade magnetite iron ore, each stage in the process (orebody modeling, mining, concentrating, and pelletizing) must be reconciled to minimize deviation from product specifications and maximize throughput and recovery, yet control cost. Engineers or geologists managing each stage should have a site-specific understanding of the standard Mine-to-Mill (M2M) approach applicable to any style of mineral deposit, which ideally optimizes overall productivity, product quality, and cost through collaborative integration of geology, mining, and mineral processing. M2M begins with a good foundation in geology and mineralogy to understand liberation characteristics of valuable minerals and where downstream processing problems could originate. This information is used in planning the optimal blend of ores and improved blasting for mine sequencing and ore liberation.

9:05 AM
Introduction to Superior-Type Iron Ore Geology
D. Halverson; Cleveland Cliffs, Iron Junction, MN

The Biwabik Iron Formation is a Lake Superior-type iron formation that hosts the mines of the prolific Mesabi Iron Range of Northeastern Minnesota, one of the principal global sources of iron ore since the 19th century. The Biwabik Formation is subdivided into four main, regionally continuous members, based on their textural components of "cherty" or "slaty" lithology, these being regional colloquial terms. The Upper Slaty, Upper Cherty, Lower Slaty, and Lower Cherty members are further locally subdivided into ore and waste units based on magnetite liberation characteristics and magnetic iron grade, metamorphism, and secondary oxidation that largely reflect macroscopic mineral textures that can be observed in drill core.

9:45 AM
Ore Characterization Methods for Low-Grade, Superior-Type Iron Ores in North America
M. Orobona; Cleveland-Cliffs Inc., Cleveland, OH

For "hard rock" metallic ore deposits, emphasis is generally on chemical recovery from reserves that are largely classified by many crude assays measuring weight-percent metal or unit-per-ton. Whereas there may be chemical digestions applied to every assay interval to estimate recovery, metallurgical characterization is often based solely on bulk pilot tests. However, for the (generally) much harder beneficiation-grade iron ores of North America, crude ore metal content is of secondary importance, including for the reporting of reserves. Emphasis is on physical processing of reserves that are classified by and modeled for expected product tonnage and quality from a comparable number of bench-scale metallurgical tests. These characterize weight recovery, product fineness and grade, and frequently even the relative comminution power required to achieve these target qualities. As such, low-grade iron ores have a geometallurgical advantage when building downstream mine-to-mill models to optimize ore blending for the energy-intensive process of mineral liberation.

10:45 AM
Superior-Type Iron Ore Geometallurgy
R. Johnson; Natural Resources Research Institute (NRRI), University of Minnesota, Duluth

Iron ore mining is a challenging business that produces relatively low value products in large quantities. The application of geometallurgy can improve the profitability of mining operations by enhancing the effectiveness and efficiency of ore characterization, mine planning, mineral concentrating, and waste management. Geometallurgy begins with characterization of ore through the identification of minerals and liberation characteristics. The successful application of geometallurgy requires a thorough understating of mining practices, concentrator plant operation, and pellet quality. Analytical methods for the geometallurgical analysis of iron ore will be discussed and examples of the application of geometallurgy to the analysis and solution of mining, concentrating, and pelletizing problems will be presented.

WEDNESDAY, FEBRUARY 28
MORNING

9:00 AM | ROOM 101C

Mining & Exploration: Operations: Mine Ventilation

Chairs: *K. Kocsis, University of Nevada, Reno, Reno, NV*
J. Brune, Colorado School of Mines, Golden, CO

9:00 AM
Introduction

9:05 AM
Concepts and Applications for Using Strain Gauges to Monitor Ore Pass Levels
S. Nelson; Electrical Engineering, Henderson Mine – Freeport McMoRan, Empire, CO

Climax Molybdenum Company's Henderson Mine, owned by Freeport McMoRan Inc., is a panel caving molybdenum mine located about 69 km west of Denver, Colorado. The mine utilizes long interconnected ore passes as part of the ore flow system. Knowing the approximate level of ore in these ore passes is beneficial for preventing increased dust concentrations in various production areas, as well as scheduling truck loading operations. Level monitoring has been achieved by using a strain gauge placed on the steel of the truck chute, an amplifier and a Programmable Logic Controller. This paper explains concepts and limitations associated with using strain gauges for ore pass monitoring as well as applying proactive dust prevention and level monitoring interfaces.

9:25 AM
Reducing the Heat Load in Hot Working Areas of Nevada's Underground Precious Metal Mines
K. Scalise[1], P. Roghanchi[2] and K. Kocsis[2]; [1]Mining Engineering/Geological Sciences and Engineering, University of Nevada, Reno, Sparks, NV and [2]Mining Engineering, University of Nevada, Reno, Reno, NV

Most of Nevada's underground metal mines are not considered to be hot mines due to the fact these underground operations do not have an extensive mine-wide heat problem. However, there are several localized areas where temperature and humidity can temporarily exceed the threshold limit values during development and production operations. Consequently, heat may be considered and treated as a contaminant, which can be mitigated by redesigning the mines' auxiliary and/or primary ventilation systems, and as a last resort by employing localized cooling systems. This paper will discuss the methods and the new technologies which can be implemented to reduce the heat which is then transferred to the ventilating air from strata, mining equipment, auto-compression and other sources. Additionally, this paper will demonstrate the importance of selecting/developing an appropriate heat stress index which can protect the underground workforce in deep and hot underground metal mines. A discussion will be made on the advantages and challenges of different approaches that underground mines used to reduce workers' exposure to elevated heat and humidity levels in underground metal/nonmetal mines.

9:45 AM

Analyzing the Health and Cost Benefits of Utilizing Electric Engines Versus Diesel Engines for Equipment Fleets in Hot Underground Mines

J. Fox[1], A. Greth[1], K. Kocsis[1] and C. Allen[2]; [1]Mining Engineering, University of Nevada, Reno, Fresno, CA and [2]Mining Geology & Technical Services, Vale Ontario Operations, Copper Cliff, ON, Canada

It is the duty of the mine operator to ensure the mine environment is healthy and safe for the mine workers. For deep and hot underground mines, this requires maintaining adequate working temperatures by means of mitigating the heat load generated by strata, auto-compression, mining equipment, explosives, ground water, and human metabolism. The heat load is best reduced by minimizing the amount of heat transferred to the mine air from these sources and through the use of efficient ventilation with effective cooling systems. The heat emitted by mining equipment and vehicles contribute a significant proportion to the combined heat load of an underground mine. This is especially a problem for diesel equipment due to the fact that besides heat, a large amount of water vapor is produced, which increases the humidity in the production workings. Diesel engines have proven advantageous in recent history due to their high power output and reliability. However, as mines continue to become more mechanized and deeper the climatic problems introduced by elevated heat generation will continue to rise. With that, the issue of heat generated by diesel equipment must be addressed.

10:05 AM

Development of a Heat Management Policy for Underground Metal Mines

L. O'Connor, P. Roghanchi and K. Kocsis; Mining Engineering, University of Nevada, Remo, Reno, NV

Safety, health and productivity at the mines greatly depend on the quality of the underground thermal climate. The costs associated with a substandard thermal work environment can be significant. Within the last decade, sliding commodity prices and the pressure on mine operators to increase production output resulted in increased mechanization and intense work rates. Consequently, the climatic conditions in underground mines have declined due to the heat and humidity, which has been transferred to mine air from mining equipment and other heat sources. Based upon this, improvements in respect to the underground climatic conditions are much needed. This paper aims to discuss the steps that are required to develop a heat management policy for underground metal mines in Nevada. Selecting an appropriate heat stress index, regular monitoring of temperature and humidity of the mine air in production stopes, an adequate method of heat mitigation, along with a training program for the underground workforce are the necessary steps that should be defined in the thermal management policy. The challenges & constraints that are considered for the development of this policy will also be covered.

WEDNESDAY, FEBRUARY 28

MORNING

9:00 AM | ROOM 101D

Mining & Exploration: Technology: Innovative Information Mining & Big Data

Chair: *L. Walker, Freeport McMoRan Inc, Morenci, AZ*

9:00 AM

Introduction

9:05 AM

LTE, WiFi and Other Magic

D. Fisk; 3D-P Inc., Calgary, AB, Canada

Your mine's network is absolutely mission critical to your mines operation, for everything from collecting production data to controlling autonomous equipment. Yet, it is no secret that many of our network provide less than stellar performance. We share some of the best practices for getting the most out of your current networks and discuss some of the pros and cons of LTE technology.

9:25 AM

Big Data and Data-Mining Techniques for Detecting Sensor Errors in Mineral Processing Circuits

R. Pothina and R. Ganguli; Mining Engineering, University of Alaska Fairbanks, Fairbanks, AK

The economics of a mineral processing circuit is dependent on the numerous sensors that are critical to optimization and control systems. The sheer volume of sensors results in mines not being able to keep the sensors calibrated. When a sensor goes off calibration, it can severely impact plant economics long before the sensor errors are egregious and detected. Unfortunately, except for egregious errors, there is no way to detect when a sensor is simply just off and not grossly wrong. This paper presents results from a multi-year Big Data research project whose goal was to use data-mining techniques in a multi-sensor environment to identify when sensors start to stray, rather than wait for errors to grow. Authors were successful in identification of induced errors (2%) in multiple sensor data streams in a carbon stripping circuit at a gold processing facility. The techniques used, methodology and results related to the research topic are presented in this paper.

9:45 AM

Reliability Analysis of a Longwall Shearer Machine Using Statistical Methods: An Application

A. Jha[1], S. Chatterjee[2] and S. Bandopadhyay[3]; [1]Mining Engineering, South Dakota School of Mines and Technology, Rapid City, SD; [2]Geological and Mining Engineering, Michigan Technological University, Houghton, MI and [3]Mining Engineering, University of Alaska, Fairbanks, AK

Longwall shearers are widely employed in underground coal mines. The reliability of such machine has significant importance for successful mining operations. This paper aims at studying reliability of a longwall shearer using failure data recorded for a year. Data was pre-processed, sorted and selected for analysis. Selected data is then examined using statistical models. Distribution fitting of time-between-failure (TBF) and time-to-repair (TTR) are accomplished using three different models. Goodness-of-fit criteria is used to ascertain the best fitting model. Reliability in terms of mean-time-between-failure (MTBF), and mean-time-to-repair (MTTR) are calculated using the model which best represents the failure data. Exponential distribution best represents the time between failure and lognormal distribution the time to repair data. A well-known risk management technique Failure Mode Effect and Criticality Analysis is used to evaluate the critical breakdowns. Critical system/parts, experiencing regular failures is delineated based on this analysis.

10:05 AM

Successful Implementation of an Asset Management Program Integrating Control and Maintenance System

E. Ingegneri, E. Botelho and M. Nicolay; ABB, Sao Paulo, Sao Paulo, Brazil

The ISO 55000 Asset Management (AM) series of standards is the baseline for implementation of an AM program. The integration of data available in the control system, expert condition monitoring tools and maintenance management system is the driver to achieve excellence maintenance performance. Critical mining production assets are large composite of electrical, automation and mechanical components. The condition monitoring algorithms were built based on maintenance engineering knowledge, such as hierarchical diagram, criticality and fault trees, increasing condition-based maintenance. Individually, the condition monitoring of components, considers its failure modes, control system data, expert condition monitoring system and data-

sheets. The result of this methodology avoids the misperception that AM is a luxury item, hard to justify as an investment. In addition, an AM program reduces unnecessary maintenance, e.g. 10% reduction of visual inspections, improves time to repair, reduces unplanned downtime, reduces people exposure to hazardous areas and take advantage of technologies, providing a smooth integration between operations, automation and maintenance staff.

10:25 AM

Best Practices for UAV LiDAR Mission Planning

T. Wolf[1], D. Stanley[1] and J. Oliver[2]; [1]HDR Engineering, San Diego, CA and [2]Maser Consulting, Denver, CO

Today it is easier than ever to collect vast amounts of high-quality spatial data through the use of LiDAR paired with Unmanned Aerial Systems (UAS). Mining companies are beginning to discover the breadth of potential value added applications of this technology in their operations. In the midst of the appropriate enthusiasm it is important that operators deploy the technology with a specific mission-based approach that optimizes the data return on investment for a given flight, and that the data obtained can be turned into useful knowledge that maximizes the utility of the information across the entire mining enterprise. This presentation will feature a systematic approach to preparing a mission plan for the use of UAV/LiDAR combinations. Participants will learn the fundamentals of mission planning and how the particular dataset and/or measurement of interest determines the parameters of a given UAV scanning mission such as flight pattern, scanning density, accuracy, safety considerations, etc. The presentation will also discuss some of the ways mining companies can prepare themselves to appropriately manage the voluminous data that is produced.

10:45 AM

Information for all: Transforming the Mining Operations Management Paradigm

H. Aguirre[2], O. Rielo[1], J. Ortiz[1] and L. Daneshmend[1]; [1]Mining, Queen's University, Canada, Kingston, ON, Canada and [2]Faculty of Engineering, Universidad del Desarrollo, Concepcion, Chile

Four decades ago, the deployment of the first computerised fleet management systems in open pit mines led to a transformation in the management of mining operations. The enabling technologies underlying such systems have advanced radically, and dropped dramatically in terms of cost, however the capabilities of the resulting systems have only increased marginally, and they still tend to be limited to larger mines. This paper outlines a novel technological paradigm for mine operations management based on adoption of non-proprietary Open Systems Architectures, and use of Commercial Off The Shelf elements, for both hardware and software. This paradigm lowers unit costs for deployed hardware and software by up to two orders of magnitude, minimises the need for technical expertise at mine sites, and transfers data analytics to the cloud. It makes the adoption of mine operations management systems feasible for a much wider range of mine sites, including small and medium sized operations, enabling the development of a highly competitive global marketplace in customised data analytics with the potential for significant enhancements in reporting and analysis capabilities, at reduced cost.

11:05 AM

Big Data in Mining

A. Chowdu and A. Brickey; Mining Engineering & Management, South Dakota School of Mines & Technology, Rapid City, SD

Big data has been a buzzword in the technology circles for the better part of two decades. A more recent entrant has been the "Interconnected Internet of Things". Together, they have the potential to provide great insights into the complex interactions occurring in our industries. While there has been many a success story of how a company leveraged big data, there have been as many or more stories of failure. As the technology has evolved, our understanding of it has also gotten better. Steadily, the minerals industry has been moving towards integrating these analytics as well. This presentation explores the current state of big data analytics in mining and the impact it has had.

WEDNESDAY, FEBRUARY 28

MORNING

9:00 AM | ROOM 200IJ

MPD: Flotation III: Chemical Aspects of Flotation

Chairs: *R. LaDouceur, Montana Tech, Butte, MT*
A. Ozkan

9:00 AM

Introduction

9:05 AM

Improved Selective Flotation Reagents for Phosphate Ore Upgrade

A. Michailovski and A. Villanueva; Mining Solutions, BASF SE, Ludwigshafen, Germany

The global depletion of easily accessible high-grade phosphate deposits leads to a rising demand for beneficiation technologies in phosphate ore processing, often requiring one or several flotation stages. As the easy-to-beneficiate deposits are being exhausted, ore bodies with higher beneficiation costs, such as carbonaceous phosphates, increase in relevance as a feedstock for fertilizer industry. The present work focuses on optimizing the collector performance for sedimentary ores based on hydrophilic-lipophilic balance (HLB) characterization of additives, a parameter that has a massive impact on both the collector adsorption selectivity and on froth properties, ultimately affecting the flotation kinetics. We demonstrate how the precise control of the HLB value of the collector system using an environmentally friendly APEO-free additive system can lead to improved flotation plant performance in both igneous and sedimentary phosphate ores, combining enhanced metallurgical characteristics with a reduction in reagent cost.

9:25 AM

Copper/Gold Optimization Utilizing Sulfur-Based Flotation Reagents

D. Laney and B. Ramos; Mining Chemicals, Chevron Phillips Chemical Company, LP, Elko, NV

Sulfide mineral flotation operations continuously strive for a balance between optimizing copper and gold mineral recovery while rejecting iron sulfide minerals. Predominately the most effective, and economical, reagents for sulfide mineral recovery fall within the thiol collector family. Chevron Phillips Chemical Company has developed a family of reagents that have demonstrated the ability to optimize copper sulfide mineral recovery, improve gold recovery, while selectively minimizing recovery of iron sulfides. This paper will provide examples of solutions of optimizing copper and gold recovery by using reagent solutions. Discussions will include test data utilizing Orfom® Collectors in copper-gold and copper-silver ores. The presentation/paper will also discuss flotation parameters including pH, retention time, percent of solids, and particle grind size.

9:45 AM

The Challenges of Successfully Introducing New Reagents into an Existing Flotation Plant

S. Hearn; huntsman, The Woodlands, TX

There are many new flotation reagents available now, often replacing existing tried and true standards with better results. This paper will discuss the challenges of introducing new reagents to an existing mill, starting with reasons for making reagent changes, which usually focusing on improved grade and recovery but also better economics. Laboratory testing to evaluate

different reagents is discussed, followed by how to conduct effective plant trials and evaluate the results. Case studies are given to illustrate how the results of some tests were achieved and interpreted. Assuming the new reagent is accepted for plant trial, its successful implementation requires that good operating practice is subsequently followed in the mill as well.

10:05 AM

Challenges in Characterization and Selection of Flotation Frothers

E. Arinaitwe, D. Nagaraj, T. Bhambhani and R. Farinato; Technology Solutions - Minerals processing, Solvay, Stamford, CT

To date, the most extensively used methods and approaches for characterizing and selecting frothers for plant application are solely based on measurements in clean water in the absence of solids and without consideration of physicochemical factors that are known to influence the properties and behavior of practical flotation froths. These factors include aquatic chemistry, collectors, modifiers, particle shape and size, and pH. It is thus not clear how fundamental measurements in 2-phase systems can be linked to, or can predict, plant metallurgical outcome. In this paper, a critical evaluation of the literature has been conducted in order to highlight the important role and relevance of several physicochemical and operational factors in characterizing frothers and froth zone properties. We also report preliminary results of a "systems approach" study designed to probe ways in which these factors a) influence frothing and bubble size in 2-phase and 3-phase systems, and b) confound correlation of fundamental measurements with flotation outcome.

10:25 AM

Investigating the Mechanism of Depression of Disodium Carboxy-Methyl Trithiocarbonate (Orfom® D8) in the Chalcopyrite-Molybdenite Flotation System

S. Timbillah[1], C. Young[1], A. Das[1], R. LaDouceur[1], J. Byers[2], B. Ramos[2] and D. Laney[2]; [1]Metallurgical, Montana Tech, Butte, MT and [2]Chevron Philips Chemical, Woodlands, TX

The high oxidation rates which result in large consumption dosages of currently used depressants in chalcopyrite-molybdenite flotation has led the industry to search for alternative reagents that can perform the same function without sacrificing operating costs including safety and social burdens. One such depressant is Orfom® D8, an organic depressant which has a low hazard profile compared to most inorganic depressants. Also, it does not easily oxidize in air and does not require an inert gas facility in the process, resulting in the overall lower consumption of the depressant and, ultimately, cost savings. Laboratory and plant scale trials demonstrate Orfom® D8 as a strong alternative to the currently used depressants. This fundamental study was conducted to determine potential mechanisms of depression. Results from electrochemistry, flotation, FT-IR Spectroscopy, Laser Raman Spectroscopy (LRS), and X-ray Photoelectron Spectroscopy (XPS) are discussed with reference to the depressing action of this reagent.

10:45 AM

Effect of Novel Depressants on the First Order Rate Constant for the Flotation of Rare Earth Minerals

R. LaDouceur[1], P. Amelunxen[2] and C. Young[1]; [1]Metallurgy, Montana Tech, Butte, MT and [2]Aminpro, Lima, Peru

Flotation involves many variables broadly ranging from hydrophobicity to energy input parameters. Consequently, numerous challenges exist with the development of precise and accurate predictive models. The response of grade and recovery to changing experimental conditions does not tell the complete story. Rather, as one solution, their effect on the first order rate constant needs to be determined. In this regard, the role of depressants on the first order rate constant was examined using kinetic modeling for the flotation of rare earth minerals. First order rate constants were determined using a three-compartmental kinetic model. Four novel depressants were identified and a parametric design of experiments study was performed. Depressant type and collector dosage were studied to generate statistically significant experimental models for responses that included grade and recovery as well as first order rate constants.

WEDNESDAY, FEBRUARY 28

MORNING

9:00 AM | ROOM 200DE

MPD: Hydrometallurgy II

Chairs: *B. Burrell, Freeport-McMoRan, Safford, AZ*
K. Garcia, Freeport McMoRan, Safford, AZ

9:00 AM

Introduction

9:05 AM

Solvent Extraction of Copper Sulfate PLS Using Impinging Flow Design and Static Mixing – a Candidate for RAPID Advancement in Process Intensification Deployment

F. Dakubo; Hydrometallurgy, Ray Mine, Kearny, AZ

The extraction from copper from copper pregnant solution (PLS) via hydrometallurgy is mostly accomplished using mechanical mixer settler system. In this study we will demonstrate a novel copper solvent extraction reactor based on the concepts of impinging flow and static mixing. This study was undertaken in support of reducing the plant footprint and energy. Initial data shows extraction efficiency of 70% compared to 97% from a three-stage mechanical agitation settler system.

9:25 AM

Response Surface Methodology Application to Solvent Extraction – Ammonium Peroxodisulfate Assisted Copper PLS

F. Dakubo; Hydrometallurgy, Asarco Ray Mine, Kearny, AZ

A response surface study of the effect of mixer speed, pH, and reagent concentration and organic to aqueous (O/A) ratio on solvent extraction of ammonium peroxodisulfate copper leached (PLS) was conducted using a pitch blade mixer. The results indicate that, mixer speed, reagent concentration, pH and O/A ratio were statistically significant to copper extraction. The response model developed has an R2 = 0.97 and Adeq precision of 28.3. A parallel study using a straight blade Rushton turbine mixer between peroxodisulfate assisted leach PLS and conventional ferric/ sulfuric acid leach PLS showed no difference in copper extraction.

9:45 AM

Theoretical Performance Predictions of an Autopressurizing (well) Autoclave

J. Werner[1] and M. Pearson[2]; [1]Mining Engineering, University of Kentucky, Lexington, KY and [2]Hatch, Mississauga, ON, Canada

Autoclaves are utilized in extractive metallurgy to increase the rates of reaction in ores that are otherwise uneconomical. The downside of conventionally designed autoclave vessels are the large capital expenditures, construction lead times, associated maintenance and operational costs of high temperature linings and high pressure rotating equipment. These present unique challenges to the development of new and continued operation of autoclaves for such ores such as: refractory gold, laterite nickel and sulfidic copper among others. To address these challenges this work evaluates the theoretical performance of a novel type of autopressurizing pipe well reactor. It is anticipated that an autoclave of this type can reduce the cost and complexity of pressurized reactors by utilizing gravity pressurization in a counter flow well. This work will evaluate the heat transfer and critical parameters as a function of well position. In addition technical feasibility and design parameters for the well components will be ascertained.

10:05 AM

Case study: Economic Evaluation of a Conventional Versus an Autopressurizing (well) Autoclave

J. Werner[1] and M. Pearson[2]; [1]Mining Engineering, University of Kentucky, Lexington, KY and [2]Hatch, Mississauga, ON, Canada

Autoclaves are utilized in extractive metallurgy to increase the rates of reaction in ores that are otherwise uneconomical. The downside of conventionally designed autoclave vessels are the large capital expenditures, construction lead times, associated maintenance and operational costs of high temperature linings and high pressure rotating equipment. These present unique challenges to the development of new and continued operation of autoclaves for such ores such as: refractory gold, laterite nickel and sulfidic copper among others. To address these challenges this work evaluates the theoretical performance of a novel type of autopressurizing pipe well reactor. It is anticipated that an autoclave of this type can reduce the cost and complexity of pressurized reactors by utilizing gravity pressurization in a counter flow well. This work will evaluate the heat transfer and critical parameters as a function of well position. In addition technical feasibility and design parameters for the well components will be ascertained.

10:25 AM

Heap Leaching Acid Feed Control

M. Ferra; REXA, West Bridgewater, MA

In the heap leaching process a key to success in producing high quality agglomerated ore is to have minimal process variation of the feed solutions entering the kiln. Tightly controlled acid feed rates can achieve stable and predictable agglomerated spheres. This will in turn lead to less acid consumption and improved leaching, which are critical for successful production at a mine. The problem at a large copper mine in Eastern Arizona, was the acid flow variation from a pneumatic actuator had to position a ball control valve. The pneumatic actuators lacked precision (2% movement) due to the compressibility of air and needed an increased pressure set point. The plant sought a solution and selected a REXA electro-hydraulic actuator that produces up to 2,000 pounds of thrust and reduced the valve movement to <0.5 degrees. Similarly, the REXA Actuator's high stiffness and exact positioning enabled the feed set-point to be lowered, reduced consumption and worker exposure, and improved leaching to having a better quality of ore post agglomeration. Acid consumption savings is estimated to be $312K per year.

10:45 AM

Process Flowsheet Development for Hydrometallurgical Recovery of Rare Earth Elements (REE) from Coal Ash

M. Peiravi[1], L. Ackah[3], R. Guru[3], J. Godbold[4], M. Mohanty[2], J. Liu[1], X. Bing[5], Z. Xiaobo[6] and C. Lunjian[5]; [1]Civil and Environmental Engineering, Southern Illinois University, Carbondale, IL; [2]Department of Mining & Metallurgical Engineering, University of Nevada, Reno, Reno, NV; [3]Mining and Mineral Resources Engineering, Southern Illinois University Carbondale, Carbondale, IL; [4]Technology Engineering Department, Southern Illinois University Carbondale, Carbondale, IL; [5]College of Chemistry and Chemical Engineering, Henan Polytechnic University, Henan, China and [6]College of Chemistry and Chemical Engineering, Henan Polytechnic University, Henan, China

The experimental program completed on an anthracite coal ash, having more than 700 ppm of total REE, included high temperature leaching, followed by solvent extraction, stripping and precipitation tests. The highest light REE recovery of 90% and heavy REE recovery of 94% were obtained from the nitric acid leaching test while maintaining the impurity recovery at less than 40%. Di-(2-ethylhexyl) phosphoric acid performed the best as an organic extractant with a 99% recovery of REE. Nitric acid and sulfuric acid (4M and 6M) were used to strip the REE from the solvent (SX concentration 10 and 30%). During stripping (in one stage), almost 40% of the total REE were stripped to the aqueous solution, more stages of stripping had to be added to improve upon the striping recovery. Oxalic acid helped precipitate more than 94% of total REE from the above aqueous solution. The same process flowsheet was also successfully tested for another coal ash sample.

11:05 AM

Molybdenum Solvent Extraction Using CYANEX® 600 Extractant: Part II, Commercial Performance

C. Lewis[1] and C. Cooper[2]; [1]Freeport McMoRan, Safford, AZ and [2]Solvay, Tempe, AZ

Following a successful SX pilot plant trial in 2016, CYANEX® 600 has been used commercially as a molybdenum extractant from concentrate leach liquor since March 2017. The metallurgical and physical results are consistent with the pilot investigation resulting in reduced base consumption and improved physical performance as compared to the previous amine extractant. This paper highlights the optimization activities from startup through normal operation focusing on the KPI targets to achieve desired performance. Additionally, physical, metallurgical, and operational optimization solutions implemented throughout the first year of commercial operation are reviewed.

WEDNESDAY, FEBRUARY 28

MORNING

9:00 AM | AUDITORIUM ROOM 1

MPD: Physical Separation I

Chairs: *T. Rauch, Jacobs, Venetia, PA*
M. Rezaee, The Pennsylvania State University, University Park, PA

9:00 AM

Introduction

9:05 AM

Complemental Developments in Lab Scale Sensor Based Sorting Systems

A. Young and C. Petter; Mining Engineering, UFRGS, Porto Alegre, RS, Brazil

Sensor Based Sorting (SBS) techniques have been incorporated in mining for many years, but very limited information is available regarding how the signals are truly processed. Raw data from sensors is often unavailable and has only been displayed in the form of pre-processed images. As this issue will probably remain a sensitive matter for industrial manufacturers of SBS equipment, the proposed modifications to the MSX model Lab Sorter are part of a larger effort to allow for comparisons in raw sensor data, with the goal of eventually assessing the efficiency of software from various sorting manufacturers. In this manner, best practices and new sorting algorithms can be established as a function of academic research in collaboration with industry. These modifications could likewise enable other researchers to use and compare results in a much more collaborative and streamlined manner, and potentially reduce the cost and installation times of new industrial scale sorting equipment. This paper outlines the proposed changes to the MSX model and the expected outcomes such changes will have on the system, as well as the potential impacts these changes could have on the mining industry.

9:25 AM

An Integrated Approach to Upgrading Calcite Ore Using Near Infra-Red (Nir) Sorting Technology

B. Mohononi; Minerals processing, Mintek, Randburg, Gauteng, South Africa

Modern sensor based ore sorting has gained increasing acceptance in the minerals processing industry over the last decade, particularly for the purpose of coarse gangue rejection. Many benefits are evident, including reduction of water and power consumption and costs in downstream processes. NIR sorting is a proven technology in the food and plastics recycling industries. The heterogeneous nature of most mineral ore bodies, however, provides a more difficult environment for incorporating NIR measurements in to a sorting algorithm. The mineralogical and geological nature of calcite ores make them a preferred candidate for upgrading by NIR sorting. The low atomic numbers, little colour difference and similar density ranges between the ore and gangue minerals restrict separation by other sorting technologies. The main aim of this study was to assess the viability of using the NIR black scan/colour/laser sensor combination sorter to reject barren waste from calcite ore samples. The preliminary results, obtained from a 50ton/hr proof-of-concept plant, confirm that the NIR black scan sorter has potential to preconcentrate calcite ores by rejecting barren waste.

9:45 AM

Scavenging of Iron from Flotation Tailings by Wet High Intensity Magnetic Separation (WHIMS)

D. Hopstock[1], J. Ribeiro[2] and C. Ribeiro[3]; [1]Independent Engineering Consultant, Roseville, MN; [2]Gaustec, Nova Lima, Minas Gervais, Brazil and [3]Gaustec, Nova Lima, Brazil

Froth flotation is commonly employed to upgrade fine-grained iron ores in which the iron occurs predominately as weakly magnetic minerals such as hematite and goethite. Typically, siliceous gangue is removed in the froth product, with the enriched iron concentrate reporting to the underflow. Significant loss of iron units, especially in the finer particle sizes, occurs. Recent advances in WHIMS make it economically attractive to recover a significant proportion of the iron in the flotation tailings. Development of larger machines has significantly reduced the capital cost of treating a given tonnage. Solutions have been found to eliminate matrix clogging problems that have in the past impaired the performance of production-scale WHIMS technology. Recently Gaustec brought a trailer-mounted full-scale GX-300 WHIMS machine on-site to process flotation tailings at two sites in Brazil at a feed rate of about 40 tons per hour. Testing was continued over a period of months. Results indicate production of a marketable magnetic concentrate with a favorable return on investment. Benefits include increased overall iron recovery and reduced cost and environmental impact of tailings disposal.

10:05 AM

Dynamic Modeling Strategies for Characterizing of Mill Charge in a SAG Mill

V. Srivastava[1], A. Sachan[1], T. Ghosh[1], G. Akdogan[2] and R. GANGULI[1]; [1]Department of Mining and Geological Engineering, University of Alaska Fairbanks, Fairbanks, AK and [2]Department of Process Engineering, Stellenbosch University, Matieland, Western Cape, South Africa

SAG Mill models have been widely used in simulating and optimizing mill performance to quantify power draw, processing capacity and product size distribution. However, these models are solved under steady state approximation and do not provide any information on mill charge distribution in real time. This paper attempts to characterize mill contents by solving Whiten's first order contents based model in Matlab/Simulink environment. The parameters in the model such as breakage rate (S), discharge rate (D) and appearance function (A) were estimated utilizing process and design data collected from a gold mine operating in Alaska coupled with nonlinear parameter estimation scheme. This model is then utilized to predict dynamic response of other key operational variables such as mill power, bearing pressure, and charge level and product size distribution. The transient response of mill behavior subject to changes in feed size distribution, tonnage and mill feed water is also presented. This dynamic simulation approach can be used for practicing different control strategy and training purposes.

WEDNESDAY, FEBRUARY 28

MORNING

9:00 AM | ROOM 200GH

MPD: Pyrometallurgy II – Iron Ore Pellets for DR

Chairs: *S.Ripke, Midrex Technologies Inc, York, SC*
D.Gagnon, DRA Americas

9:00 AM

Introduction

9:05 AM

DR-Grade Pellet Production at Northshore

P. Carlson; Cliffs Technology Group, Cliffs Natural Resources, Ishpeming, MI

In 2015 Cliffs began a new era by supplying DR-Grade Pellets from its Northshore Mining operations in Minnesota. These were the first commercially produced DR-Grade pellets made in the United States. DR-Grade pellets have more stringent quality parameters for gangue content, clustering and metallurgical performance when compared with blast furnace pellets. The Northshore pellets not only met these requirements, but performed exceptionally well in commercial DRI shaft furnaces. An overview from flowsheet development through production will be discussed along with future plans to supply Cliffs first Hot Briquetted Iron (HBI) plant in Toledo, OH.

9:25 AM

Value-in-Use of Iron Ore Pellets for Direct reduction

M. Tottie; Process and Product Development, LKAB, Malmberget, Sweden

When developing pellets optimized for direct reduction, it is important to also take the down stream part of the process route into consideration. The pellets should work well in the DR shaft furnace with good metallisation, low disintegration and resistance to clustering. Of equal importance is that it should be optimised for the electric arc furnace. Low amount of acid gangue in the DRI gives low energy consumption and high productivity. Basic gangue components are instead beneficial for the electric arc furnace resulting in improved slag forming and longer lining life. The value of these properties are different depending on local conditions and also depending on variations in market conditions for steel.

9:45 AM

Rio Tinto IOC Operations: A Continuous Focus to Improve Its DR Pellet Output and Quality to Meet Demand

R. Chaigneau; Iron Ore, Rio Tinto, Kockengen, Netherlands

Increased capacity and efficiency of DRI modules requires a continuous improvement of DR pellets. The larger sized DRI modules require a focus to meet sometimes counteracting requirements. IOC has this strong focus to meet its customer demands and whilst producing DR pellets since '94, IOC not only seeks opportunities to increase output within its current operations but in contact with its customers consistently seeks those further improvements. Implemented examples are an improvement of sizing with a tight size range, minimizing the fraction of small pellets < 9.5 mm to below a few percent. Inherent pellet strength is further improved by tight process control and also other quality aspects remain under review.

10:05 AM
Alternatives to the Blast Furnace for the Production of Metallic Iron
T. Battle; Extractive Metallurgy Consultant, Charlotte, NC

For over one hundred years, the blast furnace has been the dominant technology for the production of metallic iron from iron ore. However, this technology is not necessarily the appropriate technology in all situations, so there has been extensive research in alternate methods to produce a metallic iron feedstock suitable for the manufacture of steel. A number of technologies have been commercialized in the past sixty years to provide what the steel industry often calls 'Alternate Iron Units' (AIU). Current production of AIU is over 70,000,000 tonnes per year, and increasing steadily. The current commercial technology options to produce AIU will be discussed in this presentation. The focus will be on the most successful technology to-date, the gas-based reduction processes developed by HyL and Midrex, but other reactor designs, such as rotary kilns and rotary hearth furnaces, and other technological approaches, such as Corex, will also be discussed. The focus will be on current operations and industry trends.

WEDNESDAY, FEBRUARY 28
MORNING

9:00 AM | ROOM 101G

Research: Focus on Innovation in Mining Industry – Operations

Chairs: *A. Samal, GeoGlobal LLC, Riverton, UT*
B. Li, Michigan Technological University, Houghton, MI

9:00 AM
Introduction

9:05 AM
Technology Adoption – Balancing Scepticism with Leadership
D. Bongers; SmartCap Technologies, Milton, QLD, Australia

Despite technologies becoming commonplace in modern mining operations, our process for adoption has changed little since our first uncertain steps. The 'field trial' is a well-established tradition to test technology on a small scale, allowing minimal commitment while unconvinced of its claims. Such an approach can, however, be problematic. Firstly, there are some qualities of a technology that are not testable in a small-scale, temporary setting. Secondly, there are often confounding factors that can make a successful technology appear unsuccessful, and vice versa. Finally, a trial is a clear signal of uncertainty from management, which often impacts on workforce sentiment when being asked to embrace the very same technology if and when adopted. This paper will explore these issues, with discussion of real examples derived from the author's many years of experience deploying technology. Also discussed will be an alternative approach for technology adoption that can set up a business for future success in broader deployment while still offering the opportunity to rethink a decision before heavily investing.

9:25 AM
Innovations in Underground Hard Rock Operator Efficiency – Through Simulation Based Training Technologies and Processes
G. Karadjian and J. de le Torre Navarro; Immersive Technologies, Sandy, UT

The La Colorada underground mine in Zacatecas project focused on training the mine's experienced operators for a fleet of underground trucks, through the use of a training simulator. A training program was created targeting maintenance reduction, productivity improvement, & increased utilisation & availability. Operators were: first acclimatised to the simulated environment; had their current performance baselined; then received targeted coaching; with the process repeated to reinforce learnings. Concurrently, production, maintenance, & safety data was being measured in the real world to measure skills transfer. Due to limited telemetry available from the equipment, many of the data points for the project were sourced from maintenance logs & accounting data. Equipment failure data measured from unscheduled maintenance records showed an overall 6.5% decrease in unscheduled maintenance following the implementation of the training program. The reduction in equipment damage also increased availability & utilisation of the truck fleet. Even small scale mining operations with an experienced operator workforce can achieve positive ROI from simulation based training.

9:45 AM
Ore Pre-Concentration By Bulk Sorting Using Real Time Elemental Analysis
H. Kurth; QUT, Underwood, QLD, Australia

Conveyed coal flows have been diverted on the basis of real time ash analysis since the 1980s. While many coarse particle separation methods are available through screens, jigs, heavy media separation, particle sorters, to name a few, bulk diversion requires a representative, continuous analysis to ensure diversion decisions can be made with confidence. Sensors also need to be able to provide measurements at useful time increments so that small tonnages can be diverted for maximum selectivity. Particle separation typically requires high capital costs and there are limitations either in throughput tonnage or particle size or both. Few techniques are able to provide robust and representative analysis of conveyed flows in a useful time basis. Prompt Gamma Neutron Activation Analysis provides multi-elemental analysis of conveyed bulk materials and has been proven in the minerals industry since 2003. Bulk diversion based on sulphur and ash content has been well utilised for decades at coal fired power stations. This paper outlines the success of this technology in minerals applications in iron ore, phosphate rock and most recently in copper-gold ores.

10:05 AM
Artificial Intelligence-Based Monitoring of Mining Shovel Tooth Wear
M. Ramezani, S. Nouranian, H. Zeng, B. Sameti, E. Chow, D. Cooper and S. Tafazoli; Motion Metrics International Corp., Vancouver, BC, Canada

Mining shovel teeth wear down unevenly over time, causing reduced digging efficiency, increased cutting forces and fill times as well as potential bucket damage and tooth breakage. Conventional tooth wear monitoring requires personnel to manually measure each bucket tooth, which is time consuming and requires shovel downtime. Continuous monitoring using a rugged shovel-mounted camera and Artificial Intelligence (AI) based image processing optimizes the change-out procedure while achieving or exceeding conventional levels of accuracy. This paper presents a novel approach using AI: Prior knowledge of previously analyzed images is coded into mathematical/statistical models through a "Deep Learning" process. Manually labeled images are used to train deep neural networks aiming to localize tooth tips combined with reference points (landmarks) on the bucket. This automated, time saving approach provides an optimized solution which requires little post processing and eliminates the need for mine personnel to visit each shovel for manual measurement. Instead, images are sent to an AI-enabled web platform that provides staff with the latest shovel bucket images and tooth length statistics.

10:25 AM

FenGum(R) – Fenugreek Gum Depressant Evaluation

D. Middleditch[2] and N. Sudom[1]; [1]University of Saskatchewan, Avonlea, SK, Canada and [2]Camborne School of Mines, Penryn, UK

FenGum is a talc/MgO depressant derived from Fenugreek. It is a long chain, industrial polymer of the galactomannan hydrocolloid family with similarities to established mining industry talc depressants such as Carboxymethyl Cellulose (CMC), guar gum and Quebracho. Although Fengum has been successfully tested and trialled in Chinese nickel/copper mines, it has not been extensively tested in North America. This presentation summarizes the findings of recent reagent trials conducted at Blue Coast Research in British Columbia, Canada where FenGum was assessed as an alternative depressant to CMC and guar gum. Flotation testwork was conducted under controlled laboratory conditions using accepted laboratory testwork protocols. Variables such as reagent dosage, reagent type, pH and collector type were investigated for two different ores; 1) an ultramafic nickel-copper greenfield project in Quebec, Canada, and 2) a greenfield project in Northern Finland. The results of these trials indicates that FenGum has the potential to be used as an alternative to other talc/MgO depressants, and that future depressant screening testwork programs should consider including FenGum as a candidate reagent.

10:45 AM

New Reengineered Rotary Lobe Pump Design

J. Dean; NETZSCH Pumps North America, LLC, Exton, PA

NETZSCH design engineers toke the previous industry standard rotary lobe pump design and reengineer it to create the new world standard NETZSCH TORNADO T2 pump. This innovative design was the result of carefully considering customer needs relating to reliability, maintenance, performance, and total cost of ownership. At the center of the new design are metal lobes running inside a metal housing with elastomer liner. This ensures that during operation only elastomer and metal surfaces interface within the pump, thus eliminating the excess wear and heat generation caused by elastomer to elastomer contact in traditional rotary lobe pump designs. The new design of the T2 is also FSIP (Full Service in Place). This means that simply removing the cover plate allows easy and quick access to the pump chamber (for port to port), through which all of the wear parts can ber serviced. Finally by incorporating an innovative timing tooth belt to synchronize and drive the rotating elements, the need for maintenance intensive and costly timing gears was eliminated. This also has the benefit of being smoother, quieter, and having a smaller footprint then pumps with traditional timing gears.

11:05 AM

Planning and Construction of a Large Scale Test Facility for Flow Analysis of Vertical Transport of Water and Coarse Material as Part of the European Research Project "Blue Mining"

T. Müller and H. Mischo; TU Bergakademie Freiberg, Freiberg, Saxony, Germany

Vertical material transport is one of the major challenges for the successful implementation of deep sea mining projects. The EU research project "Blue Mining" is focusing on sustainable solutions for deep sea mining operations, with one major goal being the advancement of Vertical Transport Systems (VTS). To investigate flow effects under realistic conditions, especially clogging effects, a 136 m high test facility for flow analysis in vertical transport has been constructed using available mining infrastructure. Tests are run in a closed circuit, using a system of downfall and riser pipelines connected to a compact sediment injection- and separation unit as well as the centrifugal pump. The riser is equipped with pressure sensors as well as temperature sensors, flow meter and high speed cameras to allow comprehensive analyses of the flow regime and behavior of transported material within the flow. Additional mobile measurement devices allow wear and tear analyses of pipe material. This paper focuses on the determining factors of the tests leading to the design as well as the installation and trial of the test facility itself and explains the used components and work principles.

WEDNESDAY, FEBRUARY 28

MORNING

9:00 AM | ROOM L100J

Young Educators – Developing Your Professional Careers to Tenure and Beyond

Chairs: *B. Hebblewhite, University of New South Wales, Sydney, NSW, Australia*
E. Sarver, Virginia Tech, Blacksburg, VA
V. Kecojevic, West Virginia University, Morgantown, WV

9:00 AM

Young Educators – Developing Your Professional Careers to Tenure and Beyond

V. Kecojevic; Mining Engineering, West Virginia University, Morgantown, WV

The objective of this workshop is to guide tenure-track faculty members in mining engineering in developing their professional careers to tenure and beyond, i.e., enhance an understanding of the tenure process; a nature of competitive academic environment, and academic requirements related to teaching, research and service, and developing their career after receiving the tenure. This workshop will include an interactive discussion among national and international academics that may be helpful to those early-career faculty members planning their future academic careers and/or seeking tenure at their institutions. This workshop will be hosted by the Society of Mining Professors (SOMP).

WEDNESDAY, FEBRUARY 28

AFTERNOON

2:00 PM | ROOM 200ABC

6th North American Iron Ore Symposium: Materials & Tailing Management

Chairs: *D. Kokkinen, Barr Engineering*
G. Saucier, Guy Saucier Inc.

2:00 PM

Introduction

2:05 PM

Use of Superabsorbant Polymer to Improve Handling Process in Iron Ore Fines

F. Guimaraes, A. Araujo, S. Corrent and T. Sylow; Mining and Mineral Processing, ArcelorMittal Research Centre, Maizieres-les-Metz, France

Moisture always was a problem for all process engineers. Thinking on that new technologies have been explored to make more viable the production

of high grade iron ores. This present work represents the attempt of the utilization of a superabsorbent polymer to aid in the screening process and the ore handling process, such as stockpiles reclaiming and vessels discharge in extreme sub-zero conditions. The results have shown that the polymer can be used in certain cases to improve productivity and increase safety in the process of handling the material. However, for size separation is has been proved most inefficient.

2:25 PM

Leaching of Phosphorus from Iron Ores

T. Eisele, L. Zhang and R. Machiela; Chemical Engineering, Michigan Technological University, Houghton, MI

Many iron ores contain excessive amounts of phosphorus that does not form discrete minerals, but is instead uniformly distributed throughout the ore. Removal of this phosphorus by physical separation is thereforre not practical, and so chemical or biological leaching must be considered. Leaching of phosphorus is complicated by the fact that dissolution of phosphorus that is bonded to calcium requires acidic leaching, while phosphorus bonded to iron requires alkaline leaching. Similarly, biological leaching of phosphorus is complicated by the fact that, on one hand, the organisms need to extract phosphorus from the iron ore to use in cell growth, while on the other hand the resulting cells can remain adhering to the iron ore, keeping the phosphorus bonded to the minerals. The results of a study to examine biological and chemical leaching of phosphorus from an oolitic iron ore will be presented, with discussion of the difficulties encountered and potential routes to overcome them.

2:45 PM

Field Versus the Lab: a Comparison of In-Lab Kinetic Tests and Field Leach Tests from the Sulitjelma Mining District, Norway

F. Stopa, I. Walder, M. Tinsley, R. embile and A. Winton; New Mexico Institute of Mining and Technology, Socorro, NM

As regulation of water quality becomes more prominent in the mining industry, and further research is developed regarding A/NRD, it is important to analyze and compare the differences between lab and field tests. While both kinetic tests and field leaching tests are designed to indicate mineral dissolution rates and acid producing/neutralizing potential, the methodology is different and results can largely vary. Kinetic tests allow precise variable control, but due to material size limitations the applicability to the natural setting is restricted. Kinetic tests cannot be linearly scaled up, thus pointing towards the significances of field leach tests. In places (like northern Norway) with a short summer, field tests can indicate runoff quality after rainfall. The area used as a test case for both kinetic tests and field leach tests is the Sulitjelma mining district. The area has been sampled for three consecutive summers, and all tests were conducted on waste rock. Kinetic tests were started March 2017, and field leach tests were conducted in summer 2017. The different results can be used for better characterization, resulting in appropriate mitigation of the abandon mine area.

3:05 PM

Assessment of Liquefied Shear Strength of Iron Ore Fine Tailings Using Cone Penetration and Field Vane Shear Tests

R. Velasquez, I. Contreras, R. Ver Strate, J. Harvey, K. Schimpke and B. Zwissler; Barr Engineering Co., Minneapolis, MN

Proper tailings management (when using the upstream construction method) requires assessment of static liquefaction stability, among other potential failure modes, and consequently proper characterization of the liquefied shear strength. Empirical estimation of liquefied strength can result in overly conservative design and laboratory testing may unreliably characterize strengths due to difficulties in sampling soft materials. Therefore, an approach to estimate the liquefied shear strength of iron ore fine tailings using in-situ testing is presented. Statistical analysis of an extensive cone penetration testing (CPT) and field vane shear testing (FVT) data set was used. Advantages and challenges of this approach from a tailings management perspective are discussed and results compared with commonly used empirical formulations.

3:25 PM

Acid-base Accounting and Humidity Cell Tests for Potential Waste Rocks from the Ironwood Iron-Formation, Northern Wisconsin, USA

R. Seal, D. Hoppe, N. Piatak, C. Scott and W. Cannon; US Geological Survey, Reston, VA

Acid-base accounting and humidity-cell tests for the Yale member of the Ironwood Iron-Formation and the hangingwall Tyler Formation are being used to investigate the environmental characteristics of likely waste rock units related to potential mining of the iron formation. One composite sample of the Yale member, a shale, and three composite samples of the Tyler Formation, a sequence of interbedded graywackes and locally pyritic shales, were collected from historical drill core. Sulfide concentrations of the Tyler Formation varied from 0.2 to 0.9 percent and NP/AP ratios based on sulfide and total carbonate varied from 1.2 to 4.6. The sulfide concentration of the Yale composite was 0.7 percent with an NP/AP ratio of 8.9. The difference in NP/AP ratios between the Tyler composites and the Yale composite exerts an important influence on the humidity-cell effluent. After 25 weeks, effluent from all humidity cells had slightly alkaline pH values, but the Yale humidity cell had distinctly higher pH and alkalinity release rates, and lower sulfate release rates than effluent from the three Tyler humidity cells.

WEDNESDAY, FEBRUARY 28

AFTERNOON

2:00 PM | ROOM L100E

Coal & Energy: Coal Preparation

Chairs: *T. Ghosh, University of Alaska Fairbanks, Fairbanks, AK*
Q. Huang, West Virginia University, Lexington, KY

2:00 PM

Introduction

2:05 PM

Design and Configuration of Venturi and Packed Tubes for Pico-Nano Column Flotation Based on CFD Simulation

W. Wang-Geissler and F. Peng; Mining Engineering, West Virginia University, Morgantown, WV

Using cavitation bubbles has been proven to improve flotation recovery. This technology has been successfully developed in the lab, and thus it is important to apply it in industry. A venturi design from a previous CFD study with a minimum critical velocity was used as the standard tube. A venturi tube 15 times the size of a standard venturi diameter, a lab-scale venturi tube, and a standard venture tube were compared. Different orders of the packed tube and venturi tube in series were tested. The first design placed the packed tube first, then the venturi tube second. The second design placed the tubes in the opposite order. Vapor volume of fractions and bubble sizes generated with a scaled up venturi and multiple lab-scale venturis were analyzed. The results show that for an industry flotation column, multiple standard venturi tubes function better than one scaled-up tube. Placing the packed tube and venturi tube in series, with the packed tube first and venturi tube second, is recommended. The results and recommendations of this study will provide more optimum yield in industry.

2:25 PM

Characterization of Breakage Mechanism of Coal and Gangue Particles Using X-Ray Computed Tomography

k. zheng and P. Pan; Chinese academy of sciences, WUHAN, hubei, China

In mining processing, especially in coal preparation industries, size reduction processes are widely used to meet product size specifications. It is well known that the size distribution of daughter fragments exhibits a strong dependence on the intensity of loading mode and loading strength. X-ray computed tomography (XCT) technology has been demonstrated to have the capability of analyzing meso-structure parameters (particle size, coal type, crack types). In this regard, particle size distributions of daughter fragments are obtained from impact crushing tests from hammer crusher (different input energy levels). The breakage mechanism of daughter fragments can be obtained from XCT analysis. In this way, the breakage characteristics of coal particles are illustrated and particle size distribution of daughter fragment is also demonstrated. Acknowledgements This work was finically supported by National Key R&D Program of China (No. 2017YFC0804203) and international cooperation project of Chinese Academy of Sciences (No. 115242KYSB20160024)

2:45 PM

Partitioning of Ultrafine Particles in Fine Coal Cleaning Circuits

W. Wells[2], A. Noble[1] and G. Luttrell[1]; [1]Mining & Minerals Engineering, Virginia Tech, Blacksburg, VA and [2]Mach Mining, LLC, Marion, IL

The partitioning of ultrafine (<325 mesh) particles has long been considered as a major factor in determining the overall separation performance of coal preparation plants. To quantify this effect, an in-plant sampling program was undertaken to experimentally track the mass rates of ultrafine solids reporting to and from unit operations within the fine coal circuitry of an industrial coal preparation plant. The unit operations evaluated in this study included classifying cyclones, spirals, froth flotation, fine wire sieves and screenbowl centrifuges. Each sample of ultrafine solids was further segregated into organic and inorganic fractions using flotation release analysis such that the coal and rock fractions could be individually tracked. This article provides a summary of the important findings obtained from this field investigation and provides recommendations for minimizing the adverse impacts of misplaced ultrafine coal and clay slimes on plant performance.

3:05 PM

New Generation Reagents for Coal Flotation

S. Dickie and D. Chipfunhu; BASF, Auckland, New Zealand

The use of MIBC and diesel as the frother and collector for coal flotation is almost ubiquitous in the global coal industry. This "one size fits all" approach despite the variation in coal type, particle size range and flotation cells can lead to losses in recovery and circuit performance. To address this BASF has developed a range of reagents that are specifically designed for the coal industry, which have shown excellent performance across a range of coal types and process conditions. They have proven capable of replacing MIBC and diesel on a cost performance basis; in easily floating coals through improved dose efficiency and by providing step changes in the recovery of coals that are poorly floating due to surface oxidation or inherent poor floatability. A review of the development of these reagent and case studies including laboratory and plant results will be presented.

3:25 PM

Application of Synthetic Bio-compatible Polymers in fine coal flotation

K. Monyake, Z. Xiao, M. Hayat and L. Alagha; Mining Engineering, Missouri University of Science & Technology, Rolla, MO

The large amount of coal fines that have been generated from both mining and beneficiation processes has been reported as a chronic problem to both fine coal preparation and utilization as these fines contain a high amount of ash forming minerals. The presence of high ash forming minerals in coal adversely affects the utilization of coal. High ash content affects coal's combustion and reduces boiler efficiencies causing clinkering and slagging. The current study investigated the effect of Synthetic Bio-compatible Polymers (slimes) depressant in fine coal flotation for the possibility to enhance the combustible recovery and ash rejection. Raw coal samples containing about 25% of ash-forming minerals were crushed, grinded and floated in the presence of Chitosan polymer at different operational parameters. Flotation tests were carried out in Denver flotation cell with 1-Liter capacity. Flotation outcomes were studied as a function of polymer concentration. This study will help in contributing towards introducing polymeric ash depressants in fine coal flotation.

3:45 PM

Creating New Markets for Coal Using the HHS Process

N. Gupta[1], A. Jones[1], B. Li[1], G. Luttrell[1], R. Yoon[1], J. Reyher[2] and S. Suboleski[2]; [1]Mining & Minerals Engineering, Virginia Tech, Blacksburg, VA and [2]Minerals Refining Company, Richmond, VA

Coal slurries containing ultrafine particles (<0.045 mm) are often intentionally discarded to avoid issues associated with high processing costs and unacceptable product moistures. This practice causes significant losses of valuable resources and raises environmental concerns. In light of these problems, the Center for Advanced Separation Technologies (CAST) and Minerals Refining Company (MRC) jointly developed the hydrophobic-hydrophilic separation (HHS) process. This patented process, which simultaneously cleans and dewaters ultrafine coal from waste slurries, produces ultra-high purity carbon products that can be utilized in a variety of commercial applications both within and beyond traditional coal markets. A continuous pilot-scale HHS plant installed at an operating coal preparation facility in southwest Virginia consistently generated final products with very low-ash and -moisture contents at carbon recoveries well over 90%. The paper provides an overview of the working features of the HHS process and highlights potential applications beyond the traditional markets such as power generation and coke manufacture.

WEDNESDAY, FEBRUARY 28

AFTERNOON

2:00 PM | ROOM L100C

Coal & Energy: Mine Safety II

Chair: *S. Bealko, GMS Mine Repair, Oakland, MD*

2:00 PM

Introduction

2:05 PM

Evaluation of Different Carbon Monoxide Sensors for Battery Charging Stations

J. Rowland, L. Yuan and L. Zhou; Fires & Explosions Branch, NIOSH, Pittsburgh, PA

Hydrogen (H_2) gas released during battery charging can result in cross-interference for carbon monoxide (CO) sensors used for early fire detection and compromise the integrity of the mine atmospheric monitoring system. In this study, a series of laboratory-scale and full-scale experiments were conducted to evaluate the responses of different CO sensors to hydrogen gas. In the laboratory-scale experiments, constant hydrogen concentrations in the airflow, from 100 to 500 ppm, pass through sensors. While in the full-scale experiments, increasing hydrogen concentrations are generated as a byproduct from charging the batteries at the battery charging station rise to the sensors under different ventilation scenarios. The hydrogen concentra-

tions at the CO sensor location were measured using hydrogen sensors and were compared with the CO sensor readings. The effects of ventilation and sensor location on CO sensors responses were also analyzed in this study. The results of this study can help mining companies select appropriate CO sensors and improve the deployment of these sensors.

2:25 PM

Preparing for Innovation: SCSR Deployment in U.S. Coal Mines

L. Swanson, J. Helton and G. Luxbacher; Human Factors Branch, Centers for Disease Control and Prevention/National Institute for Occupational Safety and Health, Pittsburgh, PA

Since the early 1980s, self-contained self-rescuers (SCSRs) have been used by the U.S. coal mining industry to improve survival rates of mine emergencies and disasters such as fires and explosions. NIOSH has developed revised criteria for approval for SCSRS, which are now referred to as Closed Circuit Escape Respirators (CCERs), under Subpart O of 42 C.F.R., Part 84. The new criteria addresses critical issues associated with device durability, post-deployment wearability, and usability. Recently deferred for a two-year period due to industry concerns regarding SCSRs/CCERs, Subpart O requirements present a revitalized need to better understand current SCSR deployment practices and evaluate possible future SCSR/CCER development requirements. Through a comprehensive survey of 206 emergency response plans (ERPs) for active coal mines in the U.S. and an extensive review of the MSHA SCSR and production databases, the present study offers an exploration of how SCSRs are utilized and implemented. Key findings from the study reveal the most frequently worn and stored SCSR models as well as how recorded maximum distances to cache sites vary by mine characteristics such as seam height.

2:45 PM

Efforts to Characterize and Mitigate Hot Work Accidents in Mining and Mineral Processing

E. Charrier, H. Miller and J. Steele; Colorado School of Mines, Golden, CO

Fires and explosions caused by hot work represent a serious safety hazard common to many primary industries, including mining and mineral processing. The National Fire Protection Association estimates that there is an average of 4,440 structural fires and eight fatalities annually that stem from hot work. Of these, welding and cutting torches account for over 75% of the fatalities. This paper outlines the conclusions obtained from analyzing accident data, derived from the Chemical Safety Board, CDC NIOSH, and other sources, to determine accident causation factors and whether the implementation of improved technology or engineering interventions are needed.

3:05 PM

A Mine Refuge Chamber Model for Safety Verification

G. Danko[1], D. Bahrami[1] and C. Stewart[2]; [1]Mining and Metallurgical Engineering, Univ. of Nevada, Reno, Reno, NV and [2]Chasm Consulting, Capalaba, QLD, Australia

A Universal, Thermal, Humidity and Airflow (UTHA) model is presented for the verification of any Refuge Alternative (RA) by mines. The Miner Act mandates 95°F temperature limit at any mining condition for 96 hours of RA occupation. The UTHA model can check to meet the thermal-humidity requirement without the need for experimental verification. The model applies an advanced, Computational Energy Dynamics (CED) solver. The UTHA model is included in the Ventsim Visual software marketed for mine ventilation analysis. Verification of the model has been passed against 10 different sets of measurements of real, metal and tent-type RAs under various mining conditions and occupational capacity conducted by NIOSH from 2012 through 2016. The UTHA model correctly reproduces the NIOSH-made measurements and capable of scaling the generalized THA processes for variable conditions beyond those tested by NIOSH experiments. The variations available for the mines to meet the 95°F limit include mitigation techniques such as RA occupational reduction, inside cooling, compressed air supply, air circulation, etc. The presentation of the UTHA model will include verification and application examples.

3:25 PM

Development of an Underground Localisation System Based on Ultra-Wideband Radio Technology

C. Niestroj, A. Schulten, F. Uth, S. Schade, T. Hartmann and E. Clausen; RWTH Aachen University, Aachen, Germany

Today Ultra-Wideband radio systems (UWB) have gained special significance for accurate positioning purposes. Its physical nature, using short wave pulses, allows for precise and robust positioning tasks especially in closed, narrow spaces such as underground mining environments, but also local machine positioning in open pit applications, facing dust, humidity and vibrations. At the same time, robust, high data transfer rates can be achieved. Through smart combination by means of sensor fusion of the UWB with e.g. inertial navigation systems an even more precise positioning system is at hand. This presentation will give an overview of the research activities and results in real world applications for UWB systems for underground positioning at the Institute for Advanced Mining Technologies of RWTH Aachen University. Especially the above-mentioned fields for an integrated UWB localisation system in different underground mining applications will be presented for two different UWB hardware systems.

WEDNESDAY, FEBRUARY 28

AFTERNOON

2:00 PM | ROOM L100D

Coal & Energy: Research and Development - III

Chair: *M. Trevits, Xtraction Science and Technology, Inc, Pittsburgh, PA*

2:00 PM

Introduction

2:05 PM

Adavancing CO_2 Scrubber Chemistries Used in Respiratory Protective Devices and Refuge Alternatives

D. Murray; NPPTL, NIOSH, Morgantown, WV

The Mine Improvement and New Emergency Response (MINER) Act included the need for improved chemical technologies to address respiratory protective device inadequacies and refuge alternative development. The NIOSH National Personal Protective Technology Laboratory (NPPTL) is invested in research and development to improve the carbon dioxide (CO_2) scrubbing technologies built into these mine safety systems. We use a home-built test system containing a chemical reactor and sensors in a constant flow of simulated expired breath to evaluate chemical performance for the scrubber materials. Current testing procedures focus on device duration or capacity but does not report criteria needed to effectively optimize chemical performance. In this presentation, testing results which identify the chemical performance roles for CO_2 scrubber components will be reported, and specific component chemical activities will be linked to both duration and CO_2 absorption capacities. Chemical components being evaluated include hydroxyl, superoxides, metal, and amine active sites, distributed in salts, zeolites, metal-organic frameworks and microporous materials.

2:25 PM

Mine Air and Strata Temperature Changes Due to Use of Portable Refuge Alternatives

L. Yan and D. Yantek; CDC/NIOSH, Pittsburgh, PA

Heat and humidity buildup within refuge alternatives (RAs) may expose occupants to physiological hazards such as heat stress. Mine Safety and Health Administration (MSHA) regulations require RAs in underground coal mines to sustain life for 96 hours while maintaining an apparent temperature (AT) below 95°F (35°C). To investigate the heat transfer process during the use of mobile RAs, NIOSH tested a 10-person tent-type RA in its Safety Research Coal Mine (SRCM), and both a 23-person tent-type RA and a 6-person metal-type RA in its Experimental Mine (EM). The test results show that mine air and mine strata temperatures surrounding an occupied refuge alternative increase over the 96-hour test period. The test results suggest that RA manufactures must consider the temperature increase of the air surrounding the test article by adjusting these conditions during surface tests to account for the mine air and strata temperature increases observed underground. The RA manufactures may account for the temperature increase by using actual exterior air temperature adjustments or by calculations based on this test data to predict RA interior temperature/humidity rise during surface test.

2:45 PM

Influence of Temperature on Generator Current and Magnetic Field of a Magnetic Proximity Detection System

J. Li, A. Smith, J. Carr and B. Whisner; The National Institute for Occupational Safety and Health, Pittsburgh, PA

Magnetic proximity detection systems (PDS) are mounted on mining machinery to protect workers from being pinned or struck. These systems generate a magnetic field covering the space around a machine, and a miner-wearable component detects the field. The PDS can determine the distance of miners relative to the machine based on the detected magnetic flux density. This information can be used to establish warning and shutdown zones around the machine. Maintaining a stable magnetic field is essential for system accuracy. Magnetic field can be influenced by temperature. Depending on ventilation conditions and seasonal alternation, a PDS can be subject to significant temperature fluctuation. To better understand and quantify this phenomena, an experimental apparatus was developed to study the influence of temperature on the magnetic field of generator. Results show that the electric current across generator can be influenced by both ambient and internal temperatures, modifying the magnetic field that is produced. These findings provide the data needed to develop a control system design to stabilize the current and magnetic field of a PDS to improve the system performance.

3:05 PM

Influence of Trailing Cables on Magnetic Proximity Systems

C. Zhou, J. Li, N. Damiano, J. Ducarme and J. Noll; NIOSH, Pittsburgh, PA

Proximity detection systems (PDS) have been applied to protect miners from striking and pining hazards in underground coal mines. All of the proximity detection systems currently MSHA-approved for use in underground coal mines are magnetic field based and could be affected by metallic objects such as trailing cables. NIOSH researchers investigated the influence of trailing cables on the performance of proximity detection systems. In particular, the magnetic field coupled from proximity system generators to a de-energized trailing cable are characterized. The results show that significant energy can be coupled from the proximity system generators to a trailing cable when there is a closed loop in the cable. The effect on PDS performance from the magnetic field radiated around an energized trailing cable is also quantified for different currents running on the cable. The results show the magnetic field caused by the electric current running on the trailing cable mainly consists of 60-Hz signals and harmonics which causes little interference to the PDS. The results presented in this paper can help PDS manufacturers design better systems that are more immune to these effects.

3:25 PM

Feasibility of in Situ Coal Bio-conversion: a Reality Check

R. Pandey and S. Harpalani; Mining and Mineral Resources Engineering, Southern Illinois University Carbondale, Carbondale, IL

Microbially enhanced coalbed methane targets replicating the process of in situ microbial methane generation to recharge coalbed reservoirs. It is also believed that bio-conversion increases flowrates via enlarged cleats due to microbial activity. Although considerable work has been completed towards optimizing the amount of microbial methane generated, changes in reservoir flow properties with bio-conversion have not been evaluated. This paper presents the ongoing lab-based effort aimed at evaluating the claim of enhanced flowrates post bio-conversion. Given that gas flow characterization of coal requires evaluation of its pressure-dependent-permeability and unique sorption-induced matrix shrinkage behavior, the experimental work concentrated on these two aspects. Flow behavior of coal pre- and post- treatment revealed a significant reduction in permeability, in excess of 85%. Volumetric strain experiments with methane showed a significant suppression of the shrinkage characteristics. Finally, SEM imaging revealed cleat closure by more than 50%. The experimental results are, therefore, indicative of the negative impact of bio-conversion on flow properties of Illinois coal.

3:45 PM

Rheology of High Expansion foam

M. Barros Daza[1], K. Luxbacher[1] and B. Lattimer[2]; [1]Virginia Tech, Blacksburg, VA and [2]Jensen Hughes, Blacksburg, VA

Even with modern detection and firefighting techniques, mine fires continue to be a safety concern. However, some underground mine fires can be addressed with the remote application of high expansion foam, reducing firefighter exposure to hazards. The flow of this foam can be numerically or computationally simulated in order to gain a better understanding of its behavior, but rheology parameters are needed as inputs to produce accurate simulations. For this reason, this work studies the rheology of firefighting high expansion foam using a foam generator and Poiseuille Flow Rheometer. Rheological parameters for foams with expansion ratios between 250-500 are represented by the consistency index (k) and the power law index (n). The experimental results show strong agreement with the Power Law model for non-Newtonian fluid viscosity. In addition, the relationship between rheological behavior of high expansion foam and others parameters are studied such as specific expansion ratio, bubble diameter and flow velocity.

WEDNESDAY, FEBRUARY 28

AFTERNOON

2:00 PM | ROOM 2L100I

Environmental: Emerging Technologies in Water Treatment: Active and Passive Approaches

Chairs: *D. Levitan, Barr Engineering, Minneapolis, MN*
D. Jones, University of Minnesota, Minneapolis, MN

2:00 PM

Introduction

2:05 PM

Advances in Membrane Treatment and Concentrate Management

T. DeJournett; Geosyntec Consultants, Minneapolis, MN

Regulation of bulk chemistry parameters, such as sulfate, alkalinity, and chloride in mine water discharges can define an "entropy box" that presents a thermodynamic challenge for the modern mine. Managing entropy requires the application of energy in the chemical, mechanical, or thermal form. While application of energy results in a net increase in entropy, the location of this increase varies based on the form of energy applied. Process modeling to track the entropy inventory is beneficial for optimizing the transfer of entropy from discharge water to another compartment. Reverse osmosis technology divides entropy in water into a low-entropy permeate and a high-entropy concentrate through the application of mechanical energy. This technology has roots in Minnesota but has seen broader implementation elsewhere due to limited options for membrane concentrate management in Minnesota. However, increasing regulatory requirements for concentrate management in regions where membrane treatment is more widespread is fueling innovation in membrane technology, antiscalant chemistry, and concentrate management technologies that could apply to mining operations in Minnesota.

2:25 PM

Membrane Filtration for Removal of Selenium in a Mine Water Remediation Application

L. Linton; Membrane Filtration, WesTech Engineering, Inc., Salt Lake City, UT

Selenium is a naturally-occurring element often found in mine-influenced waters at concentrations orders of magnitude greater than the EPA-recommended chronic dissolved selenium standard of 5 μg/L. These levels pose toxicological concerns due to bioaccumulation in aquatic species. The degree of rejection is contingent on water characteristics, which dictate contaminant speciation. In this work, a full-scale 2.9 MGD open-platform (UF) system was implemented as pretreatment to an RO system for selenium removal from a mine-influenced surface water. With this rack design, the system is compatible with many UF modules. Both the UF and RO systems were also customized to meet the stringent requirements of this project. Multiple concepts are discussed including (1) importance of pretreatment chemistry and contaminant speciation, (2) value of open-platform UF design, with a highlight of project-specific customization, and (3) operational techniques including a unique backwashing strategy to achieve strict final blended selenium concentration below regulatory limits. Both pilot- and full-scale performance data is discussed to further evaluate variance and scalability of project phases.

2:45 PM

Evaluation of Conventional and Specialized Reverse Osmosis and Nanofiltration Membranes for Treatment of Mining-Impacted Waters

E. Andrews[1], C. Kearney[2] and D. Hughes[2]; [1]Barr Engineering Co., Cumberland, ME and [2]PolyMet Mining, Hoyt Lakes, MN

To support the development of water management strategies for the proposed NorthMet project, an extensive pilot testing program to evaluate the use of membrane treatment technologies for project water treatment was conducted. Conventional spiral-wound reverse osmosis and nanofiltration systems were tested for their use as primary treatment processes, and the proprietary membrane system, VSEP, was evaluated for its use as a component of the concentrate management system. The testing program assessed pretreatment requirements, recoveries, waste and treated water qualities, and post-treatment requirements. Ability of the membranes to removal sulfate and several metals, including arsenic, cobalt, copper, lead, nickel, selenium, and zinc was investigated. This presentation will provide an overview of the program and present results of the membrane system performance, focusing on the removal of sulfate and metals by the conventional and VSEP membrane systems. Design considerations for conventional and VSEP full-scale systems in this and other similar mining applications will also be discussed.

3:05 PM

Effects of Certain Industry Standard Heavy Metal Precipitant Chemicals on Selected Metalloid and Nonmetal Elements

S. Barton; Linkan Engineering, Elko, NV

Environmentally problematic metals and metalloids have long been removed from mine waters by methods that include chemical precipitation, with iron or aluminum salts typically used as the primary mechanistic coagulants. Within the industry, it is also not uncommon for heavy metal precipitants to be used to help reduce the concentrations of various elements, including Hg, Pb, Cu, Fe, Zn and Cd. However, the effects of these precipitant chemicals is less understood on certain non-metal and metalloid elements, such as As, Sb and Se, which are in abundance in many areas that are heavily mined. This presentation cites test data associated with trials conducted on mine water solutions containing high amounts of these metalloid and nonmetal elements, with a number of the more common precipitant chemicals being compared side by side (sodium sulfide, sodium dithiocarbamate, calcium polysulfide, trimercapto-s-triazine). This presentation also references the general toxicities of these precipitant chemicals, which often becomes a determining factor for their use in applications where effluent discharge has the potential to affect aquatic or terrestrial ecosystems.

3:25 PM

Passive Removal of Sulfate from Mine-Influenced Water

R. Thomas and J. Bays; CH2M HILL, Atlanta, GA

A passive treatment system pilot study was set-up at a confidential mine site in the south Midwestern United States. The site has a mine-influenced water seep interception system at the base of reclaimed mine waste rock dumps. The main contaminant of concern is sulfate with concentration of about 1,000 mg/L. A field-based pilot study was conducted at the site to test the efficacy of using a biochemical reactor (BCR)-based system coupled to a novel sulfide precipitation cell (SPC) to reduce sulfate to sulfide and then remove the sulfide through the precipitation of iron sulfides. The pilot consisted of six arrays with each array containing a single BCR unit hydraulically connected to a SPC unit. The substrate recipe for the BCRs was varied slightly between units and two units were actively fed a liquid organic carbon supplement. Substrates tested in the SPC units for sulfide removal included various types of magnetite waste rock and ore, siderite, and zero-valent iron (ZVI). The amount of sulfate removed was directly proportional to hydraulic residence time (HRT) up to 12-days HRT. The SPC substrate recipe impacted removal performance; however, cementation was also an issue.

3:45 PM

A Novel Electrode-Integrated Bioreactor to Treat Sulfate in Mine Water

C. Chun[1], D. Takaki[2], T. Deen[1] and D. Jones[3]; [1]Civil Engineering/Natural Resources Research Institute, University of Minnesota, Duluth, MN; [2]Water Resources Science, University of Minnesota, Duluth, MN and [3]Biotechnology Institute, University of Minnesota, St. Paul, MN

High levels of sulfate can alter sulfur cycling in natural systems, particularly freshwater. In northeast Minnesota, sulfate largely comes from mining operation, and increased interest has emerged for developing technologies to treat the high levels of sulfate in the circumneutral water. We have developed a novel bioreactor to stimulate biological sulfate reduction and simultaneously facilitate the subsequent removal of the reduced sulfide by applying iron electrolysis under low electrical potential. Batch and flow-through bioelectrochemical reactors were developed to test the effect of low voltage on the efficacy of sulfate reduction and iron sulfide formation. Synthetic mine water was treated within reactors operated at different voltages. The sulfur chemistry in the pore water of the reactors was assessed to determine microbial activity; this resulted in demonstrating active sulfate reduction occurred. Iron sulfide formed in the reactors were examined with scanning electron microscopy and x-ray diffraction. This work presents in a proof of concept application of electrical potential to enhance the performance of biological sulfate treatment in a controlled manner.

4:05 PM

The Development of a New Peat Based Weak Anion Exchange Material that Removes Sulfate Anions from Acidic Water

L. Kildyshova[1], R. Hallak[2] and I. Kolomitsyn[1]; [1]Natural Resources Research Institute, University of Minnesota Duluth, Duluth, MN and [2]American Peat Technology LLC, Aitkin, MN

Peat is a slowly renewable resource. Because of its limited availability it is essential to add value to products that are produced from peat. Recently, we reported the development of three peat products for the removal of dissolved heavy metals: APTsorb II™, APTsorb III™, and APTsorb II*Na™. This presentation describes the development of a peat-based weak anion exchange material that effectively removes sulfate and other anions from very acidic waters. Such water can be found as a result of oxidation of pyritic materials producing acid mine drainage. The new material is created using the Duff reaction under modified conditions. We demonstrated that a reaction of a prepared peat surface with hexamethylenetetramine formed amine groups instead of expected aldehyde groups. Moreover, a reaction of the peat surface with an adduct of acetic aldehyde with methyl amine formed amine groups as well. The new material has a measured total anion exchange capacity of 80 mEq/100 g, exhibits anion exchange properties, and is stable at a wide range of pH. A new technique for measuring anion exchange capacity as well as performance data using synthetic water will be presented.

4:25 PM

Elements of Bio-Mining: Genomics-Driven Improvements in Bioleaching, Sulfur and Selenium Stabilization in Mine Operations

R. Pedlar-Hobbs[1], V. Papangelakis[2], N. Mykytczuk[3], S. Baldwin[4] and E. Edwards[2]; [1]ERM, Toronto, ON, Canada; [2]Chemical Engineering & Applied Chemistry, University of Toronto, Toronto, ON, Canada; [3]Chemistry & Biochemistry, Laurentian University, Sudbury, ON, Canada and [4]Chemical & Biological Engineering, University of British Columbia, Vancouver, BC, Canada

Base metal extraction from sulfide minerals across Canada has created large volumes of sulfide-laden waste. When exposed to air, water, and microbes, wastes are oxidized producing acid mine drainage (AMD) resulting in tremendous rehabilitation costs. However, existing tailings and waste rock also contain valuable residual metals. Thus, there is financial and environmental incentive to improve waste management. In order to address these challenges, a consortium was formed between researchers, industrial partners, and supporting organizations to advance biomining research through the Elements of Bio-mining Project. The overarching goal of the project is to harness the capabilities of microbial communities to stabilize mine wastes to prevent AMD and make the recovery process economic by recovering valuable metals. Three research groups are tackling different aspects of the phenomenon through iterative design and operation of lab, pilot and field scale experiements treating wastes from Ontario's Sudbury basin and BC's Elk River valley. Standard operating procedures, life cycle analyses, and communication tools will also be developed to ensure successful implementation into practice.

WEDNESDAY, FEBRUARY 28

AFTERNOON

2:00 PM | ROOM L100A

Health & Safety: Open Forum for the Future of the United States Mining Safety and Health Research Agenda

Chairs: *L. Saperstein, Missouri University of Science and Technology, Nantucket, MA*
D. Snyder, NIOSH, Pittsburgh, PA

2:00 PM

NORA Research Objectives and Their Priority

L. Saperstein[1] and D. Snyder[2]; [1]Mining Engineering, Missouri University of Science and Technology, Nantucket, MA and [2]Pittsburgh Mining Research Division, NIOSH, Pittsburgh, PA

The Mining Sector Council of the National Occupational Research Agenda, NORA, has produced a Research Agenda with eight major objectives and 269 sub-objectives. Collectively, the Agenda is a global plan for research needed to alleviate identified and potential health and safety risks for miners. As NORA enters its third decade, it is time to increase the value of the the Agenda by giving a sense of priority to these objectives as was promised in the Mission statement in the Agenda's introduction. In an open session, a panel of experts will discuss these priorities assisted by comments from session attendees. The panelists have backgrounds that are linked to the major objectives of the Research Agenda.

WEDNESDAY, FEBRUARY 28

AFTERNOON

2:00 PM | ROOM 101H

Industrial Minerals & Aggregates: Mining Design, Planning, Operating for Aggregates

Chairs: *E. Tarshizi, Michigan Technological University, Houghton, MI*
J. Zdunczyk, Pike Industries, Inc., Westbrook, ME

2:00 PM

Introduction

2:05 PM

Improved Understanding of Trona Creep and its Impact on Mining

J. Nopola and S. Buchholz; RESPEC, Rapid City, SD

Trona is an evaporite mineral and, like other evaporites such as salt and potash, has generally been assumed to demonstrate some creep behavior

(i.e., time-dependent deformation). However, actual laboratory data on trona creep is rare. As a consequence, several studies have assumed that trona creep is similar to creep of salt. RESPEC performed multi-stage creep tests on samples of trona from Southwest Wyoming at two different temperature settings in order to develop a better understanding of the creep behavior of trona. These preliminary results indicate that while the temperature dependence of trona appears to be very similar to that of salt, the stress dependence of trona is much less. Analytical equations were used to estimate pillar shortening based on common mine geometries used in Southwest Wyoming trona mines. The results suggest that creep of trona does not have a significant influence on stress transfer and mine design. Pillar shortening rates were estimated to be approximately 0.25 inch per year in high extraction ratio areas and 0.025 inches per year in low extraction ratio areas, which closely match anecdotal evidence underground.

2:25 PM

Underground Limestone Mine Design, Planning and Operations Support

N. Hoffman and R. Yarkosky; Golder Associates, Ballwin, MO

The long-term sustainability of an underground (UG) limestone mine is largely dependent on mine design, mine plan sequence, and operating plans, which promote a safe and efficient operation with low operating costs (OPEX) and minimized capital expenditures (CAPEX). Due to limestone's formational depositional environment and relative abundance, many limestone deposits are not as prone to mineable seam quality and thickness constraints when compared to other mineral resources, which makes the limestone market quite competitive. For this reason, the primary constraints of an UG limestone mine include OPEX, initial, and sustaining CAPEX. On behalf of a confidential client, Golder developed a unique, long-term mine plan layout and sequence for an UG limestone operation. In congruence with this effort, Golder designed efficient and effective geotechnical pillar designs, haulage, crushing, and ventilation plans to reduce or maintain the mine's overall OPEX as well as extend the timeline requirement for additional ventilation and crushing CAPEX. This work maximized the net present value of the mine and increased the mine's financial viability and market competitiveness.

2:45 PM

Dust Mitigation Through a Program-Based Approach

S. Clark and M. Wallace; R&D, EnviroTech Services, Greeley, CO

EnviroTech Services, Inc. has developed a program-based approach to mitigating dust in mining operations where water is used as the primary method of dust suppression. We understand that each project is distinctive, and as such requires a solution designed specifically for the project. Our program is designed to deliver a comprehensive strategy that provides the customer with a program that is effective and efficient, and completely within the user's control. How the program works: Define the goals Understand shortfall of current practices Gather baseline dust level data as a benchmark of performance Develop a program using the specific historic climate conditions Modify product formulations and application rates based on using the soil samples collected from the specific project site and evaluated Field testing is conducted on the project site to validate formulations and rates Benefits of the program: Site specific and customized Results-oriented and solutions-based approach Reduced watering volumes and frequencies Improved economic efficiencies Increased safety Improved road conditions Decreased costs associated with equipment damage

3:05 PM

Improved Screening for Limestone

A. Donahue-Kelley; Marketing, General Kinematics, Crystal Lake, IL

Processing limestone can be a challenge. In this case study we investigate a quicklime application where, once extracted from the ground, the material was sorted by a preliminary screen to be a maximum size of 6". After this process, the limestone was further refined to properly feed the rotary kiln. This case study outlines how the customer achieved this process and effectively classified material using new screening equipment, reduced maintenance spend and increased production from 350 tons per hour to 600 tons per hour.

3:25 PM

Open Pit Mine Planning with Degradation Due to Stockpiling

M. Rezakhah; Economics, Colorado School of Mines, Golden, CO

The open pit mine production planning with stockpiling (OPMPS+S) problem decides when to extract each block of ore and/or waste in a deposit. In addition, this problem determines whether to send each block to a particular processing plant, a stockpile, or a waste dump. The objective function maximizes net present value (NPV), subject to constraints such as precedence, and capacities for mining and processing. Since the material within the stockpile is exposed to the environment, some time-dependent changes occur in the material's properties, which results in decreased value. In this research, we create three new linear-integer stockpiling models which consider degradation within the stockpile(s). We compare results from these models on a data set from an operational mine, and suggest the most accurate one. Finally, we show that the material degradation within a stockpile has a considerable impact on the value that a stockpile provides.

WEDNESDAY, FEBRUARY 28

AFTERNOON

2:00 PM | ROOM 101I

Industrial Minerals & Aggregates: Physical Separation of Industrial Minerals and Aggregates

Chairs: *S. Saurabh, Millcreek Engineering Company, South Jordan, UT*
R.Dube, Outotec, Centennial, CO

2:00 PM

Introduction

2:05 PM

Pre-concentration of Fluorspar Using Dense Media Separation

C. Da Corte; Minerals Processing, Mintek, Randburg, Gauteng, South Africa

South Africa possess the biggest fluorspar reserves in the world followed closely by China. In the light of the current commodity downturn this paper explores the use of Dense Media Separation (DMS) as a coarse pre-concentration method for two fluorspar deposits located in South Africa in which the dominant gangue is carbonate present in the form of dolomite and calcite. Heavy Liquid Separation indicated that conventional pre-concentration of the drill core samples from both deposits would result in unacceptably high fluorite CaF_2 losses. At a maximum CaF_2 loss to floats of 5% the benefit of DMS would be economically marginal and difficult to justify as a conventional pre-concentrator. In light of cashflow constraints, a twin-flowsheet was proposed for the sole purposes of upfront cash generation in which the majority (80%) of the CaF_2 would report to a high grade flotation plant in 40% of the mass whilst the rejects would be stockpiled for flotation at a later stage. Considering the proposed twin-flowsheet approach the high grade product split was achieved using DMS and this paper documents the challenges encountered and results achieved.

2:25 PM

High Strength WHIMS Used in Industrial Minerals Processing

R. Jain, I. Sherrell and P. Jansson; Flotation, Outotec USA Inc., Savage, MD

Magnetic separation equipment has long been used to upgrade and beneficiate a variety of Industrial minerals. These minerals have wide applications, most of which are dependent on clarity and purity of mineral. Improvement in processing techniques of these minerals can not only add value to present product but higher efficiency can lead to technological advances in the industries using these mineral. In this paper, the author makes a description of Slon Vertical Pulsating High Gradient Magnetic Separator, and puts its emphasis on iron removal from Industrial minerals using high strength WHIMS. A review of test program for different industrial mineral samples including Kaolin, Talc, Quartz, Feldspar, Spodumene etc. from around the world is included. The effect of higher magnetic intensities have been studied and a comparison has been made with lower strength WHIMS up to 1.2T to find the optimum separation efficiencies for respective mineral. Keywords: high gradient magnetic separator, industrial minerals, high gradient

2:45 PM

High Speed X-ray Tomography for Coarse Particle Characterization at Plant Sites

J. Miller, C. Lin, Y. Wang, S. Puvvada and S. Bacchuwar; Metallurgical Engineering, University of Utah, Salt Lake City, UT

Now, with advanced instrumentation and improved software tools, 3D characterization of multiphase particles is possible using X-ray tomography, and such quantitative analysis is essential for sustainable development, recovery, and the more effective utilization of our mineral resources. Spatial features, such as particle size, shape, and composition, are fundamental characteristics which determine the efficiency of plant operations in the mineral industry. High speed, automated X-ray tomography analysis for plant-site 3D characterization of coarse particles is now possible at a sampling rate of about 1 kg/min for particles ranging in size from 150 mm to 1 mm at a voxel resolution of about 100 μm. Applications include, washability analysis for the coal industry, 3D analysis of crusher plant products for the aggregate industry, and the analysis of pebble phosphate products for the phosphate industry. For larger particles >5-10 mm, high scanning rates of more than 300 tph may be possible for 3D characterization at a voxel resolution of about 1 mm.

3:05 PM

An Overview of Mintek's Competency in Phosphate Beneficiation

A. Singh; Engineering, ECSA, Prof Eng, Johannesburg, Gauteng, South Africa

Considering the dominant role of fertilizers in global phosphate production, it is evident that with the ever increasing development in agriculture there will be a growing demand for phosphate beneficiation. With the rapid depletion of high quality reserves, investigations into more complex and lower grade ore bodies are required. Owing to a solid base of expertise, extensive laboratory and pilot facilities, and historical database of knowledge, Mintek is well positioned and equipped to execute projects on a scoping, feasibility, prefeasibility and bankable level. The Minerals Processing Division has been involved in process development and flowsheet design projects on marine, igneous and sedimentary deposits since 2003, the latter constituting more than 80% of world phosphate production and hence also forming the bulk of Mintek investigations. This paper will discuss the processes that Mintek has explored and employed to upgrade various phosphate ore bodies (>30% P2O5) in preparation for end user application. These are aimed at an improved understanding of ores in terms of their varying mineralogy and the development of appropriate process routes to meet product specification.

3:25 PM

Updated Beneficiation of Industrial Minerals Using a Tribo-electric Belt Separator

P. Miranda; St Equipment and Technology, Butte, MT

Triboelectric charging has been around for thousands of years and based on materials becoming electrostatically charged based on contact or friction from other particles. During this process, electrons from materials will jump from one material to another and, therefore become charged due to differences in surface electron affinity (or work function). Recently, ST Equipment & Technology, LLC (STET) has developed a processing system based on tribo-electrostatic separation. This dry technology provides the mineral processing industry a means to beneficiate fine materials. In contrast to other electrostatic separation processes that are typically limited to particles greater than 75μm in size, the triboelectric belt separator is ideally suited for separation of very fine (<1 micron) to moderately coarse (500 microns) particles with very high throughput. The triboelectric belt separator technology has been used to separate a wide range of materials including mixtures of aluminosilicates/carbon, calcite/quartz, talc/magnesite, and barite/quartz. Recently, industrial size separators have been implemented. Current results will be discussed in this unique mineral separation.

3:45 PM

Decanter Centrifuges in the Mining Industry for Solid Liquid Separation

S. Gillig and W. Steiger; Process Engineering, Flottweg SE, Vilsbiburg, Germany

Since the 1940s, decanter centrifuges have become more important for increasingly complex solid-liquid or solid-liquid-liquid separation processes. In the mining industry the complexity is given as processed industrial or metalliferous minerals are highly abrasive or are treated with corrosive chemical agents. Traditionally vacuum belt filters and chamber filter press dominate for solid liquid separation. But the advantages of decanter centrifuges compared to the traditional technology are obvious. Modern decanters stand out by the small footprint the low water demand, the high availability and the high degree of automation combined with the excellent cost / performance ratio. Emphasis have been placed to improve the separation performance in terms of cake dryness and centrate quality and most notable modern decanters require less energy. As a result traditional technologies have been increasingly replaced by high-speed decanters during the last decade. Decanter centrifuges started to play a key role in applications such as tailing dewatering, drilling and tunneling muds processing, hydrometallurgical processes of gold, nickel or zinc and separating SX crud in copper.

4:05 PM

Slurry Densification through Hydrocyclones: an alternative to Conventional Processes.

J. Lopez, D. Switzer and E. Cepeda; Weir Minerals, Cody, WY

With the increase of processed tons of ore over the years, the generation of tailings and their subsequent disposal has been a recurring issue given the geographical considerations of the projects, environmental requirements and no less importantly, operating costs. Taking into consideration the current available technology, various tests for industrial tailings were developed at pilot scale with the objective of densifying and recovering as much water as possible, through various classification methods. It was found that it is possible – practically independently of the initial content of solids – to achieve discharge concentrations greater than 70% solids in weight, recovering the fine portion along with the water for later treatment. Fine portion can be treated to recover process water through thickening or filtering. The use of hydrocyclones to treat tailings opens several possible optimization scenarios for concentrator plants to manage tailings, be able to optimize other recovered water processes, as well as dimensioning new products, decreasing investment costs, decreasing fresh water requirements and increasing the availability of the equipment.

WEDNESDAY, FEBRUARY 28

AFTERNOON

2:00 PM | ROOM 101A

Mining & Exploration: Geology: Mining Geotechnical II

Chairs: *C. Rehn, Barr Engineering, Kamas, UT*
S. Annavarapu, IIT Kharagpur, Kharagpur, India

2:00 PM
Introduction

2:05 PM
Fragmentation Analysis of a Propagating Cave in a Block/Panel Cave Mine: A Fracture Network Approach

S. Sreekumar Ajitha[1], P. Tukkaraja[1], K. Katzenstein[2], K. Shahbazi[3] and D. Loring[4]; [1]Mining Engineering and Management, South Dakota School of Mines and Technology, Rapid City, SD; [2]Geology and Geological Engineering, South Dakota School Of Mines and Technology, Rapid City, SD; [3]Mechanical Engineering, South Dakota School Of Mines and Technology, Rapid City, SD and [4]Climax Molybdenum – Henderson Operations, Empire, CO

Block/panel caving is a bulk underground mining method that is preferred when mining large, fractured, and steeply dipping orebodies. Since caving is a dynamic process, changing cave conditions make the design of an effective mine ventilation system difficult. Due to the fact that cave propagation occurs mostly due to gravitational stresses induced by the undercutting of an orebody, properties such as cave porosity, rock fragmentation (i.e. block size), and cave and air gap size are difficult to predict and vary as a cave matures. To investigate the effect of these changing cave conditions on the ventilation system, the key parameter that needs to be estimated is the fragmentation inside the cave. This study uses the FracMan software package to assess the magnitude of rock fragmentation inside a propagating cave in a block/panel cave mine and further uses these results to investigate the airflow behaviour through the propagating cave.

2:25 PM
Geologic Risk and Underground Construction

P. Nelson; Mining Engineering, Colorado School of Mines, Golden, CO

Population increase means underground space will become increasingly important. Construction costs have been increasing and performance of underground projects is intimately linked to the management of geologic risk for both construction and life-cycle performance of subsurface facilities. This paper develops a geologic framework to assess the state-of-practice and future possibilities for improved management of geologic risk, including risk avoidance, new materials and methods, ground improvement, life cycle engineering for sustainability, and better subsurface characterization. Some geologic risks have plagued for centuries, and new risks have arisen associated with new technologies. In addition, a better understanding of the spatial variability of rock structure is needed a prior, so that site investigations become increasingly confirmatory rather than exploratory.

2:45 PM
Estimating the Effect of Mine Blasting Induced Vibrations on the Stability of Highwalls

J. Silva and A. Sharma; Mining Engineering, University of Kentucky, Lexington, KY

The stability of the highwall is one of the major concerns for open pit mines from both a safety and commercial standpoint. Of the various factors affecting the stability of highwalls, vibrations from blasting is an important one and for long it has been a point of study and concern for researchers and the mining industry. Usually, the mines look for the established government regulations for guidance to determine the peak particle velocity and frequency levels. But, most of the regulations around the globe are meant for the strutures surrounding mine and does not concern highwalls. This paper investigates the response of highwalls under the effects of vibrations from mine blasting. In this research, the relationship between the highwall response, the geometry of the slope, the frequency, the amplitude, and the duration of the ground vibration produced by blasting, is explored using numerical models in 3DEC. The models were calibrated initially with data collected from seismographs in mine. Once the calibration was accomplished, a parametric study was developed to see the relationships between various parameters and observe if they have any impact on the stability of highwalls.

3:05 PM
Stability Analysis of Waste Dumps in Water

J. Hildreth and H. Kim; Department of Mining Engineering, University of Alaska-Fairbanks, Fairbanks, AK

Recently the pit slope stability with water has become one of the issues to simulate the open pit infill dump design, as the local pit water, drained during mining operations, results in making most of the pit completely fill with standing water and become a large pond, affecting the stability of the pit. The process of dumping excess waste material into exhausted open pits as a form of reclamation and stability analysis on a waste dump in an open pit full of standing water were studied and numerically conducted using SLOPE/W software. The slope stability analysis was completed using the Morgenstern-Price method due to its relative simplicity and comprehensive evaluation technique. The scenarios modeled took place in an open pit with 30 foot benches, 10 foot berm widths, and a 60 degree face angle. The pit walls were modeled with the Mohr-Coulomb Criterion. Granite and schist waste dumps were then created at various heights, horizontal advances, and with various standing water heights. A total of 52 individual analyses were created with 96 results calculated. Based on the results, it was concluded that with increasing standing water height, the stability of a dump would increase.

3:25 PM
Passive Seismic Tomography Monitoring of Deep Narrow Vein Mine

S. Ghaychi Afrouz[1], E. Westman[1] and k. Dehn[2]; [1]Mining, Virginia Tech, Blacksburg, VA and [2]NIOSH, Spokane, WA

A microsystem including 50 sensors was used to monitor a deep, narrow vein mine in the western US. More than 12,000 microseismic events were recorded in the year of 2016 and the dataset was used for passive seismic tomography in order to image the induced stress redistribution during mining operations. Induced stress is measured based on velocity of the seismic waves traveling through the rockmass. Passive seismic tomography is used to model the velocity of the waves underground based on the arrival time of the received rays. Almost all the events, monitored by this system are correlated to the active mining face. The released energy each month due to these events is nearly constant, however in the months of February and July the number of seismic events around the mining face is increased and a corresponding rise in the released energy is observed. No persistent induced high stress zone is created after these months and the calculated velocity of the seismic waves returns to the background steady levels.

3:45 PM
The Iron-Oxides Effects on Argillic Rocks of Cheshme Hafez Region, Semnan, Iran

B. Peik and B. Abbasi; University of Nevada, Reno, Reno, NV

One of the most important factors in Mineral exploration is alteration. This can be a promising sign for finding a deposit. Also, alteration can influence rock mass mechanical properties, therefore it is important to evaluate the rock mass behavior under such condition. In this paper the Argillic alteration effect on Andezit rock has been investigated. This research is performed by collecting Andezit samples and performing mechanical and microscopic tests. The samples were collected in a lead and zinc mine at Cheshme

Hafez, Semnan, Iran. The goal of this study is determining a logical relationship between the alteration index (degree of alteration) and rock mass strengthen. The results showed, by increasing Argillic alteration, rock mass uniaxial and tensile strength decrease 84 and 41 percent respectively. However, in the moderate argillic rock, due to the presence of Iron-oxides the rock mass uniaxial strength increases 26 percent. It is included that presence of Iron Oxides reduces the negative effect of argillic alteration on rock mass strength. Keywords: Arglic-Iron Oxide Alteration, Uniaxial Compressive Strength, Tensile Strength.

WEDNESDAY, FEBRUARY 28

AFTERNOON

2:00 PM I ROOM 101E

Mining & Exploration: Management: the Challenges of a Changing Workforce

Chair: *J. Sexauer, Stantec*

2:00 PM
Introduction

2:05 PM
The Case for a Professional Master's Degree in Mining Engineering and Management

P. Nelson; Mining Engineering, Colorado School of Mines, Golden, CO

The future success of the mining industry requires a new kind of engineer – agile in management of business and technology, strategic in acquiring and controlling the flow of information, and astutely aware of the cross-culture, cross-sector and cross-disciplinary issues to be confronted in the complex environments of mining. At the Colorado School of Mines, the Mining Engineering department will launch a unique graduate educational experience for engineers with experience in the industry, and who aspire to leadership in the industry. This new on-line and on-campus graduate program will be transformative and focused toward advanced technology and management with executive content that involves industry leaders as instructors. The curriculum for the Professional Masters will be designed to build knowledge and skills in sustainability, strategic planning and decision science, management of information and technology, project and risk management, finance, valuation, policy, and social license. Mines will develop and prepare graduates who will be effective in influencing change and in solving current and future mining problems in a comprehensive, sustainable, and holistic manner.

2:25 PM
The Workforce is Changing – How Do I Communicate?

B. Archibald, B. Weaver, A. Gignac and R. Vogel; Q4 Impact Group, Canton, OH

In an industry historically dominated by "seasoned professionals" in the managemnt ranks, mine managers today could be Baby Boomers, Gen-Xers and Millenials. What's more, they could likley be manageing any of the generations as well. The rapidly changing complexion of the workforce and the inherent communication challenges are resulting in heightened levels of frustration at all levels and rapid loss of invaluable "tribal knowledge". It seems that nobody wants to talk to anybody anymore and efficiency is suffering. This session addresses the multi-generational issues faced in the mnining industry today by an industry-experienced team assembled specifically to help everyone at all levels get along and communicate effectively. The session helps attendees gain an understanding of the importance of the issue, why it exists and how to deal with it.

2:45 PM
Digital Reinvention at Barrick Nevada

E. Yalcin; SME, Elko, NV

Barrick Gold has a vision to transform its organization through the use of digital solutions; delivering enhanced safety, operating cost and production results. The organization began executing the vision at Barrick Nevada at the end of 2016, through the combination of in-house solution development and deployment of 3rd party solutions. These solutions include workforce productivity, predictive analytics and automation of select equipment within the underground, open pit and process divisions. The presentation will share lessons learned at Barrick Nevada from an organizational and technical perspective and discuss future opportunities.

3:05 PM
Approaches in Underground Strategic Mine Planning

K. Huss and B. King; Newmont Mining Corporation, Denver, CO

Newmont Mining is applying novel techniques and tools to unlock strategic value in its underground studies and operations. A case study is used to demonstrate how advanced custom models have been used to augment commercial software to provide guidance for an underground scoping study. Our process enables us to quickly evaluate a range of options and isolate value drivers while maintaining the rigor of an activity based schedule.

3:25 PM
Learn with Harry: Toward a Comprehensive Training Solution Using Serious Games

L. Brown, M. Peltier and M. Poulton; Desert Saber, LLC, Tucson, AZ

Following a multiyear research and development effort, we have created the Learn with Harry suite of "serious games," which is based on scholarly research into how adults best learn the complex nature of mining safety. These games emphasize high user engagement, critical thinking, customization, and evaluation. The Learn with Harry suite currently includes three games: Harry's Hard Choices, covering mine emergency response, Harry's Hazardous Day, covering hazards recognition and workplace examination, and Harry's Fatalgram Simulator, covering refresher fatalgrams and MSHA best practices. In this talk, we discuss the evolutionary development of Learn with Harry, aligning new game capabilities with mine operator needs. The game suite is currently being deployed and evaluated through an early adopter program. Industry feedback and training experiences will be discussed.

3:45 PM
The U.S. Mining Industry Workforce – A New Online Resource

C. Brandon; Automated Systems Alliance, Parker, CO

Since 2012 I've been reporting on labor trends in the U.S. job market at the annual SME convention. Annual reporting on a dynamic market doesn't make a lot of sense so beginning in 2017 most of this reporting will be moved online to make this information available in a timelier manner. This presentation will identify resources and discuss various visualizations available to understand employment trends in mining by location and commodity. The presentation will also include an assessment of mine counts by location, commodity, mine type, and status. Additional site development is anticipated as we begin to entrain data from other countries beginning with Canada.

WEDNESDAY, FEBRUARY 28
AFTERNOON

2:00 PM | ROOM 101B

Mining & Exploration: Operations: Lake Superior-type Iron Ore: Applied and Evolving Mine to Mill Characterization and Reconciliation, Part 2 of 2

Chairs: *H. Taylor, Cleveland-Cliffs Inc.*
D. Gebhart, Cleveland-Cliffs Inc.

2:00 PM
Introduction
This session is a continuation from the morning Lake Superior-type Iron Ore session. Both sessions are intended as a self-contained overview for mine operation supervisors, geologists, mine engineers, plant (concentrator and pelletizer) operations foremen, process engineers, or anyone interested in the idealized M2M process on the Mesabi Iron Range.

The following talks discuss the steps of reconciling planned versus actual mine-delivered ore qualities with plant performance to develop more accurate metrics for future planning and budgeting and an optimized mine plan.

2:05 PM
Mine to Mill Process – Ore Quality Team Interactions
M. Orobona; Cleveland-Cliffs Inc., Cleveland, OH

Mine-to-mill (M2M) is ideally an iterative, continuous improvement process in which a core team comprised of geologists, process engineers, and mining engineers relates the modeled properties of ores and gangue to the industrial response of their immediate environment, at critical points in time and space, through the entire mineral liberation and concentration process from ore in the ground to final product. Whereas some industry best practices of drill-and-blast optimization are not yet common, M2M as practiced at beneficiation-grade iron ore mines should generally parallel practices used elsewhere in the mining industry, with the advantage of comprehensive grind-grade-recovery (± power) models described earlier.

2:45 PM
Reconciliation – Improvement Through Understanding
K. Gitzlaff; Cleveland-Cliffs Inc., Cleveland, OH

Why do we reconcile? Reconciliation is a validation of assumptions, models, and planning with the purpose to improve planning confidence, improve planning quality, and reduce plan re-work. This session will cover a simple methodology for reconciliation of mine plans from model to execution.

WEDNESDAY, FEBRUARY 28
AFTERNOON

2:00 PM | ROOM 101C

Mining & Exploration: Operations: Resource Supply Chain: Important Factors in Connecting the Mine to the Market

Chairs: *K. Ehrenreich, Krech Ojard and Associates*
P. Padgett, Missouri Sci and Tech

2:00 PM
Introduction

2:05 PM
Logistics & Other Challenges in Northwestern Alaska
T. Krzewinski; Golder, Anchorage, AK

Red Dog Operations is one of the world's largest zinc mines, located about 170 kilometers north of the Arctic Circle in northwest Alaska. Due to the location of this mine there are challenges relating to both logistics and permafrost. This talk discusses some of the technical aspects relating to these challenges.

2:25 PM
Great Lakes Navigation Update I
M. Strum; US Army Corps of Engineers, Detroit, MI

The Great Lakes is a non-linear navigation system with over 100 federal projects. The Corps manages all of the individually authorized projects in the Great Lakes Navigation System as components of a single and comprehensive system, while recognizing the interdependency of the ports. This presentation provides an update on current status of the following system requirements: Dredging, Dredged Material Management, Harbor Infrastructure and the Soo Locks.

2:45 PM
Great Lakes Navigation Update II
M. Strum; US Army Corps, Detroit, MI

The Great Lakes is a non-linear navigation system with over 100 federal projects. The Corps manages all of the individually authorized projects in the Great Lakes Navigation System as components of a single and comprehensive system, while recognizing the interdependency of the ports. This presentation provides an update on current status of the following system requirements: Dredging, Dredged Material Management, Harbor Infrastructure and the Soo Locks.

3:05 PM
Intermodal Transportation and Mining
M. Martinie; Duluth Seaway Port Authority, Duluth, MN

Now a multimodal transportation hub, the Port is a great engine for economic growth. And the Duluth Seaway Port Authority has taken a leadership role in driving regional development efforts. DSPA acquires, markets and manages properties that add jobs and value to this region. Working collaboratively with economic development organizations and area chambers of commerce, the Port Authority is a catalyst in fostering commercial and industrial capacity. As one of Duluth's largest owners/operators of industrial land and buildings, DSPA currently works with nearly 60 businesses operating on Port Authority properties. This talk focuses on how the activities at the port support the mining industry.

3:25 PM

U.S. 53 Highway Relocation Project: Project Purpose and Overview

P. Huston; MnDOT, Duluth, MN

The Minnesota Department of Transportation constructed Highway 53 in 1960 on a private easement owned by US Steel across a taconite reserve in Virginia, Minnesota. Many state, county and local roads also were constructed across the reserve in this fashion. The terms of the easement agreement stated that US Steel would be responsible to move the highway if the ore reserve was needed prior to 1987, and MnDOT would be responsible for relocating the highway after 1987. The original agreement required the move to be made within three years of notice. In 2010, MnDOT received notice that the highway would have to be relocated to make way for mining, triggering the start of one of MnDOT's greatest engineering challenges to date. The project consists of 3.2 miles of new four-lane highway, a new 1,132-foot bridge (Minnesota's tallest when complete) across the Rouchleau Pit, a new interchange, utility and trail relocation, drainage, lighting and signal construction. The project is currently nearing 70 percent complete, two months ahead of schedule and within budget. It is anticipated to be substantially complete at the time of presentation.

3:45 PM

U.S. 53 Highway Relocation Project: Unique Project Challenges and Solutions

P. Huston; MnDOT, Duluth, MN

The presentation will cover many unique project development and construction tactics the team used to develop and construct what is currently considered MnDOT's highest risk project. The relocation of Highway 53 is a highly technical project in a mining environment and is a schedule-driven job. Failure is not an option. The presentation will tell the success story of how a team consisting of MnDOT, eight state and three federal agencies and many consultants got the job done. Topics will include project management and communication strategies, the use of the core team concept, agency subcabinet, public outreach strategy, concurrent environmental processes for schedule savings, Construction Manager General Contractor delivery, co-located design, preferred alignment selection process, bridge type selection process, identifying/quantifying and pricing mineral purchases, early steel procurement, successful DBE and Workforce goal planning and clearance strategies, risk reduction and non-traditional methods of contracting construction required for project development engineering.

4:05 PM

U.S. 53 Highway Relocation Project: Construction Update

P. Huston; MnDOT, Duluth, MN

The Minnesota Department of Transportation constructed Highway 53 in 1960 on a private easement owned by US Steel across a taconite reserve in Virginia, Minnesota. Many state, county and local roads also were constructed across the reserve in this fashion. The terms of the easement agreement stated that US Steel would be responsible to move the highway if the ore reserve was needed prior to 1987, and MnDOT would be responsible for relocating the highway after 1987. The original agreement required the move to be made within three years of notice. In 2010, MnDOT received notice that the highway would have to be relocated to make way for mining, triggering the start of one of MnDOT's greatest engineering challenges to date. The presentation will conclude with a construction update.

4:25 PM

A Forward Look into the U.S. Rare Earths Industry: How Potential Mines Can Connect to the Global REE Market

G. Barakos and H. Mischo; Institute of Mining, TU Bergakademie Freiberg, Freiberg, Germany

Mining used to be a business primarily focused on the technical aspects of getting valuable ore out of the ground and extracting the minerals efficiently. Without denying the importance of these skills, a narrow focus on technical issues is no longer enough to guarantee success when it comes to exploiting rare earth element (REE) deposits. Molycorp failed to enter the global REE market in a successful manner, while none of the many REE exploration projects has turned into an active mine so far and none is expected to commence operations in the near future. Accordingly, the world of REE is far more complex compared to other commodities. This paper looks into the REE industry to identify the factors that can connect potential U.S. REE mines to the market. The ability to break free from past thinking and become future-focused is a key driver. Mining of REE is pointless without a corresponding value-adding chain, while developing a value chain without first establishing an uninterruptible source of REE is also senseless. The mining sector must be based on the REE value chain and vise versa, along with the establishment of a market channel for the REE products that come out of the mine.

WEDNESDAY, FEBRUARY 28

AFTERNOON

2:00 PM | ROOM 101D

Mining & Exploration: Technology: Software Advances in Mining

Chair: *D. Rosenbach, Atlas Copco, Commerce City, CO*

2:00 PM

Introduction

2:05 PM

Virtual Reality: Geology's Path to the Future?

J. Baar[1] and E. Baar[2]; [1]Technical Services, Barrick Gold Cortez, Elko, NV and [2]Cortez Resource Development, Barrick Gold Cortez, Elko, NV

There are many applications for virtual reality today. We can take virtual field trips; investigate an accident on a mine site; investigate a failure either in a high wall or in an underground stope. We can do almost anything virtually; why not include geology into the fold. For years, other industries have seemingly unsuccessfully applied virtual reality to geology. But here we are, with fresh eyes; the possibilities for this product are limitless. Can virtual reality take geology into the future?

2:25 PM

Mining Project Risk Mitigation through Open Pit Production Scheduling Optimization

R. Halatchev; AusGEMCO Pty Ltd, Brisbane, QLD, Australia

Open pit production scheduling optimization plays a key role in the mitigation of the mining project risk. It provides the real basis of any project evaluation as it converts the ore reserve and waste estimates into time distributions as well as allocates the relevant capital and operating costs over the scheduling horizon with all inherent uncertainty of the available information. The paper presents an original approach for mining project risk assessment by accounting for the major sources of project uncertainty, such as geological, mining, processing, metallurgy, geotechnical, environmental and economic ones. The approach is used to reveal some important features of the mitigation of the mining project risk through a novel production scheduling optimization method, which generates a highly effective schedule type with multi-stage stabilization of mining rate over the life-of-mine. A case study is conducted for a hypothetical open pit gold mine and the results obtained demonstrate the efficiency of the production scheduling optimization method for the successful mitigation of the mining project risk.

2:45 PM

Safety: Collision Avoidance Technologies Empower Operators and Minimize Risk of Mining Operations

S. Martell; Development, PRECO Electronics, Boise, ID

Mining presents unique challenges for equipment operators and the technology that supports day-to-day operations onsite. Operating in harsh conditions, operators of heavy-duty equipment rely heavily on the latest collision avoidance technology to save lives, reduce the severity of potential accidents, protect property and minimize risk. Mr. Martell will cover current MSHA standards, best safety practices, as well as technology solutions available today for OEMs and the aftermarket. Mr. Martell will look toward the future and share how the industry is changing, the technology that is becoming available and the ROI that should be expected by adopting collision avoidance technology. Key takeaways that the audience will receive about Collision Avoidance Solutions MSHA standards: Evolving role in shaping practices and equipment builds Challenges: Safety solutions need to ensure accurate alerts Technology: Critical role in the operation today and in the future OEM vs. aftermarket: What are the options for both markets? Integration: Introduction of open solutions to fit within existing equipment

3:05 PM

Predicitive Analytics for Mobile Equipment, Remote Monitoring and Diagnostics Increase Asset Utilization

C. Toro and K. Scholey; Digital Mining, GE Mininig, Lexington, KY

In mining operations, it is well known that the costs associated with transport of ore from the mine to downstream processing, and even the removal of overburden waste material, can have a significant impact on business profitability and bottom-line. Digital strategies to drive asset performance management and operational improvements must revolve around asset health, asset reliability, utilization, operations planning and control approaches. Performance data at comminution are available from many disparate sources ranging from periodic sampling to real-time systems. However, the amount of data being collected continues to increase and the ability to develop meaningful insights becomes more challenging. In this paper, a real-time, model-based solution that uses Asset Performance Management Predictive Analytics has been applied to equipment in grinding circuit. The model generates actionable intelligent asset strategies that has reduced unexpected failures and lead to improved performance.

3:25 PM

A Data-driven Revolution, Process Optimization to the Next Level

J. Arantes; ABB Switzerland, Baden-Daettwil, Switzerland

How process optimization fits in to Internet of Things (IoT), big data, data analytics and clould. How to levarage from proven and latest technologies together in one platfoform. The latest advanced process control (APC) solutions help industrial customers to optimize and improve operations. APC technology makes use of model predictive control with moving horizon estimation strategies. Platform independent APC can be integrated into IoT plaftofrms complying with Cybersecurity standards. Softsensors are models that can be used to infer nonexistent or expensive measurement, increase the frequency, or provide backup for nonreliable measurements. Thanks to the technological advances brought by IoT, it is now possible to deploy and monitor advanced controller to and from industrial cloud. With this new approach, there is also the possibility of new operational software as a service business models and collaborative operations for multisite opimitzation, with an small initial CAPEX project.

3:45 PM

Virtual Reality: Real-World Applications for Mining Equipment Procurement

K. Kunam; rapidBizapps, Milpitas, CA

Virtual reality (VR) has held significant potential for mining applications for the past few years. However, it is only with recent advances in technology, reductions in cost, and increases in accessibility that this potential is being converted into an actionable, tangible aid for the mining industry. In this presentation, we demonstrate the potential of VR to go beyond trade-show demos and instead to integrate them into the workflow of a mining equipment procurement decision tree. The stakeholders involved in such procurement can be taken on a realistic virtual tour of the piece of equipment under specific conditions that are relevant to the specific mining operation. This leads to a substantial increases in safety and corresponding reductions in time and cost for all parties.

4:05 PM

Augmented Reality: Real-world Applications for Mining Equipment Maintenance & Training

S. Penmetsa; RapidBizapps, Milpitas, CA

Augmented reality (AR) — the layering of contextual computer-generated images and sounds on to a view of the real world — is steadily making inroads into multiple industries. One of the most promising applications for AR is in the area of equipment maintenance and the training associated with such maintenance. In this presentation, we show real-world examples of how AR can be integrated into workflows to streamline the equipment maintenance process, from diagnosis to fix. When paired with a voice recognition interface, the AR platform can facilitate rapid handsfree triaging of problems and provide step-by-step instructions on how to fix those problems — all in context, in real time. Such applications of AR are expected to generate significant cost savings for maintenance shops, reductions in turnaround times for customers, and improved safety for maintenance personnel.

WEDNESDAY, FEBRUARY 28

AFTERNOON

2:00 PM | ROOM 200DE

MPD: Hydrometallurgy III

Chair: *J. Baron, Barrick, Port Moody, BC, Canada*

2:00 PM

Introduction

2:05 PM

Leaching Kinetics of Rare Earth Elements from an Enriched Coal Source

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

The recovery of rare earth elements (REEs) from coal samples collected from the Fire Clay seam was investigated by leaching using a dilute nitric acid solution. The first step in the process was the recovery of coal using conventional flotation which upgraded the REE content in the flotation tailings to values approaching 700 ppm. REE recovery from the flotation tailings by leaching was studied under leaching temperatures from 25 to 75 °C using 1 M nitric acid which resulted in recovery values up to 84.3%. Recovery increased rapidly during the first 30 minutes and slowed over the following 24 hours until an equilibrium was reached. The leaching characteristics was adequately described by the shrinking core model and the activation energy was determined using the Arrhenius equation. Leaching kinetics associated with the REEs were used to study the leaching mechanisms relative to other individual elements.

2:25 PM
A New Treatment for Iron Containing Acidic Streams
P. James; Blue Planet Strategies, Madison, WI

A patent-pending new variant of the reagentless DeMet wastewater treatment option for iron containing acidic mining waters and discovered as an outgrowth of recent field DeMet demonstrations is discussed. Treatment to adjust target stream pH, remove iron contamination, and potentially recover selected valuable constituent contaminants while avoiding or reducing sludge generation is considered. The treatment approach is presented along with selected associated experimental results. General application of the treatment is examined along with exploration of potential metallurgical processing streams where it might be utilized.

2:45 PM
Performance Modeling and Validation for Extraction, Recovery, and Purification of Metals
M. Free; University of Utah, Salt Lake City, UT

Accurate prediction of metallurgical processing of metals from ores to final purified products is needed to facilitate accurate cost estimations and optimized designs for plant operations. Advances in modeling methods and computer hardware have enabled significant improvements in the ability of models to accurately predict performance in metallurgical processes such as leaching, electrowinning, and electrorefining under a wide range of operating conditions. Accurate models can be used to predict the effects of small changes in equipment geometries, flow rate, temperature, solution concentrations and speciation, and many other parameters. This improved capability can be utilized to optimize equipment designs and operating conditions for improved performance and reduced costs. In this presentation, the use of validated modeling will be discussed for leaching, electrowinning, and electrorefining, and associated modeling and experimental results will be presented to demonstrate the utility of advanced modeling in predicting process performance.

3:05 PM
An Innovative Electro-Chemical Process for Tankhouse Iron Control
P. James[1] and R. Washnock[2]; [1]Blue Planet Strategies, Madison, WI and [2]Process Engineering L.L.C., Tucson, AZ

Problematic iron contamination in copper electrowinning (**EW**) tankhouse electrolyte will increase power cost by 3% to 4% per equivalent copper pound plated for each g/L of iron present. Iron concentration in the electrolyte is typically controlled with a bleed stream to raffinate. This bleed stream increases operating cost by removing key components in the EW electrolyte and increasing their need for replenishment. A primary example is the loss of valuable cobalt metal added to the electrolyte to stabilize lead flaking of the anode and decreases lead contamination in the copper cathode. In addition, the iron bleed results in a recycled copper load which defers copper production from leaching operations; thereby adding incremental operating cost to copper previously recovered and possibly a loss of ultimate copper production. Application of the new DeMet technology as an alternative iron control and copper retention option in the EW process is explored. Benefits and challenges are discussed along with economic implications for representative copper EW scenarios.

3:25 PM
Fundemental Modeling of Electrowinning Processes
J. Werner[2], M. Free[1] and Z. Zhang[1]; [1]Metallurgy, University of Utah, Layton, UT and [2]Mining Engineering, University of Kentucky, LEXINGTON, KY

Understanding the fundamental processes associated with Industrial Electrowinning is critical to improve and design these process for optimal performance. Presented in this work are refinements to a finite element methodology to evaluate the effects of speciatation, roughness and deposit thickness. Critical inputs are evaluated and correlation is made to key process parameters. Short circuiting as a function of time is examined experimentally and through fundamentals-based modeling. Although copper sulfate systems are primarily evaluated, Ni and Zn will also be presented. The primary objective of this work is to present and summarize key findings of modeling industrial electrowinning to practicing engineers and decision makers.

3:45 PM
Comparative Copper Leaching from Chalcopyrite Using Alternative Lixiviants
J. Ahn, D. Shin and J. Lee; University of Arizona, Tucson, AZ

Chalcopyrite is one of the most refractory sulfide minerals and the most abundant resource of copper. Extensive research and development works have been done to enhance the extraction of copper from the minerals for the last few decades. In this study, chalcopyrite leaching was performed using copper concentrates and whole ores in a conventional sulfuric acid solution and other lixiviants. The grade of chalcopyrite concentrate was 28.8% and chalcopyrite is over 95% with very small amount of other copper sulfide minerals. The grade of whole ore was 0.37% and contains various copper minerals. Detailed results of mineralogical investigation will be discussed. Both bottle roll and beaker test methods were used in different experimental conditions. Other lixiviants are sulfurous acid, glycine, and other organic acid. Ferric ion and hydrogen peroxide were used as oxidants to enhance the kinetics of leaching. At 22°C, the copper extraction was poor but over 95% of copper extraction was obtained using the organic acid at 75°C from the concentrates. Comparative metallurgical study results will be discussed in different conditions.

4:05 PM
Automated Metallurgical Accounting at OceanaGold's Haile Operation
C. Anderson; Haile Gold Mine Inc, Camden, SC

OceanaGold's Haile operation in Kershaw, South Carolina, was recently commissioned in 2017. As part of the commissioning process, the metallurgical team transitioned from using conventional spreadsheet based metallurgical accounting to a fully automated metallurgical accounting system (Metallurgical Intelligence ®). This paper provides insight into the advantages gained from implementing the system, some examples of reporting methodologies, and identifies future development opportunities.

WEDNESDAY, FEBRUARY 28
AFTERNOON

2:00 PM | AUDITORIUM ROOM 1

MPD: Physical Separation II (Tailings)

Chairs: *M. McCaslin, WesTech Engineering, Murray, UT*
D. Perkins, Derrick Engineering, Buffalo, NY

2:00 PM
Introduction

2:05 PM

Tailing Dewatering and Disposal; the Role of Thickeners in Slurry, Surface Stacking, Dry Stacking and Paste Backfill

J. Johnson; Industrial, WesTech Engineering, Salt Lake City, UT

The dewatering and disposal of process tailings has been evolving under the today's environment requiring; improved water quality and recovery, risks of containment failures, and permitting for new sites and raising of existing sites. In the past decades the thickening industry has changed drastically developing several thickener types. Dewatering of tailings should; now more than ever, be considered like other process step; the design must be selected to best suit and optimize the downstream stages. Selecting the right thickener can increase valuable water recovery, decrease the load on downstream filters, or even allow tailings disposal as surface stacks greatly reducing the cost and risk of containment. Site specific requiements provide the basis for successful thickener selection, one type does not fit all. This paper provides case studies to present the type of thickeners and their performance

2:25 PM

Geotechnical and Other Considerations for Surface Tailings Disposal

L. Botham; Clifton Associates Ltd., Saskatoon, SK, Canada

Every tailings management project is unique: location, site characteristics, geology, climate, tailings physical and chemical properties, production rates and life of mine all impact the design of a tailings management facility. As a result, each tailings management solution will also be a unique in the requirements for safe and environmentally effective disposal of the tailings, in perpetuity. The assessment of options for tailings disposal should include all of the above characteristics for the project, but must also include socio-economic aspects as well. The evaluation may be different for a green field project when compared to expansion or re-activation of an existing site. Expansion may provide opportunities to improve the overall water management on a site, to reduce fresh water consumption while increasing reclaim to the process plant. New technologies offer opportunities to improve the safety of a tailings facility, but new technology may not be the best solution. Recent events have also resulted in increasingly stringent regulatory regimes, which can have a major impact on the economics of a project. Designs must be adaptable to these changes.

2:45 PM

Pump Selection for Slurry Transport in Tailings and Pipeline Systems

C. Walker and M. Webb; Engineering, Weir Minerals, Madison, WI

Using tailings as backfill, and in mining construction, has numerous positive environmental impacts. Minimizing power and water consumption, as well as improving the safe disposal of tailings are reasons why operators are moving from conventional methods to dewatered paste and dry stacking tailings disposal systems. Determining the optimum pipeline configuration which includes selecting appropriately sized pumps, motors and pipes is a key factor to reduce the amount of energy wasted in slurry transportation. Reducing energy waste is beneficial not just to operators bottom line, but to the environment. By focusing on the utilization of tailings and pipeline systems, we can open up new and innovative ways to not just save money, but truly minimize the environmental impacts of mining.

3:05 PM

Tailings Filtration Demonstration Plant

T. Wisdom; FLSmidth, Park City, UT

FL Smidth is working with a large scale mine in Chile on a demonstration plant for tailings filtration. This plant is intended to demonstrate the full scale capabilities of FL Smidth's newest large pressure filter for tailings; the Colossal™ automatic filter press. Expected production of the single filter plant will be roughly 10,000 tpd of filtered tailings. The filtered tailings from the demonstration plant will contain roughly 82 wt% solids, dewatered from the approximately 52 wt% solids in the thickened tailings feed stream. Components of the plant include a feed slurry tank, filter feed pumps, one Colossal filter with drip trays, an innovative hybrid apron belt feeder, take away conveyor, radial stacker, filtrate equalization tank, clarifier, floc system, pumps, and instrumentation. The design philosophies as well as some of the challenges associated with the project will be reviewed. Production data and filter performance will be discussed. This new large filter along with it Fast Filtering technology have potential to make filtered taiings production much more economical.

3:25 PM

Mining Tailings Management: from Lagooning to Dry Stacking. Successful Case Studies

A. Pezzi; Sales, Aqseptence Group SRL, Lugo, Italy

Paper will outline the issues and solutions associated with tailings management and dry stacking. We will go into details of real case studies. Detailed abstract to follow.

3:45 PM

Tailings in Paste Backfill; the Necessary Evil

M. Bachman; Paterson & Cooke, Golden, CO

Underground paste backfill has a lot of advantages: quick stope turnaround times, additional recoverable ore, improved mine stability, reduced storage of tailings on surface, potential reduction in underground emissions and ventilation requirements. Due to these advantages, more and more underground mines are considering the implementation of paste backfill. Paste backfill seems simple enough; the material looks very similar to ready-mix concrete and there are thousands of ready-mix concrete plants in the United States alone. So how hard can it be? Despite the similar appearance, paste backfill is not ready-mix concrete, and tailings is the necessary wild card ingredient that makes paste backfill unique. This paper discusses the tailings specific challenges associated with designing and operating paste backfill systems.

WEDNESDAY, FEBRUARY 28

AFTERNOON

2:00 PM | ROOM 200GH

MPD: Pyrometallurgy III – Direct Reduced Iron

Chair: *S. Ripke, Midrex Technologies Inc, York, SC*

2:00 PM

Introduction

2:05 PM

ACT™ – Increasing Carbon without Temperature Loss within the MIDREX® Process

M. Arandas, V. Chevrier and T. Astoria; Midrex Technologies, Inc., Charlotte, NC

The MIDREX® Direct Reduction Ironmaking Process has great flexibility to produce Direct Reduced Iron (DRI) with controllable carbon as desired by the plant operator. Typically, EAFs that use higher percentages of DRI require lower carbon; whereas, plants that use mostly scrap with lower percentages of DRI desire higher carbon. With the new ACT™ (Adjustable Carbon Technology), which can be retrofitted to existing MIDREX® plants, DRI carbon can now range from 0.5% to 4.5% without temperature loss. This paper will detail the technology as well as applications for merchant and captives

DRI operations. Keywords: MIDREX® Direct Reduction Ironmaking Process, DRI, HBI, HDRI, ACT™, carbon, EAF steelmaking, merchant DRI production, High-carbon, low-carbon, variable carbon

2:25 PM

Cliffs HBI – A New Era

M. Young[1] and Z. Voss[2]; [1]Cliffs Natural Resources, Cleveland, OH and [2]CIX, Pittsburgh, PA

For over 170 years, Cliffs has been a proven technical leader delivering tailor-made solutions for customers' unique steelmaking needs. With the announcement of a the Company's first Hot Briquetted Iron (HBI) plant in Toledo, OH, Cliffs enters a new era of supplying electric arc furnaces (EAF) with a high quality ore-based metallic product. Cliffs HBI will have several advantages compared with other HBI products that have been previously available. Product characteristics will include consistent chemistry, low gangue, low phosphorous and adjustable carbon levels. Value-in-use modeling to optimize Cliffs HBI for different EAF conditions will be discussed.

2:45 PM

The MIDREX® H_2™ (Green Hydrogen) Concept

S. Ripke; Midrex Technologies Inc, YORK, SC

By utilizing reformed natural gas instead of coal, the well-established MIDREX® Process is already an environmentally friendly ironmaking technology as demonstrated for the past forty years by the long list of MIDREX® Process licensees that operate the more than 70 commercial direct reduction (DR) plants. Since the MIDREX® Process utilizes natural gas, it is more energy efficient and produces only one-third the CO_2 that is emitted by modern blast furnaces (BF) which instead use coke made from coal as fuel and reductant, and is necessary to provide internal structure to the molten burden (feed materials such as iron ore in the form of sinter, lump, or pellets, and flux) whereas the SF burden (iron ore pellets or lump) does not require a separate structure because it remains solid. The reformed natural gas (55% H_2, 30%CO, balance CO_2, CH_4, and H_2O) can replaced by hydrogen (in particular "green" hydrogen renewably produced with a minimal carbon footprint). This is the concept of MIDREX® H_2 - [mid-reks green hahy-druh-juh], noun 1. An environmentally friendly ironmaking process using green hydrogen that significantly decarbonizes steelmaking by lowering CO_2 emissions even further.

3:05 PM

Optimizing the Pellet Properties for the DR Shaft

M. Rutschman; LKAB, Luleå, Sweden

The properties of the ore base will influence the behaviour of pellets in the DR shaft. To modify the inherent properties additions of fluxes are made. For designing these modifications laboratory tests are available, both metallurgical tests and tests to simulate changes during pelletizing. Although the metallurgical tests gives important information about the pellet properties they do not fully simulate the behaviour of pellets in the process. In the case of DR pellets this can partly be compensated by the possibility to use basket samples in a production unit. A comparison of results from metallurgical tests and from basket samples show the need to confirm metallurgical tests results in production plants when optimizing pellet properties.